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Multidisciplinary investigations of the continental slope in the Gulf of Alaska area

by Z.A. Filatova (ed.)

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MULTIDISCIPLINARY INVESTIGATIONS OF THE CONTINENTAL SLOPE IN THE GULF OF ALASKA AREA

Based on information collected during the 45th
Cruise of the Scientific Ship "Vityaz'"

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Edited by Z. A. Filatova

(Kompleksnyye issledovaniya materikovogo sklona v raione Zaliva Alyaska. Po materialam 45-go reisa NIS "Vityaz'". Akademiya Nauk SSSR. Trudy In-ta Okeanologii im. P. P. Shirshova, tom 91. Moskva, 1973.)

Abstract

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This collection contains the results of investigations in the Gulf of Alaska and the Aleutian abyssal trench. Quantitative data were obtained on the vertical and horizontal distribution of life along the slope of the bathyal zone and on biological zonation. There are also

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* Figures in the margin give page numbers in the original. -- TRANSL.

articles on hydrology, hydrochemistry and microbiology in the region investigated. The book is intended for hydrobiologists, oceanographers, zoologists and ichthyologists.

INTRODUCTION

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The information on the biology of the bathyal zone (the slope of the continental margin) in the Gulf of Alaska and the Aleutian trench presented in this collection was obtained in the spring of 1969 during the 45th biological cruise of the Scientific Ship "Vityaz'". The activities of that cruise were subordinated to a single purpose -- the study of the composition, distribution, quantitative abundance and trophic zonation of the fauna along the continental slope of the Gulf of Alaska and the Aleutian trench. These studies were a continuation of the biological investigations of the bathyal zone of the Pacific Ocean started with the 39th cruise of the "Vityaz'" over the Kuril-Kamchatka trench.

Academician L. A. Zenkevich, who directed this cruise, believed that the time had come to start regular studies of the biology of the continental [margin] slope which has thus far been very little studied and undeservedly forgotten (Zenkevich, infra). At the same time, judging from data obtained by the "Vityaz'" in the Kuril-Kamchatka trench, the continental slope of the Pacific Ocean, especially in its eutrophic zone, is a highly productive region where all preconditions exist for the abundant development of plankton and benthos as well as bathypelagic and benthonic fishes.

The Gulf of Alaska was chosen for the study of the bathyal zone not only because it is an open gulf of the Pacific Ocean that is covenient and easily accessible to investigation, but mainly because all vertical geomorphological zones in it are fairly well developed and inhabited by a rich oceanic fauna. This is well-nigh the only area in the northern part of the Pacific Ocean where an open and deep bay is surrounded by extensive land areas rather than island chains, so that its waters are subjected to the strong influence of the continental runoff. Therefore, biological zonation in this area is bound to be fairly complete, providing a base for the study of the distribution of biogeocenoses and trophic groupings in all their variety.

Here we are indeed dealing with a well-inhabited littoral and a sublittoral zone rich in life which gradually goes over into a gently inclined, well-developed continental slope. In some places (in the upper part) it is cut by submarine canyons, but on the whole it descends gradually into the abyssal part of the open bay, known by the name of "Alaska Mountain Province."

Because of the abundant life in the coastal zone of the Gulf of Alaska there are widespread terrigenous greenish-gray sediments with high contents of chlorophyll and organic matter. It is into this area, the bathyal zone, that the detritus from the upper water layers of the gulf and its coastal zone is being carried. Partly it is consumed by the fauna existing there, and partly it accumulates at the foot of the slope. Before the studies of the "Vityaz'" the Gulf of Alaska had been studied very unevenly. The biology of the shelf area, studied by the field parties of VNIRO-TINRO (All-Union Scientific-Research Institute for Sea Fisheries and Oceanography- Pacific Scientific-Research Institute for Fisheries and Oceanography) is known in somewhat greater detail, but as regards the greater depths (the slope), their geology and relief have been well studied, while their biology is known only in bits and pieces. Early investigations of the "Vityaz'" (Cruise 29) dealt only with the abyssal zone at the exit from the gulf, and a few stations were occupied near the Canadian coast. 6

Thus the bathyal zone of the gulf remained practically unstudied. At the same time, the shelf zone of the gulf and the uppermost part of the slope have long served as fishing grounds for a number of benthonic and bathypelagic fishes, which are abundant here and possess a good food base. This was confirmed not only by underwater photographs made during Cruise 45 but also from catches of the Large Refrigerated Fishing Trawler ("BMRT") "Ekvator," which operated in the same area.

As has been pointed out by P. A. Moiseyev, "there can be no doubt that the first steps in understanding the greath depths of the slope will lead to the commercial exploitation of new resources of the Pacific Ocean perch . . . of the Gulf of Alaska, which are at presently not being used at all." *

Cruise 45 of the "Vityaz'" began on 23 April 1969. Passing through the Sangar or Tsugaru Strait into the Pacific Ocean, the ship set its course toward the central part of the Aleutian trench, where it was to begin its first activities. However, because of a continuous storm the "Vityaz'" was forced to enter into the Gulf of Alaska, having with some

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* P. A. Moiseyev, "Some results from the investigations of the Bering Sea fisheries-research expedition." Publ. of VNIRO, vol. 53, 1964, p. 24.

difficulty occupied only one deep-sea station -- No. 6085 -- on the Aleutian trench (Fig. 1).

The activities in the gulf were carried out along four profiles running at right angles to the coast. Stations were established over depths of 100, 200, 500 and 1,000 meters from the sublittoral to the abyssal zone. The length of the profiles was 100-150 miles. At each station we carried out a full range of observations, both biological and auxiliary (in order to define the habitats), including underwater photographs and observations with the bottom bathometer (Fig. 2).

The first profile (counting from the west) starting from Kodiak Island covered depths from 200 to 4,500 meters (stations 6089-97). At a depth of about 1,500 m the catch of the Sigsby trawls frequently contained various fishes, including large grenadiers (up to 90 cm).

The second profile from Yakutat (Bering) Bay with a length of about 140 miles (stations 6098-6107) covered depths from 180 to 3,750 m. A series of underwater photographs provided quite a typical picture of the distribution of life on the bottom (benthos and nekton). The catch brought in slime flounders, Pacific Ocean perches, and grenadiers (Fig. 3).

The third profile ran from Baranof Island to an extent of 110 miles (stations 6108-23). Here we also set up a hydrological polygon with buoy placement in the "cross" pattern at a depth of 3,500 m. Underwater photographs gave a good idea of the density of bottom fauna and the occurrence of benthonic fishes (flounders) (Fig. 4).

After the third profile, the "Vityaz'" sailed south and while passing Prince of Wales Island carried out profile 3A (stations 6124-28). After visiting Vancouver, Canada, and the Biological Station at Nanaimo,

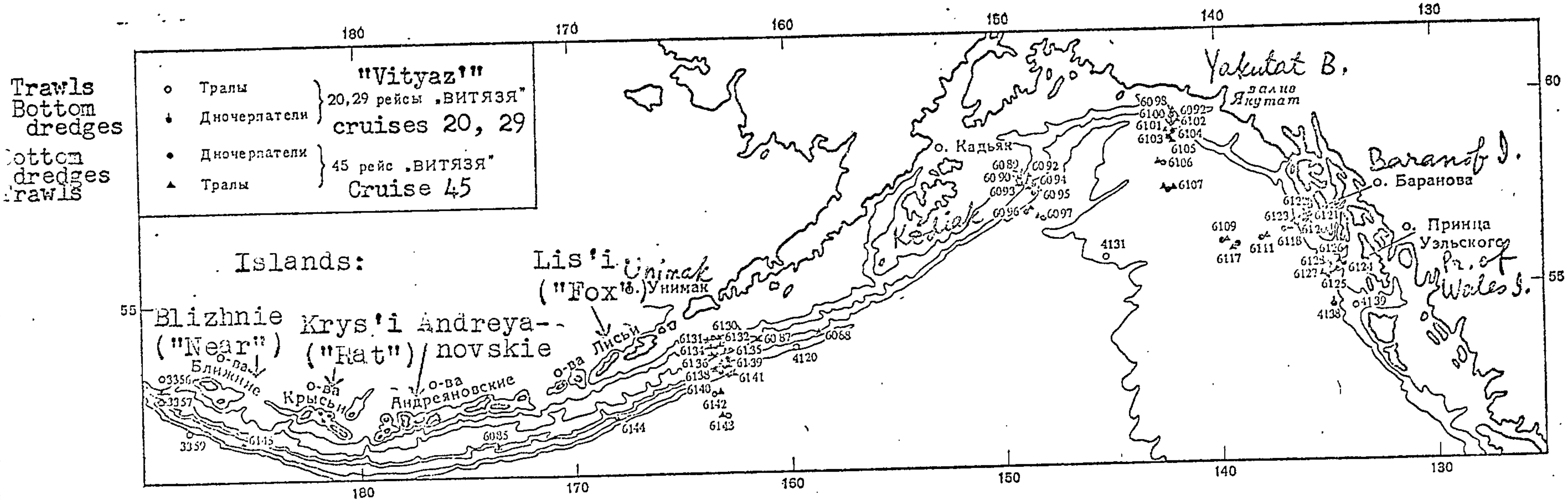

Рис. 1. Схема маршрута и расположения разрезов и станций 45-го рейса «Витязя»

Fig.1.Track and location of profiles and stations of Cruise 45 of the "Vityaz'"

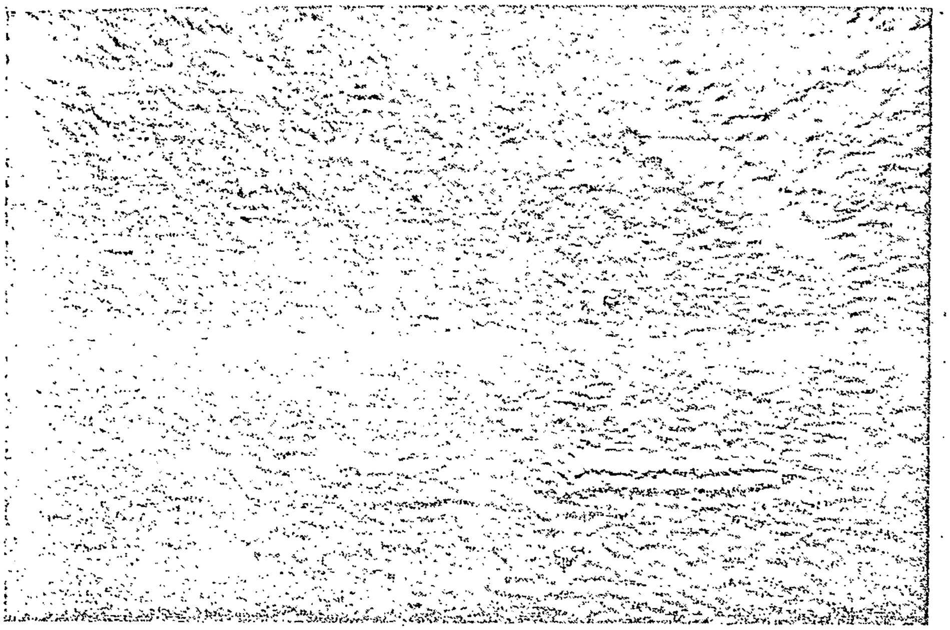

Fig. 2. Underwater photo of the slope of the Aleutian trench (station 6138, depth 5,600 m). The subsurface track may have been made by a large Polychaeta of the Aphroditidae, which during the exposure was in the anterior part; the older part of the track is washed out.

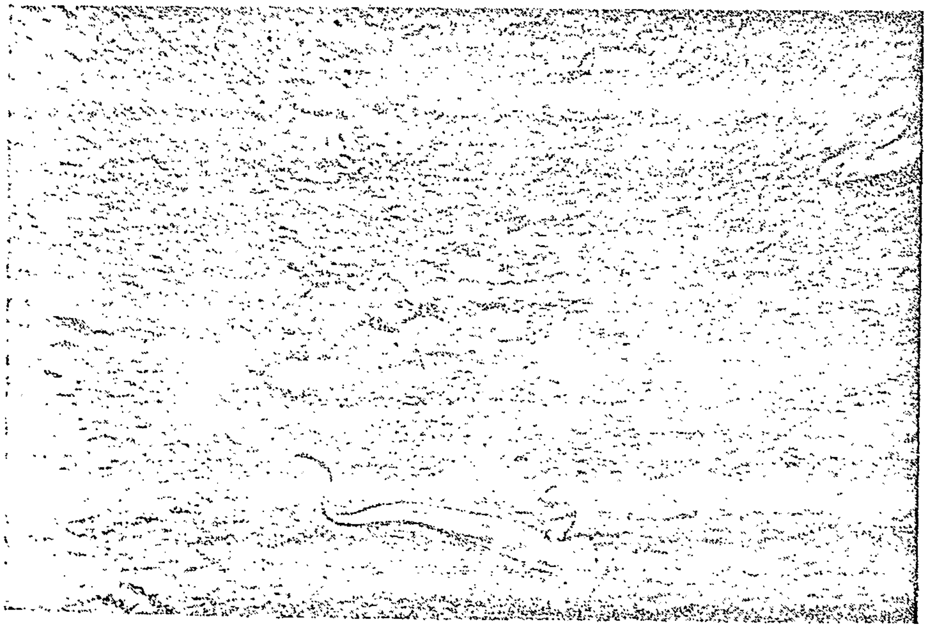

Fig. 3. Slope of the Gulf of Alaska (station 6102, depth 877 m). At top, a grenadier, at left a goby. The photo shows entrances to Polychaetae burrows (?).

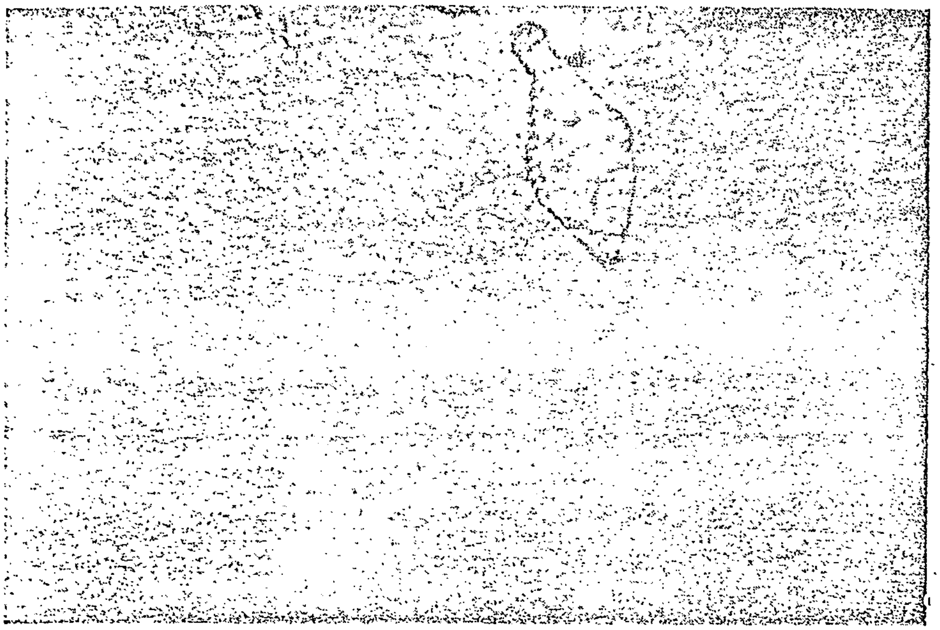

Fig. 4. Slope of the Gulf of Alaska (station 6126, depth 513 m). Showing flounder Microstomus pacificus (length 32-45 cm) living at depths of 90-750 m.

the "Vityaz'" crossed the Gulf of Alaska, making measurements, and from Unimak Island she began her work on the profile across the Aleutian trench (stations 6130-45). On this profile, we occupied three stations at depths of over 6,000 m and two stations (6144 and 6145) at a depth of over 7,000, at the bottom of the Aleutian trench.

On our southward track, we occupied another five stations: a shallow one in the Nemuro Sea (collection of fauna for the Zoological Museum of Sofia, Bulgaria); two deep-sea stations (6151 and 6152) in the northern part of the Japan trench (depths of over 7,000 m) and two (6154 and 6156) in the Idzu-Bonin trench (depth about 8,000 m). 9

After a stay at Osaka, the "Vityaz'" returned on 10 July to Vladivostok, after an absence of 78 days. During that period she had sailed 11,500 miles and occupied 78 stations.

The information on the biology of the bathyal zone of the Gulf of Alaska obtained during the cruise fills an important gap in the quantitative assessment of the abundance of life in one of the most important regions of the eutrophic zone of the Pacific Ocean.

THE INVESTIGATION OF BATHYAL ZONES IN SEAS AND OCEANS* 10

By L. A. Zenkevich

The bathyal zone, or the continental slope, occupies a vast space in the World Ocean, which in area is equal to nearly half of the entire land surface. In spite of this, owing to a number of circumstances arising from the uneven development of our knowledge of seas and oceans, the bathyal zone has until the last few years been very little studied. It is natural that the most detailed studies were carried out of the continental shelves near the coasts, which play a basic role in the commercial use of the biological resources of resources of seas and oceans. Regular investigations of the biology of the abyssal zone on a global scale were started only in the 1950's, with the commissioning of the expeditionary ship "Vityaz'," which was used for multidisciplinary studies of the Pacific and Indian oceans and adjacent waters. Thus the bathyal zone, which is intermediate between the continental shelf and the abyssal zone, turned out to be least studied. This gap must now be filled as quickly as possible in order to obtain a true understanding of the signficance of the bathyal zone in the biology of the ocean.

Fringing all continents and islands there is a tidal (littoral) zone and a zone of epicontinental, shelf** seas (sublittoral zone), extending to an average depth of 200 meters. Below the shelf zone, beyond the

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* This paper is based on Zenkevich's writings on the study of the bathyal zone, in which he had a keen interest, regarding it as of great importance for the biological resources of the ocean.

** The word "shelf" has been taken over by the Russians and is usually used by them without the qualifier "continental," which would be redundant. "Shelf," in Russian, is also used in the adjectival sense. -- TRANSL.

margin of the shelf, the gradient of the bottom increases and the continental slope, or bathyal zone, begins. This is the lateral rim of the continental massifs. It extends to depths of 2,500-3,000 meters.

Deeper still is the bed of the ocean, or the abyssal zone, with depths of up to 6,000 meters. Even greater depths are found in the abyssal trenches, or depressions; this zone has become known as the ultra-abyssal zone.

The tidal zone, the shelf and the bathyal zone fringe all continents and islands, in other words, they have a circum-continental strike, whereas the abyssal zone has a central-oceanic strike or extent.

The shelf zone (with the marginal seas) accounts for about 7.5% of the entire ocean bottom, the bathyal zone 14.5%, the abyssal zone about 77%, and the ultra-abyssal zone a mere 1%.

Investigations of these four zones in seas and oceans have been carried out unevenly. During the 17th to 19th centuries surveys directed to the opening of trade routes to distant parts of the world dealt mostly with the open parts of the oceans, and their investigation was basically of a descriptive-geographical character. With the expedition of the "Challenger" (1873-76) there began the oceanographic study of the open parts and depth of the ocean. After that there began the more thorough study of the shelf (epicontinental) seas. Important information was ob- 11
tained on the physical-geographical and biological characteristics of the marginal seas, mostly around the Eurasian continent and to a lesser degree along the coasts of North America.

The German expedition in the "Meteor" operating in the Atlantic Ocean (1925-27) began the next period in the study of the World Ocean , subsequently interrupted by World War II. Nearly unstudied until the second half of the 20th century were the deep parts of the ocean, while the commercial exploitation has until recent years been confined to the depth of the shelf seas (less than 200 m). Investigations of the ocean depths came into their own in the second half of the 1950's, particularly during the International Geophysical Year.

The continental slope and the water masses above it, the bathypelagic zone, remain thus far the least studied. Metaphorically speaking, the continents (and the oceans) are surrounded by a "blank belt" of little-studied areas -- the bathyal and bathypelagic zones.

An essential question arises: do the bathyal and bathypelagic zones posses typical characteristics, or are they merely a formal boundary between the epicontinental and the abyssal zone, between the littoral and the oceanic waters; and, if they do possess such characteristics, what are they?

Let us consider the characteristics of the bottom of the bathyal zone and the distribution of sediments thereon. Much depends on the increase in the gradient of the slope bottom in comparison with that of the continental shelf and the deep-sea basins. The boundary zone between the continents and the oceanic crust, the bathyal zone is very often characterized by vast fractures and faults, abrupt changes in the slope gradient, and abrupt changes in the character of the bottom. A considerable bottom gradient affects first of all the sedimentation process. If the shelf sea and the abyssal zone may generally be termed zones of sediment accumulation, the bathyal zone as a whole is a denudation zone (washing and redeposition of sediments and exposure of bedrock). The bathyal zone is an area of turbidity currents, of underwater canyons. In some parts of the ocean the bathyal zone is completely cut up by canyons, especially where it is not closed off by island arcs, as, for example, along the east coast of North America.

Along with turbidity currents running from the shelf across the bathyal zone, the steep slopes of the bathyal zone may be subjected to landslides and creeps of argillaceous sediments, which in turn give rise to powerful turbidity currents. Thus the bathyal zone is an area where sediments are transported from the shelf to the abyssal zone. However, where the bottom relief makes this possible, using, as it were, "any available cover," sedimentation occurs, often of great extent and thickness. Against the background of general denudation we observe a mosaic of areas of sedimentation alternating with bedrock exposures, sometimes in the shape of rocky outcrops. It is quite probable that denudation is also furthered by the action of powerful bottom currents.

As we move on to the ocean basins, all of these typical characteristics disappear: the bottom levels out, the bedrock disappears under a sediment blanket whose deposition, with rare exceptions, is quieter and more uniform.

No less peculiar are the processes in the water stratum of the bathypelagic zone. Every epicontinental water body, even if it has a wide outlet to the open ocean, possesses its own circulation system conditioned by the contour of the coast and the relief of the bottom. The circulation system of the World Ocean represents to some degree an independent and separate whole, with five vast circular water movements, cyclonic in the northern hemisphere and anticyclonic in the southern one,

with halistatic zones within them. Thus, between the water masses of the central part of the ocean and the shelf, between the circumcontinental and the central-oceanic circulation systems an intermediate zone 12
is formed.

The water masses of the bathypelagic zone are to a certain degree affected by the circulation system of the adjoining ocean, a system that arises from the effect of the relief of the continental slope and the coastal waters upon the adjacent parts of the "large" ocean system of currents. In the bathypelagic zone the currents, obeying the longitudinal arrangement of the continents, acquire a direction along the coast lines (more or less longitudinal) and are usually connected with a system of currents with an opposite direction (Kuroshio-Oyashio, Gulf Stream-Labrador Current).

All of these systems of currents and counter-currents, whether they are far from the coasts or close to the continents (Humboldt Current, Benguela Current) are characterized by deep and powerful mixing of waters, the raising of nutrient salts into the zone of photosynthesis and by high indicators of biological productivity. This expresses itself in a multiple and often extremely complex system of small cyclonic and anticyclonic circular movements, which slow down or even stop the influx of currents. Such a picture is particularly typical where the coastal waters contain cold and warm currents moving in opposite directions. This intermediate zone above the bathyal zone isolates, as it were, the coastal waters from the central ocean masses.

The term "water masses above the bathyal zone (bathypelagic zone)" should be taken somewhat conditionally, as the former correspond only partly to the latter. The term "neritic (coastal) waters" also fails to describe that zone which we are here dealing with, as the term refers to waters touching the coast. Our concept is best served by the term "intermediate," used by K. V. Beklemishev for the plankton assemblages between the properly coastal and the central oceanic circulations.

Perhaps the first example of this phenomenon was given by F. Nansen in the monograph "The Waters of Spitsbergen" (1915), in which he described the mixing of waters north is Iceland. The warm and salty water coming from the south, caught up in numerous cyclonic and anticyclonic movements and having lost its initial velocity, is cooled and irresistibly drawn downward, thus producing a compensating rise of cold abyssal water, rich in biogenic salts, into the zone of photosynthesis.

Vertical mixing processes of a similar extent, resulting in the rise of deep water, rich in biogenic salts (phosphates, nitrates),to the surface are observed in the region of the Humboldt Current along the west coast of South America. Here we have a very high level of primary production, giving rise to tremendous accumulations of anchovies that have put the fishing industry of Peru in first place in the world. A similar region exists along the west coast of South Africa, where the strong cold Benguela Current comes up from the south. In the North Atlantic warm water enters from the south, and along the coasts of South America and South Africa there flow colder waters. However, the effect is the same — powerful vertical mixing processes, accompanied by a vigorous flowering of living organisms.

The biological enrichment in such waters also embraces the benthonic fauna. A clear example of this is found on the Great Bank of Newfoundland, where the shelf area has long yielded abundant catches of fish, primarily cod.

During recent years we have gained information indicating that biological enrichment occurs not only in the coastal zones of the continental shelf but also in the bathyal and bathypelagic zone. During the expedition of the "Vityaz'" in the northwestern Pacific pelagic nets brought in large quantities of large grenadiers and other fishes. In some areas of the bathyal zone of the North Pacific and North Atlantic, depths of 400-1,000--1,500 meters yielded fish catches of several tons per hour of trawling. The catch consisted of grenadiers, ocean perch, halibut, black cod, and other semi-abyssal fishes. It is only in the bathyal and bathypelagic zones that sperm whales feed: they dive to 1,000-2,000 meters after cephalopods and other inhabitants of the deep.

The Institute of Oceanography of the Academy of Sciences of the USSR has for several years carried out surveys of the bottom surface with special photographic cameras. During Cruise 39 of the "Vityaz'" (1966) several photos were taken during each of the stations on the slopes of the Kurile-Kamchatka trench. The same was done during Cruise 45 of the "Vityaz'". The series of photos showed that the bottom of the bathyal zone is inhabited by a varied fauna.

We indicated two sources of food resources of the bathyal benthonic fauna -- the organically rich detritus washed from the shelf, and the descending remains of the abundant surface plankton, which is also rich in organic matter. The wide occurrence of stony and rocky bottoms in the bathyal zone aids the abundant development of Sedentaria, attached fauna: sponges, corals, bryozoans, hydroids, among which one finds many worms, echinoderms, molluscs and Conchifera. The bottom underneath these growths is inhabited by an abundant benthonic fauna.

The investigations of the bathyal zone of the Kurile-Kamchatka region and the Gulf of Alaska give reason to assume, when correlated with the abovenoted facts and considerations, that the information gained during the 39th and 45th cruises of the "Vityaz'" is typical not only of the investigated regions but also of the entire bathyal zone of the World Ocean. This must certainly be a feature common to the Ocean, the same as those causes that produce the rich life in the upper horizons of the bathyal zone. If this is so it may be possible that the fishing industry may obtain new and quite substantial yields from the continental slopes in various parts of the World Ocean.

METEOROLOGICAL CONDITIONS IN THE TEMPERATE LATITUDES OF THE NORTH PACIFIC DURING THE SPRING OF 1969

By Yu. A. Shishkov

That part of the Pacific Ocean traversed by the 45th cruise of the "Vityaz'" (April-July 1969), according to the classification of A. I. Sorkina,* is situated in the Temperate, Subtropical and Subarctic zones (Fig. 1). In the Temperate Zone, temperate air predominates throughout the year, and the main process in it is the cyclonic activity along the Polar and Arctic fronts. The Subtropical Zone is during the summer subjected to the effects of tropical air, in winter it is dominated by temperate air. The Subarctic Zone also has a seasonal change of air masses -- in winter, the air is cold, arctic, in spring and summer, it is sea polar (or temperate) air.

The spring and early summer of 1969, in the development of synoptic processes and the wind regime, differed notably from the norm (Fig. 2). In the Temperate latitudes of the North Pacific there was a predominance of negative anomalies of near-surface pressure. As a result, in the place of the mean climatic low at the west coast of the ocean and positive anomalies southeast of it, there were extreme pressure gradients and strong southwesterly winds in the area of the polar front east of Japan.

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* A. I. Sorkina, 1949. "Opyt klimaticheskogo raionirovaniya Mirovogo okeana po tsirkulyatsionnym priznakam." Trudy Gos. okeanograf. in-ta, vyp. 12 (24). ("Experience in the climatic classification of the World Ocean from circulation indicators." Publ. of State Oceanograph. Inst., No. 12 (24).

South and southeast of Kamchatka there were stronger westerly and northwesterly winds, and in the Gulf of Alaska, southeasterly winds.

Such a pattern of pressure anomalies is evidence of a rather intensive cyclonic activity on the polar front and the predominance of blocking processes in the Gulf of Alaska.

1. Passage from Vladivostok to the Aleutian trench (24 April-5 May). The "Vityaz'" left Vladivostok during the night of 23-24 April. At this time, an active polar front with a series of young cyclones extended from Cape Lopatka across Hokkaido and Honshu islands into South Korea and the interior of Southern China. East of this front there was an extensive subtropical anticyclone. Another cyclone dominated the Bering Sea. Above the north coast of the Sea of Okhotsk there was a deep cyclone of the arctic front (below 988 millibars), which was slowly moving northeastward. In the wake of the polar front, several high-pressure nuclei were rapidly moving eastward. It was in the frontal, southern part of the first nucleus that the "Vityaz'" was sailing. The weather was cloudy, the wind was northeasterly at force 5-6. At the approach to the Tsugaru Strait air and water temperatures rose noticeably (from 2-3 to 8°).

After passage into the ocean the temperature of the air, and later the water, again dropped to 1° at 1800 hours on 26 April.*

During the night of 25 April the "Vityaz'" first entered the area of activity of one of the young cyclones of the polar front. There

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* Here and elsewhere time is given in GMT. — TRANSL.

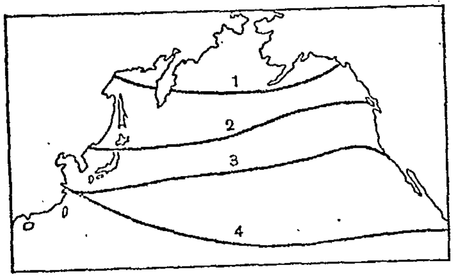
was some drop in pressure, the wind strengthened to force 6 (11.6 m/sec), the overcast was stratified, and drizzle fell. This cyclone rapidly moved off toward the east.

On 26-27 April the "Vityaz'" was situated within an anticyclonic nucleus moving eastward. The wind, at first northerly, turned toward the south and southeast after passage of the centre of the nucleus and began to strengthen.

At this time, an extensive cyclone that had moved in from the west began to strengthen along the lower Amur River and north of Sakhalin. This cyclone had a well-defined cold front along the coast of the Primor'ye [Pacific Littoral] and in North Korea. This cyclone continue its rapid eastward movement. At 0600 hours on 27 April cirrus clouds appeared, heralding the warm front of this cyclone. After less than 24 hours the southerly wind strengthened to force 6 (12 m/sec) and pressure began to drop sharply.

At 0000 hours on 29 April the "Vityaz'" found herself in the centre of a small cyclone (994.7 mb) belonging to the polar front that had moved off to the east. The cyclone strengthened abruptly owing to the influx of cold air in the wake of the low of the Sea of Okhotsk cyclone. After a brief calm, the wind shifted toward the west and strengthened to force 8 (17.8 m/sec). Until 2 May the "Vityaz'" travelled along the southern periphery of this cyclone, which moved off into the Bering Sea. There was heavy overcast with occasional clearing, with cumulus clouds, a strong westerly wind (force 6-7), and precipitation of ice and snow granules.

On 2 May a new cyclone appeared from the southwest. Ahead of its warm front, the wind calmed down somewhat, but after the front had passed,



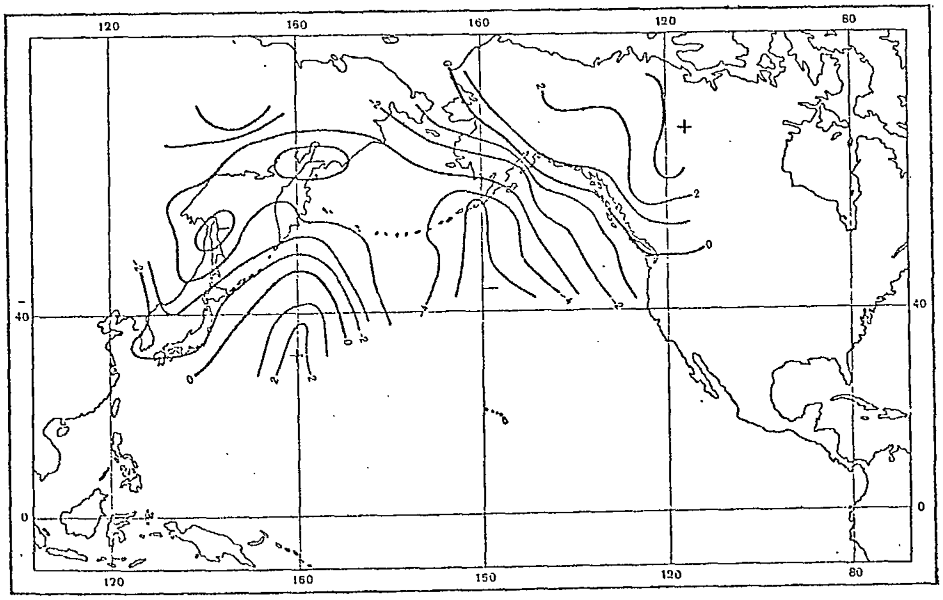


Fig. 1. Climatic zones in the North Pacific (after A. I. Sorkina, 1949). 1-- Subarctic; 2 -- Temperate; 3 -- Subtropical; 4 -- Tropical.

Fig. 2. Anomalies in atmospheric pressure at sea level, May-June 1969.

Table 1. Frequency of wind velocity and direction (in per cent)

Period	Track section	Wind velocity, force				Wind direction, compass bearings							
		3	4-5	6	7	N	NE	E	SE	S	SW	W	NW
24/4-5/5	Vladivostok-Aleut.Trench	6.2	27.1	66.7	39.6	16.7	8.3	2.1	8.3	10.4	21.9	30.2	2.1
6/5-25/5	Gulf of Alaska	35.0	51.3	13.7	5.6	16.3	11.2	9.3	19.9	13.0	8.1	13.7	8.7
1/ -20/6	Aleutian Trench	25.0	41.9	33.1	11.8	8.7	14.4	6.9	16.9	21.8	9.4	14.4	7.5
21/6-3/7	Aleut. Trench-Osaka	36.5	38.5	25.0	5.8								
6/7-9/7	Osaka-Vladivostok	23.0	30.8	46.2	30.8	6.2	14.6	7.7	10.8	22.3	28.4	6.2	3.8
	Total Cruise	26.7	41.0	32.3	14.6								

Table 2. Frequency of degrees of relative humidity and cloud cover

Period	Track section	Relative humidity, per cent					Overcast, degree			
		40–59	60–69	70–79	80–89	90–100	0–3	4–7	8–10	Fog
24/4–5/5	Vladivostok–Aleutian Trench	2.1	5.2	35.4	36.5	20.8	9.6	26.6	63.8	-
6/5–25/5	Gulf of Alaska	0	1.3	17.7	39.8	41.1	1.9	9.3	88.8	-
1/6–20.6	Aleutian Trench	0	0	0.6	19.4	80.0	0.6	1.8	88.4	9.2
21/6–3/7	Aleutian Trench–Osaka	0	0	1.0	12.6	86.4	5.8	11.5	56.7	26.0
6/7–9/7	Osaka–Vladivostok	0	0	0	15.4	84.6	0	15.4	84.6	-
	Total Cruise	0.4	1.3	11.8	26.9	59.6	3.4	10.8	78.2	7.7

which was clearly reflected in the temperature (during 3 hours it rose from 1.9 to 3.2°), the wind again blew from the southwest with force 6-7, and the overcast was intermittent, with cumulus and strato-cumulus clouds. On 6 May the "Vityaz'" began her activities on the first profile, situated southeast of Kodiak Island. The wind began to abate, but at 1200 hours it veered toward the southeast and began to strengthen noticeably. A small and shallow cyclone began to approach rapidly from the southwest. Between 0000 and 0300 hours on 7 May the wind velocity dropped abruptly from 17.8 to 6.4 m/sec, and then to 4 m/sec. After the centre of the cyclone passed (1,000.5 mb), the southwesterly wind returned, with a velocity of 13.0 m/sec that gradually decreased to 5-7 m/sec.

On 8 May, an anticyclone (1,034.2 mb) established itself over the Gulf of Alaska. However, it did not reign long, being pressed from the south by two cyclonic whirls that belonged to two fronts -- the old, southern one, and a new, northern front. On 10 May the "Vityaz'" again found herself within a shallow depression which arrived from the south. Throughout the next day there were frontal stratified-rain and stratified clouds with slight precipitation. Behind this depression the front became practically static and gradually began to disperse, and in its wake a new ridge arrived, which gradually approached from the west. On 12 May it had firmly established itself over the Gulf of Alaska and barred the path of two eastward-moving cyclones. At this time the "Vityaz'" was carrying out the second profile along the continental slope southwest of Yakutat Bay. On 12-14 May there was considerable stratocumulus overcast, and the wind had force 3-4. A slight increase in the velocity of the westerly wind (up to 10 m/sec) on 14 May was apparently produced by the collision of the Alaskan anticyclone with the mountainous coast of America. On 15 May the "Vityaz'" moved on to an area west of Baranof Island, and until 21 May she worked on the third profile. Until 18 May there was a solid stratocumulus overcast, a wind of force 3-4, mainly from the northern quarter. Toward the shore the temperature of the air increased markedly.

On 18-19 May, a front only slightly reflected by the wind passed over the ship. The temperature rose during 12 hours from 3.5 to 7.6°, pressure dropped to 1,014.1 mb.

On 20-21 May, along the western edge of the high that extended along the shore there passed a small but fairly deep cyclone, displacing the high somewhat to the east. The cyclone produced a slight drop in pressure, an increase in wind velocity to 9.3 m/sec, and drew in its wake, along the western edge of the anticyclonic ridge, the next front. In the southwest, a new cyclone of this front was already gathering strength. Under the pressure of the cyclones the ridge slowly retreated toward the east, and the Gulf of Alaska was dominated by a fairly extensive and relatively immobile cyclone.

On 22 May the "Vityaz'" set course for Vancouver. The main portion of this track was accomplished under cover of an anticyclone located along the coast. However, on 23 May the ship crossed the front of a stationary cyclone, in whose wake on 24 May there was heavy rain (up to 0.15-0.20 mm/min), the wind increased to force 5 (during some periods to force 7), and fell off only at the entrace of Juan de Fuca Strait.

During the activities in the Gulf of Alaska the paths of the cyclones of the arctic and polar fronts (Fig. 3) were situated either

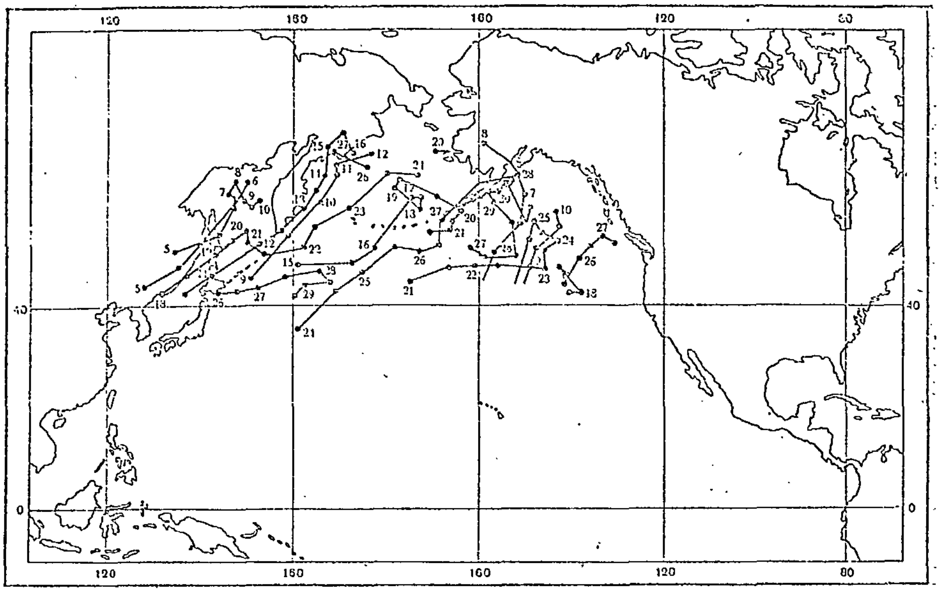


Fig. 3. Paths of cyclones during 6-25 May 1969

along the Asiatic coast into the western part of the Bering Sea, or they ran across the ocean from Hokkaido Island to the Alaska Peninsula, but they did not cross the east coast of the Gulf of Alaska. The trajectories of the cyclones that approached nearest to the coast had a longitudinal orientation. On the whole the weather favored our activities, in the great majority of cases (86.3%) wind velocity did not exceed force 5.

May of 1969 in Alaska and in western Canada was warmer than usual, and spring arrived early. During our stay in Vancouver the weather was cloudy with abundant rain showers. On 29 May the rain was continuous for about 11 hours, during which precipitation amounted to 26.7 mm. On
31 May there were only a few clouds, due to the eastward movement of an 18
outrunner of a North Pacific anticyclone.

3. Voyage from Nanaimo to the Aleutian trench and activities over the trench (1-20 June). On 31 May the "Vityaz'" left Nanaimo and set course to the Aleutian trench. The synoptic setting in the northeastern part of the ocean changed little. The American coast, as before, was barred by an anticyclonic ridge. Immediately west of it there was a large cyclone, which moved fairly slowly toward the northeast. From the occlusion point (about 50° north lat., 150° west long.,) a warm front, crossing the ridge, extended toward the coast of the United States, and a cold front extended toward Hawaii. Farther west, along a front extending approximately along 40° lat., genesis of cyclones continued to be active.

On 1 June the "Vityaz'" sailed in an anticyclonic ridge. The wind calmed down gradually, and at 1200 hours it dropped to 1.2 m/sec. Dense stratocumulus clouds and stratus clouds appeared. After 2100 hours pressure began to drop noticeably, and the wind, changing from west to southwest and south, began to strengthen from 2.6 to 11.6 m/sec at 0900 hours on 2 June. The air temperature dropped from 10.8 to 9.2° between 2100 and 2400 hours on 1 June. A dense fog, obscuring the sky, descended to the water surface. At 1800 hours on 2 June pressure dropped to 1,005.8 mb and began to rise again gradually. The cyclone passed into the corner of the Gulf of Alaska. However, slightly to the west another cyclone appeared with a front formed in its trough, and it, too, moved toward the northeast. Pressure again began to drop, wind velocity decreased from 10-14 to 3.2 m/sec in the centre of the cyclone, the weather was foggy, with stratus clouds, the air and water temperatures were decreasing monotonously as the ship continued its travel.

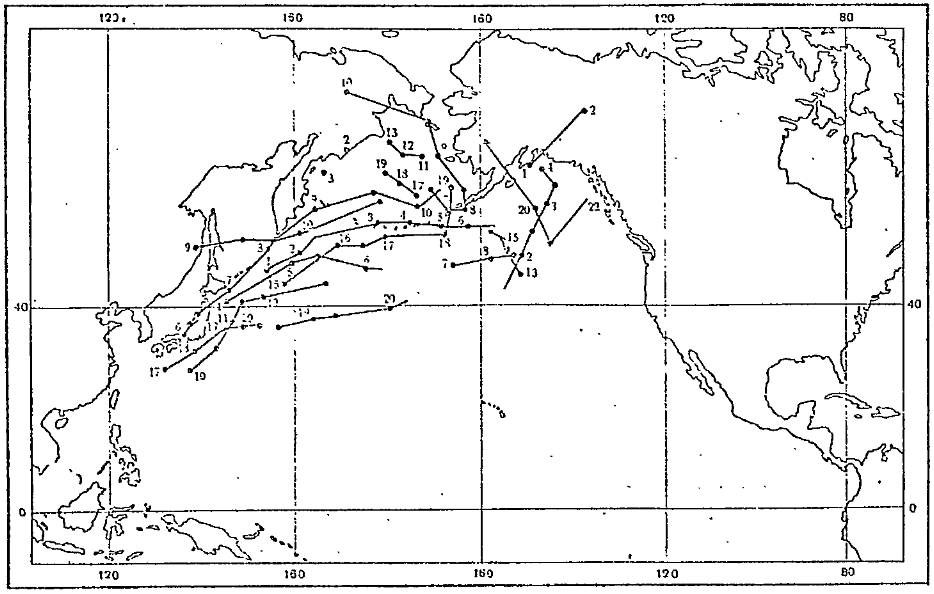


Fig. 4. Paths of cyclones during 1-20 June 1969.

After the ship passed out of the central part of the cyclone the wind increased to 9.2 m/sec and veered toward the north and northeast, the fog disappeared, and cloud cover decreased.

At the same time, the western islands of the Aleutian chain were being approached from the southwest by a deepening cyclone, which began to move along the chain toward the east (Fig. 4). The ship was separated from it by a weak mobile ridge, which the "Vityaz'" reached on 3 June. At 0900 hours on 4 June pressure reached its maximum and began to drop rapidly. The wind changed toward the south, then to the southeast, and increased to 15.4 m/sec. Stratus clouds again began to predominate, and 7.3 mm of precipitation fell during six hours. The air temperature rose from 5.4 to 6.5°. This cyclone, which had already become a high cold pressure feature over the eastern part of the Aleutian Islands, turned into an immobile central cyclone.

On 5 June the "Vityaz'" started on its 4th profile from Unimak Island across the Aleutian trench. The wind, still southeasterly and easterly, gradually weakened because of the rapid decay of the cyclone.

Along the polar front, which was situated along 40° lat., the active formation of cyclonic whirls continued. On 6 June one of these whirlwinds passed from the southwest into the sphere of circulation of an old central cyclone. The wind weakened completely, to 3.0 m/sec at 0000 hours on 7 June. A convection appeared and grew quickly, even heavy cumulus clouds made their appearance. However a high anticyclone which was situated over Kamchatka and somewhat north of it began to move to the east. Within the stratum between the surface and 500 mb the influx of cold air increased abruptly, and a daughter cyclone* deepened (from 996 to 984 mb) and moved toward the northeast. In the area of our activities stratus clouds appeared and precipitatinn began. The northeasterly wind increased to 18.4 m/sec, then turned toward the west and weakened (6-8 m/sec).

On 8 June, in the area of the old cyclone a new one appeared, gradually moving toward the north, and in the region of the Kurile Islands a new cyclone was already raging. On 9 June the ridge separating these two cyclones began to weaken considerably, and north of the Aleutian Islands

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* Here, as elsewhere in this chapter, the lack of a definite or indefinite article in Russian makes precise translation difficult, i.e., the translator is often in doubt whether reference is made to "a cyclone" or "the cyclone," "a front" or "the front." — TRANSL.

there arose a single zonally oriented depression, south of which, from Kamchatka to Alaska [the Aleutians], strong westerly winds were dominant. In this zone, several frontal sections were moving eastward. One of these reached the area of activities of the "Vityaz'" on 10 June. Stratus-rain clouds appeared, rain fell, the wind increased to storm force (20.4 m/sec), and in the wake of the front the wind weakened to 8.6 m/sec. On 11 June two more pressure waves passed. On 12 June the cyclone began to fill up rapidly, and the following day the minimum velocity of the wind was registered — 3.3 m/sec. On that day, the entire North Pacific was dominated by a dispersed pressure area. Along the polar front at 170° west long. there was a weak disturbance (1,008 mb) in the stage of a wave moving eastward. In the afternoon of 13 June it deepened abruptly (to 998 mb). The emerging cyclone rapidly drew into its circulation air masses within a radius of over 600 miles, within 12 hours pressure in its centre was already less than 988 mb, and the direction of its movement gradually changed from northeasterly to northwesterly.

In the working area the wind began to strengthen in the evening of 13 June. During the next two days a northeasterly wind of force 6 continued, the weather was overcast mostly without precipitation. In the west, south of Kamchatka, another extensive and deep cyclone moved eastward, rapidly approaching the first.

On 15 June the "Vityaz'" moved westward in order to make several trawls in the deepest parts of the Aleutian trench. The following day the cyclones approached so close to one another that at their juncture the structure of the two whirls began to break down, and a broad zone of weak winds was formed, in which the "Vityaz'" found herself on

17 June. On 18 June the wind strengthened to 14.0 m/sec, but the following day it began to weaken. On 20 June the "Vityaz'" left the Aleutian trench and set course for the southwest.

4. Transit Aleutian trench-Japan trench-Osaka-Vladivostok (21 June-10 July). During the transit from the Aleutian to the Japan trench the ship travelled mostly in the wake of the polar front, with relatively calm weather. Only twice, on 23 and 26 June, did the wind increase to force 6 and 8, which was due to the rapid movement of cyclones in this front.

Another typical characteristic of the weather on this portion of the track was dense and extensive fog over the cold waters of the Oyashio current, and subsequently fog bands over cold-water areas in the zone of intermingling of Oyashio and Kuroshio waters.

During this period there arose over northeastern China (Manchuria) a little-mobile high cyclone, which controlled the movement of the young cyclones of the polar front, determining their longitudinal trajectories along the Tsushima current into the Sea of Okhotsk.

After passage of the cyclone on 26 June the front moved off towards the south, and for 48 hours the "Vityaz'" travelled in an anticyclonic zone of weak winds. On 29 June the "Vityaz'" crossed a warm section of the polar front and found itself in tropical sea air of a summer monsoon. During 6 hours the air temperature rose from 19.8 to 23.5°, and the buoyancy of the water vapor rose from 22.2 to 27.0 mb. During 30 June-2 July the "Vityaz'" sailed in this warm (up to 24.8°) moist (up to 29.1 mb) air. The front extended along the isobars, hung over the east coast of Japan, and became nearly static; throughout this period the wind was quite even -- force 5-7.

On 2 July on our way from the area of activity on the Idzu-Bonin trench toward Osaka, the "Vityaz'" again crossed the front, the wind ceased, and humidity decreased (during one period to 22.4 mb). On 3 July the ship arrived at Osaka. During 4-5 July a strong cyclone passed with heavy wind and abundant rain; during 20 hours, there was 34.2 mm of precipitation. On 6 July we had hot, sunny weather. On that day the ship left Osaka and throughout the next day there was pouring rain from the heavy overcast of the polar front. On 7 July the "Vityaz'" passed through the Shimonoseki Strait into the Sea of Japan. During the night the cyclone deepened abruptly toward the south of the Korean Peninsula. Along our path, the cyclone caused on 8 July northeasterly wind up to force 7 and steady rain. The cyclone accompanied the "Vityaz'" to Vladivostok, where we arrived on 10 July.

WATER MASSES AND WATER DYNAMICS OF THE GULF OF ALASKA AND THE EASTERN PART OF THE ALEUTIAN TRENCH

By V. S. Arsen'yev, L. I. Galerkin, V. V. Leont'yeva

The Gulf of Alaska and the adjacent part of the Aleutian trench belong to the eastern subarctic region of the Pacific Ocean. Hydrologic conditions and the dynamics of the waters of this area are quite peculiar, and derive primarily from the general system of currents that form part of the subarctic cyclonic rotation (Burkov, 1968).

A direct influence on the hydrologic conditions of the area is exercised by the Aleutian (Subarctic) and the North Pacific currents, which make up the Alaska Current (Fig. 1). At intermediate depths (200-1,000 m) the circulation, it seems, also affects the water of the California abyssal countercurrent, which penetrates into the Gulf of Alaska in the form of an independent flow up to the latitude of Baranof Island (Dodimead, Favorite, Hirano, 1963).

Among the factors contributing to the specific characteristics of the hydrology of the Gulf of Alaska and the eastern part of the Aleutian trench we should note the excess of precipitation over evaporation throughout the entire year: over 90 cu. centimeters per year (Jacobs, 1951), and the abundant continental runoff of such rivers as the Copper, Fraser, Columbia, etc. The melting of sea ice, snow and glaciers during the summer increase still further the freshening of the sea water. As a result, the water of the Gulf of Alaska has a structure which has been described by many investigators, following Tully and Barber (1960) as that of an estuary.

(Text cont. on page 39)

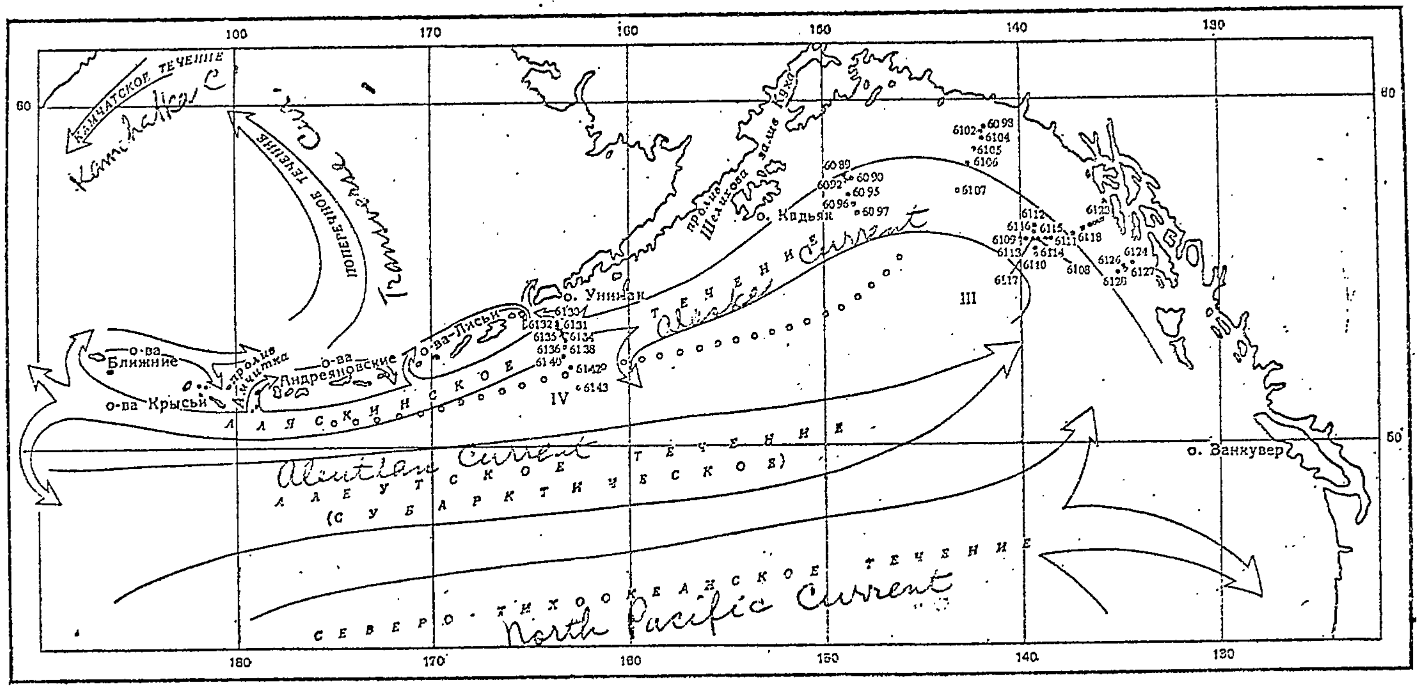

Fig. 1. General circulation scheme in the eastern part of the Subarctic region of the Pacific (Favorite, 1967) and the Aleutian waters (Arsen'yev, 1967). (Roman numerals designate profiles of the 45th cruise of the "Vityaz'," Arabic numerals designate hydrologic stations.)

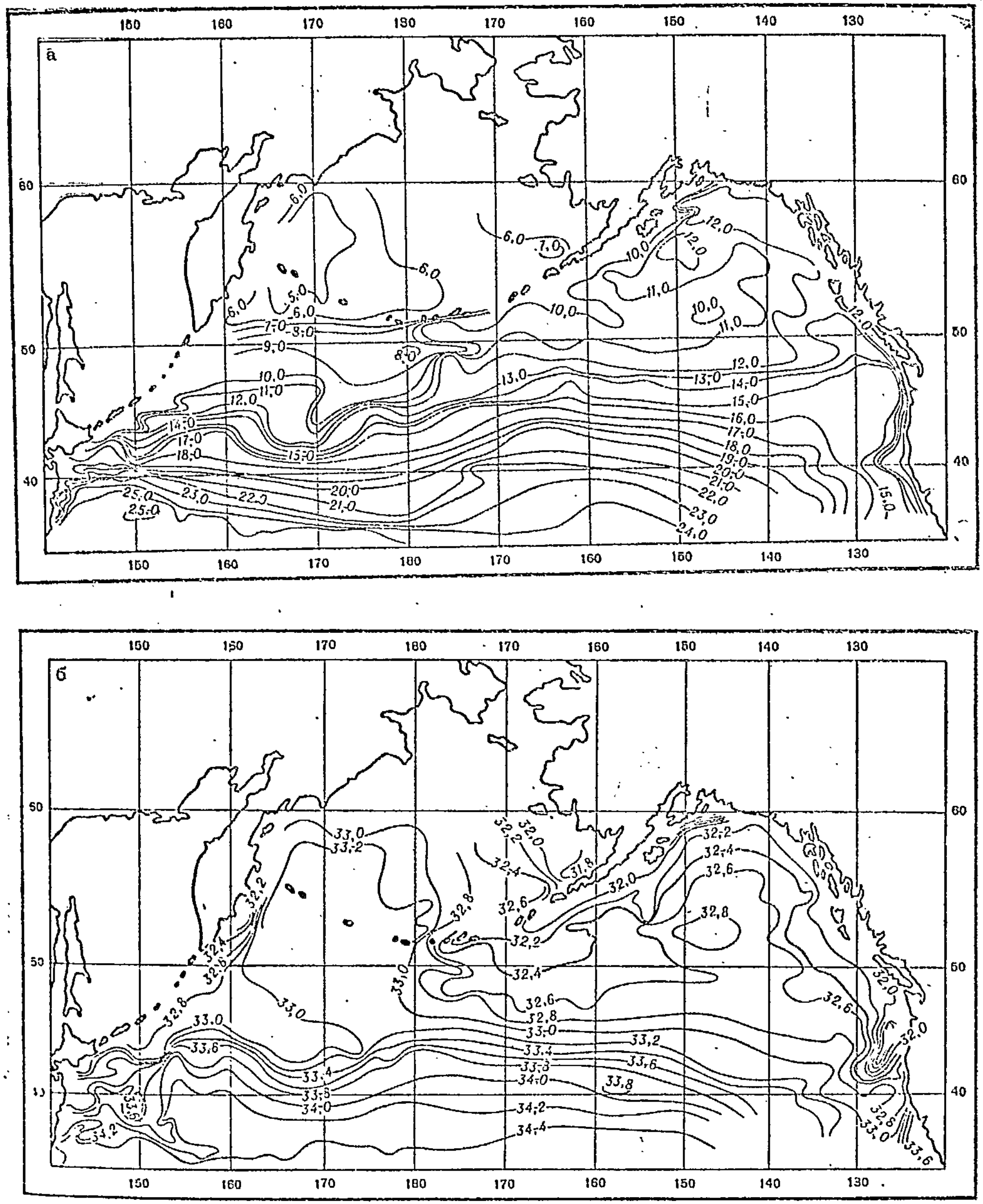

Fig. 2. Temperature (a) and salinity (b) in the surface layer of the North Pacific, after data from the "Norpac" expedition, summer of 1955.

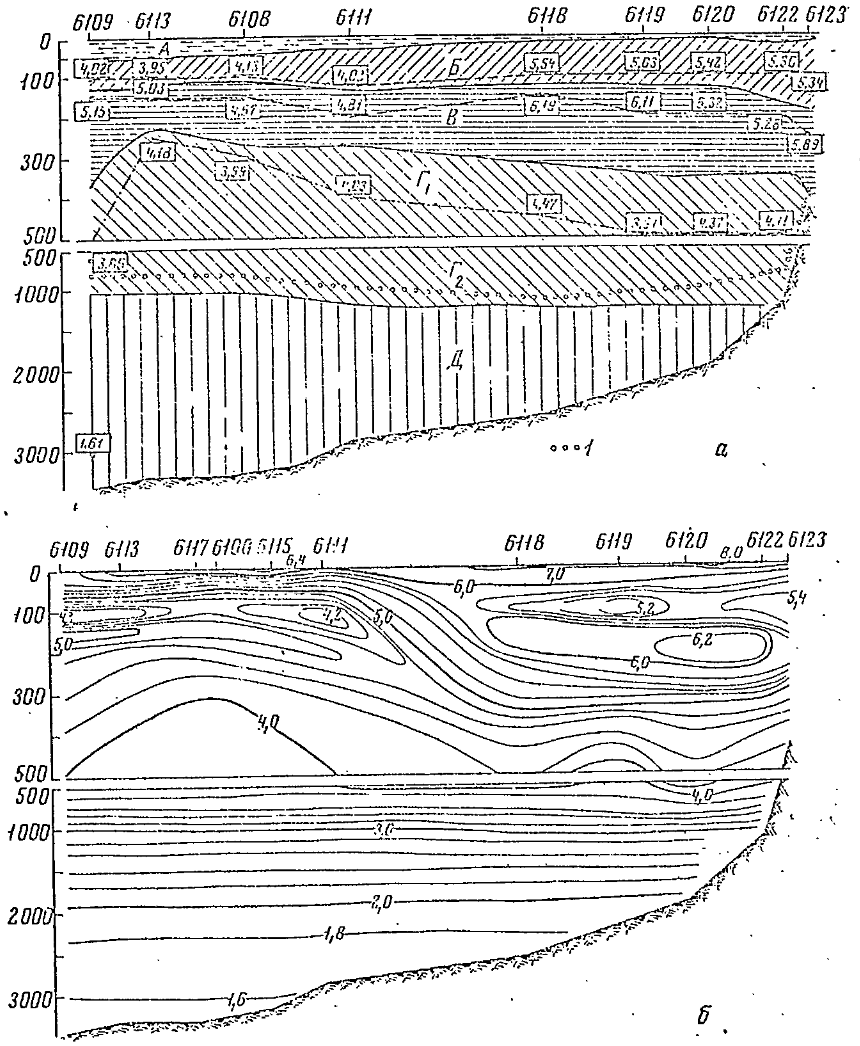

Fig. 3. Water masses (a) and temperature (b) at the third profile in the Gulf of Alaska. 1 -- position of oxygen minimum.

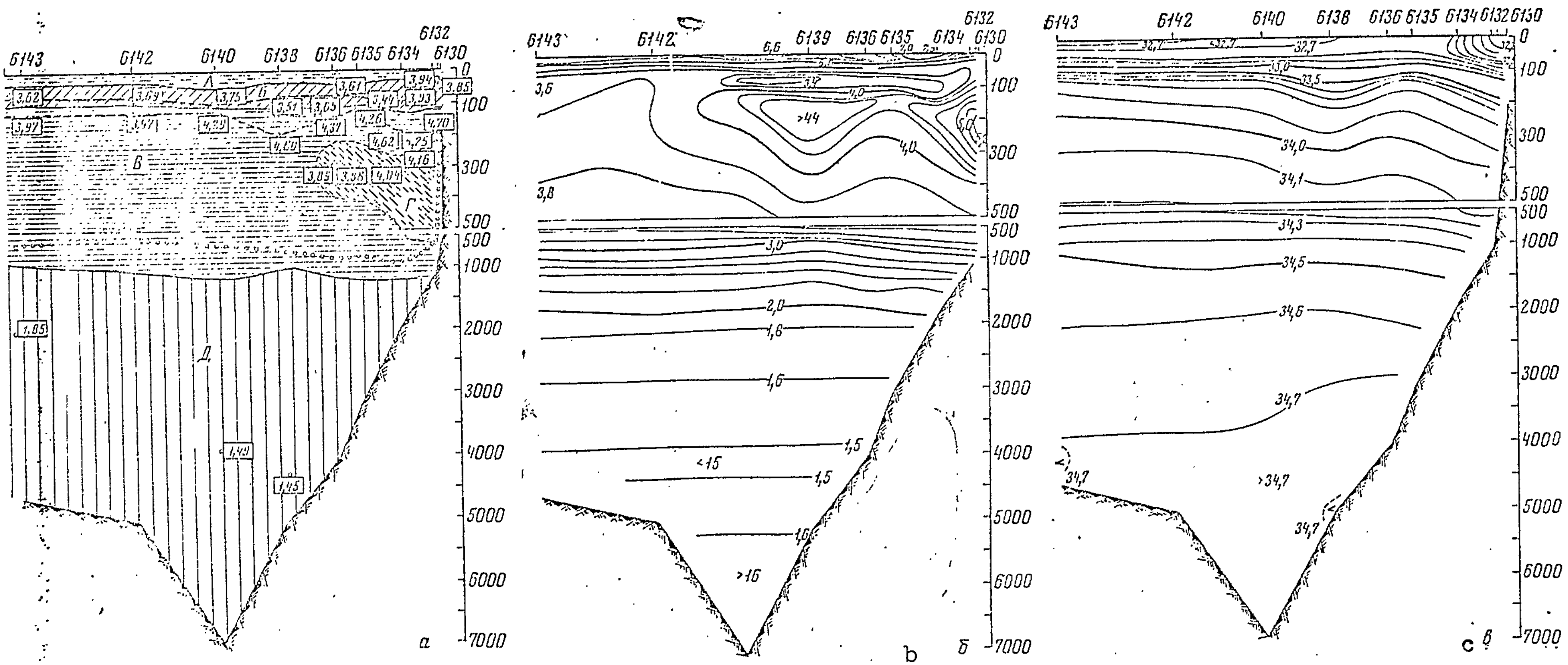

Рис. 4. Водные массы (*а*), температура (*б*) и соленость (*в*) на 4-м разрезе к югу от о-ва Унимак

Fig. 4. Water masses (a), temperature (b) and salinity (c) at the third profile, south of Unimak Island

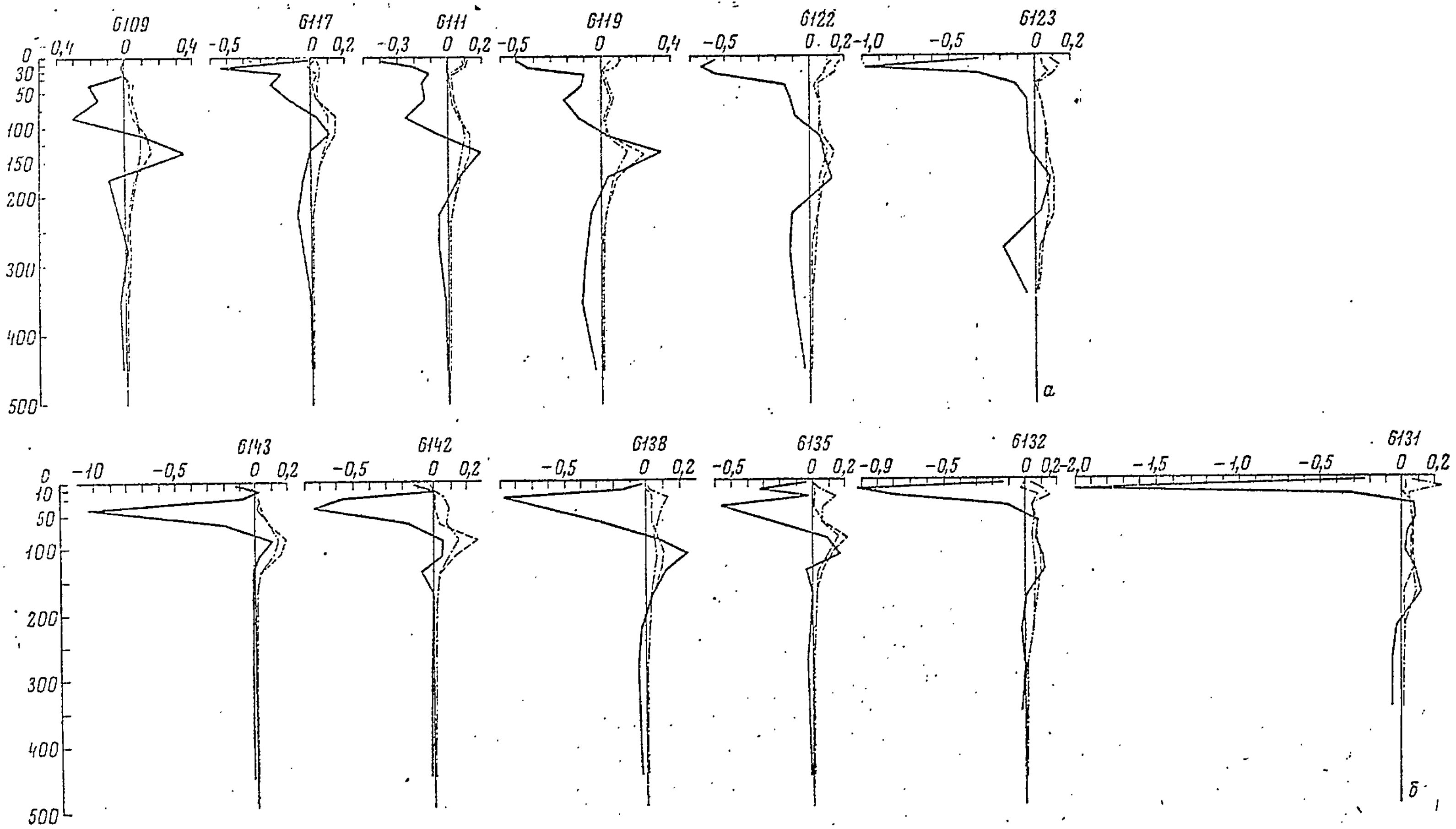

Fig. 5. Vertical gradients of temperature (°C/m·10), salinity (°/oo/m·10) and density (conventional units of density/m·10) at the stations of the third profile (a) and fourth profile (b).

In order to give a clearer idea of the area under investigation against the general hydrologic background of the North Pacific, we have provided (Fig. 2) detailed maps of the temperature and salinity from the survey of the "Norpac" in the summer of 1955. Distinctive characteristics of the Gulf of Alaska are a relatively high temperature (in comparison with the western part of the ocean) and low salinity. Two freshening "hearths" can be distinguished, where salinity is below 31.6°/oo -- the area northeast of Kodiak Island, and an area south of Vancouver Island, outside the gulf. These are areas of the main continental runoff.

During April-June 1969, in the course of Cruise 45 of the "Vityaz'", biological studies were accompanied by hydrologic observations during 4 profiles (Fig. 1), which made it possible to define the main water masses and to draw some conclusions concerning their dynamics. For their analysis we used generally known methods and equipment (Shtokman, 1943; Radzikhovskaya, Leont'yeva, 1968).

The main water masses of the area of investigation were most fully represented at the third profile (Gulf of Alaska, Fig. 3) and the fourth profile (eastern part of the Aleutian trench, Fig. 4).

The surface water mass, resulting from spring modification, was shown on profile 3 to extend into the Gulf of Alaska to a depth of 15-20 m along the shore and up to 50 m in the seaward part.
In the eastern part of the profile (stations 6118-6122) one notices the 23
influence of coastal waters: the surface salinity is less than 32.4°/oo, the temperature reaches 7-8°. In the western part of the section the thermosaline characteristics of the surface water mass are nearer to those of the open gulf and the ocean: the temperature is 5-7° (Fig. 3-b), the

salinity is 32.4-32.5°/oo. Throughout the greater part of profile 4 across the Aleutian trench the surface water mass, like in the Gulf of Alaska, extended to depths of 40-50 m, and along the northern margin, to 20-25 m. The thermosaline characteristics differed little from those of profile 3, although salinity was somewhat lower.

Subarctic waters are characterized by a distinct annual 24
cycle of the surface temperature. Toward the end of the summer the surface water mass is warmed up considerably, and the seasonal thermocline attains its maximum. During winter, owing to thermal convection and wind-produced mixing, the layer warmed during the summer is destroyed, and a cold isothermic layer is formed, extending from the surface to 120-200 m.

During the period of observations in the thermocline*[1], separating the surface water mass from the lower cold subsurface water mass, the vertical temperature gradient was always small (table, Figs. 5-a, 5-b); this again shows that the hydrologic spring had only recently begun in the area.

The cold intermediate (or subsurface) water mass was shown during profile 3 (Fig. 3-a) to be most fully developed in the coastal area, in the transitional zone from continental shelf to slope, where its lower boundary 27
runs at a depth of over 200 m, while at the ocean end of the profile the

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* Although the authors are evidently familiar with this term, they use here the Russian word "skachok," lit., "jump." -- TRANSL.

[1] Owing to the small gradients, the term "thermocline" can only be used conditionally here. Many investigators (Filyushkin, Kuksa, 1968) define a thermocline as having a temperature gradient of not less than 0.1°/m.

Maximum gradients of temperature (seasonal thermocline) density and salinity (halocline) in profiles 3 and 4

Station	T	S	D	Stn.	T	S	D
Profile Разрез 3				Profile Разрез 4			
6109	0,316	0,158	0,092	6130	0,860	0,200	0,130
6113	0,248	0,202	0,123	6131	1,930	0,131	0,088
6117	0,550	0,145	0,112	6132	1,030	0,102	0,068
6108	0,340	0,223	0,108	6134	1,350	0,166	0,104
6115	0,540	0,168	0,116	6135	0,560	0,212	0,160
6111	0,400	0,133	0,100	6136	0,955	0,093	0,072
6118	0,640	0,172	0,068	6138	0,880	0,088	0,056
6119	0,570	0,254	0,156	6140	0,865	0,122	0,084
6120	1,530	0,115	0,072	6142	0,740	0,267	0,156
6122	0,630	0,144	0,104	6143	1,035	0,189	0,140
6123	0,990	0,104	0,076				

T -- Temperature gradient, °C/m·10

S -- Salinity gradient, °/oo/m·10

D -- Density gradient, density units/m·10

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boundary does not drop below 125 m. This is understandable, as the process of formation of the cold subsurface layer takes place under the influence of the brumal cooling of the active layer, which (like the vernal-estival warming) always begins at the shore and is particularly intensive there.

The core of the cold subsurface water mass in the profile was located at a depth near the lower boundary of that mass (Fig. 3-a). The lowest temperature in the core was 4-5°, the corresponding salinity was about 33°/oo.

At profile 4, south of Unimak Island, the temperature of the core of the cold subsurface layer was considerably lower than in the Gulf of Alaska, and it never exceeded 3.8°.

The warm intermediate water mass (or warm intermediate layer) extended in the eastern half of profile 3 to a depth of 300-400 m, and in the western half to 240-300 m.

The characteristics of this layer in the western and eastern parts of the profile differ mainly in temperature; the maximum temperature of the core east of station 6111 was up to 6.3°; west of it, it was up to 4.7-5.2°; the corresponding salinity throughout the profile was about 33.5°/oo. The core of the layer was nearer the upper boundary.

A comparison of the position of the lower boundary of this layer (Fig. 3-a) with the character of the distribution of the temperature (Fig. 3-b) leads to the assumption that, against the background of the general cyclonic circulation of the water of the Gulf of Alaska, there exists west of station 6118 a local cyclonic whirl causing a rise in the water in the region of stations 6108, 6113, 6115, and 6117.

Opinions differ as to the origin of the warm intermediate layer in the Subarctic region of the Pacific. However, in the Gulf of Alaska the relatively high temperature of the core of this water mass (about 6°) could probably be maintained only if an advection brought in warmth from the North Pacific Current.

A TS analysis points to the presence in the study area of yet another intermediate water mass. In profile 3 the water mass is situated between the warm intermediate layer and abyssal waters; its upper boundary is at a depth of 250-300 m, its lower boundary at 1,000-1,200 m; the geometry of the TS curves of all stations indicates that it has two layers (Fig. 3-a).

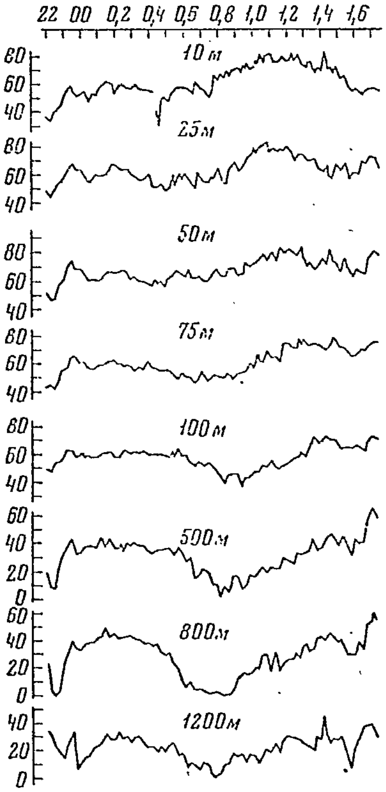

Fig. 6. 24-hour record of velocity of currents at horizons of 10, 25, 50, 75, 100, 500, 800 and 1,200 m.

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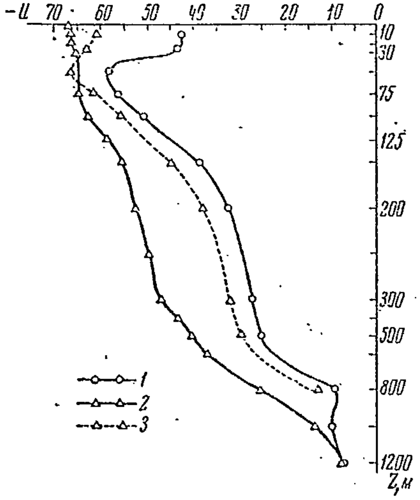

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Fig. 7. Vertical distribution of zonal component of velocity at station 6137
1 -- vector average; 2 -- arithmetic average; 3 -- geostrophic component of velocity in the race of the Alaska Current.

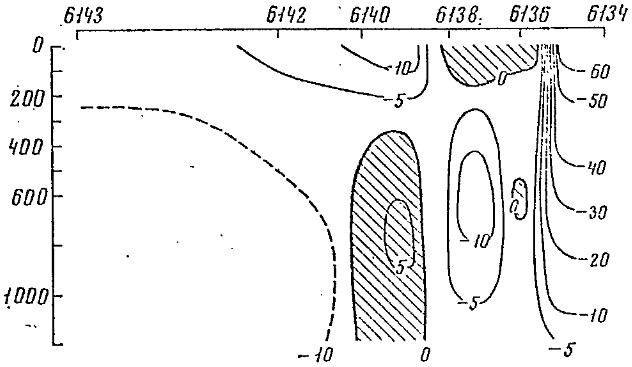

Fig. 8. Geostrophic component of zonal velocity at profile 4 south of Unimak Island.

The temperature of its core ranges from 3.9° at the western end of the profile to 4.5° in the eastern part (station 6118); the corresponding salinity is about 34°/oo.

A reference to this layer is found in only one source known to us (Dodimead, Favorite, Hirano, 1963). There it is called the Central Subarctic Water Mass, and is regarded as typical of the greater part of the Subarctic region of the Pacific. However, as shown by data from mass observations, it is not found west of 180°. The genesis of this mass is not explained. It is possible that its formation at intermediate horizons of the northeastern Pacific is due to the mixture and subsequent descent of warm (over 12°) and salty waters of the North Pacific Current and the relatively cold (less than 3.5°) and less salty waters of the Subarctic (Aleutian) Current.

In profile 4 in the eastern part of the Aleutian trench the Central Subarctic Water occupies only a small space along the islands (Fig. 4-a); the temperature of this water mass and the entire intermediate warm layer is here considerably lower than in the Gulf of Alaska.

The abyssal and benthonic waters situated below the intermediate layer are distinguished by relative uniformity; their thermosaline characteristics fluctuate narrowly. Thus, in profile 3 the temperature at the upper boundary of the abyssal waters was 2.9-3.2°, the salinity 34.3-34.4°/oo; at 3,000 m and deeper the corresponding values were 1.5-1.6° and 34.6-34.7°/oo. It is believed that these water masses are of Antarctic origin, although the views as to their paths in the Pacific differ considerably. There is, however, no doubt that these are the "oldest" water masses in the Subarctic. 29
Some scientists (Bennet, 1959; Tabata, 1961, and others) assume that in

the region of the quasistationary Alaska cyclonic rotation ("Alaska gyral") there occurs a rise of abyssal waters to the subsurface layers (80-100 m).

In order to understand the character of water transfer and the vertical structure of currents in the area, we carried out instrumental measurements at two points. The most interesting results were obtained at a station south of Unimak Island. Even at a depth of 1,200 m observed rates of velocity exceeded 40 cm/sec (Fig. 6). From the 75-m horizon and lower one can observe an increase in the 12-hour tidal component. It is most distinct at the 800-m horizon, where two velocity maximums are noted at 0300 and 1500 hours. The maximums are less distinct, but fairly well marked, throughout the entire water stratum from the surface to 1,200 m; the time of their arrival is almost the same throughout the vertical line.

A hodograph of average velocity constructed from 12 horizons to 1,200 m shows the persistent predominance of a zonal component with a westerly direction. The scattering of average directions throughout the stratum is grouped in a sector of about 70°, and in the upper layer from 10 to 500 m the sector does not exceed 30°.

The zonal component of average velocity (Fig. 7) attains its maximum (about 60 cm/sec) at the 50-m horizon and decreases at the surface to 40 cm/sec and at the 1,200-m horizon to 7 cm/sec. The decrease of the average zonal component in the upper 10-25-m layer is probably due to observation characteristics. We know that on windy days current meters in the uppermost horizons experience on the wind wave strong chaotic movements behind the support buoy. Because of this, the scattering of equipment readings is usually greatest in the upper horizons. During vector averaging (geometric method) for any particular period of time this leads to a very substantial reduction of the velocity module. Equipment at deeper levels is more protected against the buoy tugs and the damping action of the cable and the weight of equipment suspended above.

Therefore, while retaining the computation of average direction by the geometric method, it is useful to carry out an arithmetic averaging of the velocity module. A vertical distribution of arithmetically averaged velocities is shown in Fig. 7-c. As could be expected, these velocities turned out to be somewhat higher than the geometric ones. The zonal component (Fig. 7) was determined from the same geometric directions, the shape of the two curves is nearly identical.

The longitudinal component of average velocity is substantially less than the zonal one, and does not exceed 15-17 cm/sec. From the surface
to a depth of 150 m it is directed toward the north, and beginning at 200 30
meters, toward the south. Its maximum values were observed at 100 and 800 m.

In order to obtain an idea of the currents throughout the profile across the Aleutian trench, we calculated at the standard horizons by the dynamic method current velocities in relation to a surface reading of 1,500 db (Fig. 8). In order to compute the velocity of geostrophic currents we used all data from hydrologic observations obtained during the profile. Inasmuch as the profile runs almost longitudinally, the computed velocities may with sufficient approximation be regarded as that zonal component of the full geostrophic velocity which would be obtained from the computation for a hydrological survey covering the area.

The highest velocities of geostrophic currents were observed in the northern part of the profile and were directed toward the west. Relatively high velocities persisted throughout the vertical line. The distribution of values of zonal geostrophic velocity along one of the dynamic vertical lines of the profile is shown in Fig. 7. In the central and southern part of the profile the velocities do not exceed 5-12 cm/sec, and there is a weak easterly countercurrent. Single hydrologic measurements along the profile do not allow deductions concerning the persistence of the computed current. However, our results from the computation of zonal components are in good agreement with charts of average geostrophic currents lasting many years (Arsen'yev, 1967; Burkov, 1968). Judging from these charts, the Alaska Current consists of a relatively narrow band of a very intensive westerly geostrophic flow that clings to the southern coasts of the Aleutian Islands.* South of Unimak Island this flow is very narrow and does not exceed 50-60 miles, while somewhat farther to the south there arises a cyclonic vortex with low horizontal velocities and easterly countercurrents.

It is interesting to compare computed and observed velocities. The location of the vertical line with the highest dynamic velocities is only 18 miles distant from the point of instrument observations, and such a comparison of computations and observations is therefore justifiable. The zonal component of dynamic velocity exceeds observed values at all depths (Fig. 7). The general appearance of the curve indicates a fairly

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* This is also confirmed by data from instrument observations (Favorite, 1967).

uniform drop in velocity. The coincidence of observed and computed velocities at the lowest horizon (1,200 m) may serve as fairly solid evidence that the read-off dynamic surface was chosen correctly and provides reliable results in computing the zonal component.

It is customary to assume that dynamic velocities ought to be less than observed ones. The reason given for this is that the dynamic velocity is a certain average value related to the mid-point between two hydrologic stations, whereas the observed velocities relate to real currents at an actual point. In our case, the dynamic velocities are greater than the observed ones throughout the vertical extent. This may be due to a difference in the geographic position of the vertical lines: the dynamic vertical line is situated nearer the islands, in the race of the main, strongest, flow, while instrument observations were carried out 18 miles to the south. A second reason may be that the dynamic velocities were obtained from one-time hydrologic stations over relatively short periods of time, while observed velocities are averaged over 24 hours, which substantially reduces their maximum values. A comparison of dynamic velocities with observed ones after arithmetic averaging yields a somewhat better coincidence.

A decrease in observed velocities in the upper layer 31
(10 and 25 m) is probably due not only to the jerking of the buoy but also to the distribution of wind stresses and the development of purely drift-type components of the surface current. Their zonal components may be directed toward the east and produce corresponding distortions in the regular vertical pattern which, it seems, are caused mainly by horizontal pressure gradients in the water stratum.

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Instrument observations in the Gulf of Alaska have shown weak currents of unstable direction. Not only observational data but also those averaged over 24 hours indicate a chaotic and erratic movement of vectors from day to day, in all directions. A joint correlation of current vectors in time and vertically also fails to reveal any persistent pattern or a layered current structure.

Concluding the analysis of our data, we shall note the findings of most interest.

1. The transfer of waters in the Alaska Current is accompanied by a substantial transformation of the surface mass and especially the intermediate masses: as one moves in a westerly direction, these water masses increase in salinity and become colder. The temperature of the core of the cold intermediate layer in the eastern part of the Aleutian trench (profile 4) averages 2° less than in the Gulf of Alaska (profile 3); in the core of the warm layer the correponding difference in temperatures is 1-1.5°.

2. The central Subarctic water mass gradually peters out from east to west in the Alaska flow; occupying a tremendous space in the Gulf of Alaska, it is found only along the northern margin of the flow in the Aleutian trench. Its place is taken by the intermediate warm water mass.

3. Vertical gradients of basic hydrologic elements in the area under study reveal no substantial differences. These gradients are always small, even though they do fluctuate within two orders of magnitude.

4. In the Alaska flow south of Unimak Island, a single-layer current structure of the predominant westerly direction persists to a depth of about 1,000 m, with a gradual drop in velocity from surface to bottom.

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WATER STRATIFICATION IN THE GULF OF ALASKA IN THE SPRING OF 1969

By V. N. Novozhilov

The formation of water structures, temperature fields and salinity in the northeastern Pacific has been the subject of numerous Soviet and foreign studies. However, the investigators have concerned themselves mainly with the qualitative aspect of the problem; among the published studies there are none dealing with the characteristics of the layers having the greatest vertical gradients of temperature and salinity. An assessment of the parameters of these layers is of great importance in the analysis of the distribution of organisms in the active layer of the ocean. In the present study we have made an attempt to provide a quantitative characteristic of the vertical gradients of temperature, salinity and density of the sea water on the basis of standard hydrologic observations carried out during Cruise 45 of the "Vityaz'" with a methodology adopted by by Institute of Oceanography of the Academy of Sciences of the USSR (Aratskaya, Filyushkin, 1963).

As we know, the structure of the upper 100 meters of Subarctic water is subjected to pronounced seasonal changes. Nearly complete isothermality during the winter is replaced during the summer by a persistent and distinct thermocline. Spring is a transitional period, when, as a result of the beginning warming trend and strong winds, the homogeneity of the surface layer is disturbed and initially small vertical temperature gradients emerge.

The "Vityaz'" worked in the Gulf of Alaska during May and June 1969. Data from observations on four profiles show that the formation of a seasonal thermocline was in the initial stage.

In the character of the distribution of vertical temperature gradients the upper 500-meter stratum of the ocean may be divided into three layers: a surface layer of negative gradients (decrease of temperature with depth); a layer of positive gradients; and a second layer of negative gradients. Let us review the general characteristics of the temperature stratification that was typical of all profiles. We shall take as an example the distribution of gradients in profile 3 (Fig. 1) at the start of May.

The top 30 meters were almost homogeneous. Below that layer, negative temperature gradients gradually increased, and at the 50-meter horizon, on the average, they attained the maximum (seasonal thermocline). In subsequent profiles an increase in the gradient in the surface layer was observed. Wind-induced mixing caused this intermediate thermocline to descend somewhat. In its place, a new thermocline emerged, etc. As a result of this, some stations indicated several steps in the increase of negative gradients between the surface and the seasonal thermocline. Canadian investigators (Dodimead et al., 1963) call such layers "temporary." A stepped distribution of vertical temperature gradients indicates that the formation of a seasonal thermocline in spring seems to have a pulsating character. The same assumption was made by P. P. Ganson (1961), who investigated the thermal structure of the layer in the same region, but during autumn.

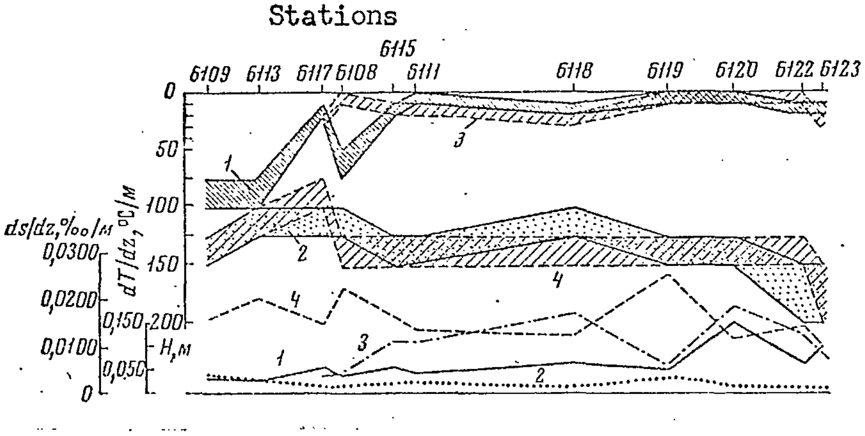

Fig. 1. Maximum vertical gradients of temperature and salinity on profile 3, and their position by depths.

1 -- layer of negative temperature gradients; 2 -- layer of positive temperature gradients; 3 -- secondary halocline; 4 -- main halocline.

Below the seasonal thermocline there is a layer of positive vertical temperature gradients. This inversion layer was observed on all four profiles, differing only in the values of the gradients, their thickness and position. However, as has been emphasized by Dodimead (1961), such a structure is more typical of the Subarctic waters in the northwestern Pacific. Its emergence in the northeastern part of the ocean is governed by the degree of cooling during the preceding winter. 33

Below the inversion level there is a layer of negative vertical temperature gradients. It has relatively low gradient values, which decrease gradually from a maximum in the upper part of the layer to practically zero at the 400-500-meter horizon.

Along with common features, the distribution of gradients in individual profiles also had distinctive characteristics.

In profile 1, which was run on 6-9 May, the upper layer from

0 to 30 m was almost homogeneous. Negative vertical temperature gradients did not exceed 0.006°C/m. With depth, the gradients gradually increased to the top values of 0.025-0.027°C/m in the 50-75-meter layer. At some stations of profile 2 (10-14 May), as the sea warmed up, relatively high negative gradients (maximum 0.064-0.076°C/m) arose in the levels 0-10 and 10-20 m. Throughout a large part of profile 3 this temporary layer was observed without interruption, and the values of maximum gradients in it varied from 0.050 to 0.150°C/m. At the same time we also continued to observe the layer of maximum negative gradients found in profile 1 between 50 and 75 m. In other profiles, the thickness of the layer and the gradient values did not undergo any basic change, but in profile 3 the depth at which the layer was located was less stable than in profile 1: it varied from 30 to 100 m. At two near-shore stations of that profile -- 6122 and 6123 -- the layer was not observed at all. Data from standard observations show that these two layers of negative vertical temperature gradients are most distinct. In addition, bathythermograph observations at some stations have shown that between them there are small intermediate maximums of vertical gradients.

These basic features of the thermal structure also persisted in profile 4, although it was run later and far from the first three. Here, too, we observed beneath the top 30 meters of homogeneous water an increase of gradients to a maximum of 0.080-0.100°C/m in the layer 30-50 m. At the near-shore stations of the profile this layer rose to 10-20 or 0-10 m, 34
and the gradients in it increased to 0.193°C/m. At the three stations located farthest out to sea we observed a renewed increase in gradients to 0.023°C/m in the 0-10-meter layer. Nevertheless, some data indicate that the thermocline in this profile arises in a somewhat different way

than in the preceding ones. A comparison of bathythermograph series of 24-hour stations 6111 (profile 3) and 6144 (profile 4) showed that with identical temperatures at the upper boundaries of the thermocline (6.0-6.2°) the temperature at the lower boundary at station 6144 was lower by 1.0-1.5° than at station 6111, occupied a month previously.

Another peculiarity of the thermal structure in this profile was a layer of positive vertical temperature gradients, situated immediately below the seasonal thermocline. Positive vertical gradients were observed in profile 1 within the layer 75-125 m, with the exception of the near-shore station 6089, where a temperature inversion was observed in the layer 50-100 m. Maximum positive gradients were noted in the layer 75-100 m, namely, 0.020-0.050°C/m. The same distribution of gradients was observed at the outermost stations of profile 2 (6107 and 6106). In the remaining part of the profile the layer with positive gradients lay somewhat deeper: from 150-200 m at station 6105 to 100-200 m at the shore, and the maximum gradients were less: 0.010-0.020°C/m. In profile 3 the position of the layer of positive temperature gradients varied from 75-125 m to 150-250 m, with a certain tendency to descend near the shore. Approximately the same pattern was noted in the variation of gradient maximums: from 0.030°C/m at 100-125 m in the seaward part of the profile to 0.010°C/m at 150-200 at the shore. At the near-shore stations of profile 4 the layer with positive gradients was much thicker: from depths of 20-120 m at station 6130 to 100-200 m at station 6134. Farther south the upper boundary of the layer remained at the 75-m horizon, while the lower boundary rose to 125 m (station 6143). Gradient maximums fluctuated from 0.005 to 0.034°C/m and occurred mainly between 100 and 125 m.

Below the layer with positive gradients we again observed negative vertical temperature gradients, whose values, as a rule, did not exceed 0.020°C/m, and even so this occurred mainly directly below the positive-gradient layer. With depth, the gradients gradually decreased to 0.000-0.003°C/m at 400-500 m.

As we know, the values of vertical gradients computed from standard observations are lower than the actual values. In our own computations the diminution varied from 0 to 93%, averaging 51% of bathythermograph readings. During summer, when the seasonal thermocline is more pronounced, the diminution is obviously bound to be greater.

Apart from long-term processes (brumal cooling, estival warming), there are a number of factors that affect the formation of the thermocline over 24-hour periods. It is interesting to assess the hour-by-hour changes in the thermocline parameters at the start of the warming period. This can be done most conveniently in layers with the greatest vertical gradients.

In the course of 24 hours, we observed all three abovenoted layers -- the temporary near-surface layer with negative vertical temperature gradients, the seasonal thermocline, and the layer of positive vertical gradients. Twenty-four-hour changes in solar radiation affected only the near-surface layer. The parameters of the other layers underwent irregular changes in the course of 24 hours. As an example we may cite a 20-hour bathymetric series carried out at station 6111 (Fig. 2). During the hours of greatest warming (1000-1400 hours local time) the maximum gradients were stable in the 10-20-meter layer. During the night, the thickness of this near-surface layer decreased to 1-5 m, and the position

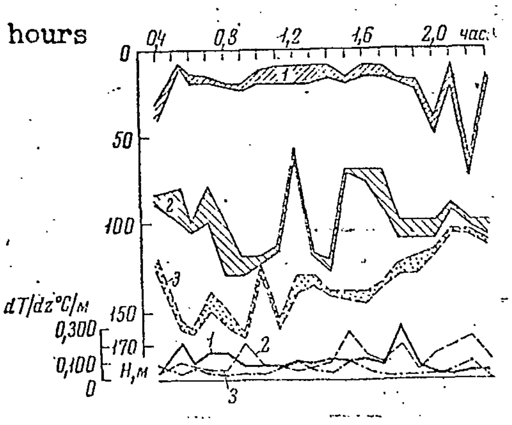

Fig. 2. Hourly changes in maximum vertical temperature gradients and their depths at station 6111.

1 — temporary layer of negative gradients; 2 — seasonal thermocline; 3 — layer of positive gradients.

Change in the parameters of layers with maximum temperature gradients during 24 hours (station 6144)

Indicator	Seasonal thermocline		Layer with temp. inversion	
	Range	Average	Range	Average
Vertical gradient, °C/m	0.1-0.6	0.276	0.01-0.1	0.03
Thickness of layer, m	2-7	4	2-20	9
Depth of layer, m	28-48	39	112-140	119

varied from 10 to 70 m. The seasonal thermocline, on the average, was located at a depth of 100 m. During 24 hours, its position varied from 60 35
to 130 m, and its thickness from 2 to 20 m. The negative vertical gradients in these layers were approximately the same and varied during the period of observation from 0.020 to 0.300°C/m. The decrease in the gradients of the temporary layer, as a rule, corresponded to an increase of gradients in the thermocline, and vice versa. The depth at which the layer with the greatest

positive temperature gradients was located fluctuated from 105 to 165 m, averaging 140 m, and the thickness of the layer fluctuated from 2 to 10 m, averaging 5 m. Toward the end of the observations the depth and thickness of the layer decreased somewhat. Vertical gradients in the layer were relatively small, from 0.2 to 0.1°C/m.

As a second example of the 24-hour cycle in vertical temperature gradients we may cite a 24-hour bathythermograph series carried out at station 6144 (22 measurements). A near-surface layer of high temperature gradients was not observed here. The depth and thickness of the seasonal thermocline fluctuated narrowly. Gradients in this layer were greater than at station 6111 (table).

In terms of salinity, the main feature of the top 500 meters was the existence, at a depth of 100-150 m, of a layer of increased vertical gradients. This halocline has often been mentioned in scientific papers. Dodimead and his co-authors (Dodimead et al., 1963) reviewed the salinity structure at station "R" (50° north, 145° west) and showed that the basic halocline persists throughout the year. During summer there is a secondary halocline that coincides with seasonal thermocline, which is highly distinct at that time (Dodimead, 1961). A secondary halocline arises and develops, it seems, in the same manner as the temporary thermocline.

Observations during Cruise 45 of the "Vityaz'" confirmed these deductions. The distribution of vertical salinity gradients in depth was simpler than that of temperature gradients. To a depth of 500 m the former were always positive, and only at some stations the 0-10-meter layer showed a decrease of salinity with depth. Usually the vertical salinity gradients increased gradually with depth from 0 in the 0-10-meter layer to a maximum 36 of 0.014-0.023°/oo/m in the 75-100-meter layer in profile 1, and in the seaward part of profile 2. In the landward part of profile 2 the maximum salinity gradients (like those of temperature) were noted in the 150-200-meter layer and amounted to 0.010-0.016°/oo/m. In profile 3 and the larger part of profile 4 the maximum vertical salinity gradients -- 0.010-0.026°/oo/m -- were observed mainly in the 125-150-meter layer. At stations 6131 and 6132 near the Aleutian Islands the 25-200-meter layer had almost uniform salt content (gradients below 0.010°/oo/m).

Apart from the main halocline we noted the first indications of an increase in salinity gradients in the near-surface layer, i.e., the emergence of a secondary halocline. It was most distinct in profile 3 (Fig. 1). The secondary halocline was situated in the 0-10-meter layer directly below the temporary thermocline, and at the landward stations the two layers coincided. The maximum vertical gradients of the main and the secondary halocline had the same averages. In the other profiles the maximum gradients of the emerging secondary halocline were 0.01°/oo/m.

In all profiles, vertical salinity gradients below the main halocline decreased with depth, and approached zero in the 250-500-meter layer.

The peculiar pattern of vertical gradients of temperature and salinity left its imprint on the pattern of vertical density gradients in the area under study. As shown by the curves of these three parameters, the role of temperature gradients was small, and the vertical density gradients were determined mainly by those of salinity: their vertical-distribution curves are almost the same.

The surface layer from 0 to 30 m was almost uniform in density. 36
Below it, density gradients increased to the maximum values of 0.020 conventional units per square meter in the 100-500-meter layer, i.e., in the main halocline; in the same layer we observed the maximum positive temperature gradients. Where negative temperature gradients were noted in the near-surface layers, corresponding density maximums were also observed, irrespective of the value and sign of the salinity gradients. If there was also a secondary halocline, the surface maximum of density gradients was particularly distinct.

As the seasonal thermocline develops, the corresponding vertical density gradients will also increase. During the period of maximum warming this pycnocline will, apparently, be more distinct than the pycnocline corresponding to the main halocline. During autumn, the seasonal thermocline and the corresponding pycnocline will gradually decay and descend, and there will be a tendency toward the merger of the two pycnoclines.

Conclusions

1. During the period of observations the seasonal thermocline was in the initial development stage.

2. The maximum values of vertical temperature gradients did not exceed 0.2°C/m. In the 0-500-meter layer they changed their sign twice [i.e., from positive to negative and vice versa].

3. Twenty-four-hour changes in the characteristics of layers with the maximum temperature gradients were of the same order as spatial changes in the area under study.

4. Vertical temperature gradients computed for standard layers are on the average lower by a factor of two than the actual gradients. The maximum gradient from bathythermograph readings was 0.6°C/m.

5. During May-June, the main halocline was situated in the 100-500-meter layer. The maximum salinity gradient was 0.027°/oo/m. In profile 3, the emergence of a secondary halocline was observed in the near-surface layer.

6. Vertical density gradients are governed mainly by salinity gradients; their maximum values did not exceed 0.036 conventional density units.

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HYDROCHEMICAL CHARACTERISTICS OF THE WATER IN THE GULF OF ALASKA AND THE ALEUTIAN TRENCH IN THE SPRING OF 1969

By A. M. Chernyakova

The investigations carried out during Cruise 45 of the "Vityaz'" in the Gulf of Alaska and the Aleutian trench were made in May and June 1969. Hydrochemical studies included the determination of dissolved oxygen, pH, alkalinity, phosphates, silicic acid, nitrites and nitrates, and were carried out on three profiles in the Gulf of Alaska and one profile across the Aleutian trench. Profile 1 (st. 6089-97) was situated southwest of Kodiak Island, profile 2 (st. 6098-6107) was situated south of Yakutat Island, profile 3 (st. 6109-23) was situated west of Baranof Island; profile 4 crossed the Aleutian trench south of Unimak Island.

The Gulf of Alaska and the Aleutian trench are areas with water having a Subarctic structure. The main patterns of chemical characteristics in Subarctic waters are as follows: A thin (30 m) surface layer during summer; large vertical gradients of all characteristics at the upper boundary of the intermediate layer; range of the intermediate layer to depths of 800-1,000 m. In abyssal waters there is little change in contents of biogenic elements down to the bottom, and a gradual increase in oxygen content (Fig. 1).

Waters of a Subarctic structure typically have a highly distinct annual cycle of warming and cooling of the surface layer, which causes a seasonal variation in the distribution of hydrochemical characteristics and biological factors, which is most prominent in the coastal areas. The warming period lasts from April to September, the cooling period from October to March. During the cold season there arises a layer with homogeneous temperature and salinity from the surface to the depth of a constant halocline at about 100 m; during the warm season there develops above the halocline at 30-75 m an estival thermocline, which is destroyed toward winter through cooling and mixing (Fig. 2). Thus, the distribution of temperature maintains the stability of the water column only during summer, whereas the distribution of salinity provides for stability throughout the year. However, the emergence and development of an estival thermocline has a great effect on the formation of water structure in the Gulf of Alaska and on the distribution of hydrologic and hydrochemical indicators.

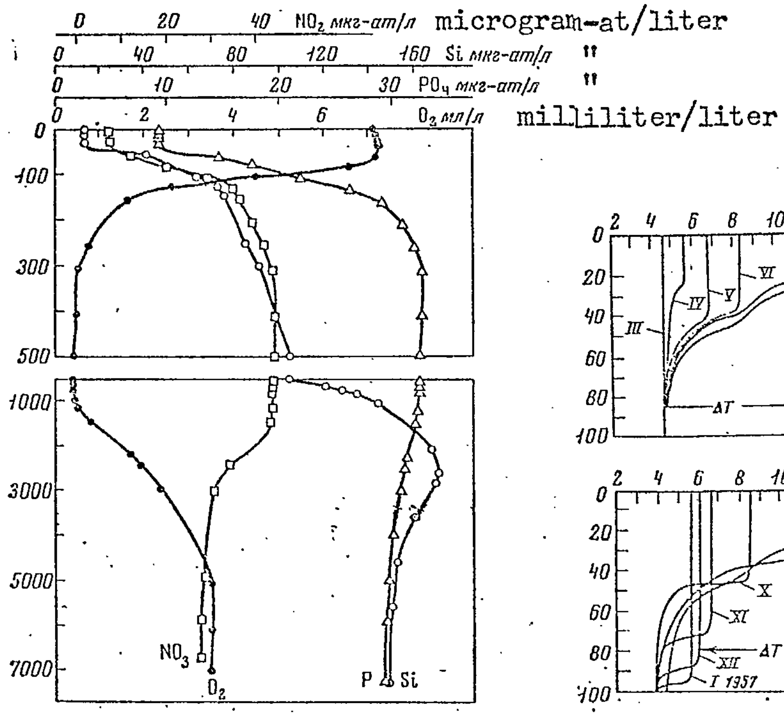
The seasonal thermocline effectively protects the lower water masses from warming and freshening. The sediment surplus accumulates during summer above the thermocline, which leads to minimum salinity values at the ocean surface toward the end of the warming season. The pycnocline has a great effect on the formation of the estival subsurface oxygen maximum; concentration therein was usually by 1-2 ml/l greater than at the surface. In addition, a reduction in the concentration of phosphates, nitrates and silicic acid in the entire surface layer during summer is due to the emerging pycnocline, which hinders the influx of these elements from the lower layers, while they are required urgently by the phytoplankton. 39

During the cold season the entire layer of brumal convection is in a state of free exchange with the oxygen of the atmosphere. Oxygen distribution with depth is homogeneous, its content is about 7 ml/l.

Because of low temperatures (4-5°) and convection, the water in the surface layer is unsaturated with oxygen (97-98%), and this causes an influx of oxygen from the atmosphere into the ocean (here and infra the saturation percentage is computed from the Green-Carritt solubility tables (1967)).

The investigations in the Gulf of Alaska coincided with the start of hydrologic and biologic spring. At the stations of profile 1 the water temperature at the surface did not exceed 5°, on profile 2 it increased to 6.4°, on profile 3 to 8°. The change in temperature from the first to the third profile is caused, on the one hand, by the cooling of water during its transport from east to west by the Alaska Current, and, on the other, by the warming by solar radiation during the period between the profiles. As a result of warming and wind mixing the thickness of the homogeneous layer decreased to 50-75 m at the seaward stations and to 15-20 m near the shore. The thermocline layer at the lower boundary of the surface layer, distinct during summer, only began to develop; the temperature gradients in it were everywhere small.

Absolute oxygen content at the surface of the Gulf of Alaska is fairly high — 7.2-8 ml/l (Fig. 3, 4). The distribution of oxygen in the surface stratum is almost uniform, the concentration decreases slightly from the surface to the lower boundary. At some stations we observed an increase in oxygen content at the 10-20-meter horizons because of its secretion during photosynthesis, but it does not exceed 0.1-0.2 ml/l (1-2%). In other words, a well-developed layer of a subsurface oxygen maximum is lacking during spring. This is due to the fact that the 40 pycnocline at the lower boundary of the surface layer during spring is fairly indistinct and cannot hinder the free influx of oxygen into deeper



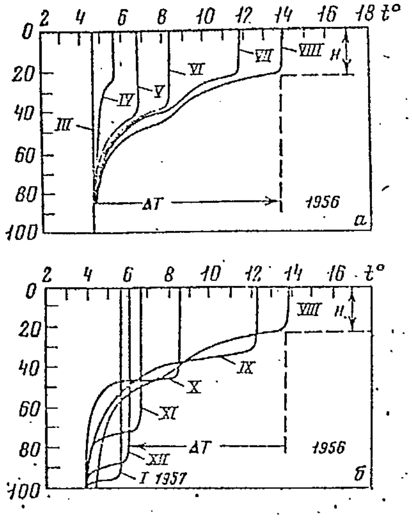
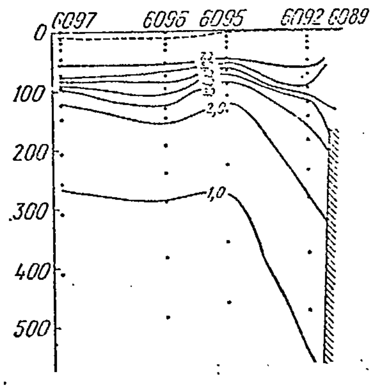


Fig. 1.

Fig. 2.

Fig. 1. Vertical distribution of chemical elements in the Subarctic water structure, from a case study of the Aleutian trench.

Fig. 2. Development and decay of estival thermocline: station "R", spring and summer 1956 (a), fall and winter 1956/57 (b).



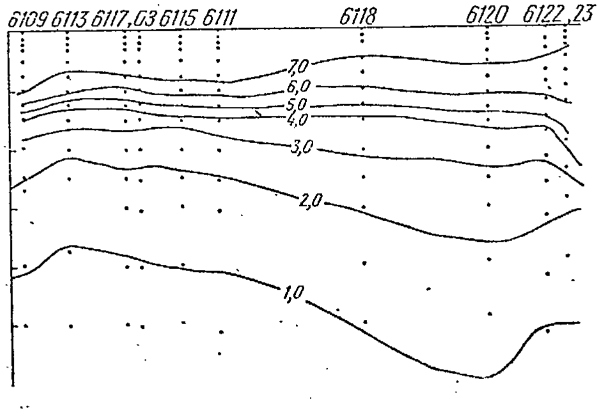


Fig. 3. Oxygen distribution (ml/l) at profile 1, Gulf of Alaska.

Fig. 4. Oxygen distribution (ml/l) at profile 3, Gulf of Alaska.

horizons. The warming of the surface layer is still insignificant, and therefore the loss of oxygen to the atmosphere because of a reduction of solubility does not exceed its rate of production. As a consequence, the maximum concentrations of oxygen in the surface layer are observed precisely during spring.

The oxygen saturation of the water in the surface layer in the Gulf of Alaska increased from the first to the third profile. At profile 1 oxygen saturation in the 0-30-meter layer is nearly 100%; at profile 2 some supersaturation is observed (100-105%) in the 0-50-meter layer; at profile 3 the saturation value increases to 110%, reaching 118% at st. 6120. Maximum values at many stations were noted in the 10-30-meter layer. An increase in the saturation percentage is caused both by higher temperatures and by the absolute increase in oxygen content during photosynthesis.

The distribution patterns of pH values in the surface layer point to an intensification of the photosynthetic activity of the phytoplankton. Active photosynthesis leads to an increase of pH from 8.13-8.18 at profile 1 to 8.24-8.33 at prof. 3. The maximum values were observed in the 20-30-meter horizons, where the oxygen content is increased by photosynthesis and where the CO_2 drops.

The change in the concentration of biogenic elements in the surface layer from the first to the third profile also indicates an intensification of processes of assimilation and decomposition of organic matter. The decrease in the concentration of phosphates from 1.3-1.4 microgram-at/l at the seaward stations of profile 1 to 0.8-0.9 microgr-at/l at Baranof Island (Fig. 5, 6) is due to their utilization during the spring bloom of phytoplankton. The surface content of silicon, whose main consumers are the diatoms which are the main representatives of phytoplankton in the Subarctic zone, decreased from profile 1 to profile 3, in accordance with the seasonal changes in the development of phytoplankton. Thus, in the profile at Kodiak Island, where brumal conditions still prevailed, silicon concentration was 50-80 microgr-at/l, at profile 3 it had dropped to 20-30 microgr-at/l.

Nitrate nitrogen is the main form of fixed nitrogen, which is a food source of phytoplankton. In the surface layer of the Gulf of Alaska the concentration of nitrates decreases from west to east from 10-13 microgr-at/l at profile 1 to 5-7 microgr-at/l at profile 3. Such a drop is also due to changes in the hydrological environment and to the 41
start of biological spring.

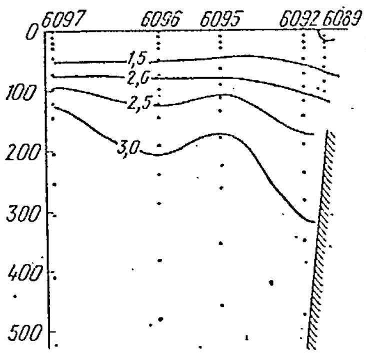
The nitrate nitrogen is the end product from the mineralization of organic matter, whose nitrogen passes during oxidation through an ammonia and a nitrite stage. The content of nitrites in the surface layer of the Gulf of Alaska remains practically constant throughout the area because the decomposition of organic matter and the regeneration of biogenic elements were not yet fully developed. A concentration of nitrites of about 0.20 microgr-at/l was observed in the entire layer from 0 to 50-75 m, increasing slightly (up to 0.22-0.24 microgr-at/l) at depths of 30-50 m, in the pycnocline. An exception was presented by the station nearest to Baranof Island (6123), where the nitrite concentration increased almost by a factor of two, attaining a maximum of 0.32-0.36 microgr-at/l.

The distribution of chemical elements is well correlated with the distribution and the activity of phytoplankton. From the data of N. N.

Strel'nikova (report on Cruise 45), on profiles 1 and 2 (6-13 May) phytoplankton was still uncommonly sparse, and only on profile 3 (13-21 May) did its biomass increase. The content of chlorophyll "a", a reliable indicator of the quantitative development of phytoplankton, according to data of R. Z. Kovalevskaya (Kovalevskaya, Giginyak, 1973), increased from 0.3-0.5 milligram/m^3 on the first profile and 0.4-0.9 milligram/m^3 on the second profile to 0.9-2.1 milligram/m^3 on the third. The highest values were observed at shallow near-shore stations. Such a gradual increase in the biomass of phytoplankton and the concentration of chlorophyll "a" in the surface layers is due to the start of biological spring.

The Gulf of Alaska is an area of maximum freshening of the surface waters of the Pacific Ocean; the amount of precipitation there exceeds the amount of evaporation. The greatest surplus of precipitation is noted along the coasts of British Columbia (90 cm^3/year); west of 180° it decreases gradually (to 20 cm^3/year) (according to "Norpac" surveys, 1955). A considerable proportion of freshwater is supplied by the runoff of rivers flowing into the Gulf of Alaska. The strongest freshening is noted in spring and summer in the coastal parts of the Gulf of Alaska. Some investigators, basing themselves on salinity patterns, assume that the structure of the Gulf of Alaska water resembles that of estuaries (Tully, Barber, 1965).

The great excess of precipitation over evaporation leads to a decrease in salinity values to 32°/oo and of alkalinity to 2.24-2.22 milligram-equiv/l (Alk/Cl 0.125-0.126). Toward the open sea, where the influence of little mineralized coastal water declines, salinity increases to 33°/oo, and alkalinity increases to 2.28-2.30 milligram-equiv/l and more.



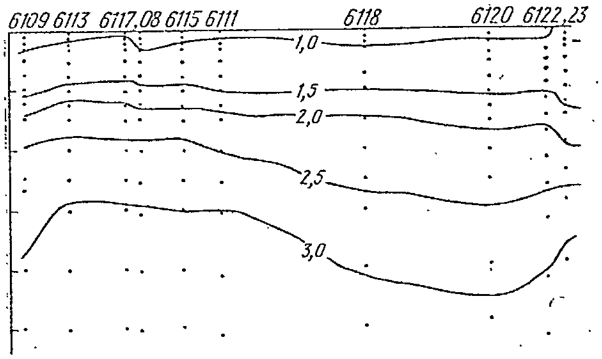
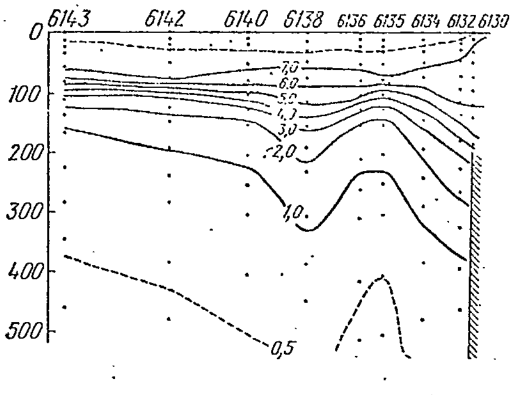


Fig. 5. Distribution of phosphates (microgr-at/l) on profile 1, Gulf of Alaska.

Fig. 6. Distribution of phosphates (microgr-at/l) on profile 3, Gulf of Alaska.



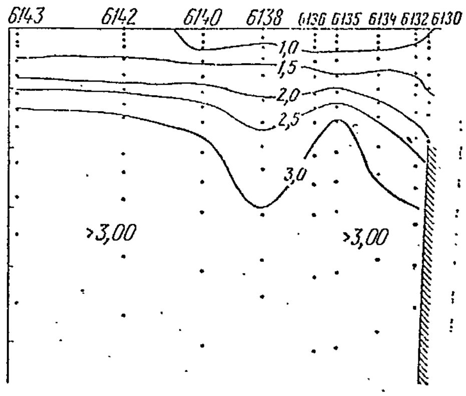


Fig. 7. Distribution of oxygen (milliliter/liter) on profile 4, Aleutian trench.

Fig. 8. Distribution of phosphates (microgr-at/l) on profile 4, Aleutian trench.

The distribution of oxygen, biogenic elements, pH and alkalinity in the surface layer on the profile south of Unimak Island (Fig. 7, 8) on 5-15 June coincides generally with the distribution of these characteristics in the Gulf of Alaska. However, the difference between the seaward and the shelf part of the profile is much more pronounced. The surface layer over the continental shelf and slope contains high concentrations of oxygen: 7.5-8.2 milliliter/liter, the saturation reaches 112-116%. The pH values are very high, up to 8.41. Concentration of phosphates at the near-shore stations is by 0.3-0.6 microgr-at/l lower than in the ocean part of the profile (Fig. 8). The content of nitrates in the surface layer near the shore does not exceed 8 microgr-at/l, at the seaward stations it increases to 12-15 microgr-at/l. These facts provide an indirect indication of the high productivity of the coastal area. At the coastal stations we found a great biomass of phytoplankton and high primary production — 90-165 milligram C/m^3/day, but with distance from the shore the production drops to 16 mg C/m^3/day (Kovalevskaya, Giginyak, 1973).

At the start of our investigations (5 May) in the area of Unimak Island we occupied stations 6087 and 6088 where we observed an abundance of phytoplankton. A month later (5-15 June) repeat investigations in the area showed that there was less phytoplankton. An increase in nitrite contents in the surface layer to 0.46 microgr-at/l indicates an intensification of the decomposition of the organic matter that had formed during the period and the regeneration of biogenic elements. In the Aleutian trench, the nitrate-bearing layer is approximately three times as thick as in the Gulf of Alaska.

Alkalinity distribution in the surface layer on the profile across the Aleutian trench was similar to that in the gulf, and corresponds to the character of the change in salinity (increase from coast to sea).

Below the surface layer the concentration of oxygen and biogenic elements changes drastically with depth, attaining extreme values. The lowest contents of oxygen -- 0.39-0.42 ml/l -- are found at the 600-800-meter horizons. At the same levels we found the maximum concentrations of phosphates (3.34 microgr-at/l) and the minimum pH values (7.72-7.75).

In the oxygen distribution in the intermediate layer, the water of the Gulf of Alaska and the Aleutian trench belongs to Type 1 (Chernyakova, 1966), which defines a simple water structure without intermediate maximums and minimums of salinity. The oxygen reaches the subsurface layers mainly through vertical exchange, produced by seasonal cycles of warming and cooling. Directly below the pycnocline conditions arise favoring the development of an oxygen minimum, inasmuch as the water with a simple structure is characterized by high productivity arising from the high concentrations of biogenic elements, which flow into the surface layer during winter as a result of convective mixing.

The layer with an oxygen minimum is well developed throughout the gulf. The position of the upper and lower boundary of the low-oxygen layer has been conditionally located at the iso-oxygen of 1.0 ml/l. The upper boundary of the layer is located fairly near the surface, at depths of 200-400 m, the lower boundary is located at 1,500-1,800 m. A particularly abrupt change in hydrochemical characteristics occurs in areas where deep waters rise and in the area of subpolar divergence, where the upper boundary of the extreme concentrations of chemical elements ascends to 150-200 m.

Thompson and his co-authors (Thompson et al., 1934) believed that in the eastern part of the Gulf of Alaska the low-oxygen layer touches the bottom, and that concentration at the bottom is very low, less than 0.5 ml/l. They assumed that the gulf represents a peculiar "factory" of minimum oxygen concentrations for the entire northeastern Pacific. However, in actual fact the low-oxygen layer reaches the bottom only near 43 the coasts of the gulf, along the continental slope, where depths do not exceed 1,000 m. At stations where the depth exceeded 2,000 m the benthonic oxygen minimum does not persist. In areas with depths of 3,000-4,000 m we observed a gradual increase in oxygen from the lower boundary of the low-oxygen layer to the bottom.

The distribution of oxygen and biogenic elements in the intermediate layer is governed mainly by the decomposition of organic matter and is determined by the peculiarities of the circulation in the Gulf of Alaska and the area of the Aleutian trench. This part of the Pacific is characterized by a complex system of currents, which form a subpolar cyclonic rotation (Aleutian, Alaska, Transverse, Kamchatka, Kurile currents) (Burkov, 1968). In the area of the Alaska cyclonic rotation there occurs a rise of deep water, which is more saline than the surface water, enriched with biogenic elements, with a low oxygen content. This water can be traced to depths of 80-100 m. Thus, the crowding of isolines of contents of oxygen and biogenic elements in the area of stations 6140-43 on the profile across the Aleutian trench is due to an intersection of the subpolar divergence (Fig. 7, 8). In addition, the presence of a large area of water uplift, clearly expressed in the shape of a divergence zone south of the Aleutian Islands, as well as local cyclonic vortexes complicate the distribution pattern of chemical elements. The disturbance of the trend of isolines of all chemical characteristics in the area of stations 6108, 6113, 6115, and 6117 (Fig. 4) is due to a cyclonic vortex which was discovered during our activities on the profile at Baranof Island. Evidently, the high primary production in this area -- 70-165 milligram C/m^3/day -- is connected with the removal of biogenic elements from the centre of the vortex.

The profile at Unimak Island is interesting because it allows us to review the characteristics of the distribution of hydrochemical parameters in deep water filling the Aleutian trench. V. N. Ivanenkov (1970), using the Kurile-Kamchatka trench as an example, analyzes the reasons for the homogeneity of the chemical composition of the water in abyssal trenches in terms of area, depth and time. Ivanenkov believes that the concentration values of chemical elements in the trench water are equal to those at the depth of the upper margin of the trench, i.e., at the depth of the ocean basin fringing the trench. For the deep or abyssal water of the Aleutian trench Ivanenkov (1971) cites the following chemical parameters: salinity, 34.69°/oo; O_2, 3.7 ml/l; pH, 7.9; Alk, 2.48 milligr-equiv/l; P, 2.7 microgr-at/l; Si, 145 microgr-at/l. 44

In order to study the distribution patterns of hydrochemical characteristics in the Aleutian trench we used five abyssal series taken at depth of over 6,000 meters in 1957 by the U.S. expedition on the "Brown Bear," and two series taken on Cruise 45 of the "Vityaz'". After correcting the "Vityaz'" data for the effect of the interior surface of bathometers, we may say that no anomalies of any kind were noted in the distribution of oxygen, phosphates, nitrates and silicic acid: oxygen content increases gradually with depth from the lower boundary of the minimum-oxygen layer to 3.5-3.6 ml/l at depths over 6,000 m. Concentration of phosphates, nitrates and silicic acid below the bottom of the maximum-layer [sic] decreases very gradually, and from 5,000 m on it remains practically constant: resp. 2.5, 29, and 145-150 microgr-at/l. Alkalinity does not exceed 2.48 milligram-equiv/l. From these data it is clear that the water of the Aleutian trench is mixed, well ventilated, and does not possess a stagnant character. The concentrations of hydrochemical characteristics in the trench are the same as in the deep water surrounding the trench.

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PRIMARY PRODUCTION AND CONTENT OF CHLOROPHYLL "A" IN THE WATER OF THE NORTHEASTERN PACIFIC OCEAN IN THE SPRING OF 1969

By R. Z. Kovalevskaya and Yu. G. Giginyak

This paper gives data on the size of primary production, content and photosynthetic action of chlorophyll a in the water of the Gulf of Alaska and the eastern part of the Aleutian trench during early spring.

Methods of Investigation

Samples for the determination of primary production and content of chlorophyll a were obtained on long-term stations by a 17-liter polyethylene bathometer from the horizons of 0, 5, 10, 15, 20, 35, 50, 75 and 100 meters; on intermediate stations and while the ship was under way, by bucket from the surface.

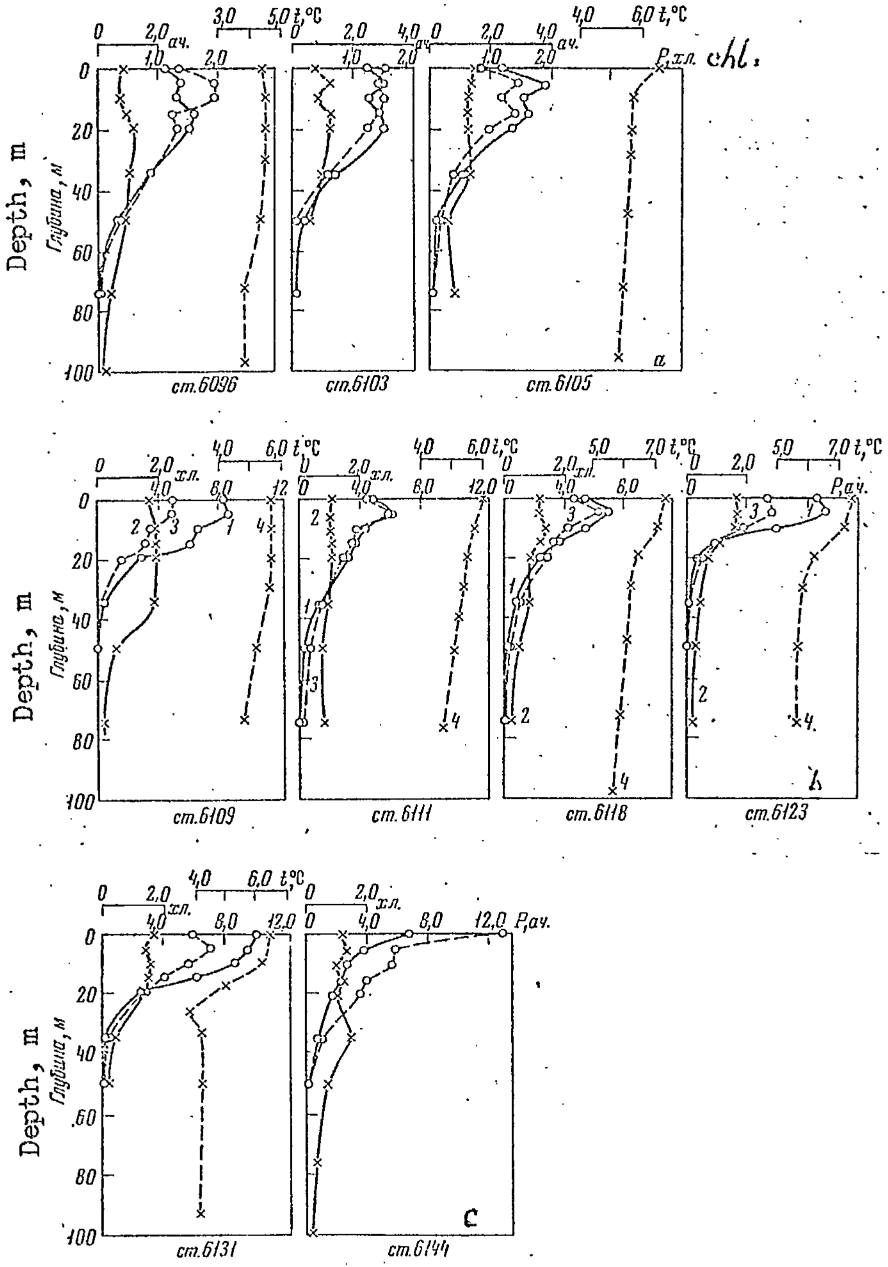
Primary production was measured with the radiocarbon method (Vinberg et al., 1960). Samples taken from the surface were exposed on deck in an aquarium with running water under natural illumination. Values of primary production in one square meter were measured in series in situ and indirectly from the content of chlorophyll in plankton. Samples for the determination of the intensity of photosynthesis were generally taken immediately before sunrise or before noon and, after addition of 1 milliliter of a solution of radioactive carbon (3.11 x 10^5 counts per minute per milliliter), they were exposed resp. during the first or second half of the day. In each series of observations, to account for C^{14} accumulation during darkness, we used both light and dark flasks. After exposure, the samples were filtered through membrane filters No. 5. Filters with settled plankton were dried over silica gel in darkness and, after being treated with with HCl vapor (2 minutes) were read off on the measuring equipment "DP-100" with the end-on counter "BFL-25". Computation was done according to the usual method (Vinberg et al., 1960). No correction was introduced for isotope effect.

To measure chlorophyll concentration, the plankton was settled on membrane filters No. 5 with the filtration of 1.5-10 liters of water under a weak vacuum. Chlorophyll content was measured according to the UNESCO (1966) recommendations either on the day the samples were taken or on the next day. In order to speed up and improve extraction, ground-up filters with plankton were wetted with distilled water in darkness for 15 minutes, after which the chlorophyll was extracted with 100% acetone. Extraction lasted not more than 2 hours. The extracts were measured in a spectrophotometer "SF-10" with 1-centimeter cells. All measurements were repeated two to three times.

Results 46

Primary production of phytoplankton in the surface layer.

The similarity of hydrologic conditions on the first and second profile (Fig. 1-a) led to similar values of primary production of phytoplankton. At stations occupied over depths of 1,500 m or more the intensity of photosynthesis near the surface amounted to 0.8-2.0 mg C/m^3/hour,



Vertical distribution of primary production, mg C/m^3 per hour (1); concentration of chlorophyll, mg/m^3 (2); assimilation numbers, mg C/mg chlorophyll per hour (3); and temperature (4), by stations. P -- primary production, mg C/m^3; a -- profiles 1 and 2; b -- profile 3; c -- profile 4. (хл = chl.)

Table 1. Primary production, content of chlorophyll a and assimilation numbers (a. ч.) of plankton in the surface layer of the northeastern Pacific during May-June 1969

Date	Station	Primary production, mg C/m^3 per hour	Primary production, mg C/m^3 per day	Content of chloroph. a mg/m^3	Assimilation number, mg C/mg chlor. per hour
	1-й разрез profile				
May Май 6	6089	3,72	55,9	0,52	6,73
	6090	1,77	26,5	0,46	3,85
	6092	2,02	30,3	0,31	4,92
	6093	—	—	0,41	—
7	6094	0,79	11,8	0,41	1,92
8	6096	1,08	16,2	0,41	2,63
	2-й разрез profile				
10	6098	—	—	0,86	—
	6099	—	—	0,74	—
11	6101	—	—	0,65	—
	6102	—	—	0,48	—
	6103	1,17	17,5	0,38	3,07
12	6105	1,64	24,6	0,71	2,31
13	6106	1,14	17,1	0,54	2,11
	6107	1,35	20,2	0,41	3,29
	3-й разрез profile				
15	6108	—	—	1,64	—
	6109	8,56	128,3	1,66	5,16
16	6110	—	—	0,92	—
	6111	4,75	7,12	1,05	4,52
17	6112	6,02	90,3	1,73	3,47
	6113	4,94	74,1	1,73	2,85
	6114	—	—	0,75	—
	3-й разрез profile				
17	6115	—	—	1,02	—
18	6117	6,60	99,0	1,84	3,58
19	6118	5,09	76,3	1,17	4,35
20	6121	—	—	2,09	—
	6122	—	—	1,20	—
21	6123	8,54	128,1	1,60	5,34
22	6124	11,00	165,0	1,84	5,98
	6126	—	—	2,22	—
	4-й разрез profile				
June Июнь 5	6130	—	—	1,44	—
	6131	10,15	162,4	1,71	5,93
6	6131	8,35	133,6	1,68	4,97
	6132	2,68	42,9	1,00	2,68
	6133	—	—	0,40	—
	6134	—	—	0,20	—
7	6135	1,76	28,2	0,33	5,36
8	6136	2,06	33,0	0,25	8,24
10	6138	1,01	16,2	0,43	2,35
11	6139	2,33	37,3	0,37	6,29
14	6142	2,45	39,2	0,48	5,10
15	6143	1,49	23,8	0,30	4,96
16	6144*	5,57	89,2	0,53	10,51
20	6145*	—	—	3,32	—

Note. Production values per day are obtained by multiplying average hourly values per exposure on 15 May and on 16 June. .

* Episodic stations.

which, with daylight lasting 15 hours (during May), amounted to 12-25 mg C/m^3/day (Table 1). Somewhat higher values were observed at the near-shore stations of profile 1.

At the polygon of profiles 3 and 3a, where investigations were carried out at the start of hydrologic and biologic spring (Chernyakova, 1973), the values of primary production in the surface layer increased greatly in comparison with previous profiles, and amounted to 70-165 mg C/m^3/day. The same high values are typical of the neritic areas of the boreal region along the coasts of Japan, Kamchatka, and Canada (Koblentz-Mishke, 1967).

Complex hydrologic conditions on profile 3 -- a strong influence of coastal waters in its eastern part, the presence of a cyclonic vortex in the area of stations 6108, 6113, 6115, 6117 -- led to considerable spottiness in the distribution of primary-production values.

In the profile across the Aleutian trench values of production of phytoplankton at the surface, like the hydrochemical conditions, did not differ notably from those observed in the gulf. However, differences in primary production in the seaward part of the profile and on the shelf 48 were very great there (Table 1). In the coastal zone production values (133-165 mg C/m^3/day) were close to those at the most productive stations of profile 3, the seaward part typically had values just as low as those on profiles 1 and 2 in the gulf -- not exceeding 40 mg C/m^3/day.

Content of chlorophyll a in the surface layer. Analogously to primary-production values, the lowest content of chlorophyll (0.3-0.5 mg/m^3) was found in profile 1, where winter conditions still existed at the time, and the phytoplankton represented by diatoms, was relatively sparse (N. I. Strel'nikova, report on Cruise 45). Chlorophyll concentration at the surface at the near-shore and seaward stations did not differ noticeably and was on the whole close to the values obtained by Canadian investigators at station "R" (about 50° north, 145° west) in May 1958-64 (Parsons, LeBrasseur, 1968). From the first to the third profile, as the top water layers warmed up, chlorophyll content increased and reached at the near-shore and some seaward stations of profile 3 the amount of 1.5-2.1 mg/m^3 (Table 1). The intensive development of phytoplankton, represented by diatomic and partly bluegreen algae, led to a noticeably lowering of the concentration of nitrate nitrogen and silicon (Chernyakova, 1973). However, the content of biogenic elements remained fairly high, and could not limit primary production. We shall note that according to Anderson, Parsons and Stephens (1969), concentration of nitrate nitrogen in the Subarctic waters of the northeastern Pacific practically never drops to values that would limit the growth of phytoplankton.

In the eastern part of the Aleutian trench the concentration of chlorophyll was fairly close to those in the gulf. A high concentration of chlorophyll (1.4-1.7 mg/m^3) was found in the near-shore stations 6130-32, as well as at station 6145 near the Rat Islands (3.32 mg/m^3). With increasing distance from the coast, the concentration of chlorophyll decreased greatly, and amounted to 0.20-0.50, averaging 0.35 mg/m^3 (Table 1).

On the passage from the Aleutians to the Gulf of Alaska, we obtained four samples from the surface as the ship was under way: on 3 May, at 53°57' north, 162°04' west; on 4 May, at 54°14' north, 157°50' west; on 5 May, at 55°20' north 154°10' west; and at 56°50' north, 150°38' west.

In the samples taken on 4 May the concentration of chlorophyll was the highest in the entire region under study: 4.84 mg/m^3; in the samples taken on 3 and 5 May it was, resp., 3.29, 1.85 and 0.39 mg/m^3. In June the concentration of chlorophyll at near-shore stations located close to the sampling of 3 May was lower (1.7 mg/m^3), which indicates a drop-off in "bloom."

Assimilation numbers of surface plankton. Assimilation numbers (a.n., mg C per mg chlorophyll per hour) provide an important indicator of photosynthetic activity of phytoplankton, and are used by many investigators for computing the size of primary production in a water stratum by indirect methods (Finenko, 1970; Ryther, Yentsch, 1957, etc.). It is therefore not without interest to review the values of the assimilation numbers and their changes in the region under study.

During early spring, the assimilation numbers of plankton in the Gulf of Alaska were fairly high, averaging on all profiles 2-5 mg C/mg chlorophyll/hour. The highest a.n., as a rule, were found near the shore. At the seaward stations of profiles 1 and 2 the a.n. were on the whole lower than on profiles 3 and 4 (Table 1), where some stations showed readings of 8-10 mg C/mg chlorophyll/hour.

Table 2. Vertical distribution of chlorophyll a (in mg/m^3) in the northeastern Pacific, May-June 1969

Depth, m	6.V	7.V	8.V	11.V	12.V	15.V	15.V	16.V	17.V	18.V	19.V	21.V	5.VI	5.VI	11.VI	14.VI	16.VI
	6090	6094	6096	6103	6105	6109	6110	6111	6114	6117	6118	6123	6130	6131	6139	6142	6144
	profile 1-й разрез			pr. 2-й разрез		profile 3-й разрез							profile 4-й разрез				
0	0,46	0,41	0,41	0,38	0,71	1,66	0,92	1,05	0,75	1,84	1,14	1,60	1,44	1,71	0,37	0,48	0,53
5	0,32	0,23	—	0,64	0,65	—	—	0,99	—	1,21	1,15	1,60	—	1,36	—	0,46	0,64
10	0,32	0,37	0,33	0,42	0,65	1,89	1,11	1,13	0,76	1,81	1,33	1,57	0,79	1,54	0,32	0,47	0,48
15	—	0,46	0,47	0,62	0,57	1,89	—	1,13	—	1,87	1,17	1,08	—	1,52	0,41	0,53	0,60
20	0,30	0,39	0,56	0,61	0,65	1,88	0,74	1,10	1,04	1,32	0,84	0,66	0,47	1,37	0,35	0,48	0,50
35	—	0,33	0,47	0,58	0,65	1,89	0,78	0,98	1,10	0,73	0,87	0,45	0,45	0,41	0,41	0,48	0,72
50	0,36	0,27	0,44	—	0,28	0,60	0,54	0,72	0,29	0,31	0,52	0,29	—	0,33	0,59	0,61	0,33
75	0,25	0,10	0,18	—	0,39	0,28	0,21	0,84	0,20	0,08	0,25	0,14	—	—	0,22	—	0,17
100	—	—	0,09	—	—	—	—	—	—	—	—	—	—	—	—	—	0,14

Primary production and content of chlorophyll in the water stratum. The results of the determination of production in the water stratum with flask exposure in situ, along with the distribution of chlorophyll contents and assimilation numbers, are given in Fig. 1.

On profiles 1 and 3, the curves showing the vertical distribution of photosynthesis were similar, with two maximums at the depth of 5 and 15-20 m. Starting with the depth of 20 m, the intensity of photosynthesis dropped sharply, showing a typical dependency on light intensity. With a similar thickness of the euphotic layer (about 50 m) and low differences in the absolute values of photosynthesis, the primary production in the water column of one square meter at the stations of profiles 1 and 2 was quite similar: 756-817 mg C/m^2/day.

In line with the high primary production at the surface on profile 3, its integral value per m^2 was much higher: 1,734-2,431 mg C/m^2/day.

Production of phytoplankton in the water column on the profile across the Aleutian trench was measured in situ only at one near-shore station (6131). With intensive development of phytoplankton, the thickness of the euphotic layer at that location did not exceed 30 m. In spite of this, high intensity of photosynthesis in the surface layers led to a value of primary production in the one-square-meter column that was the highest in the region studied -- 2,913 mg C/m^2/day.

The distribution of chlorophyll concentration in the water column was considerably affected by the changes in water temperature and the depth of lighted layer. In the absence of a distinct seasonal thermocline at profiles 1 and 2, chlorophyll concentration was more or less constant 50 down to the lower boundary of the euphotic layer: about 50 meters (Fig. 1, a, Table 2). In deeper layers chlorophyll content decreased markedly with depth. On profiles 3 and 4, where observations were made during the period of formation of the thermocline, the vertical distribution of chlorophyll was more or less uniform in the upper homogeneous layer and decreased with decreasing temperatures (Fig. 1, b, c, Table 2).

The character of the distribution of assimilation numbers by depths resembles the curves showing the distribution of intensity of photosynthesis.

Computation of primary production of phytoplankton from chlorophyll content. The computation of primary production in the water column from chlorophyll content, based on the relationship between assimilation numbers of light intensity, has often been undertaken both for fresh as well as sea water. This method is less laborious than, for example, the well-known method of Yu. I. Sorokin (1956), and is therefore attracting the attention of many investigators.

Not having data on the intensity of light in the water stratum, we used for the computation of the value of primary production per square meter on the basis of chlorophyll a provisional method based on expressing the intensity of photosynthesis at any depth by its intensity at the surface, measured on shipboard with natural illumination. In order to determine the intensity of photosynthesis at a given depth, it suffices to multiply the assimilation number at the surface by the concentration of chlorophyll at the given depth and by the correction factor K_a, which reflects the dependence of the assimilation number of plankton upon an assemblage of conditions (light, temperature, concentration of biogenic elements, etc.) typical of

Table 3. Comparative results of the determination of primary production in the water column with various methods (mg C/m^2 per day)

Station	From *in situ* measurements	From chlorophyll content	Sorokin method	Remarks
6090	-	853	798	From K_t* measurements, st. 6096
6094	-	474	500	id.
6105	768	855	913	From K_t and K_a, station 6103
6117	-	2,462	1,665	From K_t and K_a, station 6111
6118	1,996	2,113	-	id.
6123	1,734	1,842	-	From K_a, station 6109

* The meaning of this factor is unclear, as there is no reference to it in the text. -- TRANSL.

of the given depth and the given type of water, and is determined in series in situ. Photosynthesis at depth h will equal: $P_h = C_h \times K_a \times A_s$, where C_h is the concentration of chlorophyll (mg/m^3) at depth h; K_a is the factor reflecting the relative change in assimilation numbers (mg C/mg* chlorophyll/hour) with depth (the unit is the assimilation number at the surface); A_s is the assimilation number at the surface.

The factor K_a was determined from in situ observations at long-term stations, with hydrologic and hydro-optical conditions typical of the given area. In order to compute the value of primary production under one square meter, we constructed a curve showing the vertical distribution of $C_h \times K_a$ values (which corresponds to the K_c curve in Sorokin's method), determined the area delimited by it (K_c), whose size was multiplied by the assimilation number at the surface, i.e., the productivity 51
of photosynthesis (P) in the water column under one square meter equals $P_{m^2} = K_c \times A_s$.

Table 3 gives comparative results of the determination of primary production of plankton by various methods (in situ, by chlorophyll content, and by Sorokin's method).

The values obtained with the different methods are fairly similar. Bearing in mind the complexity of hydrologic conditions in these parts of the ocean during spring, we can say that the method used yielded satisfactory results.

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* The text has m^2 instead of mg, evidently in error. -- TRANSL.

The information given here on the values of primary production, content of chlorophyll in plankton and its photosynthetic activity are in good agreement with concepts concerning the distribution and productivity of phytoplankton in the water stratum of the northeastern Pacific (Semin, 1967; Koblents-Mishke, 1967). In the northwestern Gulf of Alaska (profiles 1 and 2), where in early May winter conditions still existed, the low primary-production values (12-25 mg C/m^3/day at the surface) and chlorophyll contents (0.3-0.5 mg/m^3) characterized both the coastal and the open part of the gulf. The development of phytoplankton, whose biomass is indicated fairly accurately by chlorophyll readings, is limited largely by the depth of the euphotic zone. In the southeastern gulf and at the near-shore stations of the Aleutian trench, where observations were carried out during the formation of the seasonal thermocline, we obtained readings of primary production typical of the eutrophic parts of the ocean.

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MICROBIOLOGICAL INVESTIGATIONS IN THE NORTHEASTERN PACIFIC

By. A. V. Tsyban'

The microbiology of the Pacific has been studied in the central, southeastern, northern and northwestern part of the ocean (Kriss, 1959; Sorokin, 1962a, b; Sieburth, 1965; Seki, 1968b, 1970; Kriss, Mitskevich, 1970), in the Japan and Kurile-Kamchatka trenches (Kriss, Biryuzova, 1955), along Southern California (ZoBell, 1946), and in the seas fringing Japan (Seki, 1966, 1968a; Seki, ZoBell, 1967; Taki, Seki, 1962).

No microbiological investigations have previously been carried out in the northeastern Pacific (Gulf of Alaska, Aleutian trench).

In the study of the vertical-distribution patterns of microorganisms in the sea, the attention of investigators was usually concentrated on horizons of the water stratum, and the flowering of bacterial life was noted in the euphotic zone as a whole, in the thermocline layer, and in the benthonic layers. The thin microhorizon at the air-sea interface usually escaped the attention of investigators.

The detailed bacteriological investigation of the near-surface microlayers of the sea and the associated films of surface tension which we began in 1962 on the continental shelf of the Black Sea with the use of a special methodology for sampling has revealed the existence of a rich and varied near-air assemblage of microorganisms -- the bacterioneuston

(Tsyban', 1965-71; Tsyban [in translation], 1971). Its existence is governed by a number of specific physical-chemical processes which occur continuously at the air-sea interface and in the adjacent water layer.

Bacterioneuston comprises the first link in the trophic net of the assemblage of neuston and pleuston (Zaitsev, 1970; Savilov, 1969), which occur widely in the World Ocean. Possessing varied enzymatic action with high concentration in the surface film, bacterioneuston may play an important role in the biological self-cleansing of water bodies.

The results of the study of bacterioneuston in the landlocked seas have suggested the question as to its existence in the ocean. In this paper we are providing information on the bacterioneuston and bacterioplankton of the northeastern Pacific, their make-up, numbers and physiological properties, and we discuss the paths and sources of the formation of oceanic bacterioneuston.

Material and Methodology

The microbiological investigations were carried out in the Gulf of Alaska and in the Aleutian trench during Cruise 45 of the "Vityaz'" in April-June 1969 (Fig. 1). At 19 stations samples of ocean water were taken from the standard hydrologic horizons from surface to bottom, at the remaining stations, down to 125 m. At all stations we took samples from 53
the near-air micro-layers of 150-200 microns and 1-2 centimeters. Samples from the water stratum were taken with bathometers sterilized with a steam jet from an autoclave for 7-10 minutes, followed by treatment with 96° alcohol. From the bathometers we made control cultures of sterile sea water, which as a rule yielded no

bacterial growth.

Samples from the atmospheric micro-horizons of the ocean were collected by using the micro-bathometers "BNS" (Tsyban', 1967) and "BNS-II" (Tsyban', 1970a), developed by us, which operate respectively within the micro-horizons of 1-2 cm and 150-200 mc. Before use the microbathometers were sterilized in the autoclave.

Extraction of samples from the near-air micro-layers was done during the first few minutes of activity at a station at the bow of the ship or from a hinged platform on the bow deck, taking into account the drift of the ship, wind-induced waves and currents. The sampling point was chosen in reference to these factors. In the Japan trench we carried out a control station from a launch at a distance of 2-3 miles from the "Vityaz'".

When the microbathometer "BNS-II" is lowered to the water surface and raised to the ship, the screen or baffle of the sampler remains open for 5 seconds. To collect the required amount of water (50-75 ml) we usually needed 14-15 screens. In view of the possibility of the screens becoming dirty during that time and also because the near-air complex of micro-organisms contains microflora carried to the water surface by air currents, aeolian deposition, rain, snow, we included in our study program the microflora of air and precipitation. At all stations we carried out control cultures of air with an exposure equal to the total period of operation of the "BNS-II" screen (15-20 minutes), and at 10 stations we carried out cultures of rain and snow.

The main object of our investigations was saprophytic microflora, which is an indicator of the accumulation and intensity of the decomposition of organic matter in a water body (Kuznetsov, 1970).

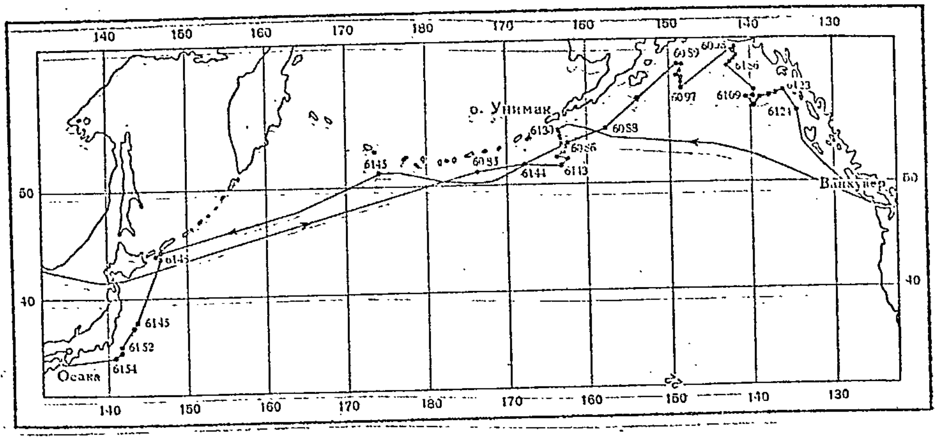


Fig. 1. Location of microbiological stations

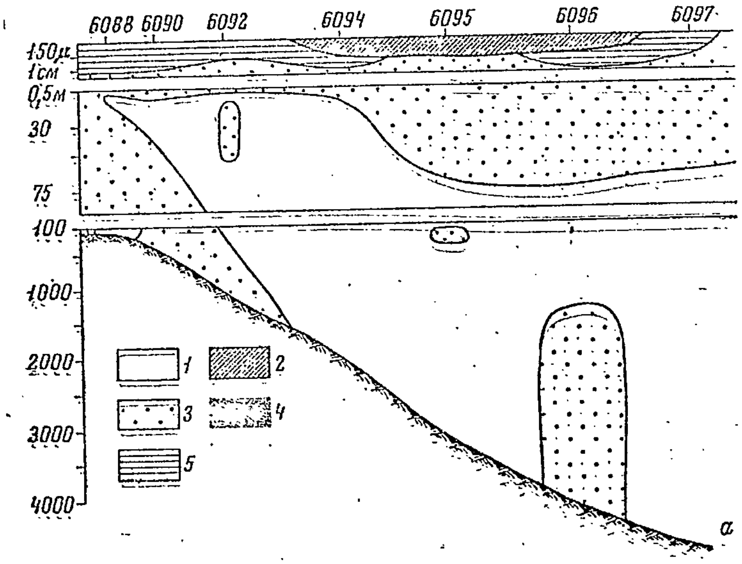
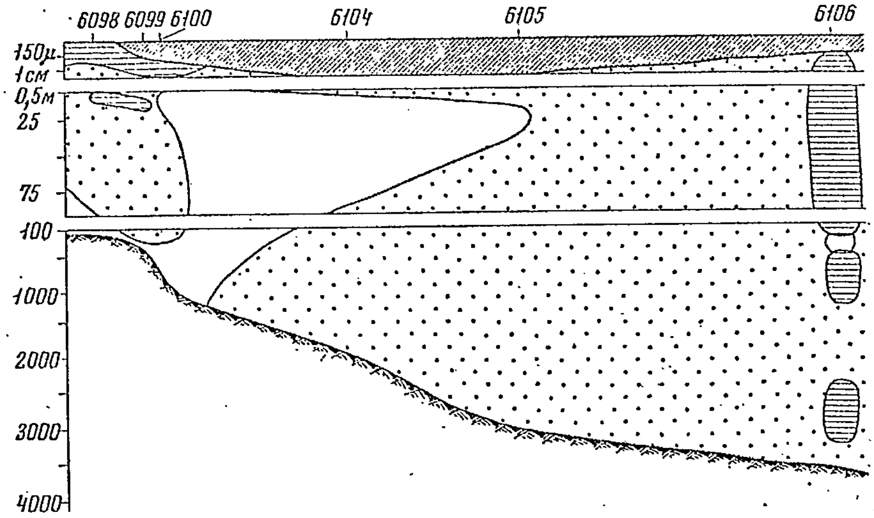


Fig. 2 (pp. 94 and 95). a -- profile from Kodiak Island southward; b -- profile from Yakutat Bay southwestward; c -- profile from Baranof Island westward; d -- profile from Unimak Island southward. Abscissa shows station numbers, ordinate shows depth (in microns, centimeters and meters). Number of cells in 40 ml of water: 1 -- 0; 2 -- few; 3 -- tens; 4 -- hundreds; 5 -- thousands.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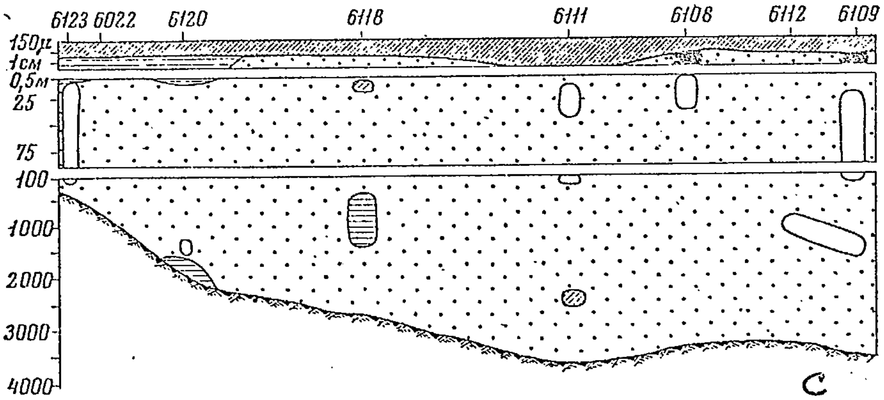
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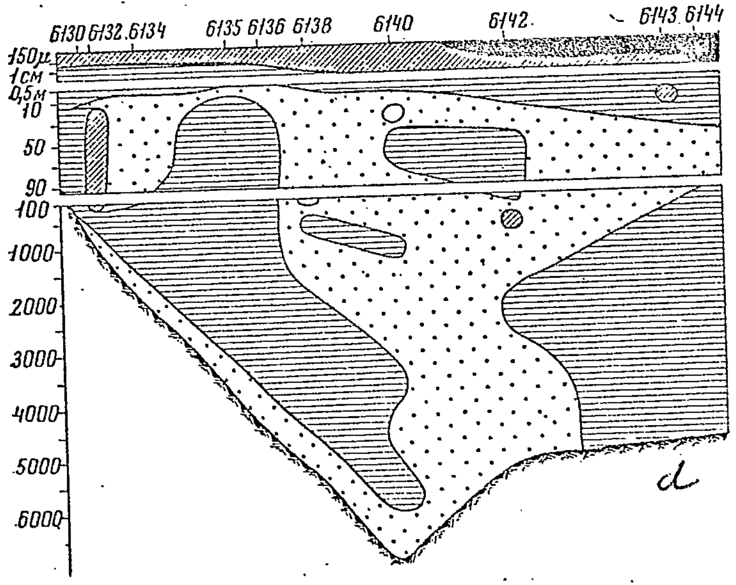
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d

The water samples were immediately subjected to bacteriological analysis. In order to isolate the saprophyte microflora we used the method of germinating ultrafilters on nutrient agar (Kriss, 1959). After filtering 40 ml of water from the ocean stratum and 5-10 ml from the near-air micro-layers, the filters were placed upon the mediums: "RPA" (20 grams of tryptic hydrolysate of fish meal plus 1,000 ml of sea water; Kriss, 1959); "RPAP" (20 grams of tryptic hydrolysate of fish meal plus 10 ml of settled skimmings plus 1,000 ml of sea water; Tsyban', 1970a); and so-called "ecological mediums" prepared from fish 55 broth and algae extracts (Tsyban', 1971).

The quantity of saprophyte bacteria was determined by counting in a Wolfhügel chamber. Colonies differing in external appearance were isolated. The resulting collection -- 600 bacterial cultures -- were determined down to genera (Krasil'nikov, 1949), with study of their morphological, cultural and biochemical properties. Electron microscopy was carried out with the "EM-5" microscope.

The proteolytic activity of the microorganisms was established from their capacity to liquefy fish-peptone gelatine. The lipolytic activity was determined with a methodology developed by us (Tsyban', Teplinskaya, 1973) using a two-layer indicator medium. The bottom layer consisted of 1 liter sea water plus 30 grams "RPA" [sea above] plus 0.1 gram bromocresol green or Nile blue. The upper layer consisted of 1 liter sea water plus 60 grams "RPA" plus 10 ml sperm-whale blubber plus 10 ml yeast extract, pH 7.6. The secretion of lipase by the microorganisms was assessed from the appearance of an orange halo around growing colonies on the upper layer of the medium. The capacity of microorganisms to develop through the consumption of petroleum hydrocarbons (petroleum, vaseline oil, solar oil) was studied with the Shaposhnikov method (Shaposhnikov, Kozlova, Arkad'yeva, 1968). The consumption of petroleum and its hydrocarbons was assessed from the dimensions of growths surrounding circles of filter paper or the size of the zone in which no growth occurred. Parallel with this the destruction of petroleum was studied in a liquid Towson medium with the addition of 1 per cent (by volume) of petroleum. Results of the experiments were noted after 14 and 30 days of growth. Activity of stock was assessed from the color change of the petroleum and the disappearance of the oil film.

In the statistical treatment of the data we used the method of prismatic ecograms (Tsyban', Shnaidman, 1969) and determined the reliability of the difference with the aid of the χ^2 criterion (Panovskii, Braier, 1967).

Results of Investigations 56

The Gulf of Alaska is characterized by an abundance of microflora in the surface-tension film and extreme paucity of bacterial populations in the water stratum. On the first to third profiles the number of saprophyte bacteria fluctuated from tens to thousands of cells per 40 ml of water in the near-air micro-layers, while only single cells were found in half the samples from the water stratum; in the remaining samples saprophytes were not found at all.

On the profile at Kodiak Island (Fig. 2a) the concentration of bacterioneuston consisted of tens and hundreds of cells per 40 ml of water. The density of bacterioplankton was low (single microorganisms per 40 ml). Below the 20-50-meter layer most stations of the profile revealed no saprophytes. The content of chlorophyll a was low throughout profile 1: 0.2--0.5 mg/m^3 (Kovalevskaya, Giginyak, 1973), the temperature of the water did not exceed 4-5°, biological spring had not yet started in the area. This appears to be true of profile 2 (Yakutat Bay) as well: content of chlorophyll a was 0.4-0.9 mg/m^3, water temperature was 4-8°. The numbers of bacterioneuston were in the order of hundreds of cells, those of bacterioplankton amounted to a few colonies in 40 ml of water (Fig. 2b). At some stations — though not as often as in profile 1 — no bacterial growth was noted (stations 6100, 6104, 6105).

On the profile from Baranof Island (Fig. 2c) the area of the zone with zero bacteria content was smaller, and the numbers of saprophytes in the water stratum sometimes reached tens of cells per 40 ml. The concentration of bacterioneuston also increased to hundreds, less often thousands, of bacteria per 40 ml. Intensification of microbe life coincided with an increase in the concentration of chlorophyll a to 1.5-2.5 mg/m^3 and an increase in water temperature to 7-8°.

In the Aleutian trench (Fig. 2d) we found a higher concentration of saprophytes than in the gulf. There were no large areas of zero contents. In vertical series we found an alternation of layers with abundant bacterioplankton (tens and hundreds of cells per 40 ml) and layers with sparse saprophyte flora (single specimens). The numbers of bacterioneuston at all stations exceeded by an order of 2-4 those of bacterioplankton. The density of bacterioneuston in the ocean part of the profile (thousands of cells per 40 ml) was higher by one order than in the coastal part, nearer Unimak Island.

At all stations, without exception, carried out in the Gulf of Alaska and in the Aleutian trench the quantity of saprophytes in the near-air micro-horizons of 150-200 microns and 1-2 cm was greater by an order of 1-3, and sometimes 4, than in the water stratum. In some cases the numbers of saprophytes in the 1-2-cm micro-layer equalled or exceeded 5-10 times those in the micro-layer from 150 to 200 microns, but on the average the abundance of bacterial life in the surface-tension film was higher than at the depth of 1-2 cm.

The difference of concentrations of bacterioneuston and bacterioplankton in the Gulf of Alaska becomes statistically significant at the 99.99% level ($\chi^2_{obs} = 60.3$; $\chi^2_{comp} = 16.3$, number of degrees of freedom = 3). The difference in the concentrations of bacterioneuston and bacterioplankton in the Aleutian trench is significant at the 99.9% level ($\chi^2_{obs} = 36.2$; $\chi^2_{comp} = 13.3$; number of degrees of freedom = 4).

Bacterial strains isolated in the Gulf of Alaska belong to the genera Bacterium, Chromobacterium, Mycobacterium, Bacillus, Pseudomonas, Micrococcus and Streptococcus.

An analysis of the data with the aid of the method of prismatic 57
ecograms (Tsyban', Shnaidman, 1969) has shown the reliability ($p > 99.9\%$) of the different frequency of occurrence of microbe taxons in the surface-tension film and in the water stratum (Fig. 3a). The bacterioneuston of the Gulf of Alaska is dominated by the genera Micrococcus, Pseudomonas, Chromobacterium. The water stratum (layer from 0.5 to 125 meters) is dominated by Bacillus, Micrococcus, Bacterium. The remaining genera are rare and small in numbers.

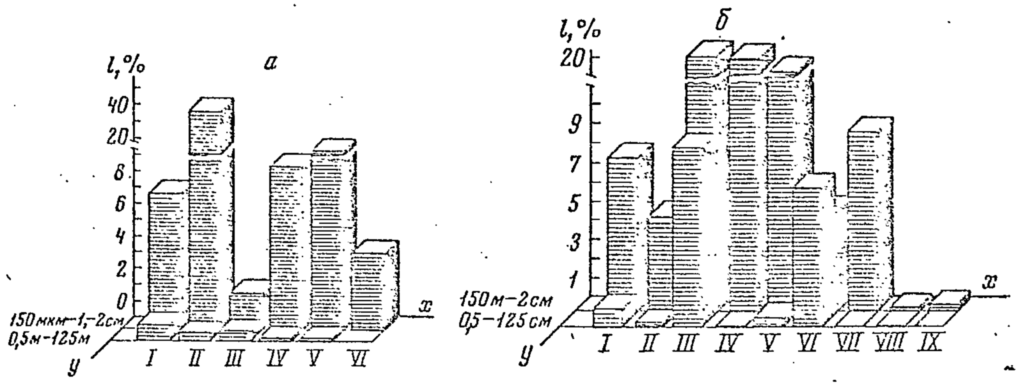

Fig. 3. Ecogram showing frequency of occurrence of individual genera of saprophytic microorganisms in bacterioneuston and bacterioplankton.

a -- Gulf of Alaska; b -- Aleutian trench. I -- Bacillus, II -- Micrococcus, III -- Bacterium, IV -- Chromobacterium, V -- Pseudomonas, VI -- Mycobacterium, VII -- Planococcus, VIII -- Streptococcus, IX -- Pseudobacterium. X axis shows index of genus, Y axis shows layers studied; vertical axis shows frequency (in percentages) of a given genus related to the number of all bacterial strains isolated in the area under investigation.

In the Aleutian trench the saprophytic microflora is more varied: in cultures of bacterioneuston and bacterioplankton we found Pseudomonas, Micrococcus, Bacillus, Bacterium, Mycobacterium, Chromobacterium, Pseudobacterium, Planococcus, Streptococcus.

Differences in the composition of microorganisms in the near-air micro-layers 150 mc-1-2 cm and 0.5-125 m are certain, $p > 99.9\%$ (Fig. 3b). Cultures of bacterioneuston from the Aleutian trench are dominated by Bacterium, Chromobacterium, Pseudomonas, cultures of bacterioplankton are dominated by Bacterium and Mycobacterium. Chromobacterium, Streptococcus and Planococcus were found only in the near-air micro-horizons. Pseudomonas and Chromobacterium are confined mainly to the surface-tension film.

Thus, the bacterioneuston of the northeastern Pacific has been shown to contain a great variety of microbe taxons, dominated by *Pseudomonas* and *Chromobacterium*, as well as some members of groups found in the euphotic zone of the ocean. This fact can be illustrated in frequency diagrams for individual genera of saprophytes in the micro-horizon of 150-200 microns and in the 0.5-meter layer at stations in the Gulf of Alaska. Thus, on the profile from Kodiak Island the genera that are most common in the half-meter layer are *Bacillus* and *Bacterium* (Fig. 4a). They were also predominant in the surface-tension film (Fig. 4b).

On the profile from Yakutat Bay, the water stratum (0.5-meter horizon) was dominated by *Micrococcus* (st. 6098-6100, 6104), or else only *Pseudomonas* was found (st. 6105-6) (Fig. 4c). In the surface-tension film we found a large variety of microbe taxons, most abundant among them being *Micrococcus*, *Chromobacterium*, and *Pseudomonas* (Fig. 4d).

On the profile from Baranof Island, *Micrococcus* was the most 60
abundant in the 0.5-meter horizon, and it was the only genus registered at all stations (Fig. 4e). Members of the remaining genera -- *Bacillus*, *Chromobacterium*, *Pseudomonas*, *Bacterium* -- were found singly. In the surface-tension film (Fig. 4f) the numbers of variety of saprophytes were in sharp contrast to the sparse microbe population of the water stratum. Predominant were *Pseudomonas*, *Bacterium* and *Mircococcus*. Species of *Mycobacterium* were found on this profile only in the near-air horizon.

The ecogram showing the distribution of saprophyte genera in the Aleutian trench (Fig. 3b) emphasizes the high frequency of *Bacterium* in the near-air micro-layer -- a genus that is predominant in the euphotic zone.

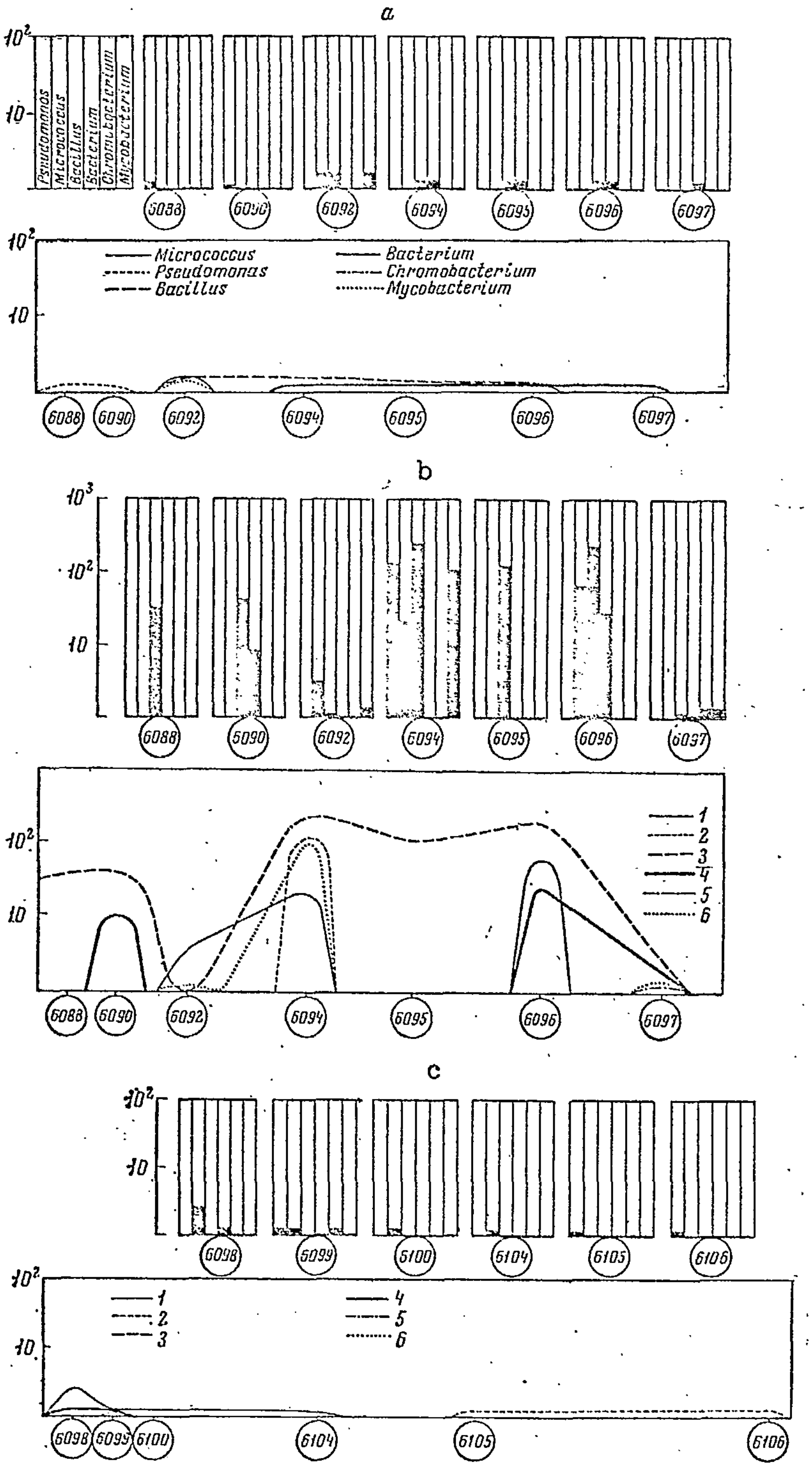

Fig. 4. (Caption on p. 104)

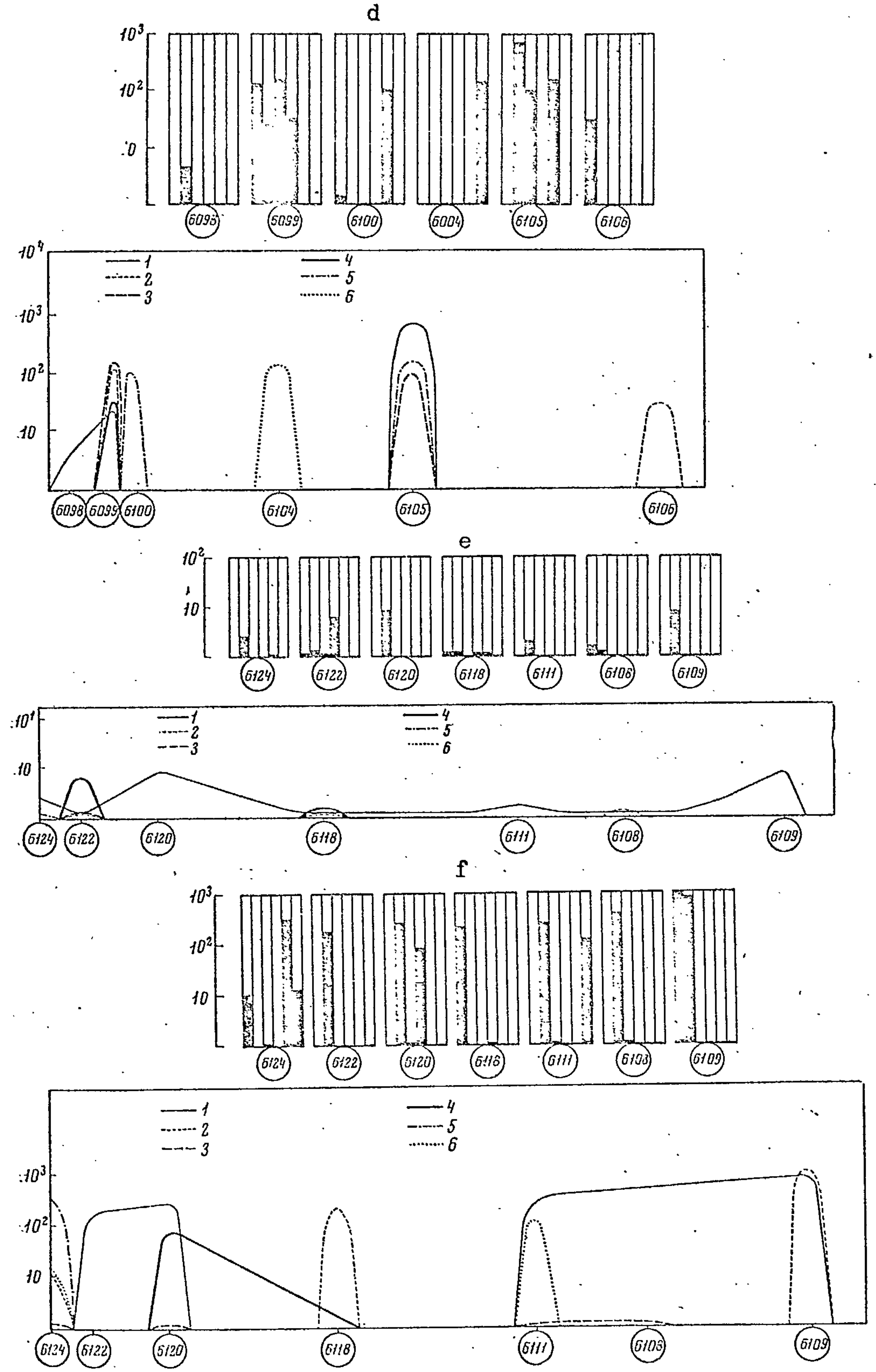
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Fig. 4, cont.

Caption for Fig. 4.

Distribution (top to bottom) and quantities (number of cells per 40 ml) (bottom to top) of saprophyte genera in the 0.5-meter layer (a, c, e) and in the micro-horizon of 150 microns (b, d, f), by stations.

a, b -- profile from Kodiak Island south; c, d -- profile from Yakutat Bay southwest; e, f -- profile from Baranof Island west. Circled figures are station numbers.

Genus	Gulf of Alaska	Aleutian trench	Genus	Gulf of Alaska	Aleutian trench
Bacillus	82*	81	Microbacterium	95	80
Bacterium	90	74	Micrococcus	80	60
Pseudomonas	95	95	Chromobacterium	50	85

* Percentage of active cultures of total number of strains of given genus.

In order to gain information on the physiological properties the collection of cultures isolated by us was studied in terms of capacity to split albumin, fats and hydrocarbons. The results show intense biochemical activity on the part of the bacterial strains studied (see table). Thus, proteolytic properties were possessed by 50-95% of cultures of a given genus.

The highest percentage of active microorganisms was found among Pseudomonas and Mycobacterium. A greater proteolytic activity was shown by the "Alaskan" strains. Among bacterioneuston cultures, albumins were split by 70% of strains, among bacterioplankton cultures, by 77%.

In the study of the assimilation of hydrocarbons (Table 1) it was found that petroleum and vaseline oil were not toxic for the microorganisms studied (no growth-suppression zone was observed) and were assimilated by a considerable proportion of the cultures (40-60%).

Assimilation of solar oil was accomplished by 20-30% of cultures, while a number of strains showed growth suppression. The highest percentage of active cultures accomplishing the destruction of petroleum was found among _Bacillus_, _Bacterium_, _Mycobacterium_. Among the bacterioneuston cultures, petroleum was assimilated by 50%, and in the bacterioplankton the number of active cultures dropped to 35%.

In view of the high concentrations of fatty acids and lipides in the surface film, it was of interest to inquire into the lipolytic properties of the microorganisms, separately for bacterioneuston (BN) and bacterioplankton (BP). As shown by Table 2, splitting of fats was accomplished by 40-70% of bacterioneuston cultures and 40-55% of bacterioplankton (the bacterioplankton of the Aleutian trench contained no _Pseudomonas_ and _Chromobacterium_). The highest number of lipolytic cultures was found in _Pseudomonas_, _Micrococcus_, and _Bacterium_. Data on the lipolytic properties of _Pseudomonas_, which inhabits ocean "slicks" and sea foam, have already been reflected in the scientific literature (Sieburth, 1965; Tsyban', 1971).

Table 1. Assimilatinn of petroleum, solar oil and vaseline oil by saprophyte bacteria in the Gulf of Alaska (percentage of active cultures)

Genus	Test results from Shaposhnikov method			Petroleum assim. on Towson medium
	Petroleum	Solar Oil	Vaseline Oil	
Bacillus	48	31.7	43.8	65
Bacterium	61	9.5	52.4	50
Pseudomonas	50	27.7	20	42
Mycobacterium	50.5	45.5	55.5	60
Micrococcus	32	35.4	47.8	32
Chromobacterium	40	30	70	35

Table 2. Lipolytic properties of saprophyte bacteria

Genus	Gulf of Alaska		Aleutian trench	
	BN	BP	BN	BP
Bacillus	40*	53	36	40
Bacterium	62	38	64	63
Pseudomonas	66	55	45	-
Mycobacterium	57	50	57	63
Micrococcus	71	40	66	50
Chromobacterium	17	33	44	-

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* Percentage of active bacteria of total number of cultures, BN or BP.

Discussion of Results

The water of the Gulf of Alaska is extraordinarly poor in saprophyte microflora in bacterioplankton. Its numbers in some samples from the water stratum consisted of single cells in 40 ml of water, and in extensive areas of the pelagic zone of the gulf no bacterial growth was found at all. This is apparently due to the fact that the water flow enters the Gulf of Alaska from the central part of the Pacific, and these waters are poor in organic matter that can easily be assimilated by microorganisms. Also, our investigations were carried out at the start of biological spring, when the melting of snow and glaciers along the coasts, which enrich the gulf with fresh water and terrigenous matter, had only just started.

In the Aleutian trench, saprophyte bacterioplankton was developing more intensively. There we found along with zones containing only sparse saprophyte bacteria (single cells in 40 ml), layers with abundant microflora (tens and hundreds of cells). The reasons for the increase in saprophyte concentration in the Aleutian trench are probably to be found in the complex dynamic structure of the water traversed by that profile and in the fact that the investigations occurred during biological spring. Data on bacterioplankton numbers in the Aleutian trench are similar to those obtained by Seki (1970) in the Subarctic waters of the Pacific (40-50^{0} north).

Microbiological investigations during Cruise 45 of the "Vityaz'" revealed the existence of a specific complex of microorganisms developing in the area of the surface-tension film and characterized by large numbers 62 and considerable variety of microflora. The abundance of the bacterial population in the near-air micro-layers of the ocean contrasts sharply with the paucity of saprophyte microflora in the water stratum of the area studied. The profiles indicated an increase in bacterioneuston concentration from near-shore waters toward the open sea. The quantitative predominance of bacterioneuston over bacterioplankton is in the order of 1-4, and holds true for every one of the stations. Statistical analysis of the data has confirmed the reliability of the predominance of microflora in the near-air micro-horizons and has allowed us to establish the pattern of this phenomenon and the persistence of the processes causing it.

The predominance of bacterioneuston over bacterioplankton has been observed both in intracontinental water bodies (Tsyban', 1970a) and in the open ocean, and may be viewed as a natural consequence of basically common factors of the environment prevailing at the air-water interface and that favor the intensive development of bacterial life.

Recent investigations have shown that the near-air micro-layers and the surface-tension film constitute a special biological zone of the ocean, with specific physical-chemical characteristics. In it occurs the concentration of hydrophobic matter, particles with a specific weight that is less than that of water (Parker, Barsom, 1970), hydrocarbons, albumins (Dietz, LaFond, 1950, Ewing, 1950), dissolved organic matter, phosphates, nitrates, nitrites (Cooper, 1948; Goering, Menzel, 1965; Goering, Wallen, 1967), surface-active substances with high sorption capacity (Bernal, 1969), structural components of decomposed organisms, the so-called "anti-rain" of corpses (Zelezinskaya, 1966), pesticides, products of radioactive decay (Assaf, Gat, 1970). The base of the non-soluble components of the surface micro-layer is made up of fatty esters, free fatty acids, fatty alcohols and hydrocarbons (Garret, 1967). According to Riley (1964) and Nishizawa (1969), the surface of the sea is an environment of active formation of organic aggregates, aided considerably by the rise of air bubbles from below, adsorbed to whose surface there are organic-phosphate substances. The air bubbles are playing the role of peculiar "garbage collectors " (Nishizawa, 1969), transporting from the water stratum to the air-water interface adsorbed organic matter. Bursting, they shed the latter in the surface film. This results in the formation at the surface of the sea of "moire," "slicks." Under the influence of wind and waves the surface film is beaten into sea foam. The concentration of organic matter in the near-surface micro-horizon of the sea may also result from secretions of neuston organisms (Zaitsev, 1970) and pleuston organisms (Savilov, 1969), from vertical migrations of neuston, precipitation of rain, dust, spores, pollen, terrestrial insects introduced by wind from land.

The above data indicate that the near-surface micro-biotope of the sea represents an environment composed of special abiotic and biotic factors. Nonetheless, the connection between the bacterial population of the surface film and the bacterioplankton is evident. Our investigations have shown that the number of saprophyte microflora in the near-surface micro-horizons of the Gulf of Alaska and the Aleutian trench increases from tens to thousands of cells in 40 ml of water synchronous with the increase in quantitative content of saprophytes in the euphotic zone. Bacterioneuston reflects, as it were, but on a higher quantitative plane, the degree of development of bacterial life in the underlying water masses. The existence of a correlational link between the density of bacterioneuston and bac- 63 terioplankton in the 0.5-15-meter layer has also been established on the continental shelf of the Black Sea (Tsyban', 1970a). Furthermore, we discovered that the number of saprophytes in the stable foam formed over a water stratum with an abundant bacterial population definitely exceeds the content of saprophyte bacteria in the unstable sea foam floating over a water stratum with sparse microflora. One is led to the hypothesis that there exists a regulatory system incorporating a direct link: the richer the bacterial life in the water stratum (at least in its upper layers), the richer the microflora in the surface-tension film and in the sea foam resulting therefrom. In view of the mechanism of formation of foam, in which suspended and dissolved organic matter and bacteria (Carlucci, Williams, 1965; Rubin, 1968) are transported from the water stratum to the air-sea interface, it seems entirely logical to prognosticate the abundance of bacterial life in the upper layers of the ocean on the basis of bacterioneuston.

Oceanic bacterioneuston consists of a large assemblage of taxons with the predominance of brightly colored microorganisms of the genus Chromobacterium and physiologically active forms of Pseudomonas. That these groups are confined to the surface-tension film is typical also of the central Pacific (Sieburth, 1965), the Black Sea and the Sea of Azov (Tsyban', 1970a). The predominance of pigmented forms among bacterioneuston cultures may be due to the action of ultraviolet rays. As we know, pigmented forms of microorganisms are more resistant to radiation (Imshenetskii, 1946; Swart-Fruchtbauer, 1957). It has also been shown that pigmented bacteria appear on the surface of water bodies in large masses precisely during summer (Fonden, 1969).

Thus the make-up of the bacterioneuston is characterized by a great variety of taxons, a specific assemblage of genera that are similar in different parts of the World Ocean, and the predominance of colored forms. At the same time it has been established that the group of microorganisms that is most common and most abundant in the euphotic zone is among the dominant forms of saprophyte bacteria populating the near-air micro-horizons of the ocean. This fact, like the previously noted link between the numbers of saprophyte microflora in the euphotic zone and in the near-air micro-horizons, indicates considerable similarity among the microbe population in the water stratum and points to the source of origin of the bacterioneuston. First place in its formation belongs to the process of foam formation (Tsyban', 1970b), which plays the role of a link between bacterioneuston and bacterioplankton. Direct proof of this is the increase in the numbers and variety of bacterioneuston during intensive foam formation, observed during a station lasting several days in the Black Sea (Tsyban', 1970a), and in the Pacific. Thus, in the Aleutian trench at station 6140 we carried out two series of activities: at a wind velocity of 3.7 m/sec and several hours later, when the wind had strengthened to 11 m/sec. With the stronger wind, the number of microflora in the air-sea interface zone rose also:

Wind velocity, meter/second	Number of saprophyte bacteria in 40 ml of water in near-air micro-horizons	
	0.15-.020 mm	1-2 cm
3.7	424	636
11.0	2,628	1,206

At ten of the stations occupied in the Gulf of Alaska and in the Aleutian trench, water samples were taken at a wind velocity of 0-5 m/sec, at the remaining stations wind velocity was 6-19 m/sec. 64 Everywhere the numbers of bacterioneuston exceeded those of bacterioplankton by an order of 1-4.

If we add, that according to Kinsman (cited in Assaf, Gat, 1970), waves with a height of 2-4 m prevail at any time in at least 20 per cent of the surface of the World Ocean, it would seem to us that the process of foam formation is a gigantic mechanism contributing to the wide distribution of bacterioneuston in the World Ocean.

The microflora of the air and atmospheric sediments, which often contain organic and biologically active substances, along with an abundant microflora (Parker, 1968; Wood, 1963; Tsyban', 1970a), may be the sources of enrichment of the bacterioneuston of inland water bodies, particularly in their coastal parts. However, in the open parts of the ocean, distant from the coasts of continents and islands, the air is practically sterile. At all microbiological stations we made control cultures of air, rain and snow. In some cases they resulted in the growth of 1-8 colonies of microorganisms, but in most cases no bacterial growth was found.

Thus the infinitesimal quantities of bacteria in the air and in the precipitation in the open parts of the ocean cannot be a substantial source of replenishment of the bacterioneuston. Finally, bacterioneuston develops in a biotope affected also by the stimulating action of ultraviolet rays, which, as we know (Nadson, 1967) accelerate the rates of biological processes and the development of organisms.

Laboratory study of the biochemical characteristics potentially possessed by the marine microorganisms indicates the general trend of biochemical processes in the water body. As has been shown by our investigations, isolated microbe cultures actively decomposed albumins (in bacterioneuston, 70%, in bacterioplankton, 77% of cultures), fats (in bacterioneuston, 40-77%, in bacterioplankton, 40-50% of cultures), and accomplished the destruction of petroleum (in bacterioneuston, 50% of cultures, in bacterioplankton, 35%). These data indicate the important role of microorganisms in the cycle of substances in the ocean.

In the water stratum and particularly in the euphotic zone of the ocean there occurs a continous process of the decomposition of vegetable and animal remains. The resulting lipides, thanks to their low specific weight, rise to the surface, forming natural marine films, the "slicks." It appears that that thanks to the lipolytic microflora of the bacterioneuston the sea surface is freed to a considerable degree of fatty substances and this governs the normal gas exchange between ocean and atmosphere.

The near-air micro-layers of the ocean are particularly subjected to petroleum pollution. Oil films cover extensive areas of the pelagic zone and persist over long periods. It has been estimated that only in 1969 one billion tons of petroleum was transported across the ocean, and that 400 million tons of petroleum was produced on the continental shelf (Hunt, Blumer, 1971).

It is assumed that these figures will triple or quadruple in the next decade. We are faced with the threat of a disruption of the biologic productivity of the water, a disturbance of the oxygen balance in the atmosphere, a reduction in the quality of sea water, etc.

Among the "living" resources of the ocean capable of countering the damaging effect of petroleum pollution and of "managing" the content of petroleum and petroleum products in sea water are the microorganisms. They accomplish the transformation of hydrocarbons in the ocean in spite of the fairly low temperature and the low content of easily accessible forms of nitrogen and phosphorus.

The near-air microflora that forms considerable accumulations 65 in the surface film and that possesses such active enzymatic properties undoubtedly plays an important role in the biological self-cleansing of water bodies. This fact evidently emphasizes the role of the bacterioneuston in the biology of the ocean.

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CONTENT OF EASILY ASSIMILATED ORGANIC MATTER IN THE BOTTOM SEDIMENTS OF THE NORTHEASTERN PACIFIC

By I. A. Mel'nikov

The studies of several investigators (Turpayeva, 1954; Sokolova, 1958, 1964; Sokolova, Neiman, 1966) have shown that the distribution of the biomass of the main groups of benthos correlates with the content and composition of organic matter in the surface layer of bottom sediments. Associated with the organic matter of bottom sediments are, first of all, the detritovores -- benthonic invertebrates that collect detritus from the bottom surface and non-selectively consume bottom material.

The organic matter varies in nutritional value. It is customary to speak of organic fractions as either easy or hard to assimilate by marine organisms. The easily assimilated fraction of organic matter comprises that part which is easily dissolved in the hydrolysis of 5% HCl (Tyurin, 1937). In the trophic cycle "organic matter of bottom sediments -- benthos" the link between easily assimilable organic matter and heterotrophic microflora is of great significance, as the saprophyte bacteria play the main role in the transformation of organic sediments and the transfer of their easily assimilable portion into the trophic cycle of the benthonic invertebrates (S. I. Kuznetsov, 1970).

During Cruise 45 of the "Vityaz'" we investigated the distribution of easily assimilable matter in the bottom sediments of the Gulf of Alaska and the Aleutian trench. As the criterion of relative content of easily assimilable organic matter we used the constant of biochemical consumption of oxygen by the sediment, determined in standard conditions. Along with the determination of this constant we analyzed the calorie content of the sediments by bichromatic oxidation.

Methodology

The biochemical consumption of oxygen (BCO)* by sediment was determined by the flask method (Sorokin, 1970).

From the bottom dredge we took about 100 cubic centimeters of the upper ooze layer with a thickness of 1-1.5 cm, from which we prepared a suspension. To the 100 cm^3 of ooze we added 1 liter sea water, which had previously been obtained from a depth of 750 m, kept for five days in an open container for full saturation with oxygen from the air, and filtered to remove phyto- and zooplankton. With a graduated burette we drew off 100 ml of suspension, introduced it into oxygen flasks with a capacity of 600 ml and with ground stoppers, and filled the flask up with the same deep water. The contents of the closed flasks were then mixed. If, after some time, bubbles appeared beneath the stopper, the flask was again filled up with water. From above, bell glasses with water were placed on the flasks. The control flasks were filled in an analogous manner, but without addition of ooze. The flasks were exposed in darkness at a temperature of about 20°, and their contents stirred every day. After 1, 68
3, 7 and 15 days we determined in the test and control flasks the content of oxygen dissolved in the water above the ooze. For this purpose we carefully poured off the water through a siphon into calibrated oxygen flasks. The oxygen was determined after the Winkler method.

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*Revisor's note. An alternate and perhaps more common expression is "biochemical (or biological) oxygen demand" (BOD).

The constant of the rate of biochemical oxidation (K) was computed with the formula:

$$a_1 = a_o \cdot e^{-kT},$$

where a_o and a_1 are oxygen contents after 7 and 15 days of exposure, in ml/l, and T is the time of exposure, in days.

The calorie value of the sediments was determined by bichromatic combustion (Ostapenya, 1968). For calorie analysis, the ooze samples were dried at a temperature of 50° and kept in hermetic vessels. Into the combustion retort we placed 2-4 milligrams of ground dry sediment. Oxidation was carried out in 10 ml of 0.1 N solution of $K_2Cr_2O_7$ in concentrated H_2SO_4 in the presence of a catalyst (100 mg Ag_2SO_4) at 140°. After combustion, the bichromate residue was titrated with a 0.02 N solution of Mohr's salt in the presence of phenyl-anthranilic acid.

Calorie value (Q) was computed with the formula:

$$Q = V \cdot 3.38 \text{ cal/mg},$$

where V is the bichromatic oxidizability of the sample, mg O_2/mg dry sediment.

The calorie value depends on the relationship between the mineral and the organic fraction of the dry substance. According to Paine (1966) where a substance has an ash yield of 50%, a correction of 3-4% must be applied to the determined calorie value. Ash yield of the sediments in the northeastern Pacific reached 88-97% (after roasting in a muffle furnace at 500° for four hours), and therefore, in order to determine the correction for the effect of the mineral fraction we carried out a number of calorimetry tests at 140° (after our methodology) and at room temperature, where the

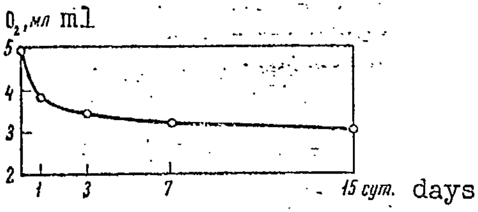


Fig. 1. Biochemical consumption of oxygen by sediment, station 6093.

oxidation of the reduced products took place without oxidation of the organic matter. The error was 8%. The total correction in the method of bichromatic oxidation (together with the error from the incompletely oxidized albumins, equalling 10%) for sediments in the northeastern Pacific amounted to 18%.

Results of Analyses

Observations of the kinetics of the biochemical consumption of oxygen in reduced sediments revealed intensive consumption of oxygen during the first few days of exposure, due, apparently, to the oxidation of mineral reducers of the sulfide type. In computing the constants of the BCO rate we left out of consideration the oxygen used up in the oxidation of mineral components of the exposed sample during 1-3 days. For our computations we used the results of 7-15-day exposures, assuming that during that period the oxygen was consumed mainly in biochemical oxidation of easily assimilable 69 organic matter by heterotrophic microflora (gently sloping part of the kinetic curve, Fig. 1).

Table 1 gives the results of measurements of the constant of the BCO rate in the surface layer of bottom sediments and the calorie value of sediments on four profiles.

Table 1. Easily assimilable substances and calorie value of sediments in the Gulf of Alaska (profiles 1-3) and the Aleutian trench (profile 4)

Station	Depth, m	Nature of sediments	Rate constant $K_{BCO} \cdot 10^{-2}$	Calorie value kcal/gram of dry material
		Profile 1		
6090	465	Sand with pebbles	1.16	0.082
6092	1,092	Silty-clayey ooze	1.59	0.166
6093	1,500	Clayey ooze	1.58	0.124
6094	2,200	id.	1.52	0.103
6095	3,200	Silty-clayey ooze	1.49	0.094
6096	4,190	Clayey ooze	1.02	0.078
		Profile 2		
6100	560	Pebbles, sand, coquina	1.49	-
6102	1,000	Clayey ooze	2.10	0.127
6104	2,080	id.	1.42	0.120
6105	2,970	id.	1.26	0.101
6017	3,800	id.	1.02	-
		Profile 3		
6121	1,600	Clayey ooze	-	0.308
6120	1,960	id.	0.49	0.236
6118	2,300	Silty-clayey ooze	0.47	0.146
6111	2,880	id.	0.24	0.103
6109	3,600	id.	0.20	0.066

cont. on page 124

Table 1, cont.

Profile 4

6131	390	Pebbles, sand, rock bits	1.37	-
6132	1,550	Pebbles, gravel, sand	1.27	-
6134	1,950	Silty-clayey ooze	-	0.171
6136	4,260	id.	1.19	0.137
6139	6,500	id.	0.85	0.074
6140	6,980	Clayey ooze	0.68	0.100
6141	5,960	Silty-clayey ooze	0.69	0.106
6138	5,050	id.	0.44	0.089

On profile 1 (at Kodiak Island), from the upper part of the continental slope (station 6090, depth 465 m) to the ocean basin (station 6096, depth 4,190 m) we observed a decrease in the value of the constant, which indicates an increase in the transformation of organic matter with depth and a decrease in the proportion of the easily assimilable fraction of organic matter in the bottom sediments. On profile 2 (Yakutat Bay), we noted a similar trend on both profiles [sic] in the upper part of the continental slope (stations 6095, 465 m; station 6100, 563 m) the rate constants are lower than in the deeper part of the slope. This phenomenon is evidently due to the coarsening of bottom sediments with strengthening [sic] and mobility of the bottom water, typical of the shelf edge (Strakhov, 1962). Sediments at these stations were represented by typically terrigenous material: sand and pebbles.

On profile 3 (at Baranof Island) the rate constants were determined at four stations with depths of 1,960-3,600 m. They were noticeably lower than in the preceding profiles. 70

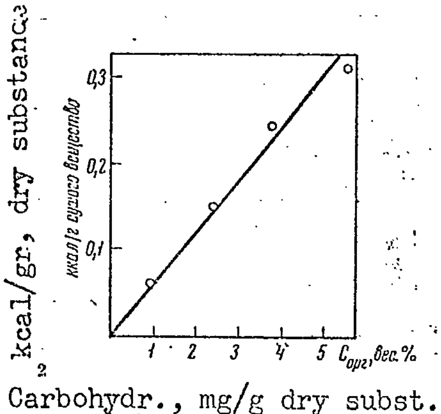
On the profile across the Aleutian trench we clearly observed a typical distribution of contents of easily assimilable organic matter by depth — a decrease of K_{BCO} values from $1.37 \cdot 10^{-2}$ on the upper part of the slope (station 6131, 390 m) to $0.68 \cdot 10^{-2}$ at the bottom of the trench (station 6140, 6,980 m) and a further decrease at the transition to the ocean slope of the trench to $0.44 \cdot 10^{-2}$ (station 6138, 5,050 m). These results are in good agreement with known data on the distribution of easily assimilable organic matter by depth (Bordovskii, 1964).

A comparison of our data on the ocean basin in the northern eutrophic region with analogous data on the northern and southern oligotrophic regions of the Pacific (Sorokin, 1970; Mel'nikov, 1971) shows that the northern eutrophic region is 10-15 times richer in easily assimilable organic matter than the oligotrophic ones.

The distribution of the benthonic biomass by depths on all of the abovelisted profiles corresponds to the distribution of easily assimilable organic matter in the surface layer of bottom sediments, and both values decrease parallel with increasing depth. However, in the clearly observable eutrophic conditions of the region studied, whose benthos contains all trophic groups (A. P. Kuznetsov et al., 1973), no correlation was observed between the biomass of the benthos and the content of easily assimilable organic matter ($r = +0.13$). A high correlation ($r = +0.87$) between the benthonic biomass (represented mainly by detritovores) and easily assimilable organic matter was noted on the first profile. This fact confirms the hypothesis (Sokolova, 1964) that a high content of easily assimilable organic matter in bottom sediments favors primarily those organisms that feed on the surface of the sediments (selective detritovores) and from the body of the sediments (non-selective detritovores)

Table 2. Distribution of C_{org}, N_{org} and carbohydrates in sediments, and calorie value of the upper sediment layer in the Gulf of Alaska (prof. 3)

Station	Depth, m.	Nature of sediments	C_{org}, %	N_{org}, %	Carbohydrates microgram/gram	Calorie value kcal/gram dry substance
6124	180	Sand with pebbles	0.41	0.046	1,170	-
6122	730	Pebbles, sand, coquina	1.07	0.125	3,244	-
6121	1,600	Clayey ooze	2.73	0.339	9,433	0.308
6120	1,950	id.	1.88	0.250	7,189	0.236
6118	2,300	Silty-clayey ooze	1.18	0.155	3,644	0.146
6117	3,350	id.	0.60	0.095	3,311	-
6109	3,460	id.	0.48	0.076	2,800	0.066



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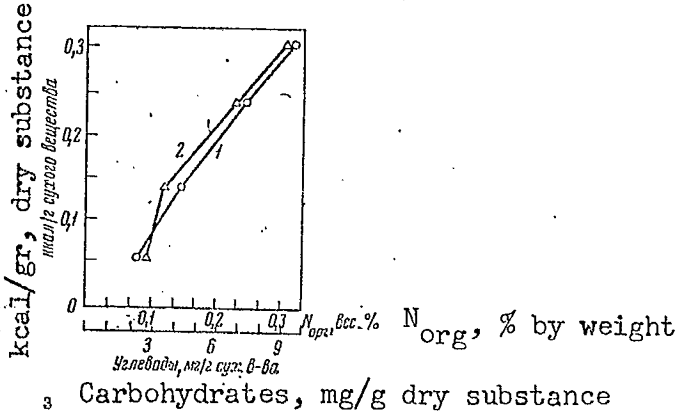

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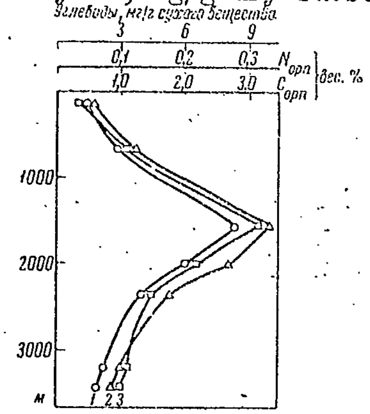

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Fig. 2. Relationship between calorie value and content of organic matter in the sediment.

Fig. 3. Relationship between calorie value and composition of organic matter in the sediment. 1 -- organic nitrogen; 2 -- carbohydrates.

Fig. 4. Distribution of organic carbon (1), organic nitrogen (2) and carbohydrates (3) by depth, in the sediments of the Gulf of Alaska (profile 3).

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which make use of organic matter via hetertrophic microflora.

Data on the calorie value of the surface layer of bottom sediments and contents of C_{org}, N_{org} and carbohydrates in the Gulf of Alaska are given in Table 2.

The calorie value of dry substance in the surface layer of bottom sediments in the bathyal part of the Gulf of Alaska equals 0.066-0.308 kcal/gram and depends primarily on the composition (Fig. 2) and quantity of organic matter in the sediments (Fig. 3). The lower boundary of the calorie readings is close to the value obtained by Hughes (1969) for the sediments of Menai Strait (Wales) at a depth of about 100 m, namely 0.070 kcal/gram in dry substance.

The distribution of organic carbon by depth observed on profile 3 resembles that of easily assimilable organic matter on profiles 1 and 2: in the sediments of the continental slope there occurs an increase in organic-carbon contents; toward the abyssal depths of the ocean the concentrations gradually decrease. A similar picture of distribution by depth is presented by organic nitrogen and carbohydrates (Fig. 4).

Conclusions

1. The rate constant of BCO in the surface layer of bottom sediments in the Gulf of Alaska and the Aleutian trench averages $1.49 \cdot 10^{-2}$ for the continental slope and $0.82 \cdot 10^{-2}$ for the abyssal region.

2. The distribution of the rate constant of BCO in sediments correlates with the biomass of soil- and detritus-consuming organisms, which confirms the link between the distribution of the latter and the content of easily assimilable organic matter.

3. It has been shown that the method of bichromatic oxidation may, with certain allowances, be used for the determination of calorie values of marine sediments.

4. The calorie values of dried sediments fluctuate from 0.066 to 0.308 kcal/gram and depends on the quantity and composition of organic matter in the sample.

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QUANTITATIVE AND ECOLOGICAL CHARACTERISTICS OF THE BENTHOS IN THE BATHYAL REGION OF THE GULF OF ALASKA

By L. I. Moskalev, O. N. Zezina, R. K. Kudinova-Pasternak and T. L. Muromtseva

The Gulf of Alaska, the benthonic population of whose sublittoral region is fairly well known in faunistic terms (Dall, 1877; Hartman, 1948; Eyerdam, 1960; Semenov, 1965), was long represented by a blank spot on maps showing the quantitative distribution of the benthos.

The first bottom-grab samples from that area were obtained during Cruise 29 of the "Vityaz'" (1958) at the foot of the continental slope (station 4138, 54°24' north, 134°41' west, depth 2,620 m). The computed value -- 2.615 gram/m^2 -- provided the first indication of the benthonic biomass in the gulf and, in the compilation of a map of the biomass of the deep-water benthos of the Pacific (Filatova, Levenshtein, 1961; Filatova, 1969) made it possible to run the isobenthonic line in the northeastern part of the ocean at 1 gram/m^2.

Systematic study of the benthos on the continental shelf of the Gulf of Alaska was begun in 1960 by an expedition of the All-Union Scientific-Research Institute for Sea Fisheries and Oceanography ("VNIRO") with the ships "Pervenets," "Zhemchug," and "Orlik." As a result of these activities about 300 bottom-grab samples were obtained from depth of 40-1,180 m, whose analysis led to a fairly detailed understanding of the distribution of the biomass, trophic groups and biocenoses of benthonic fauna on the continental shelf and in the uppermost part of the slope (Shevtsov, 1964; Semenov, 1965).

Information obtained during Cruise 45 of the "Vityaz'" has substantially complemented existing data on the benthos of the Gulf of Alaska, and has made it possible to provide a description of the bottom population of this region in the bathyal area, the least-studied zone of oceanic life, (Zenkevich, 1967, 1968) and partly also in the abyssal area, at the base of the continental slope.

During Cruise 45 of the "Vityaz'" we obtained from depths of 100 to 7,250 meters 45 quantitative bottom grab samples (bottom grab "Okean-50" with a coverage of 0.25 m^2) and 49 qualitative samples with a Sigsby-Gorbunov trawl or dredge (length of frame 250 cm, with a caprone screen with 0.5-mm mesh). According to a methodology adopted by the Institute of Oceanography, Academy of Sciences of the USSR, (Lisitzyn, Udintsev, 1955; Belyayev, Sokolova, 1960; Belyayev, Vinogradova, Filatova, 1960; Fedikov, 1960), samples were flushed on a caprone screen with a mesh of 0.4 mm. The washed sample was elutriated from the container through a caprone net with the same mesh, and both parts of the sample, "soft" and "hard," were fixed separately with 80° ethyl alcohol. The animals were taken from the fixed samples under a binocular microscope and segregated by systematic groups (see table).* The weighing of grab samples

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* This paper uses data from a preliminary analysis of grab and trawl samples. Identification of faunal species was carried out only for some systematic groups (see papers in this volume).

was done on torsion scales with a margin of error of 1 mg, that of trawl samples, on technical scales with a margin of error of 0.1 g. The total 74 biomass was computed from grab samples summarily for macro- and miobenthos.

The distribution of the total biomass in the Gulf of Alaska is shown in a map (Fig. 1) compiled from data collected on Cruises 29 and 45 of the "Vityaz'" and the VNIRO expedition. The graphs (Fig. 2) have been compiled from data gathered on profiles of Cruise 45 of the "Vityaz'." The results show shelf depths exceeding 40-50 m are characterized by a biomass of several tens of grams per square meter. Patches with greater biomass -- 100 g/m^2 and more, as shown in the VNIRO studies -- are confined to areas dominated by immobile sestonophages (Semenov, 1965) and are found mostly along the outer margin of the shelf. Below the shelf margin, which in this area is located at depths of 130-250 m (Gershanovich, Kotenev, Novikova, 1964), the benthonic biomass decreases with an increase in depth, and below 2,000 m does not exceed 3 g/m^2 at any of the profiles. Minimum values of the biomass at the base of the continental slope and in the ocean basin within the gulf are never less than 0.2 g/m^2, which is typical of eutrophic conditions of existence of abyssal benthos, as defined by M. N. Sokolova (Sokolova, Neiman, 1966; Sokolova, 1970).

Of particular interest is the quantitative distribution of the bottom population on the profile south of Unimak Island (Fig. 3), which cut across the eastern part of the Aleutian trench. The pattern of change in the biomass in a vertical direction resembles that found 76 on other profiles, but the quantity of animals is much greater: at a depth of 2,000 m the biomass attains tens of g/m^2 and decreases to a few

Frequency of main taxons of benthonic invertebrates in different vertical zones (from data from Cruise 45 of the "Vityaz'")

Systematic group	Frequency, %				System. group	Frequency, %			
	Trans'. horizon 200–500 m	Bathyal region 500–3,000 m	Abyssal region 3,000–6,000 m	Ultra-abyssal region over 6,000 m		Transitional horizon 200–500 m	Bathyal region 500–3,000 m	Abyssal region 3,000–6,000 m	Ultra-abyssal region over 6,000 m
Spongia	100	68	57	17	Amphipoda	72	91	64	83
Hydrozoa	86	50	14	33	Cumacea	—	50	43	17
Scyphozoa	—	14	21	—	Mysidacea	14	18	—	—
Gorgonaria	—	5	—	—	Decapoda	100	82	7	—
Alcyonaria	—	23	—	—	Pantopoda	43	50	29	—
Pennatularia	14	73	29	—	Loricata	57	23	—	—
Actiniaria	86	77	57	67	Solenogastres	—	32	21	17
Madreporaria	—	9	29	17	Bivalvia	86	100	86	100
Antipatharia	—	18	7	17	Gastropoda	86	100	79	50
Zoantharia	—	—	7	—	Scaphopoda	43	77	79	17
Ceriantharia	29	5	7	—	Cephalopoda*	43	23	21	17
Nemertini	14	36	7	17	Bryozoa	86	32	—	—
Hirudinea	14	—	—	—	Brachiopoda	57	50	7	—
Polychaeta	100	100	100	100	Pogonophora	—	18	29	33
Echiuroidea	—	36	7	33	Crinoidea	86	41	36	17
Sipunculoidea	29	50	36	17	Asteroidea	100	73	86	50
Priapuloidea	—	5	—	50	Ophiuroidea	100	95	100	67
Ostracoda	—	5	—	—	Echinoidea	43	36	79	17
Cirripedia	43	27	14	17	Holothurioidea	72	88	93	83
Isopoda	86	77	79	50	Enteropneusta	—	9	—	50
Tanaidacea	—	27	50	—	Ascidiae	57	23	64	50

* Included are pelagic forms that were captured in the trawl during hoisting.

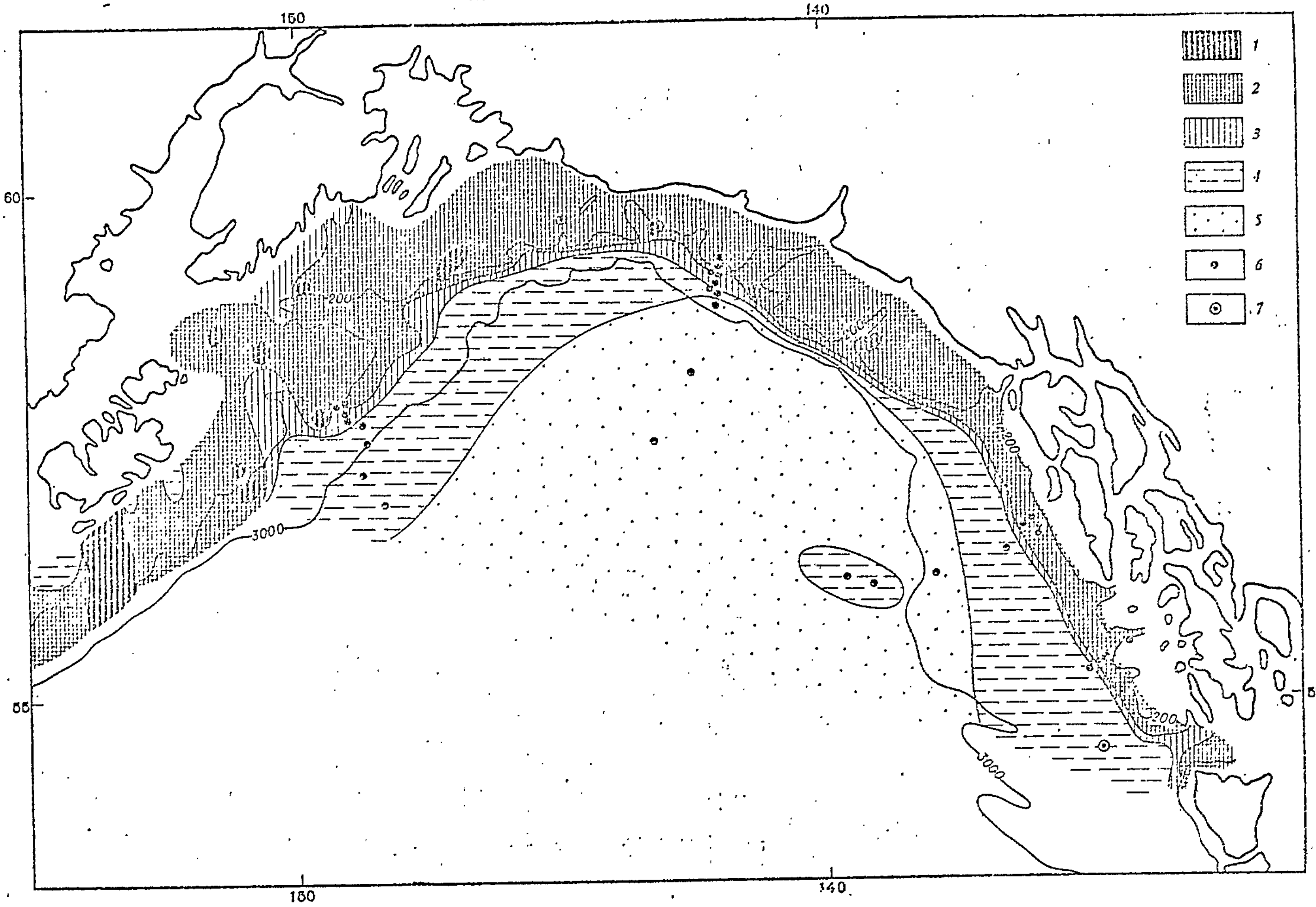
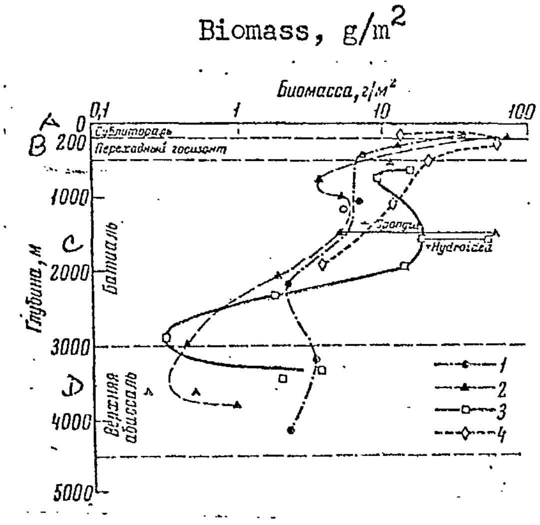


Fig. 1. Distribution of benthonic biomass in the Gulf of Alaska (g/m^2).

1 -- over 100; 2 -- 100-10; 3 -- 10-5; 4 -- 5-1; 5 -- less than 1;
6 -- grab samples on Cruise 45 of the "Vityaz'"; 7 -- id., Cruise 29.



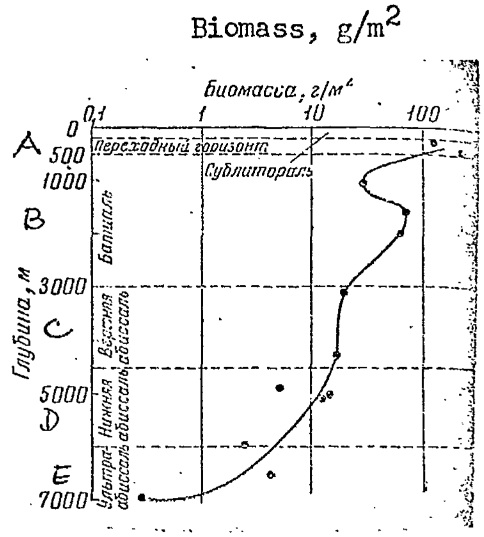


Fig. 2. Variation of benthonic biomass with depth, Gulf of Alaska. A -- sublittoral area; B -- transitional horizon; C -- bathyal area; D -- upper abyssal area. Profiles: 1 -- from Kodiak Island; 2 -- from Yakutat Bay; 3 -- from Baranof Island; 4 -- at Prince of Wales I.

Fig. 3. Variation of benthonic biomass by depth in the Aleutian trench, profile from Unimak Island. A -- transitional horizon; B -- bathyal area; C -- upper abyssal area; D -- lower abyssal area; E -- ultra-abyssal area.

grams only at a depth of 5,000-6,000 m. This faunal abundance appears to be due to the specific sedimentation on the continental slope of the trench, where an abundant influx of suspended organic matter creates favorable conditions for the feeding of benthonic invertebrates even at the greatest depths.

On three of the five profiles (at the islands of Baranof, Prince of Wales and Unimak) there is a typical sag in the curve showing the biomass, indicating a decrease at depths of 500-1,000 m, with a subsequent increase at depths of 1,500-2,000 m. The zone of reduced biomass corresponds to the location of the layer of oxygen minimum in the Gulf of Alaska (Fedosov, Azova, 1964). It is possible that it is this oxygen lack that limits the development of benthonic invertebrates on the upper part of the continental slope.

The relatively large benthonic biomass beneath the low-oxygen layer indicates favorable ecological conditions for bottom dwellers in the bathyal region. Grab samples at a depth of about 1,500 m were found to contain members of the macrobenthos (sponges and hydroids) in numbers comparable with those in the lower sublittoral region (Fig. 2). The abundance of invertebrates in trawl catches down to depths of 1,700-1,800 m (Fig. 4) confirms this conclusion.

The lower bathyal region, whose upper boundary apparently coincides with the boundary between the intermediate and deep water masses, is much poorer than the upper bathyal region and in eutrophic regions, such as the Gulf of Alaska, in respect of benthonic fauna resembles the upper abyssal region.

In the upper and lower bathyal region of the gulf the benthos is somewhat sparser quantitatively than in the bathyal region of the Kurile-Kamchatka and the Peru-Chile trenches (Zenkevich, Filatova, 1958; Filatova, 1966; Savilov, Moskalev, Zevina, 1969). The biomass of the miobenthos in these trenches is close to the biomass of the benthos at the corresponding depths of the Aleutian trench (profile from Unimak Is.).

An ecological (trophological) analysis of the benthonic population of the Gulf of Alaska from grab samples has been carried out in studies by V. V. Shevtsov (1964), V. N. Semenov (1965) and A. P. Kuz- 77
netsov et al. (this collection). Here we shall deal only with a description of the macrobenthos from trawl catches.*

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* A distinction of the terms "macrobenthos" and "miobenthos" is given in a study by M. N. Sokolova (1970, p. 348).

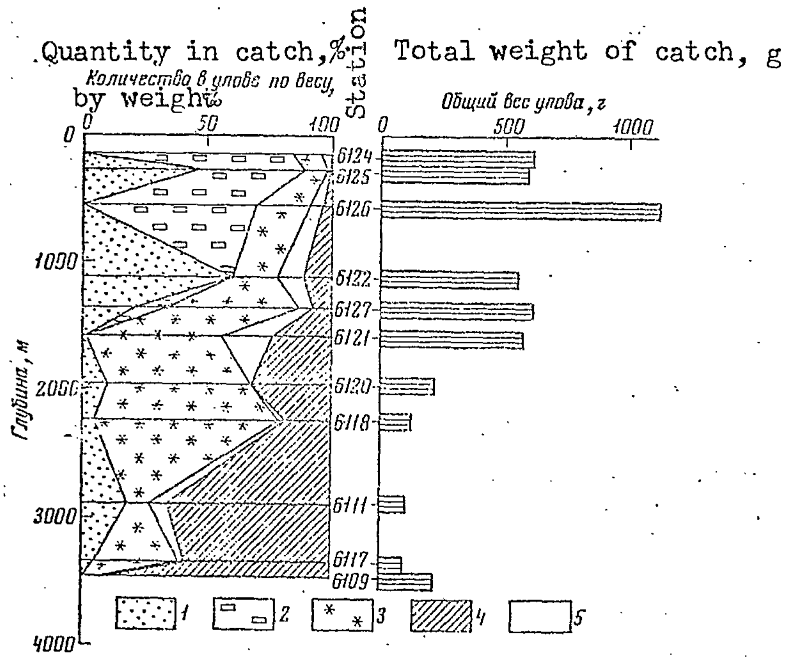

Fig. 4. Proportions of trophic groups of macrobenthos (by weight in trawl catches) in the bathyal region of the Gulf of Alaska. Combined data from profiles at Baranof Island and at Prince of Wales Island. 1 -- sestonophages; 2, 3 -- carnivores (2 -- shrimps, 3 -- actinia, crabs, Ophiuroidea, etc.); 4 -- detritovores; 5 -- animals with undetermined type of alimentation.

In frequency of occurrence in the various vertical zones (Table 1), the large taxons of benthonic invertebrates observed during Cruise 45 present the following pattern:

1. Groups rarely found in trawl catches and, in our own material, found only in 1-2 vertical zones: Zoantharia, Gorgonaria, Hirudinea, Priapuloidea, Ostracoda, Leptostraca, Mysidacea, Enteropneusta.

2. Groups having a broad vertical distribution: Actiniaria, Antipatharia, Nemertini, Polychaeta, Echiuroidea, Isopoda, Tanaidacea, Amphipoda, Bivalvia, Gastropoda, Crinoidea, Asteroidea, Ophiuroidea, Holo-

thuriodea Ascidiae. Many of these are highly heterogeneous in trophic characteristics.

3. Groups found mostly in the sublittoral and the transitional horizon: Hydrozoa, Ceriantharia, Loricata, Cephalopoda, Bryozoa.

4. Groups typical of the transitional horizon and the bathyal region: Cirripedia, Decapoda, Pantopoda, Brachiopoda. According to the information of the VNIRO expedition, they are also found in the lower sublittoral region.

5. Groups found only in the bathyal region: Alcyonaria, Pennatularia.

6. Groups found in the bathyal and abyssal regions: Scyphozoa, Sipunculoidea, Cumacea, Solenogastres, Scaphopoda.

7. Groups found mainly in the abyssal and ultra-abyssal regions: Madreporaria, Echinoidea, Pogonophora.

Thus, at the level of the large taxons the bathyal fauna of the Gulf of Alaska is less specific than the fauna of the sublittoral and abyssal regions. In this sense the bathyal regions serves as a sort of transitional zone from sublittoral to abyssal. To what extent this holds true of the small taxons can be elucidated only through detailed faunistic analysis based on species determinations of the collections.

Data from a preliminary systematic study of the trawl catches 78 make it possible to trace in general outline the shift in trophic structure of the macrobenthos from the shelf margin to the abyssal depths. Such an analysis has been provided for the profiles from Baranof and from Prince of Wales islands (Fig. 4). By using the method of M. N. Sokolova (1960), we computed the weight proportions in the catches of fauna with different types of alimentation: sestonophages (feeding from the water stratum), detritovores (feeding on bottom sediments), and carnivores (feeding on other animals or their remains).

With an increase in depth from 200 to 3,500 m, there is a gradual increase in the role of detritovorous forms and a decrease in the role of sestonophages and carnivores. Sponges, hydroids, sestonophagous Holothuroidea, sea pens and Alcyonaria yield to detritovorous starfishes, Polychaetae, and Holothuroidea. The total weight of the trawl catch also decreases two to three times (from 500-600 to 100-200 grams). At all depths of the bathyal and the transitional horizon from sublittoral to bathyal region we noted a large quantity of carnivorous animals. In the bathyal region, these are crabs of the genus Chionoecetes, predatory starfishes, Ophiuroidea, Actinia, and Pantopoda. At depths of 200-600 m a considerable part of the catch (43 to 84 per cent by weight) is made up of shrimps of the genus Sclerocrangon. At these fairly considerable depths they find in the growths of epifauna favorable conditions for existence, similar to those on the continental shelf. With increasing depth there is only a change in the objects but not in the type of alimentation of Sclerocrangon (Sokolova, 1957). The abundance of shrimps in the trawl catches in the upper bathyal region leads us to conclude that the region contains considerable reserves of these invertebrates.

Our findings confirm the hypothesis of L. A. Zenkevich (1967, 1968) that the bathyal or at least the upper bathyal zone may represent an area of concentration of various commercial fishing objects.

Conclusions

1. The benthonic biomass on the continental slope of the Gulf of Alaska decreases from several tens of grams per square meter on the margin of the continental shelf (130-250 m) to tenths of g/m^2 at the foot of the slope.

2. On the slope of the Aleutian trench opposite Unimak Island the benthonic biomass is greater by one order of magnitude than at the same depths in the Gulf of Alaska. This is apparently due to more favorable alimentary conditions for bottom invertebrates, created by the transfer of a large amount of organic matter from shallower water to the slope of the trench.

3. On some profiles, the benthonic biomass at depths of 500-1,000 m decreases, apparently because of oxygen content that is unfavorable for benthonic invertebrates where the bottom meets the layer of oxygen minimum.

4. The benthonic biomass in the upper bathyal region (to 2,000 m) resembles that of the sublittoral region; in the lower bathyal region (below 2,000 m), it resemblas that of the abyssal region.

5. With increasing depth the predominance of the weight of sestonophagous forms of the macrobenthos is replaced by a predominance of detritovorous animals. At all depths of the bathyal region an important role in the macrobenthos is being played by carnivores.

6. The upper bathyal region down to 600 m and the transitional horizon from the sublittoral to the bathyal region contains abundant shrimps of the genus Sclerocrangon.

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BIOCENOSES OF THE BENTHONIC FAUNA IN THE BATHYAL ZONE OF THE GULF OF ALASKA

By Z. A. Filatova

Investigations of the benthonic fauna on the continental slope (bathyal zone) of the Gulf of Alaska during Cruise 45 of the "Vityaz'" were carried out on four profiles, oriented at right angles to the coast, starting from the near-shore zone all the way to the abyssal zone in the open gulf. Stations were arranged by depth in such a manner that it was possible to trace the change in composition and quantitative distribution of benthonic fauna in a vertical direction and to correlate these data with analogous information obtained previously in the Kurile-Kamchatka trench. At each station we made quantitative collections with the bottom grab "Okean-50" with a coverage of 0.25 m^2, qualitative samples were collected with Sigsby or Galatea trawls, and photos were taken of the sea bottom. We also used data from several stations carried out earlier in the Gulf of Alaska during Cruise 29 of the "Vityaz'." Although analysis of the information on benthonic fauna during Cruise 45 is not yet complete, it seemed interesting to record the most tentative conclusions concerning the composition and distribution of the main biocenoses of benthonic fauna characterizing the bathyal region of the Gulf of Alaska.

Determinations of species of index forms of benthonic fauna were carried out by a number of specialists in the benthos laboratory of the Institute of Oceanography of the Academy of Sciences of the USSR, the Institute of Biology of Southern Seas of the Academy of Sciences of the Ukrainian SSR and the Department of Invertebrate Zoology of Moscow State University. Thus, sponges were determined by V. M. Koltun, pennatularians and antipatharians by F. A. Pasternak, sipunculids by V. V. Murina, echiuroids by L. A. Zenkevich, polychaetes by R. Ya. Levenshtein, brachiopods by O. N. Zezina, pantopods by Ye. P. Turpayeva, Tanaidacea by R. K. Kudinova-Pasternak, barnacles by G. B. Zevina, Ophiuroidea by N. M. Litvinova, starfishes by G. M. Belyayev, Irregularia by A. N. Mironov, bivalve molluscs by Z. A. Filatova.

We used information concerning the geomorphology of the bottom of the Gulf of Alaska and the composition and distribution of bottom sediments in the sublittoral region and the upper continental slope from the studies of D. Ye. Gershanovich et al. (1964) and foreign scientists (Gibson, 1960; Menard, Dietz, 1964, etc.). This information was complemented to some extent by data from Cruise 45 of the "Vityaz'." The present paper makes reference only to the most general features of the bottom morphology of the slope, which have a direct bearing on the distribution of the benthonic fauna inhabiting them.

One of the typical features of the structure of the coastal zone of the gulf is the strongly broken-up coastline and adjacent part of the continental shelf. A large number of bays, fiords, cliffs, archipelagi of large and small islands are typical of the entire coast of the Gulf of Alaska. The sublittoral zone of the gulf is developed highly unevenly: it is narrowest in the eastern part of the gulf (Alexander Archipelago, Queen Charlotte Islands, Vancouver Island) and considerably wider in the north and northwest (Kodiak Island, Cook Inlet). The outer margin of the continental shelf also varies in depth: 120-130 meters at Unimak Island, 150-160 meters at Kodiak Island, 200-220 meters at Yakutat Bay. These depths mark the start of the gulf's bathyal zone. 81

The bathyal zone in the Gulf of Alaska is well developed, but also in a very uneven manner. Unlike the sublittoral zone, the slope attains its greatest width in the east. Here, thanks to the relatively narrow sublittoral zone, great depths on the bathyal zone (1,000 m and more) are found fairly close to the shore. In the northwest the bathyal zone is considerably narrower and bounded on the south by the eastern part of the Aleutian trench, which here extends into the gulf itself. As we go eastward, the trench gradually peters out and is lost in the basin of the gulf. In the open gulf bathyal depths increase gradually to 3,000-3,500 meters and merge into the abyssal zone of the northeastern Pacific.

The composition and distribution of the bottom sediments on the continental shelf and the upper continental slope in the Gulf of Alaska have been described in considerable detail (Gershanovich et al., 1964).

Most common are soft terrigenous deposits (gray and greenish-gray ooze and clayey ooze). On the lower part of the slope one also finds organic sediments -- globerina and diatom ooze.

As has been shown by biological investigations carried out in recent years in the Sea of Okhotsk and the Bering Sea and the trenches of the Pacific, a close relationship exists between the productivity of the fauna inhabiting the sublittoral zone (both benthos and neritic plankton) and the productivity of the fauna in the bathyal zone. The wider the sublittoral zone and the more abundant its population, the greater the productivity of the slope.

According to L. A. Zenkevich (1968), the general abundance of the population of the bathyal zone depends primarily on good food resources: "on the one hand, resources that have been washed in from the shelf across the 'continental ridge' which is rich in organic detritus, on the other, remains of the abundant plankton of the coastal waters, also rich in organic matter, which have descended from the bathypelagic zone." Such an enrichment appears to be typical of the bathyal zone of the entire World Ocean, with some fluctuations resulting from local peculiarities of the bottom relief, i.e., the steepness of the slope and the proximity of great depths to the sublittoral zone, as well as from the system of dominant currents. The quantitative distribution of the benthonic fauna in the sublittoral zone, the bathyal zone and the abyssal zone of the gulf follows certain regular patterns (Moskalev et al., 1973). The steep gradient of the slope, due to which the abyssal zone in this region is considerably close to the coasts, affects the distribution of the total benthonic biomass in a vertical direction: even in the depths of the abyssal zone the biomass is still quite considerable.

The fairly large numbers of sublittoral biocenoses of benthonic fauna, found in the narrow shelf zone of the gulf, have been studied in considerable detail by VNIRO-TINRO expeditions, and will be referred to here only incidentally. As may be seen from these studies (Semenov, 1965), a very large number (over 40) of biocenoses is given for the bottom fauna of the shelf zone of the gulf. These biocenoses were defined according to a methodology that assigns decisive weight to a single index form, and Semenov's paper, unfortunately, does not provide any quantitative data in respect of these biocenoses or in respect of the ratios between index and typical forms, even though Semenov was able to draw on quite considerable amounts of data. A close scrutiny of the lists of "biocenoses" and a comparison of the composition of index forms reveals that they are certainly similar, and the suspicion arises that many are not independent communities but rather groupings of large biocenoses many of which are found widely in the seas of the northern hemisphere. The similarity of the general ecological features of the index forms in similar habitats, while their numbers differ, is usually also typical of 82 individual groupings of large biocenoses, of which they form part (Brotskaya, Zenkevich, 1939; Filatova, Zenkevich, 1957; Filatova, Barsanova, 1964). Such, for instance is the case with the temperate-cold-water biocenoses found in the silted-up shallow portions of the Northern and Far Eastern seas of the USSR. There the index forms are such mass species as Ophiura sarsi, Ctenodiscus crispatus, Golfingia margaritacea, Nucula tenuis, Macoma calcarea, a number of Pacific species of Astarte, Maldane sarsi, Spiochaetopterus typicus, etc. These biocenoses and their groupings usually develop on soft, greenish-gray muddy or muddy-sandy soils of coastal areas in the Far Eastern seas (Vinogradova, 1954; Savilov, 1961; Neiman, 1963, Filatova, Barsanova, 1964). In the western Arctic and in the marginal seas of the North Atlantic they make up a typical element of benthonic fauna that is common for the temperate-cold sublittoral zone. In the Gulf of Alaska (judging from the data of the VNIRO-TINRO expedition) these biocenoses and their groupings are also found widely. Here, in the extreme northeast, they remain ecologically close to the initial biocenoses. Along with the index forms noted earlier we also find here a number of endemic North Pacific species, which, as it were, replace the ecologically similar North Atlantic and Lower Arctic forms inhabiting the western sector of the Arctic. Thus, of the Astartidae we find here instead of the Atlantic Astarte crenata and its subspecies among the biocenoses Astarte derjugini, A. multicostata, two species of Rictocyma; along with Nucula tenuis we find species of Acila, etc.

One of the typical and widely occurring communities in the upper sublittoral region of the Gulf of Alaska is the biocenosis of sand dollars Echinarachnius parma. This is an amphi-north-boreal biocenosis which, in the Gulf of Alaska, is located almost on the eastern boundary of its distribution in the Pacific. Farther south (Oregon, California) the stretches of sandy shallows that favor the development of this biocenosis become smaller and smaller, owing to the narrowness of the sublittoral zone itself and the steepness of the slope, and it begins to occur only in separate patches and then disappears altogether.

The biocenoses of benthonic fauna in the Gulf of Alaska are closely linked in their origin and distribution with the shallow-water fauna of the marginal seas of the Pacific -- Bering Sea and Sea of Okhotsk -- as well as with the fauna of the Arctic seas. Also, among these biocenoses we find representatives of the Oregon fauna that have penetrated from the south. All of this, it seems, has made of the shallow coastal zone of the Gulf of Alaska a place where faunas of different zoogeographical character meet, so to speak a nodal area of distribution. However, to form a definite opinion on this point we would have to have lists of forms comprising the biocenoses in the sublittoral zone of the Gulf of Alaska, which, regrettably, are not given in Semenov's study of 1965. As we shall show further on a similar phenomenon in the intermingling of faunas is observable in the bathyal zone of the gulf.

Until now, almost nothing was known of the biocenoses in the bathyal zone of the Gulf of Alaska. Disconnected samples taken by various expeditions only incidentally could not, of course, provide the basis for any judgments as to composition or distribution of the bathyal biocenoses.

According to the scheme of vertical biological zonation adopted by the Institute of Oceanography of the Academy of Sciences of the USSR (Belyayev et al., 1959), there exists between the lower boundary of the sublittoral zone (200 m) and the bathyal zone proper (500-2,500 m) a transitional zone (200-500 m). Another transitional zone (2,500-3,000 m) separates the bathyal zone from the abyssal zone (3,000-6,000 m). Naturally, this scheme is highly tentative and indicates only that there can be no sharply defined boundaries in the ocean, particularly in respect of vertical zonation and the distribution of fauna. It is also certain that the 83
population of each of these zones has some effect on the composition of the faunas in the other, overlying and underlying zones. Therefore the bathyal zone cannot have "its own" assemblage of typical species, but rather it usually has a mixed population consisting, as a rule, of four groups of species differing in composition, origin, ecology and the pattern of vertical distribution: (1) eurybathic species, whose range in term of depths is the greatest; (2) relatively shallow-water species, descending from the sublittoral zone to greater depths; (3) deepwater species, ascending under the influence of local conditions -- mostly

temperature -- from abyssal to lesser depths; (4) properly bathyal, "slope" forms, whose habitat is usually associated mainly with the bathyal zone. In our case, this last group is of the greatest interest, including species many of which often form massive populations in the bathyal zone and are index forms of a number of biocenoses of benthonic fauna.

Unfortunately, it did not prove possible for nearly all of the groups to designate forms whose habitat coincided mostly with the slope. We shall therefore have to limit ourselves to the listing of only some forms, which are the most typical. In the course of time this list will undoubtedly be improved and expanded.

It seems quite likely that each part of the ocean has its own "slope" species, peculiar to the bathyal zone of that area.

Thus far, only a few such species are known. In the bathyal zone of the Gulf of Alaska they are represented by a large group of pennatularians (Pasternak, 1973). Of the polychaetes we may name Aphrodite talpa, Onuphis pallida, Potamilla symbiotica, Travisia pupa, etc. In the lower horizons of the bathyal regions, which border on the abyssal region, one often finds various species of Laetmatonice, Kesun abyssorum, Nephtys brachycephala, etc. Of the brachiopods there are Frieleia halli, less often Terebratulina unguicula and T. kiiensis. Of the decapods, the bathyal reginn commonly contains the large Chionoecetes angulatus angulatus, which here replace the shallower C. opilio, as well as Munidopsis beringiana. Of bivalves, there are the large Yoldia beringiana, and in the upper part of the slope, Astarne derjugini, Rictocyma zenkewitchi and R. esquimalti, and various species of Acila. In the middle and lower part of the slope one fairly often finds

Neilo fiora, *Myonera garetti*, *Crenella columbiana*, *Nuculana leonina*, as well as *Halicardissa perplicata*.

For the lower part of the slope one could also, it seems, list a whole series of Echiuridae, but at the moment (owing to the fact that a large part of the material is not determined) we can name only the large *Prometor grandis* (Zenkevich, 1951, 1958). Of the echinoderms, typical inhabitants are various Ophiuroidea, which often form massive settlements, first of all *Ophiophthalmus cataleimmoidus* and *O. normani*. Typical of the upper and middle horizons of the bathyal region of the gulf, as of the Bering Sea, are Irregularia of the genus *Brisaster*, as well as *Urechinus loveni*. In the lower horizons of the bathyal region one finds two types of starfishes of the family Porcellanasteridae -- *Eremicaster tenebrarius* and *E. pacificus*.

Judging from available data, the properly bathyal fauna in the Gulf of Alaska begins to appear at depths of about 400-500 m. At these depths there are extensive soft muddy and fine-silted sediments, and only rarely abyssal muddy sand. The total biomass of the benthonic fauna in the upper part of the bathyal zone is fairly large -- about 10-12 g/m^2. It is usually made up of a large number of polychaetes (occasionally to 500 specimens per square meter, with a biomass of up to 10-11 g/m^2) small Ophiuroidea (up to several hundred per catch) and bivalves. The numbers and biomass of the benthonic fauna in the upper bathyal region of the gulf are several times greater than in the adjacent parts of the abyssal zone.

The population in the lower bathyal zone of the gulf (1,500- 84
2,500 m) is greatly affected by the benthonic fauna of the adjacent

parts of the abyssal zone. Among the biocenoses of this part of the bathyal zone are a number of oceanic forms, which gives them a more deep-sea character.

Let us consider some of the most typical biocenoses of the benthonic fauna in the Gulf of Alaska. There can be no doubt that there are still other biocenoses and groupings, but the incomplete analysis of the material has not made it possible to distinguish them. We were also unable to provide a sufficiently complete quantitative description, inasmuch as the bottom grab samples have not been fully analyzed, either. We were compelled to limit ourselves mainly to describing the composition and range of these biocenoses on the continental slope of the Gulf of Alaska.

1. Biocenosis _Ophiophthalmus cataleimmoidus_ -- _Astarte derjugini_ -- _Onuphis pallida_ -- _Aphrodite talpa_

It is situated in the upper part of the bathyal zone, at a depth of 450-570 m (stations 6090, 6100). The bottom is gray and greenish-gray ooze with pebbles. The temperatures of the bottom monolith (t^o_m)* were respectively 4.2 and 3.5°. The index forms are _Ophiophthalmus cataleimmoidus_ (biomass up to 2.5 g/m^2, up to 60 specimens per trawl catch),

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* The temperature of the bottom monolith (t^o_m) was measured by a soil thermometer at the time the grab sample reached the deck. The thermometer was pushed 15-20 cm into the bottom and kept there 4-5 minutes.

Onuphis pallida (over 100 specimens in trawl catch), the large Aphrodite talpa (5 spec. in trawl catch), Astarte derjugini. All of these forms were found at both stations. The total biomass was resp. 4.7 and 12 g/m^2, with a predominance of Ophiuroidea and polychaetes.

Apart from the abovenoted forms, typical are: among Echinodermata, Ophiura leptoctenia, O. sarsi, Henricia sp., Heliomethra glacialis, fairly large Brisaster latifrons (?); of the polychaetes, Onuphis conchylega, Pectinaria koreni; of the brachiopods, Frielleia halli, Tetebratulina unguicula and Laqueus californianus; of bivalves, various Cuspidaria and Dermatomya, Crenella columbiana, Delectopecten sp.; of the pantopods, Hedgpethia californica; of the Cirripedia, Scalpellum columbianum and S. vegae. There are small numbers of sponges, hydroids, and actinias. This biocenosis still contains a whole series of sublittoral and eurybathic species, which gradually disappear with greater depths.

2. Biocenosis Onuphis pallida -- Pavonaria pacifica -- Ophiophthalmus normani -- Ophiura leptoctenia

Found in the upper and middle bathyal zone (525-1,500 m, st. 6101-03, 6122-23, 6126-27). The bottom was mostly gray (sometimes liquid) clayey ooze, stones; t^{o}_{m} 3.0-4.1°. Total biomass, 5.1-16.8 (average 10.5) g/m^2.

Index forms: Onuphis pallida (100% occurrence, over 100 spec. in trawl catch) and large Pavonaria pacifica (North Pacific bathyal species, typical representative of the epifauna of soft bottoms, ecological and trophic habitat on the slope of the continental margin).

Typical are three small Ophiuroidea which often form massive settlements: the North Pacific *Ophiura leptoctenia* and *Ophiophthalmus normani*, endemic in the North Pacific, which with greater depth gradually replaces the more shallow *O. cataleimmoidus*.

The biocenosis consists of three groups: 85

2a. Group *Onuphis pallida* -- *Pavonaria pacifica* -- *Ophiophthalmus normani* -- *O. cataleimmoidus*. Occurs at the depth of 525-770 m (st. 6101, 6122-23, 6126). The bottom is gray ooze, t^o_m 3.5-4.1° (average 3.7°). Total biomass 3.7-21.1 (average 12.2) g/m^2. Ophiuroidea predominate (4-5 species, numbers up to 50 spec. per square meter, biomass 8 g/m^2, up to several hundred spec.in trawl catch). Polychaetes are also numerous -- up to 500 spec. per square meter, biomass 11 g/m^2. *Onuphis pallida* was found at every station, over 100 specimens in the trawl catch. Large *Ophiophthalmus cataleimmoidus* was gradually being replaced by *O. normanni*. Typical are large *Pavonaria pacifica*, as well as small bivalves.

In addition to the abovenoted forms, we found large decapods *Chionoecetes angulatus angulatus* and *Munidopsis beringiana*, brachiopods *Frieleia halli*, *Terebratulina kiiensis*, *T. unguicula*; pantopods *Hedgpethia californica*, bivalves *Delectopecten randolphi* (many), small *Dermatomya* sp., *Nuculana minuta*, *Yoldiella derjugini*, *Thracia* sp., *Lyonsiella* sp.

In addition to the index forms, this group contains a large number of various Ophiuroidea -- *Ophiopholis aculeata*, *Ophiophthalmus longispina*, *Ophiura cryptolepis*, *Amphiura* sp., large holothurians *Psolus*, crinoids *Heliometra*, as well as *Asteronyx*, always attached to pennatularians, which gives this group a peculiar character. At every station we found many large and small actinias, a small number of sponges (of the

Lissodendoryx, Heliclona, Chonelasma etc.), there was the fairly rare stem bryozoan Kinetoskias sp.

In its composition and average biomass (12 g/m^2) this is an upper bathyal group, in spite of the fairly considerable depth of occurrence (525-770 m), it is complete, varied in composition and rich in numbers. Predominant are infauna and onfauna,* forms feeding on detritus and organic matter in the soil, there is admixture of filtrators and large predators, fairly common in the bathyal region. Many mass species (polychaetes, small molluscs and brittle stars) are valuable food sources for fishes.

2b. Group Onuphis pallida -- Syncoryne sp. -- Potamilla symbiotica -- Ophiophthalmus normani. This interesting group was found in the Gulf of Alaska only at one station (6103, depth 990-1,030 m). The bottom was clayey ooze; t^o_m 3.0°; total biomass 5.3 g/m^2. The index forms of this group present a clear example of the adaptation of organisms from various benthonic faunal groups to habitation on a very soft, fine clay bottom. This is an epifauna of soft bottoms at its most typical (Filatova, Zenkevich, 1957). Small hydroids of the Athecata type (Syncoryne sp.) use the long (up to 35-40 cm) and fairly hard tube of the polychaete Potamilla symbiotica as a substrate, covering it entirely on the outside with their cenosarc. Their hydrorhizae create flat, rounded meshes around the tubes, which with their lower ends grow into these meshes, which serve as a kind of parachute, supporting the tubes on the "liquid" bottom. As a result of this the polychaetes are enabled to rise above the soft bottom, which is not suited to their lifestyle, and to maintain themselves in a vertical position. This marks the first find of a [the?] symbiotic community

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* Infauna -- living in the ground; onfauna -- living on the ground. --TR.

outside the Sea of Okhotsk, where it was first discovered and described (Ushakov, 1950a, b; Savilov, 1961). In the Gulf of Alaska this group occurs at an average depth of 1,000 m. In the Sea of Okhotsk it was found 86 by the "Vityaz'" at seven stations at depths of 460 and 900-3,374 meters in an extensive area on slopes and in the southern part of the sea on "swampy" diatom ooze and described in detail by A. I. Savilov (1961). In the Bering Sea the group is not found, however, it is entirely possible that it will also be found there, as in other parts of the continental slope of the Pacific.

Apart from the abovenoted index forms, the group 2b typically contains: large Pavonaria pacifica with Chondractinia; polychaetes -- a large number of Spiochaetopterus (mainly tubes), Maldanidae in clayey tubes (up to 160 specimens per square meter, biomass 0.6 g/m^2); young Chionoecetes opilio; large holothurians of the Stichopodidae type (up to 30 specimens in the trawl catch); brittle stars Ophiophthalmus normani (not many); of bivalves, small Nucula cardara, Yoldiella derjugini, large Delectopecten randolphi, etc.

2c. Group Onuphis pallida -- Ophiura leptoctenia -- Pavonaria pacifica -- Halicardissa perplicata. Found at a depth of 1,110-1,500 m (st. 6103, 6127), bottom muddy, gray clayey ooze and strongly muddy sand. The total biomass is resp. 12.2 and 5.1 g/m^2 (with sponges, 61.1 g/m^2). Among the index species common to this biocenosis the group contains the large bivalves Halicardissa perplicata (Dall) (order Septibranchia, family Verticordiidae), which are fairly rare in the North Pacific. This bathyal species lives along the Pacific coast of America, not reaching Southern California and the Galapagos Islands. Its northern boundary appears to be located in the Gulf of Alaska, as it has not yet been found in the Far Eastern seas. The large Pavonaria pacifica living here is found in tens of specimens in each trawl catch, usually with attached large Asteronyx.

A very large quantity of small Ophiura leptoctenia (about 500 and 1,100 specimens in trawl catches) provides the general background and gives to this group a peculiar appearance. Among the forms typical of group 2c we shall note: sponges, Hyalospongia, Lissodendoryx (up to 54 g/m^2), Aulosaccus sp., small solitary actinias and large chondractinias, colonies of hydroids. For the first time we found in the gulf a small solitary coral of the Caryophyllia genus, as well as fairly large rhizopods Bathysiphon. Of the brachiopods, common are Frieleia* halli, Terebratulina kiiensis and T. unguicula; of the polychaetes, Onuphis conchylega (up to 30 specimens in the trawl catch) and Euphrosyne borealis (up to 60 spec.). The fact that these typically sublittoral species were found at such depths emphasizes their eurybathic nature.

Of the Cirripedia we shall note Scalpellum alascensis, and of the decapods, a considerable quantity of Chionoecetes angulatus angulatus and two species of shrimps of the genera Pandalus and Sclerocrangon. We found a large number of various bivalves: Cuspidaria (2 species), Dermatomya sp., Lyonsiella sp., Myonera garetti, Nuculana leonina and Dacridium pacificum. There were many small Delectopecten, as well as various Trochidae. Of the Echinodermata we should note particularly a large number

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* Also spelled "Frielleia." -- TRANSL.

of small deepwater Irregularia Pourtalesia laguncula beringiana (20 spec. and many fragments in the trawl catch) . Their frequency points to a link of the lower-bathyal fauna in the Gulf of Alaska not only with the Pacific but also with the Bering Sea. Thus, an important role in the 2c group is being played by a number of sublittoral and eurybathic forms and the abyssal oceanic fauna. In addition, forms of Californian origin that have penetrated this far north are found with species of Bering Sea origin. The place where such forms "join" is the lower bathyal region of the Gulf of Alaska.

3. Biocenosis Onuphis pallida -- Yoldia beringiana -- Ophiophthalmus normani -- Ophiura leptoctenia -- Virgularia cystifera

This biocenosis has been observed in the middle and lower bathyal zone of the Gulf of Alaska (stations 6092-93, 6121, 6128), depth 1,090-1,930 m, soft clayey ooze, t^o_m 1.9-2.0°, total biomass 3.9-18.5 g/m^2 (average 8.7 g/m^2).

Among the index forms of this biocenosis we must note first of all the large bivalve Yoldia beringiana, which is highly typical of the bathyal zone in the entire North Pacific and its seas (Savilov, 1961; Kuznetsov, 1963; Filatova, Barsanova, 1964; Semenov, 1965, and others). This species lives nearly exclusively in the bathyal region, from its upper to its lower horizons; in the sublittoral and abyssal zones it has not been observed.

Virgularia cystifera is found widely in the bathyal zone (700-

2,000 m) of the North Pacific. It clings to the depths nearest the shore, which is due to its feeding habits. Together with Protoptilum orientale this species belongs to the ecological group of "inshore deepwater forms" (Pasternak, 1973). P. orientale also forms part of this biocenosis (depth 1,600 m), so that, along with Kophobelemnon affine and Pavonaria pacifica (depth 1,050 m), we find here nearly the entire assemblage of pennatularians, which are typical of the lower horizons of the bathyal region.

Represented in this biocenosis are both detritovorous and sestonophagous forms and predators. Typical are: the pennatularians Kophobelemnon affine (3-4 spec. in trawl catch), Protoptilum orientale, Pavonaria pacifica; large chondractinias and other Actiniaria (up to 50 in trawl catch); brachiopods Frieleia halli (sparse); polychaetes, in addition to the index forms (more than 100 spec. in trawl catch) are represented by Brada irenaia (15 spec.), Samythella neglecta (54 spec.), Travisia forbesi (about 40 spec.), Amphicteis sp. (20 spec.), Spiochaetopterus, Pectinaria; among the bivalves there are many forms belonging to the lower bathyal and greater depths of the genera Lyonsiella, Cuspidaria (Myonera), as well as Delectopecten randolphi, Vesicomya pacifica, Malletia pacifica, Myonera garetti, Poromya sp., etc. Echinoderms are represented mainly by a mass of Ophiuroidea -- large Ophiophthalmus normani and small Ophiura leptoctenia -- as well as Ophiolimna bairdi. Of the deepwater forms we shall note small Irregularia Pourtalesia laguncula beringiana as well as large holothurians belonging to the Sichopodidae and the Molpadonia. The large echiuroid Prometor sp. and several Pogonophora belonging to the Siboglinidae give this biocenosis a rather abyssal appearance.

The relatively large average biomass (8.7 g/m^2), the large numbers and variety of species in this biocenosis lead us to consider it rich and typical of the bathyal region of the Gulf of Alaska.

4. Biocenosis Prometor grandis -- Onuphis pallida -- Yoldia beringiana -- Pennatularia

This peculiar biocenosis belongs to the lowest horizons of the bathyal region (1,960-2,340 m) and is located in the open part of the Gulf of Alaska and the foot of the continental slope (stations 6094, 6104, 6118, 6120). Some of these stations, where the slope is steeper, were situated fairly close to the inshore part of the gulf. The importance of the proximity of great depths to the inshore zone, in respect of the composition and abundance of the benthonic fauna, has been noted more than once. The nearer the great depths are to the productive coastal zone, the shorter the path to be traversed by the organic remains and detritus that are washed off the sublittoral zone and accumulate there (Lisitsyn, 1966). 88
In such "coastal" deepwater areas the biomass, numbers and species variety of the fauna are always greater than at the same depths in the open sea. This is one of the highly productive areas within the bathyal region, which forms part of the circum-oceanic eutrophic zone of the ocean. The biocenosis described here is found on soft, gray, clayey ooze, $t^o_m = 1.8-2.2^o$. The feeding conditions of the benthonic invertebrates in this area seem to be quite good, judging from the large sizes, large numbers and the biomass of the fauna living in it. The total biomass varies from 1.8 to 14 g/m^2; the numbers of the polychaetes sometimes reach 600 specimens per square

meter, with a biomass of 11.2 g/m^2. The dimension of the holothurians Stichopodidae is up to 20 cm (with more than 30 spec. in the trawl catch). The weight of a single large actinia with a diameter of 12 cm reached 180 grams, of one echiuroid Prometor, 20 grams, and of three large proboscises of the latter, 10 grams; the weight of a young Chionoecetes angulatus exceeded 100 grams. Grenadiers that were caught in the Sigsby trawl had a length of 50-60 cm. Also very large were the rhizopods Bathysiphon and several bivalves.

Onuphis pallida -- a Californian bathyal species -- continued to function as one of the index forms of the biocenosis, even though its numbers were somewhat smaller than in shallower waters. The most impressive component of the biocenosis were large echiuroids Prometor grandis, whose wide and long proboscises were constantly found in the trawl samples; whole specimens were much rarer. These proboscises evidently lie on the bottom surface and, during trawling, are easily torn off the body of the echiuroid which is submerged in the ooze. It appears that the marginal areas of the eutrophic zone, where feeding conditions for bottom-consuming organisms are still quite good, as at the foot of the continental slope, are the chief habitat of these nearly immobile animals, which are very closely associated with the upper layer of soft bottom sediments into which they burrow and on which they feed, spreading over the surface their wide and apparently mobile proboscis (Zenkevich, 1957, 1958).

A no less interesting, but ecologically entirely different group is the numerous pennatularians found here, which rise considerably above the bottom. Here we find Virgularia cystifera, Protoptylum /sic/ orientale, Kophobelemnon affine, Stylatula elegans. The first two species are on the whole very typical of the inshore bathyal zone (Pasternak, 1973).

Among the typical forms of the biocenosis are large Bathysiphon and other foraminifers (mainly agglutinating). Of the polychaetes, we found at nearly every station Travisia pupa, Nephthys brachycephala, the eurybathic Terebellides stroemi, Anobothrus sp., etc. The brachiopod Frieleia halli is becoming rare. Still common are Chinoecetes angulatus angulatus, Munidopsis beringiana (?) and Scalpellum regium. There are many small Scaphopoda (Siphonodentatium), Nucula sp., N. cardara, Neilo fiora, Malletia pacifica, M. truncata, various Tindaria, Delectopecten, Lima, Myonera garetti and others. We found young specimens of the typically abyssal starfish Eremicaster (Porcellanasteridae) and large holothurians belonging to the Stychopodidae. There are few brittle stars -- two species of Ophiophthalmus, Amphiura, large Ophiomusium lymani and small eurybathic Ophiura leptoctenia. Finds of the Irregularia Pourtalesia laguncula beringiana and the Pogonophora Siboglinidae and Polybrachia point to a considerable influence of abyssal fauna on this biocenocis and its close link with the great depths of the Bering Sea. On the whole, this lower-bathyal biocenosis is a peculiar community, characterized by a large biomass, massive development of some species, which attain very large sizes.

5. Biocenosis Abyssaster tara -- Echinocrepis rostrata -- Urechinus loveni -- Hyalonema 89

The distribution of this biocenosis in the abyssal region of the open Gulf of Alaska is closely linked, on the one hand, with the lower-bathyal biocenoses of the gulf and, on the other, with the abyssal fauna of the adjacent northeastern Pacific. The biocenosis is found at a depth of 3,200-3,950 m (stations 6095, 6106-07, 6109, 6117; and stations 4131, 4147 of Cruise 29 of the "Vityaz'"). The bottom consisted of soft gray clayey ooze, usually with round pumice pebbles, t°_{m} 0.7-1.6° (average 0.9°). Total biomass 0.24-1.9 (average 1.7) g/m^2.

Among the index forms of the biocenosis are deepwater starfishes, several species of irregular sea urchins and four species of glass sponges of the genus Hyalonema, including H. ovulum and H. apertum. In addition, we also found other deepwater species of sponges -- Cladorhiza longipinna, Abyssocladia bruui, Polymastia sol pacifica, Bathydorus laevis.

Of the pennatularians, the biocenosis has abyssal forms -- Umbellula thomsoni and Kophobelemnon stelliferum (sparse). On the spicules of Hyalonema one finds small actinias, soft Ceriantharia, small ascidians and numerous Stephanoscyphus. Most common of the polychaetes are Laetmatonice sp., Melinna cristata, Leanira areolata, abyssal Kesun abyssorum. Of the bivalves there are the deepwater Neilo fiora, Malletia truncata, various small Tindaria and Myonera garetti, Cuspidaria, Vesicomya. Fairly varied are the pantopods: Hedgpethia articulata, Nymphon procerum, Anoplodactylus typhlops. Of the Cirripedia one finds Scalpellum levinsoni. Most numerous and varied are the irregular sea urchins as well as starfishes belonging to the Porcellanasteridae. In addition to the index forms we should point out the small irregular echinoderms Echinosigra gracilis, various Pourtalesia, as well as Aporocidaris fragilis belonging to the Cidaridae. One finds the brittle star Amphilepis platytata, as well as small numbers of the large, soft holothurians Psychropotes, various Elasipodidae and small Myriotrochus (?). Fairly varied are the small Tanaidacea and Isopoda.

The stations at which this biocenosis was found concluded the profiles extending from the shore. They extended nearly to that part of the gulf known as the "Alaska Seamount Province" (Menard, Dietz, 1951), owing to the large number of small, separate mountains scattered over the abyssal plain that completes the open part of the gulf on the south. The habitat of the deepwater benthonic fauna in this area is quite different from that of the properly bathyal zone to the north. Here the bottom temperature is lower, being close to that of the ocean basins, there is less organic matter in the bottom sediments, the benthonic biomass decreases, even though it still remains considerably greater than in more southerly regions of the northeastern Pacific (Filatova and Levenshtein, 1961). The benthonic fauna living here is still fairly varied. There is some decrease in the numbers of polychaetes, molluscs and Ophiuroidea, and an increase in the number of echinoderms, Irregularia, holothurians and deepwater starfishes (Porcellanasteridae), which are so typical of the abyssal region of the Pacific. These typical ooze eaters feed by swallowing the upper ooze layer. Here we no longer find any of the typically bathyal mass species, such as brittle stars of the genus Ophiophthalmus, a number of polychaetes, bivalves, Echiuridae, decapods, there are fewer pennatularians, which were common in the bathyal zone of the gulf. There is a noticeable change in the general ecological character of the fauna: instead of a well-developed onfauna, a wandering benthos and organisms raised above the bottom, the fauna descends, as it were, it burrows and becomes "submerged" in the soft, fine, clayey ooze. A fine and brittle external skeleton distinguishes the irregular sea urchins living here (various Echinocrepis, Pourtalesia, Aeropis etc.), as well as the highly brittle deepwater sponges Hyalonema. Forms begin to predominate that are wholly dependent in their lifestyle on the upper layers of the soft sediments, a large part of the fauna begins to feed on ooze (i.e., organic remains, detritus and bacteria contained in the latter). An entire "bouquet" of ecologically similar species is created along the abyssal margins of the gulf by irregular sea urchins, starfishes, bivalves and, it seems, Pogonophora (thus far not all of them determined to the species level). Especially typical in appearance are the large, tall, unusually brittle sea urchins Echinocrepis rostrata, found previously in the northwestern Pacific, as well as a number of species of Pourtalesia, Cystocrepis, Acropsis, etc.

As we move into the open ocean and as depths increase, the composition of the biocenosis changes still further; there are more types of the open ocean, and the biomass and variety of the fauna decrease markedly. Thus, at stations 6096 and 6097 (depths 4,190 and 4,740 m), with fine gray ooze, the Irregularia almost disappear, being replaced by holothurians belonging to the Elasipoda (Scotoplanes, Peniagone, etc.), there are small abyssal brittle stars Ophiura bathybia, rarely small, long Irregularia Echinosigra gracilis, starfishes Eremicaster tenebrarius, Vityazaster djakonovi, Pteraster sp. Among the molluscs one usually finds various Malletiidae, Neilo fiora, Tindaria brunnea, long Scaphopoda. Frequent are single Pogonophora and deepwater pennatularians Pennatula phosphorea.

The t_m^o in this area is about 1.2^o, the total biomass attains

2.2 g/m^2, thanks to the small Ophiura bathybia, polychaetes and bivalves. Further into the ocean the benthos becomes still sparser and assumes an appearance common of the oligotrophic zone of the abyssal region; the total biomass does not exceed fractions of a gram per square meter, and the macrofauna yields to very small organisms.

Conclusions

As may be seen from the above (as yet incomplete) data on the biocenoses of the benthonic fauna in the Gulf of Alaska, they are distinguished by a considerable variety of fauna, include a whole series of properly bathyal species belonging to various groups, and are characterized by a fairly large total biomass and numbers of individual forms. The size of these indicators is entirely comparable even to those typical of the sublittoral region of the Gulf of Alaska. Well represented among the biocenoses of the region studied are infauna, onfauna, large vagile benthos (mainly predators), and a special ecologic group that is quite typical of the bathyal zone -- the epifauna of soft bottoms (Filatova, Zenkevich, 1957; Savilov, 1961). This group has developed a number of adaptive properties (up to symbiosis), which enabled it to exist in an elevated position above the bottom on the unfavorable soft (even liquid) muddy soil.

Evidently, in the quantity and accessibility of food the bathyal zone of the Gulf of Alaska (particularly at the foot of the slope) is quite favorable for the development of such a varied and quantitatively fairly rich benthonic fauna. This agrees with the concept that the entire gulf, including its great depths, is located within the circum-oceanic eutrophic

zone of the Pacific. The biocenoses of benthonic fauna found in this eutrophic zone possess a number of characters that are common to all parts of the ocean forming part of this zone. Typical are (1) a fairly large total biomass (on the average, not less than 1 g/m^2); (2) considerable variety of species and groups, which guarantees the development of rich, viable, polymix biocenoses containing the most varied ecologic groups of 91
macro-, mio- and microfauna; (3) relatively large sizes of individual specimens, due to local accumulation of a large amount of nutrients in the bottom sediments, especially at the foot of the continental slope. In this zone of accumulation of organic matter one usually observes a second maximum of quantitative development of benthonic fauna (in terms of vertical changes in biomass). As we move into the open ocean, however, all of these indicators gradually decrease, reaching a minimum in the open areas of the abyssal region that are far from the coasts and that belong to the oligotrophic zone. These indicators, which are typical of the slope fauna, show that there are entirely favorable conditions for the existence of that fauna, above all a sufficient amount and good accessibility of nutrients for benthonic organisms. The main source of this food, as pointed out by Zenkevich (1968) is situated in the highly productive coastal zones, the sublittoral and the neritic zone. Thence the nutrients move to the slope area and, from there, to the foot, where they may partially accumulate and partially be carried off by bottom currents flowing along the slope into other regions.

The benthonic fauna, which serves as food for benthos-feeding fishes, is here well developed and, it seems, provides sufficient food for the latter. In fact, many underwater photographs show a considerable number of benthonic and near-benthonic fishes, and they can be found even in the catches of bottom trawls, where they turn up accidentally (grenadiers, flounders, gobies, black cod), but only if their numbers are fairly high. Fish catches with the commercial trawl of the refrigerated ship "Ekvator" (which worked the same profiles and stations as the "Vityaz," though somewhat later) were also quite considerable (up to 100-150 kg per hour of trawling). Thus, the hypothesis put forward early by Zenkevich (1968) that the continental slope has considerable value for commercial fisheries is entirely correct.

If we assume that the quantitative development of benthonic fauna reflects to some extent the intensity of the production processes in the overlying water stratum and at the water surface, we may say that, judging from the development of the benthos in the bathyal region of the Gulf of Alaska, the total productivity of the gulf, including the quantities of benthonic fishes, is bound to be considerable.

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TROPHIC STRUCTURE OF THE BENTHONIC FAUNA IN THE GULF OF ALASKA

By A. P. Kuznetsov, Ye. A. Romankevich, Yu. G. Giginyak

The study of the trophic structure of marine benthonic fauna -- its composition, the interrelationships and distribution of the feeding communities of benthonic invertebrates -- is one of the most important tasks of modern marine ecology.

Such investigations are presently being undertaken in many parts of the World Ocean and are expanding our knowledge of the general patterns and local peculiarities of the trophic structure of the benthos.

In the Gulf of Alaska, information on the trophic structure of the benthos was first provided in 1960-62 by the Bering Sea Expedition of the All-Union and Pacific Scientific Research Institutes for Fisheries and Oceanography (VNIRO and TINRO) on the Medium Fishing Trawlers "Pervenets" and "Zhemchug" and the Medium Fishing Trawler-Refrigerated "Orlik." V. V. Shevtsov (1964a, b) and V. N. Semenov (1965) described the distribution of the total biomass, the feeding communities and the trophic zones on the continental shelf of the gulf.

During Cruise 45 of the "Vityaz'" the main attention was directed to the collection of data on the composition and distribution of feeding communities on the slope and in the ocean basin of the gulf, where until then only three trawl and two grab samples had been taken by the "Vityaz'" expedition of 1958.*

We obtained 49 bottom-grab and 49 trawl samples from three profiles across the slope: profile 1 southeast of Kodiak Island; profile 2 west of Yakutat Bay; and profile 3 west of Baranof Island, from the continental shelf to the start of the ocean basin. Samples were taken with the bottom grab "Okean-50", capacity 0.25 square meters, and a Sigsby trawl. Taking part in the sampling were L. I. Moskalev, N. F. Fedikov, V. M. Koltun and I. A. Mel'nikov. The initial analysis was done by O. N. Zezina and R. K. Pasternak.

The fauna was classified into trophic groups according to current practice (Turpayeva, 1953; Sokolova, 1954; Savilov, 1961; Kuznetsov, 1963; Neiman, 1963).

Simultaneously with the collection of data on the trophic structure of the zoobenthos, at one of the profiles (No. 3) we took samples of the zoobenthos for the determination of its total calorie value and samples of bottom sediments for the determination of the content and composition of organic matter, which is the food source of detritovorous benthonic invertebrates, i.e., those that take up and non-selectively ingest the bottom material. An attempt to take samples of suspended organic particulates in bottom waters, which serve as food for sestonophages, did not produce the desired results. The determination

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* These samples were used by M. N. Sokolova (1969) in a study on the trophic zonation of the deepwater zoobenthos in the northeastern Pacific.

of total organic matter and its components in the sediments was carried out by Ye. A. Romankevich. Analysis for calorie value were carried out by Yu. G. Giginyak.

The resulting data make it possible to trace the trophic structure of the benthos on the slope and in the abyssal region of the Gulf of Alaska. Together with analogous data on the continental shelf (Shevtsov, 1964b; Semenov, 1965), they give an idea of the trophic zonation of the 94 zoobenthos throughout the gulf.

The trophic analysis of the benthos is based on grab samples, whose advantages over trawl catches were noted by us earlier (Kuznetsov, 1964, 1970). Trawl catches were used in a complementary way. In most cases the ratios of feeding communities in the trawl catches coincided with data derived from bottom grabs. An important additional source of information on the benthos was underwater photography (photo profiles) carried out by P. A. Fominykh.

Living Conditions of Benthos in the Gulf

The ecologic structure of the benthonic population of the sea is finally dependent on its productivity and the physical-chemical setting. In the Gulf of Alaska these factors have their peculiar characteristics that affect the composition and distribution of the feeding communities of the zoobenthos.

The Gulf of Alaska is a bay that is wide open to the ocean. Its area is 1,327,000 square kilometers, its average depth is 2,437 meters, with a maximum depth of 5,639 meters (Gershanovich et al., 1964). The coastline of the gulf is much broken up. The shallow strip is narrow, of a geosynclinal type, with numerous canyons (Gershanovich et al., 1964). The continental slope is steep (gradients up to 15-20°) abyssal depths in some places -- in the east -- occur close to the shore, occupying a large part of the gulf.

The bottom is covered with terrigenous, volcanic, organic and mixed sediments, in various shapes, from boulders to clayey ooze (ibid.).

Most typical of the shelf is sand (with an admixture of gravel and pebbles along the margins of plateau-like surfaces and on the rim of the shelf), which in some places continues along the slope. On the upper slope one usually finds transitional types of deposits -- from sand to sandy ooze (ibid.). During our cruise, we most commonly found in that area fine sand and silt (O. G. Kozlova, cruise report). At greater depths the bottom is covered mainly with silty-clayey and clayey ooze, with the oxidized surface layer measuring 20 cm and more (Skornyakova, 1961), and a ratio of pelite of 70% and more (Table 1).

Since, in its bottom morphology, hydrodynamics and sedimentation processes, the gulf belongs to water bodies of the open oceanic type (Lisitsyn, 1966; Gershanovich et al., 1964), a considerable part of the suspended material (including organic) is carried off beyond the shelf and is deposited at great depths. This was clearly demonstrated by A. P. Zhuze, O. G. Kozlova and N. I. Strel'nikova (in print) from data on the succession of bottom sediments in the gulf and the pelagic diatoms contained therein. These investigators found that the greatest accumulations of diatom cells occurred on the lower continental slope and at its foot. On all three profiles they noted an increase in the quantity

of diatom cells in the sediment as one moves from the shelf to the foot of the slope. Farther on, the diatom content drops sharply (by a factor of 6 at maximum depths). They conclude that on the lower slope and at its foot there occurs the intensive accumulation of diatom ooze. A similar trend is observable in the distribution of amorphous silica in the sediments. As regards organic matter (total, nitrogen and carbohydrates), if we judge from data collected on profile 3, it reaches its maximum in silty-clayey ooze on the lower slope, whereas in clayey ooze in the shallow part of the gulf its quantity is smaller (Skornyakova, 1961, Table 1). This agrees with the general distribution pattern of organic matter in the sediments of deep seas and oceans (Lisitsyn, 1959, 96
1966, etc.).

The current system in the Gulf of Alaska contributes to the accumulation of soft ooze and organic matter at the lower margin of the slope. According to V. S. Arsen'yev et al. (1973), the Aleutian and the North Pacific currents terminate in the gulf. These currents press upon the shelf waters from the direction of the ocean. Under these circumstances the suspended particulates on the shelf and those introduced from the ocean (along with particulates originating in the gulf from the abundant phytoplankton through the interaction of coastal and ocean waters) accumulate and are precipitated within a relatively narrow "juncture" zone above the depths of the slope. R. Z. Kovalevskaya and Yu. G. Giginyak (1973) have shown that the quantity of primary production in this zone is noticeably greater than in the open gulf and the waters of the shelf. Here we also find the largest numbers of diatom cells in the surface water (data of A. P. Zhuze, O. G. Kozlova and N. I. Strel'nikova -- in print) and a higher

(text cont. on page 184)

Table 1. Geochemical characteristics of bottom sediments in the Gulf of Alaska from profiles in its southeastern part (Fig. 2).

Station number	Depth, meters	Sediment type	Particle size, in mm, per cent				Layer, cm	Humidity, %	$CaCO_3$	SiO_2, amorphous	C_{org}	N	C/N	SO_{org}	Free bitumoids*				Carbohydrates			
			> 0.1	0.1 - 0.05	0.05 - 0.01	< 0.01													% of total: Mono- and oligo-saccharides	Water-soluble	Non-water-soluble	Carbohydrate factor, $\frac{C_{carb}}{C_{org}}$ %
6124	180	Fine-grained sand	81,18	12,31	1,23	5,28	0,2	25,62	1,45	1,83	0,41	0,046	8,91	4,5	3	15	20,0	1170	15,3	28,1	54,6	11,4
6127	1100	id.	45,53	12,22	17,23	25,02	0,2	47,08	3,27	2,52	0,81	0,168	4,82	3,1	10	400	2,5	3833	—	—	—	18,9
6128	1900	Fine silty ooze	2,24	28,16	33,06	37,54	0,2	59,49	2,77	6,09	1,36	0,178	7,64	4,5	50	400	12,5	4244	—	—	—	12,5
6122	730	id.	8,49	10,15	37,45	44,01	0,2	50,34	4,18	2,22	1,07	0,125	8,56	2,1	50	400	12,5	3244	—	—	—	12,1
6121	1600	Silty-clayey ooze	0,32	4,16	35,01	60,51	0,2	74,69	4,27	12,39	2,73	0,339	8,05	4,5	50	100	50,0	9433	9,9	23,6	66,5	13,8
6120	1950	id.	0,42	9,13	34,85	55,60	0,2	69,00	2,68	11,90	1,88	0,250	7,52	6,3	50	1060	3,1	7189	5,3	33,2	61,5	15,3
6118	2300	id.	0,67	3,37	33,43	62,49	0,2	71,56	1,68	12,00	1,18	0,155	7,61	10,1	6	50	12,0	3644	6,9	18,8	74,3	12,4
6117	3350	Clayey ooze	0,38	2,43	22,44	74,75	0,2	67,77	0,64	15,90	0,60	0,095	6,32	26,5	3	100	3,0	3311	—	—	—	22,1
6109	3460	id.	0,61	1,35	26,44	71,60	0,2	67,38	0,23	8,10	0,48	0,076	6,31	16,9	3	100	3,0	2800	6,0	32,5	61,5	23,3

*The abbreviations under this heading are not referred to in the text, and their meaning is uncertain. -- TRANSL.

Table 2. Relationships of feeding communities among the benthonic fauna of the Gulf of Alaska (profile 1)

Trophic groups	St. 6089 180 m, sand w/ coquina, pebbles		St. 6090 490 m sand with silt		St. 6082 1,080 m silty-clayey ooze		St. 6094 2,350 m		St. 6095 3,230 m, silty-clayey ooze		St. 6096 4,200 m, clayey ooze	
	1	2	1	2	1	2	1	2	1	2	1	2
Immobile sestonophages	16,55	58,8	1,00	13,0	0,60	8,4	0,012	0,8	0,01	0,3	0,03	1,3
Mobile sestonophages	0,28	1,1	0,09	1,2	—	—	—		0,08	2,5	—	
	16,83	59,9	1,09	14,2	0,60	8,4	0,012	0,8	0,09	2,8	0,03	1,3
Collecting detritus from bottom surface	0,36	1,2	6,11	79,5	3,53	49,5	0,33	26,0	0,39	11,9	0,01	0,4
Non-selective geophages	1,17	4,2	—	—	1,72	24,2	0,13	10,2	2,08	63,5	2,12	94,7
	1,53	5,4	6,11	79,5	5,25	73,7	0,46	36,2	2,47	75,4	2,13	95,1
Predators and scavengers	4,28	15,2	0,48	6,3	0,58	8,1	0,70	55,1	0,30	9,2	—	—
Others	5,53	19,5	—	—	0,70	9,8	0,10	7,9	0,42	12,6	0,08	3,6
Total	28,17	100	7,68	100	7,13	100	1,272	100	3,28	100	2,24	100

Note. In Tables 2 to 4, Column 1 designates biomass, in g/m^2; column 2 designates percentage of total biomass.

Table 3. Relationships of feeding communities among the benthonic fauna of the Gulf of Alaska (profile 2)

Trophic groups	St.6098 200 m, sand		St. 6099 300 m sand, pebbles, stones		St.6100 563 m, sand w/ silt, pebbles		6101, 755 m, silt, ooze with sand		6102, 1,100m clayey ooze		St.6103 1,700 m silty-clayey ooze	
	1	2	1	2	1	2	1	2	1	2	1	2
Immobile sestonophages	0,56	0 8	7,41	59,0	0,17	1,5	0,01	0,3	0,04	3,8	—	—
Mobile sestonophages	4,00	5,7	0,20	1,6	0,02	0,2	0,15	4,3	0,02	1,9	—	—
	4,56	6,5	7,61	60,6	0,19	1,7	0,16	4,6	0,46	5,7	—	—
Collecting detritus from bottom surfac	44,46	63,0	1,20	9,6	5,30	45,61	1,45	40,8	0,24	23,0	0,66	13,5
Non-selective geophages	21,04	29,7	2,32	18,5	2,43	20,8	0,83	23,4	0,30	28,8	3,78	77,5
	65,50	92,7	3,52	28,1	7,73	66,4	2,28	64,2	0,54	51,8	4,44	91,0
Predators and scavengers	0,56	0,8	1,10	8,8	2,81	25,2	1,12	31,2	0,36	34,7	0,44	9,0
Others	—	—	0,30	2,5	0,83	6,7	—	—	0,08	7,8	—	—
Total	70,62	100,0	12,53	100	11,56	100	3,56	100	1,04	100	4,88	100

Table 3, concluded.

Trophic groups	St. 6105 3,000 m clayey ooze		St. 6106 3,610 m clayey ooze		St. 6107 3,780 m clayey-diatom ooze	
	1	2	1	2	1	2
Immobile sestonophages	0,01	0,5	—	—	0,03	1,6
Mobile sestonophages	0,01	0,5	0,02	7,4	—	—
	0,02	1,0	0,02	7,4	0,03	1,6
Collecting detritus from bottom surface	0,42	20,7	—	—	0,82	46,4
Non-selective geophages	0,88	43,4	0,17	63,0	0,87	49,2
	1,30	64,1	0,17	63,0	1,69	95,6
Predators and scavengers	0,59	29,0	0,04	14,8	0,01	0,6
Others	0,12	5,9	0,04	14,8	0,04	2,2
Total	2,03	100,0	0,27	100,0	1,77	100,0

Table 4. Relationships of feeding communities among the benthonic fauna of the Gulf of Alaska (profile 3)

Trophic groups	St.6125 180 m, bottom not known		St.6123 650 m fine silt		St.6120 1,953 m clayey ooze		St.6118 2,340 m clayey ooze		St.6117 3,350 m clayey ooze		St.6009 3,450 m clayey ooze	
	1	2	1	2	1	2	1	2	1	2	1	2
Immobile sestonophages	0,02	0,2	0,03	0,1	2,90	19,7	0,03	1,2	0,02	0,6	0,05	2,5
Mobile sestonophages	0,51	4,8	1,20	7,3	—	—	—	—	—	—	0,01	0,5
	0,53	5,0	1,23	7,4	2,90	19,7	0,03	1,2	0,02	0,06	0,06	3,0
Collecting detritus from bottom surface	4,60	43,5	1,18	7,2	1,59	10,7	1,20	47,6	1,00	30,5	0,54	27,5
Non-selective geophages	3,40	32,5	2,84	17,4	1,63	10,9	0,11	4,4	2,20	67,1	1,22	61,0
	8,00	76,0	4,02	24,6	3,22	21,6	1,31	52,0	3,20	97,6	1,76	88,5
Predators and scavengers	2,00	19,0	7,25	51,0	7,72	52,0	1,12	44,4	—	—	0,15	7,0
Others	—	—	2,79	17,0	1,10	7,7	0,06	2,4	0,06	1,8	0,03	1,5
Total	10,53	100,0	16,29	100,0	14,94	100,0	2,52	100,0	3,28	100,0	2,00	100,0

content of total organic matter and its components than on the shelf and in the ocean basin. The amount of authigenous SiO_2 and the C/N ratio show that the organic matter in the sediments is mostly of phytoplanktonic origin.

Feeding Communities of Benthonic Fauna and Their Distribution in the Gulf

Results from the expeditions of the "Pervenets," "Zhemchug," and "Orlik" (Shevtsov, 1964a, b; Semenov, 1965) and Cruise 45 of the "Vityaz'" (Moskalev et al., 1973) have shown that the benthonic fauna of the Gulf of Alaska is fairly rich in quantitative terms, even though it 97 does not attain the biomass of many regions of similar depth in the northwestern Pacific basin (Belyayev, 1960a, b; Savilov, 1957, 1961; Kuznetsov, 1963, 1964; Filatova, Barsanova, 1964; Neiman, 1963; Zenkevich, Filatova, 1958, etc.). The distribution of the biomass on the continental slope and in the ocean basin has been considered by Filatova (1973) and Moskalev et al. (1973). The amount of zoobenthos decreases gradually from the shelf margin toward the centre of the gulf. The benthos of the Gulf of Alaska, like that of any other fully saline marine water body, contains representatives of all feeding communities of benthonic organisms: immobile and mobile sestonophages, detritovores that consume the bottom material selectively or non-selectively, and carnivores (feeding either on live or decaying organisms) (Tables 2 to 4).

The previously noted features of the geomorphology and the physical-geographical setting of the gulf had already raised the presumption that the distribution pattern of the feeding communities in the gulf was bound to be fairly complex. Results from the Bering Sea expedition of VNIRO-TINRO in 1960-62 (Shevtsov, 1964b; Semenov, 1965) confirmed this hypothesis: they revealed a rather uneven distribution of trophic groups and of the regions in which they flowered on the continental shelf of the gulf. Most widely distributed and most abundant were sestonophages and organisms collecting detritus from the surface, whereas non-selective geophages merely represented a typical group of the benthos. The structure and zonation of the zoobenthos bore marks of a transitional nature, peculiar to the continental shelves of a transitional type of structure (between platforms and geosynclines).

Different in character was the distribution of feeding com- 99 munities on the continental slope and in the abyssal basin of the gulf. Here the communities and the area in which they were predominant were found to be arranged in belts, along depth contours.

According to data from Cruise 45 of the "Vityaz'," the slope exhibited a predominance of selective detritovores (Fig. 1), represented by detritovorous brittle stars, bivalves of the superfamily Tellinacea (species of the genera Nucula, Acila, Nuculana, etc.), polychaetes of the families Aricidae (Scoloplos armiger, Aricia sp.), Spionidae, Ampharetidae (Ampharete, Lysippe, etc.), Terebellidae, Trichobranchiidae, Oweniidae (Myriochele oculata, Myriochele sp.), cumaceans and certain other groups of detritovores, which find fairly abundant food in this area. In the upper-bathyal biocenoses of the gulf, described by Semenov (1965), most index species (those occurring in the greatest numbers) belonged precisely to this trophic group: Amphioplus macraspis, Ophiophthalmus cataleimmoidus, Oph. normani, Amphiophiura ponderosa, Macoma calcarea, Nuculana pernula, Acila castrensis, etc.

The biomass of the detritovores reached 5-6 g/m^2 and more, dropping to 1-2 g/m^2 and less at the lower boundary of the slope. Also abundant on the slope are predators, which make up a considerable share of the fauna even in bottom grabs. Predators were particularly numerous in trawl catches taken in the bathyal region. These are Chionoecetes, starfishes, actinias, sea spiders, Sclerocrangon shrimps, etc. (Moskalev et al., 1973).

In the central and southeastern part of the gulf the fauna of detritus-collecting organisms was replaced by a region inhabited mainly by geophages at depths of about 1,000-2,000 m, whereas in the northern and northwestern part of the gulf the predominance of the detritovores could be established to depths of 2,500-3,000 m.

In the southeastern part of the gulf the geophages could also be found at depths of 600-800 m, which was not the case in the western and central gulf (profiles 1 and 2), apparently because of the steepness of the slope. It may be that these depths define the predominance of the geophages, while greater and lesser depths belong predominantly to selective detritovores. It is noteworthy that it is precisely at a depth of about 1,000 meters that Semenov (1965) established the biocenosis of Brisaster latifrons. As we know, these depths in the Bering Sea and along the coast of eastern Kamchatka also typically contain the biocenosis of irregular sea urchins -- Brisaster townsendi, and, in the Sea of Okhotsk, B. latifrons (Ushakov, 1953; Savilov, 1961; Kuznetsov, 1963, 1964; Filatova, Barsanova, 1964).

The upper margin of the zone of selective detritovores is usually situated along the transition from shelf to slope, where sediments become coarser and contain more lumps. It seems that a large part of this bottom region (where shelf waters intermingle with ocean waters) is populated by a sestonophagous fauna (Fig. 1), dominated by sponges, hydroids, brachiopods, bryozoans, Ophiuroidea *Ophiopholis aculeata*, holothurians *Psolus*, sedentary polychaetes Sabellidae and a considerable number of predators. In some places the sestonophagous fauna descends to considerable depths, whereas in other places it continues high on the shelf, e.g., in the area of Unimak Island, where there are extensive gravel-pebble bottoms (Shevtsov, 1964b; Semenov, 1965). On the other hand, in a number of places the shelf fauna dominated by selective detritovores extends close to the rim of the shelf, being replaced at the rim by immobile sestonophages (profile 1, stations 6098, 6099).

On the lower part of the continental slope and at its foot, where sedimentation is very intensive and where the bottom sediments contain large amounts of organic matter, the selective detritovores are replaced by geophages, as noted earlier. Here begins the realm of polychaetes from the families Maldanidae, Opheliidae, Capitellidae, 100
Sipunculoidea, Isopoda, Tanaidacea. Typical among the macrofauna are the holothurians Stichopodidae, starfishes Porcellanasteridae, sea urchins Spatangidae. However, the biomass of the geophages does not nearly always increase; it increases noticeably only on profiles 1 and 3, and no distinct relationship can be observed between the quantitative abundance of geophages and the total content of organic matter and its components (this may be due to insufficient data). Furthermore, at the deepest stations of profile 3 (stations 6117 and 6009) a much lower total content of organic
matter and its main component, carbohydrates, contrasts with a geophagous 101

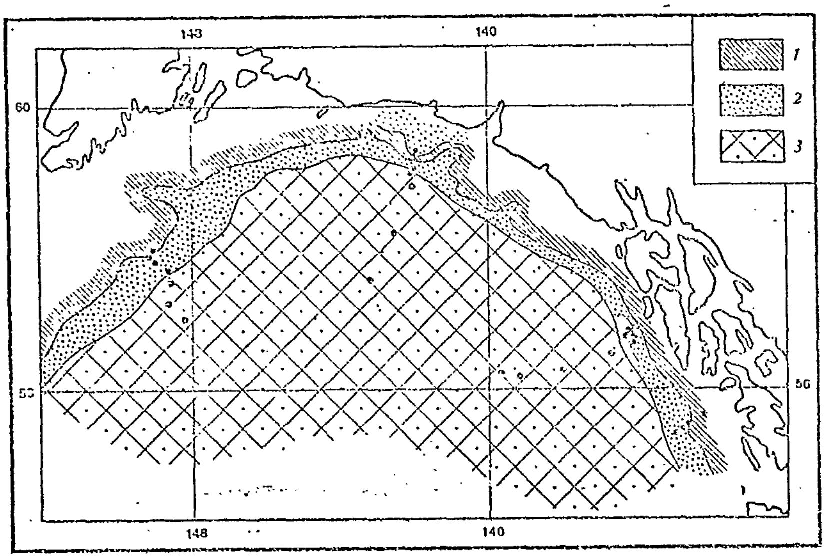

Fig. 1. Regions of dominant feeding communities (trophic zones) in the Gulf of Alaska. 1 -- immobile sestonophages; 2 -- selective detritovores; 3 -- geophages.

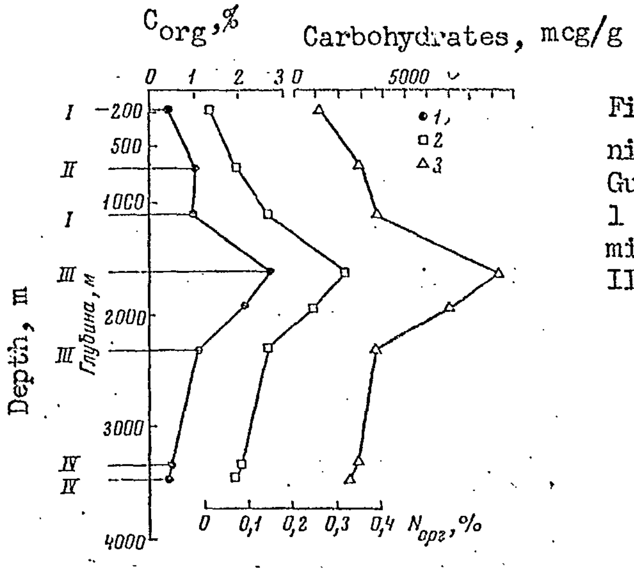

Fig. 2. Content of organic carbon (C_{org}), nitrogen (N_{org}) in the sediments of the Gulf of Alaska (profile 3). 1 -- C_{org},%; 2 -- N_{org}, %; 3 -- carbohydrates, microgram/gram. I -- sand; II -- fine silt; III -- sandy-clayey ooze; IV -- clayey ooze.

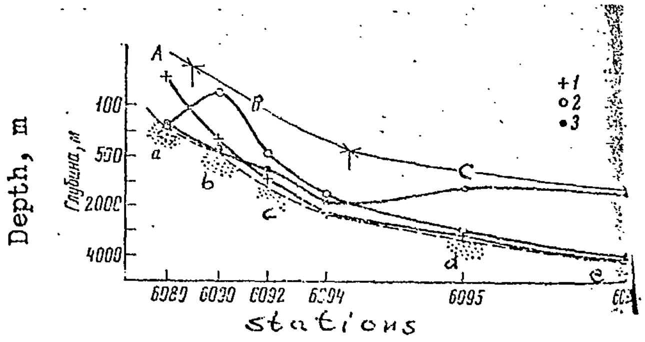

Fig. 3. Succession of trophic zones on profile 1. 1 -- immobile sestonophages; 2 -- selective detritovores; 3 -- geophages. A, B, C -- zones were above groups are dominant. Dotted line -- bottom. Nature of bottom: a -- sand with pebbles and coquina; b -- sand with silt; c, d -- silty-clayey ooze; e -- clayey ooze.

Table 5. Energy characteristics of benthonic fauna in the Gulf of Alaska (profile 3)

Depth, meters	Nature of bottom	Dry weight of benthonic organic matter, g/m^2		Energy equivalent of organic matter, cal/m^2	
		average	range	average	range
Less than 200	Fine sand	0.214	-	534.4	-
200-1,100	Fine sand, fine silt	0.603	0.330-0.897	1,878.5	697.9-2,903.5
1,500-2,500	Fine silt - silty-clayey ooze	0.650	0.429-1.143	2,219.1	1,163.7-3,424.8
2,500-3,500	Silty-clayey ooze - clayey ooze	0.174	0.050-0.242	491.0	182.5-371.1

		Cal/mg of organic matter		Organic matter as percentage of dry weight	
		average	range	average	range
Less than 200	Fine sand	2.50	-	18.4	-
200-1,100	Fine sand - fine silt	3.10	2.23-4.23	56.3	38.4-65.8
1,500-2,500	Fine silt - silty-clayey ooze	4.07	2.71-6.40	60.4	42.0-80.1
2,500-3,500	Silty-clayey ooze - clayey ooze	3.02	-	-	-

biomass that is even somewhat greater than at shallower stations.

A positive correlation between the abundance of the marine benthos and the content of organic matter in the bottom waters and bottom sediments should only be posited with the greatest caution, and only in the most general, large-scale terms, e.g., a decrease of the benthos as a whole in correspondence with the reduction of food resources with depth and distance from the coast, with a transition from the productive regions of the ocean to less productive ones, etc. A more detailed approach will often reveal numerous deviations from this trend, indicating complex general relationships between the benthos and the content of organic matter in the sediments and the bottom waters. "Classic" examples of such deviations are presented by entire, large water bodies — the Black Sea, the Gulf of Aden, the Peru-Chile trench, etc. The abundance of organic matter at the bottom of these waters contrasts with the nearly complete absence of benthonic life, owing to the unfavorable gas environment of the bottom waters.

In the Sea of Azov and in the Baltic Sea the same causes lead to an almost negligible share of geophages among the benthos, even though the sediments of these seas are rich in organic matter, including material that is easily hydrolyzed (Kuznetsov, 1964, 1970).

In many cases the disproportion between the amount of benthos 102
and the total amount of organic matter on the bottom may be due to organic factors, the actual interrelationships between the groups, etc. (Kuznetsov, 1970).

In the Gulf of Alaska we also failed to find a distinct connection between the abundance of zoobenthos (on the whole and for individual feeding communities) and the content of organic matter (including its various components) in the bottom sediments. Evidently, more detailed investigations are needed. At the same time we must not overlook that there is a coincidence between regions with high organic contents in the sediments and high numbers of detritovores (selective and geophagous). In these terms, the association is more pronounced, especially if we relate the shelf margin to the flowering of sestonophages, and the slope and its foot with that of selective detritovores and geophages. In the latter zone, there are both more detritovores and more organic materials in the sediments than in other parts of the gulf (Fig. 2, Table 2, 3, 4).

Fig. 3 shows the trophic structure of the zoobenthos found on profile 1. The succession of the communities was analogous on profiles 2 and 3. We may say that it is typical of the entire slope and basin of the gulf.

Worth mentioning are the data concerning the total calorie value of the zoobenthos obtained from profile 3 (Table 5). Although they are thus far difficult to interpret in relation to the distribution of benthonic feeding communities, one can note the clear pattern in the downward succession of energy values of the benthos and organic content in the sediments, as well as the link between maximum average calorie values of the benthos and that depth zone containing a large amount of organic matter, a large biomass, and a predominance of detritovores and geophagous benthos.

A decrease in ash content in the zoobenthos from this zone, dominated by detritovores and geophages, as compared with the zoobenthos from the shelf margin (dominated by sestonophages) serves only as a partial explanation of this fact, as the specific calorie value (cal/mg of the organic matter of the zoobenthos) changes in the same direction as the total calorie value. This may perhaps be due to the fact that with depth there is an increase in the fat content of the benthonic organisms. Working on the scientific ship "Alpha Helix" in 1970, Patton found higher fat contents in the bodies of bathypelagic fishes than in surface fishes.

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DISTRIBUTION OF BENTHONIC FORAMINIFERS IN THE GULF OF ALASKA AND THE EASTERN PART OF THE ALEUTIAN TRENCH

By T. A. Khusid

The quantitative distribution of benthonic foraminifers in the Gulf of Alaska had not been studied until the present, and the scientific literature contains only a few data on the distribution of individual foraminifer species (Cushman, 1927; Loeblich, Tappan, 1953; Todd, Low, 1967).

This study of foraminifers is based on 34 bottom grab samples taken during April-May 1969 during Cruise 45 of the "Vityaz'" on four profiles: at Yakutat Bay, at Baranof Island, Kodiak Island, and Unimak Island. From the grab samples we skimmed off the top layer with a thickness of one centimeter, after which we measured the volume of the sample, flushed it through a screen with a mesh size of 0.05 mm, and fixed it with alcohol. In order to extract live foraminifers, whose tests at the moment of sampling contained plasma, we use a "Bengal pink" dye. In each sample we determined the number of live benthonic foraminifers, separately by secretory and agglutinating forms, which were then counted in specimens per square meter. The biomass of the foraminifers (gram per square meter) was computed for each station according to Saidova's method (1967). From these data we constructed graphs showing the quantitative distribution of benthonic foraminifers and their biomass by depths (see figure).

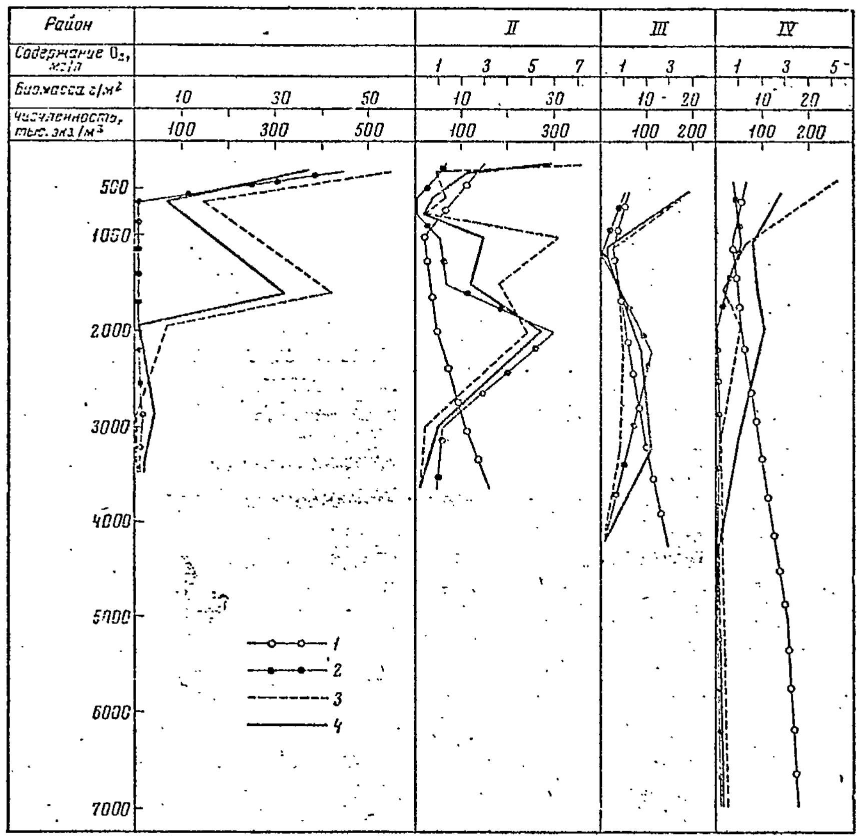
Most complete were the data obtained on the profile carried out in the northeastern gulf, at Yakutat Bay, at depths of 200-3,620 meters (stations 6098-6106).

Curves showing the numbers of secretory and agglutinating foraminifers run nearly parallel, forming two maximums. The upper maximum pertains to the transitional horizon between sublittoral and bathyal region. There the number of agglutinating foraminifers reaches 60 to 70 thousand, that of secretory, 360 thousand. The lower maximum pertains to the bathyal region, at depths of 1,500-2,500 meters. There the number of agglutinating foraminifers is 200-300 thousand, that of secretory, 180-300 thousand. The total biomass of the foraminifers in the zones of greatest occurrence is 27-20 grams.

The least quantity of foraminifers was found at depths of 500-1,000 meters, where the number of agglutinating forms does not exceed 3,000, and the calcareous ones, 70,000; the biomass is 2-3.5 grams. At depths of 1,000-1,500 m, the amount of agglutinating foraminifers increases to 50,000, that of secretory ones, to 360,000. In spite of the fairly considerable increase in the numbers, the biomass at these depths is small, 11-15 grams, as these depths are populated mainly by small species. There are also few foraminifers at depths exceeding 3,000 m, where the number of secretory types drops to 15-28 thousand and that of agglutinating types to 50 thousand; the biomass is 1.3-5.3 grams.

In the southeastern part of the gulf, at the islands of Baranof and Prince of Wales, samples were obtained from depths of 310-3,450 m (stations 6109, 6111, 6117, 6120-6121, 6123, 6125). Here, as in the preceding profile, the upper maximum pertains to the transitional horizon 105 between sublittoral and bathyal region and is situated at a depth of 310 m.

Area
Oxygen, mg/l
Biomass, g/m²
spec/m², '000



Distribution of benthonic foraminifers on profiles in the Gulf of Alaska. I — at Baranof and Prince of Wales islands; II — from Yakutat Bay; III — from Kodiak Island; IV — from Unimak Island. 1 — oxygen content; 2 — number of agglutinating foraminifers; 3 — number of secretory foraminifers; 4 — biomass of foraminifers.

The number of agglutinating foraminifers reaches 44,000, that of secretory, 550,000; the biomass is 37.2 g. Unlike the Yakutat Bay profile, the number of agglutinating foraminifers at this profile, at depths over 650 m, is low, amounting to 10,000-30,000. The secretory foraminifers make up the lower quantitative maximum at depths of 1,300-1,700 m; their number attains 420,000 spec/m²; the total biomass of foraminifers is 32.2 g/m². Here the lower maximum is narrower and situated higher than at Yakutat Bay.

The quantity of secretory foraminifers at depths of 500-1,500 m does not exceed 150,000 spec/m^2, the biomass is not more than 7.7 g. A sharp drop in the quantity of calcareous forms occurs at the depth of 2,500 m, where their number decreases to 5,000-10,000. The total biomass of foraminifers at depths of 2,500-3,620 is 1.3-4.2 g.

In the western part of the Gulf of Alaska, at Kodiak Island, collections were made at depths of 486-4,190 m (stations 6090, 6092-96). The upper maximum pertains to a depth of 500 m, the number of agglutinating foraminifers is 50,000, that of secretory ones, 200,000, the total biomass is 19 g. The lower maximum is indistinct and deeper than in the eastern areas, and embraces a greater depth interval: from 2,000 to 3,500 m. 106
Agglutinating foraminifers predominate here, numbering up to 100,000, the number of secretory ones is 50,000, the total biomass is 8.7-12.1 g/m^2. The smallest number of foraminifers was found at depths of 700-1,500 m, where the number of agglutinative forms is 2,000-3,000, that of calcareous ones, below 30,000. At depths of 3,500-4,190, both groups are quite sparse — about 3,000. The total biomass of foraminifers at depths of 700-1,500 m is 1.3-1.7 g/m^2, at 3,500-4,190, about 0.3 g/m^2.

In the area of the northeastern end of the Aleutian trench, near Unimak Island, foraminifers were collected from depths of 390-6,980 m (stations 6131-32, 6134-36, 6138-40), and another three samples were taken along the ocean slope of the trench at depths of 4,800-5,960 (stations 6141-43). The distribution of foraminifers resembles that at the Kodiak Island profile. The upper maximum is situated at depths of 400-500 m, where the number of agglutinative forms is 50,000, that of secretory ones, 250,000, the biomass is 15.4 g/m^2. At 500-1,500 m, the number of

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foraminifers drops to 30,000, the biomass to 8-8.7 g/m^2. At depths of 2,000-3,000 m the quantity of foraminifers rises to 50,000, the biomass to 10.4 g/m^2 (lower maximum). Below 3,000 m, down to the greatest depth (6,980 m) the quantity of foraminifers is quite small. On the outer slope of the trench the number of foraminifers is just as small as on the inner slope: secretory forms number 100-2,000, agglutinative, 200-30,000; the biomass is 0.1-2.1 g/m^2.

Thus, we observe throughout the area studied two quantitative maximums of foraminifers. The upper maximum pertains to the transition from sublittoral to bathyal region, 200-500 m (we had no collections from lesser depths). This maximum probably reflects the high productivity of the continental shelf and the upper continental slope in the Gulf of Alaska (Fedosov, Azova, 1964). The lower maximum pertains to the lower bathyal region. In the eastern gulf it is situated at depths of 1,500--2,500 m, in the west it is wider — 1,500-3,500 m — but it is less distinct. The shift in the maximum is due to the fact that in the western part of the gulf the continental slope, at a depth of 3,500 m, goes over into a slightly inclined plain at the foot and into the slope of the Aleutian trench; in the east the steep gradient of the slope continues to 2,500 m, adjoined by a broad, gently sloping plain (Gershanovich, 1964). The main accumulation of sediments and the organic matter associated therewith occurs on the lower continental slope, where we observe the greatest quantity of benthonic foraminifers.

At the depths of 500-1,500 all profiles indicated minimum quantities and biomasses of foraminifers, which, it seems, is due to the oxygen deficit (below 1 ml/l); the low-oxygen layer touches the bottom at these points. The oxygen deficit not only exercises a negative effect upon the number of foraminifers, it also leads to the development of an "oppressed" fauna (small, thin-walled tests). From 2,500-3,000 meters down to the greatest depths of the gulf the number and biomass of the foraminifers are low, which is due to the shortage of nutrients at these depths.

The number and biomass of benthonic foraminifers in the eastern part of the gulf are 2-3 times greater than in the western part, which is due to the higher contents of organic carbon and authigenous silicic acid in the sediments in the eastern part (Gershanovich, 1964).

The proportion of live individuals in the total number of foraminifer tests was high in all samples. Secretory foraminifers with plasma, at depths of 200-3,000 m, make up 5-40% in the eastern gulf and 20-50% in the west; below 3,000 meters, they make up 80-100% of all tests everywhere in the gulf. Agglutinating foraminifers with plasma make up 10-50% of the total at all depths. Just as high a percentage of live foraminifers in relation to all tests — 20-50 — was noted in August — 107
October in the Kurile-Kamchatka (Saidova, 1967) and the Peru-Chile trenches (Khusid, 1971). In the tropical region of the Indian Ocean at depths of 2,600-4,300 m calcareous foraminifers with plasma in May-July made up only 3-15%, agglutinating, 10-30% of the total (Khusid, 1971).

In terms of species, the foraminifers of the Gulf of Alaska show little variety, and changes are related only to depth. It is possible to define groups of species of benthonic foraminifers typical of the bathyal, abyssal and ultra-abyssal zones.

In the bathyal zone (200-3,000 m) secretory species considerably predominate over agglutinative species. In this zone we find about 80 species. Typical of the entire bathyal region are <u>Alabaminella weddellensis</u>

(Earland), Uvigerina peregrina Cushman, Fursenkoina bramletti (Galloway et Morey). In the transitional horizon from the sublittoral to the bathyal region (200-500 m), index forms are Karreriella necata Saidova, Buccella inusitata (Andersen), Angulogerina fluens Todd., Cassilamellina californica (Cushman et Hughes); in the bathyal zone itself (500-3,000 m), Ioanella tumidula (Brady), Uvigerina curticosta (Cushman), Angulogerina angulosa (Williamson), Lernina subcarinata (Uchio). In the abyssal zone (3,000--6,000 m) we find about 50 species of foraminifers, most of which (90%) are agglutinative species. Particularly numerous are Rhizammina algaeformis Brady, Saccorhiza ramosa (Brady), Reophanus guttifera (Brady), Cribrostomoides profundum Saidova.

In the ultra-abyssal zone of the Aleutian trench (6,000-6,980 m) the number of species drops to 30, with a predominance of the same species as in the abyssal zone.

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DEEPWATER SEA FEATHERS (OCTOCORALLIA, PENNATURALIA) OF THE ALEUTIAN TRENCH AND THE GULF OF ALASKA

By F. A. Pasternak

For the last two decades, investigators travelling on the scientific ship "Vityaz'" have carried out numerous multidisciplinary and specialized biological cruises, which covered with a grid of stations nearly the entire Pacific Ocean. Unfortunately, not all of these areas were studied to the same degree. One of the least studied areas turned out to be the area of the Aleutian island arc and the Gulf of Alaska. At the same time this part of the ocean is of particular interest for faunists and zoogeographers, in as much as it is the scene of the juncture of two different faunas — the Asiatic and the North American one. In the opinion of a number of investigators, conditions arose during the relatively recent geological past that made possible a partial interchange of elements of both faunas. A. P. Andriyashev (1939), who was the first to direct particular attention to the existence of discrete territories in the North Pacific and who developed the theory of amphi-Pacific territories, expressed the assumption that at the place of the modern fault or break in the region of the Bering Sea there were occasions, repeated over various geological periods, when conditions favored "individual elements of two different faunas to migrate northward and to move into the opposite sides." The theory of amphi-Pacific territories was constructed on the example of shallow-water and pelagic species. If there were possibilities for the interchange of shallow-water elements, the possibilities for the interchange of deepwater species were bound to be even better.

During the operation of the "Vityaz'" in the Pacific scientists collected a large number of deepwater sea feathers -- quite typical and sometimes numerous representatives of the bathyal and abyssal benthos. To a considerable degree this collection has been analyzed previously. Pennatuloid material was lacking only from the above-mentioned Aleutian trench, as during the first and non-systematic collections of deepwater benthos, carried out in that area in 1955 and 1958 during cruises 20 and 29 of the "Vityaz'," these colonial Coelenterata were not found in the samples.

Only in 1969, during the specialized 45th cruise of the "Vityaz'," were the Aleutian trench and the Gulf of Alaska subjected to detailed investigation. As a result of this cruise we obtained extensive material of many groups of benthonic invertebrates, including deepwater sea feathers. It is not difficult to appreciate the exceptional value of this material, obtained for the first time from one of the zoogeographically most interesting areas of the Pacific.

With few exceptions, the Aleutian collection contains numerous colonies of each species. We are giving a list of stations during Cruise 45 of the "Vityaz'" at which the pennatularians considered in this paper were collected (Table 1).

As may be seen from this list, most common in the area studied were Pavonaria pacifica (9 stations) and Virgularia cystifera (4 stations). These are Pacific species with a large vertical range, which, however, live mostly in the upper bathyal region. Least common were the abyssal species Kophobelemnon biflorum and Umbellula thomsoni, as well as the

Table 1. List of stations on Cruise 45 of the "Vityaz'" at which sea feathers were collected

Station	Coordinates		Depth, m	Species
	N. Lat.	W. Long.		
6089	58°01', 7	149°01', 8	170	*Pavonaria pacifica*
6092	57°52', 5	149°04', 0	1050	То же idem
6093	57°51', 0	148°57', 0	1540—1340	*Virgularia cystifera*
6096	57°12', 0	148°43', 8	4190	*Pennatula phosphorea*
6101	59°10', 2	142°01', 0	798—756	*Pavonaria pacifica*
6102	59°13', 8	142°05', 2	1030—990	То же idem
6103	59°06', 8	142°06', 2	1500	» "
6105	58°55', 0	142°03', 0	2980—2970	*Pennatula phosphorea* *Kophobelemnon stelliferum*
6106	58°15', 0	142°34', 0	3620	То же idem
6117	56°12', 0	139°12', 1	3350—3370	*Umbellula thomsoni*
6120	56°40', 0	136°25', 6	1965—1960	*Kophobelemnon affine* *Protoptilum orientale* *Stylatula elegans* *Virgularia cystifera*
6121	56°45', 4	136°10', 0	1600—1560	*Kophobelemnon affine* *Protoptilum orientale* *Virgularia cystifera*
6122	56°45', 5	136°02', 0	1100—1180	*Pavonaria pacifica*
6127	55°20', 8	134°50', 0	1340—1370	То же idem
6132	53°46', 0	163°41', 0	1100—830	» "
6134	53°43', 0	163°35', 7	1740—1690	*Kophobelemnon affine* *Pavonaria pacifica* *Stylatula elegans* *Virgularia cystifera*
6136	53°25', 0	163°23', 0	4180—4186	*Kophobelemnon biflorum* *Funiculina quadrangularis*

universally occurring Funiculina quadrangularis. Three of these species are represented by single specimens.

We must note the excellent state of preservation and the good fixation of the colonies collected.

ORDER PENNATULARIA

FAMILY KOPHOBELEMNONIDAE

1. Kophobelemnon stelliferum (O.F. Müller), 1776

Synonyms: see Pasternak, 1961b: 218

Material: Station 6105, 10 spec.; station 6106, 1 spec.

Remarks. Colonies of *K. stelliferum* have often been described previously. The colonies in this collection do not in their basic characters transcend intraspecific variation, as presently understood. We need dwell only on two peculiarities of our colonies that make them stand out 110 against the background of the wide morphological variety of *K. stelliferum*. The arrangement of the large autozooids on the rachis among the Aleutian colonies exhibits a tendency toward the reduction of the number of the longitudinal rows of polyps. In several specimens the autozooids are arranged in two ventral-lateral rows, which provides the colonies with a bilateral symmetry. Within each of such rows the autozooids are alternately oriented forward and sideways, imitating a doubling of the row.

Among the remaining specimens, in addition to autozooids arranged in ventral-lateral rows, there are also polyps displaced toward the ventral side of the rachis. The latter form indistinct complementary rows of autozooids.

The same applies to the arrangement of the siphonozooids, which are grouped in two bands along the lateral surfaces of the rachis. In the lower part of each of the band there may be one or two and, in the upper part, three to five rows of siphonozooids. Only rarely are these polyps based on the ventral side of the rachis. The lower siphonozooids are larger than the upper ones, which is typical of K. stelliferum.

The arrangement of the autozooids in two distinct lateral rows was found in one damaged colony from the North Atlantic, which Kölliker (1880) described as a new gen and species of the Kophobelemnonidae — Bathyptilum carpenteri. It may be that the same arrangement of autozooids occurred in yet another, also damaged colony from the Indian Ocean, described as yet another species of the same genus — B. indicum (Thomson, Henderson, 1906). Kükenthal and Broch (1911) convincingly demonstrated the inadmissibility of the definition of the genus Bathyptilum. In their view, both colonies belong to the genus Kophobelemnon and, it seems, may be either young or aberrant forms of the widely found species K. stelliferum. There is even less doubt as to the inclusion of the Aleutian Kophobelemnonids in the species K. stelliferum, in as much as they either form complementary ventral rows of autozooids, or within each of the ventral-lateral bands there is an indication of a doubling of the rows of autozooids.

Another distinctive feature of these colonies is that in the body and tentacles of the autozooids, along with the usual acicular and rod-shaped spicules with three longitudinal facets and terminal inflations, one finds massive elongated-oval protrusions with three barely distinguishable facets and a rough surface. These skeletal elements are situated in the body of the autozooids without any regularity, transversely and longitudinally, so that the polyps have wrinkles and angular outlines. Dimensions of the spicules are: 0.3-0.6 mm in length, 0.05-0.08 mm in width. Directly below the crown of the tentacles the arrangement of the spicules becomes more regular: they are grouped between the mesenteries in such a way that their longitudinal axes more or less coincide with the longitudinal axis of the autozooids. On the tentacles they form a ribbon on the aboral surface composed of closely contiguous spicules, which serves, so to speak, as a ridge for the tentacles. Such spicules are usually lacking in the autozooids of K. stelliferum. However, Marshall (1883) found such features in the tentacles of K. stelliferum colonies studied by him. Analogous examples may also be found among other Kophobelemnonidae. Thus, a support brace of large, oval spicules was found in the tentacles of K. pauciflorum from the East China Sea, although among the typical specimens of this species such features seem to be lacking (Pasternak, 1961a; Hickson, 1916). Although the presence of massive skeletal corpuscles in the body of the autozooids is here noted for the first time, there are no reasons for considering our specimens of Kophobelemnonidae as a new species. The appearance of such large spicules is probably due to phenotypic variation, which is quite common among sea feathers. We shall give the main measurements (in mm) of the 111 colonies collected.

Character	Station 6105 (10 spec.)	Station 6106 (1 specimen)
Total length of colony	73-124	81
Length of peduncle	49-65	33
Width of peduncle	2.5-3	2
Length of rachis	44-92	41
Width of rachis	2-4	3
Length of peduncle bulb	4-6	7
Length of autozooids	8-13	8
Width of autozooids	1-1.5	1.2
Length of tentacles	5-9	5
Number of autozooids	19-36	18

Occurrence. Of all the Kophobelemnonidae, K. stelliferum occurs most widely. The species is found in the North Atlantic (Labrador Basin, Davis Strait, West European Basin, North and Norwegian seas), the Mediterranean, the northern basin of the Indian Ocean, the northwestern Pacific, and it has been found once in the waters of southeastern Australia. Depth of habitat 40-3,620 m.

2. Kophobelemnon affine Studer, 1894

Studer, 1894: 57.

Material: Station 6120, 23 spec.; station 6121, 4 spec.; station 6134, 30 spec.

Remarks. The specimens collected possess all the basic characters of K. affine. The autozooids are arranged in two lateral rows on the digitiform rachis with a bluntly-conical apex. Each row has two to four polyps, depending on the size of the colony. The autozooids are fairly large, most often numbering 4-6.

The polyps extend from the rachis alternately, as in the typical* specimens and colonies collected in the Bering Sea (Pasternak, 1960). Young colonies with a length of up 50 mm usually have only two autozooids.

The siphonozooids are small and are barely covered by the folds of the rachis. Unlike the typical specimens, they are to a much greater degree concentrated in the upper part of the rachis, while on the remaining

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* The author uses both "typical specimens" and "type specimens" (plural). The two terms are given here as in the Russian original. -- TRANSL.

polypoid part of the colony they are sparsely scattered, especially along the centre line of the dorsal surface of the rachis, the same as among the typical individuals. The siphonozooids of our colonies retain a single configuration and the same dimensions throughout the length of the polypoid part, in which K. affine differs sharply from the similar K. stelliferum, whose siphonozooids are distinctly dimorphous.

The spicules in the various parts of the colonies resemble those described previously. On the tentacles of the autozooids they have the shape of long, thin rods with slightly inflated ends and a length of 0.3-0.37 mm. The rachis spicules are also rod-shaped, but shorter (0.18-0.28 mm). The skeletal corpuscles at the base of the colonies do not differ from the spicules of the colonies from the Bering Sea, but they differ notably from most spicules described by Kükenthal and Broch (1911) in that they have a slight covering of tubercles and protrusions.

Mature colonies of K. affine from the Aleutian trench and the Gulf of Alaska are notably larger than those described previously (Table 2). Young colonies have better-shaped outlines, their thin, relatively long peduncle bears a short rachis, which widens only slightly at the level of the autozooids. The growth of the polypoid part of the colony overtakes that of the peduncle, so that in mature specimens the length of the rachis may exceed that of the peduncle, which is particularly noticeable in the type specimen of K. affine, which had 9 large autozooids (Studer, 1894).

Ecological remarks. In all colonies collected in the Aleutian trench we noted small, colorless, spherical actinias, which had succeeded in 112 penetrating fairly deeply into the soft tissues of the rachis. A similar case of commensalism has previously been described for colonies of K. biflorum

Dimensions of colonies of Kophobelemnon affine (in mm)

Character	Colonies from the Gulf of Alaska and the Aleutian trench				Typical colonies (mature)
	Young		Mature		
	St. 6120	St. 6134	St. 6120	St. 6134	
Total length of colony	30-57	37-46	58-92	70-136	52-112
Length of rachis	8-20	14-22	15-47	25-76	25-50
Width of rachis	1.3-3	2-4	3-6	4.5-8	4-5
Length of peduncle	17-22	22-24	34-45	47-70	27-40
Width of peduncle	1-1.5	1-2	1-2.5	1.5-3	2-4
Length of peduncle bulb	2-5	3-6	5-8	5-15	-
Width of peduncle bulb	1-3	1.5-2.2	1.5-3	2-4.5	-
Length of autozooids	5-9.5	6-7.5	10.5-21	8-24.5	11.2-15
Width of autozooids	1-1.5	1-2	2.5-3	2.5-3.5	2-4
Length of tentacles	4-8	4.5-6	8-17	6-20	7.5-9
Number of polyps	2	2	3-5	3-7	4-9

(Pasternak, 1960, 1961a). It is possible that the actinias that settled on the colonies of K. affine and K. biflorum belong to the same species. On the exposed distal parts of the axial polyps of K. affine found at station 6120 (Gulf of Alaska) we found small actinias and zoantharians.

Occurrence. Colonies of K. affine have been found along the coasts of Japan, in the Bering Sea, along the Aleutian Islands and in the Gulf of Alaska at depths of 1,310-1,965 m, and in the Gulf of Panama at a depth of 2,360 m.

3. Kophobelemnon biflorum Pasternak, 1960

Pasternak, 1960: 329.

Material: St. 6136, 1 spec.

Remarks. The specimen studied is a young colony with all the basic characters of K. biflorum. The relatively very thin peduncle, barely widening toward the distal end, goes over smoothly into a short, thin, nearly cylindrical rachis. Its diameter increases only slightly where the autozooids begin. The colony is much more delicate and thinner than adult specimens, even though it already has two autozooids. A similar configuration was observed in young colonies from the Bering Sea (Pasternak, 1960), which had only one autozooid each.

As in mature specimens, the autozooids of our colony are arranged approximately at the same level (6 and 7 mm from the distal end) and are slightly displaced toward the ventral side of the rachis. The body of the autozooids is nearly cylindrical, widening slightly toward the distal end, where it reaches its greatest width directly below the crown of tentacles.

The siphonozooids differ from those of the typical specimens only in their smaller size (0.1-0.2 mm) and are less numerous, which is due to the youth of the colony.

Among the skeletal corpuscles one can distinguish all six types of spicules typical of K. biflorum. The spicules differ only in their smaller size and in the fact that their surface is less densely covered with conical protrusions and tubercles. The largest spicules form a 113 supporting ridge for the tentacles. Their length is 0.8-1.5 mm, their width is 0.1-0.2 mm.

Ecological remarks. Although the colony is still very young and small, a typical commensal of K. biflorum had managed to attach itself to the rachis -- a spherical actinia, apparently belonging to the genus Sicyopus.

Occurrence. Colonies of K. biflorum are found in the Pacific Ocean at the Kurile Islands, at southern Kamchatka, in the Bering Sea, at the Aleutian Islands and along the west coast of the United States, usually at depths of 2,843-4,186 m. Three specimens are known to have been found at a depth exceeding 6,000 m.

FAMILY FUNICULINIDAE

4. Funiculina quadrangularis (Pallas, 1766)

Synonyms: See Kükenthal, Broch, 1911.

Material: Station 6136, 1 spec.

Remarks. We share the view of Jungersen (1904), according to which F. armata represents a form of F. quadrangularis. Kükenthal and Broch (1911) once more attempted to demonstrate the independence of the species F. quadrangularis and F. armata, but their arguments seem highly unconvincing.

In their view, the most typical character distinguishing these species is the ratio of peduncle length to the length of the polypoid part of the colony. However, it is hard to imagine a more variable character than this ratio. Kükenthal himself was compelled to admit that the more mature a colony becomes, the longer, in relative terms, will be the rachis. In the diagnosis of F. quadrangularis he states that the ratio of peduncle to rachis, in small specimens, is 1 : 4, in large specimens (up to 693 mm), 1 : 6. For F. armata we are given a ratio of 1 : 16, but Kükenthal was able to observe only two small specimens of this Funiculina. Our own material includes colonies which in a number of characters resemble F. armata, but with peduncle-rachis ratios of 1 : 5 and more, which makes them similar to F. quadrangularis. The only Funiculina colony obtained in the Aleutian trench, on the other hand, resembles in several respects F. quadrangularis, but the peduncle-rachis ratio is 1 : 4 with a length of 787 mm, which fails to coincide with the diagnosis of F. quadrangularis. We should add that in computing their ratios, Kükenthal and Broch committed disappointing errors, and in a number of cases the index determined by them as 1 : 16 or 1 : 10 is actually 1 : 6 or 1 : 4.

Such characters as the elasticity of the axial polyp in the polypoid part of the colony and a tendency toward a spiral curling of its distal end, which, in the view of Kükenthal and Broch, characterize F. quadrangularis, are also unacceptable as sufficient criteria for diagnosing species of sea feathers. The same applies to the shape of the peduncle cross section, which depends on the degree of contraction of the coenosarc during fixation. We might note here that the Aleutian colony has a four-faceted peduncle, while the upper part of the rachis is curled into a spiral: again a mixture of characters that had been considered specific of F. armata and F. quadrangularis.

Among the Funiculina specimens reviewed by us only some had 114 inflated propeller-shaped spicules, whose presence, according to Kükenthal and Broch, sharply distinguishes F. quadrangularis from F. armata, the dorsal spicules on whose rachis have the usual shape. It is indicative that the sparse propeller-shaped spicules were observed by us both in specimens with relatively long and elastic rachis and in colonies with short rachis and a heavily calcified axial polyp. In the coenosarc of the Aleutian colony such spicules are lacking altogether. All remaining structural features of quadrangularis and armata coincide fully. Jungersen's proposal that these two Funiculina are conspecific therefore appears justified, and we follow that investigator in including F. armata among the synonyms of F. quadrangularis.

The main dimensions of the Aleutian colony of F. quadrangularis are as follows (mm):

Total length	787	With of peduncle (max.)	4.5
Length of rachis	632	Length of autozooid calyx	4-4.5
Width of rachis (max.)	2	Width of calyx	1.2-1.6
Length of peduncle	155	Peduncle-rachis ratio	1 : 4.1

Occurrence. Colonies of F. quadrangularis have been found in the northern and northwestern Atlantic, in the North and Norwegian seas at depths of 130-2,070 m, along the coasts of Morocco, in the Bay of Biscay, in the Mediterranean and the Adriatic at 45-2,600 m, in the Indian Ocean and near Indonesia (650-1,644 m), in the Pacific north of New Zealand, near Japan, the Aleutian Islands and California (150-1,384 and 3,880-4,186 m).

FAMILY PROTOPTILIDAE

5. *Protoptilum orientale* Nutting, 1912

Nutting, 1912: 49, pl. 6, fig. 1, 1a.

Material: Station 6120, 42 spec.; station 6121, 6 spec.

Remarks. Among the Protoptilidae with a small number of longitudinal rows of autozooids and siphonozooids we know only two species having numerous spicules in the autozooid body. One of these, *P. orientale*, was described by Nutting (1912) from Japanese waters, the other, *P. celebense*, was defined by Hickson (1916) after study of three colonies of Protoptilidae from the area of the Malay Archipelago. The other species of this group lack spicules in the autozooids. Hickson noted that *P. celebense* differs from the other Protoptilidae in the complete absence of spicules on the peduncle. This statement was based on the fact that none of the investigators having studied *P. carpenteri* and *P. orientale* had stated whether or not spicules were present along the lower part of the colony. Peduncular spicules were stated to be present in the other species. However, *P. orientale* also seems to lack spicules on the peduncle. In Nutting's description there is no information on this score, although in describing *P. wrighti* he noted the presence of small acicular spicules in the coenosarc of all sections of the colony. Hickson perceives a difference between *celebense* and *orientale* also in the arrangement of the polyps on the rachis. This difference must evidently be considered the only one.

An analysis of the skeletal corpuscles of the colonies collected by the "Vityaz'" in the Gulf of Alaska has shown that spicules are present in all parts of the autozooid body, but are entirely lacking in the soft tissues of the peduncle.

All colonies studied bore on the rachis only two distinct rows of autozooids. Within one of the rows one sometimes noted a displacement of individual autozooids onto the ventral-lateral surface, however, 115
this did not alter the general arrangement of the polyps. The siphonozooids are arranged in one dorsal-lateral row on either side of the rachis, in one row at the base and one to two siphonozooids at the margin of the calyx of the autozooids. In each dorsal-lateral row the siphonozooids are distributed in such a way that for every autozooid calyx there are three siphonozooids. Such an arrangement of the polyps on the rachis is found on the two Japanese colonies that are the type specimens of P. orientale. The holotype had a length of 133 mm, of which the peduncle took up 63 mm; this falls within the range of colony lengths established from our own material.

P. celebense is typified by a different arrangement of the polyps on the rachis. In the largest specimen (of which only a part of the rachis was preserved, measuring 145 mm in length and 7 mm in diameter) the autozooids were arranged in two lateral and two ventral-lateral rows, and the siphonozooids were found everywhere on the rachis surface, with the exception of a narrow central band. In another colony (240 mm), in addition to the two lateral rows, there was one ventral row of autozooids.

Table 3. Dimensions of mature colonies of *Protoptilum orientale* (in millimeters)

Character	St. 6120 (8 spec.)	St. 6121 (3 spec.)	Type specimen
Total length of colony	78-201	122-155	133
Length of rachis	19-72	34-56	70
Width of rachis	0.6-2.5	0.6-1.5	3.5
Length of peduncle	43-132	88-112	63
Width of peduncle	0.6-2.1	0.6-1.0	2.5
Length of calyces	1.8-2.7	2.8-3.0	3
Width of calyces	0.6-1.0	1.0-1.3	-
Distance between calyces in one longitudinal row	4-7	4-5	5
Length of tentacles	5-7	4-6	3.5

The siphonozooids of this colony were just as numerous as in the preceding one. In a third specimen, the smallest of all (23 mm), there were only four autozooids -- two lateral and two terminal ones, but they, too, judging from the drawing, were arranged in such a way that the tendency to the formation of four autozooid rows in the future was quite distinct.

Thus, the Aleutian specimens, like those collected in the Bering Sea, in the arrangement of auto- and siphonozooids are undoubtedly similar to the type specimens of *P. orientale.* The spicules in the autozooid body of our specimens were grouped in several longitudinal strands, as in the type specimen of *P. orientale*. At the same time, there is no complete certainty that the abovenoted tendency toward the displacement of the autozooids within each longitudinal row may not lead, during growth, to the formation of additional rows of autozooids. If larger colonies should be found with 3-4 rows of autozooids, the question will arise as to the combination of *P. orientale* and *P. celebense*.

The dimensions of *P. orientale* colonies are given in Table 3.

Occurrence. Colonies of *P. orientale* have been found in the Pacific along the coasts of Japan, in the Bering Sea and in the Gulf of Alaska, at 455-2,160 m.

FAMILY UMBELLULIDAE 116

6. *Umbellula thomsoni* Kölliker, 1874

Synonyms: see Pasternak, 1964: 192.

Material. Station 6117, 1 specimen.

Remarks. A juvenile colony of *Umbellula*, obtained in the Gulf of Alaska and, regrettably, damaged during trawling. It undoubtedly belongs to *U. thomsoni*, as it possesses the basic characters noted in the descriptions (Kölliker, 1874; Brock, 1957). The colony bears on its elongated-conical rachis five autozooids: a terminal one and two pairs of lateral ones. The autozooids of the proximal pair are shifted slightly toward the ventral side of the rachis. The arrangement of the polyps provides the bundle with a bilateral symmetry, which is emphasized by the fact that the entire bundle is greatly compressed in a lateral direction. The greatest length of the autozooid body is 6 mm, the length of the straightened tentacles is 10 mm, the length of the rachis is 17 mm, its width at the level of the distal pair of autozooids is 3.5 mm. The thickness of the four-faceted peduncle below the rachis is 0.4 mm. In spite of this inconsiderable thickness, the axial polyp is very brittle, which is due to the high degree of calcification.

Spicules are observable in all sections of the colony and are represented by rod-like corpuscles with pointed ends and barely noticeable constriction in the middle. All types of spicules have three distinct costa. The surface of nearly all skeletal corpuscles is covered fairly densely with tubercles and conical protrusions, especially at the ends of the spicules. While they do not differ from the usual spicules of U. thomsoni in shape, the spicules of the Aleutian colony are smaller. In the autozooid tentacles their length is usually 0.15-0.20 mm, their width 0.02-0.03 mm. Somewhat larger are the spicules in the autozooid body: length 0.45-0.60, width 0.03-0.05. The acicular spicules of the rachis attain a length of 0.25 mm and a width of 0.015 mm. Among typical specimens the spicules are usually 1½ times larger. The smaller dimensions of the skeletal corpuscles may be due to age or individual variation.

Occurrence. Colonies of U. thomsoni have been found in the North and Mid-Atlantic, the Indian Ocean, the North Pacific, along the Kurile Islands, in the Gulf of Alaska, in the Coral Sea and along the coast of Antarctica, at 2,000-6,235 m.

FAMILY PAVONARIIDAE

7. *Pavonaria pacifica* (Nutting), 1909

Balticina pacifica Nutting, 1909: 704

Material: Station 6089, 5 spec.; st. 6092, 4 spec.; st. 6101, 2 spec.; st. 6102, 6 spec.; st. 6103, 1 spec.; st. 6122, 11 spec.; st. 6127, 21 spec.; st. 6132, 15 spec.; st. 6134, 1 spec.

Remarks. The species was described by Nutting (1909) from material collected near California at depths of 350-1,950 m. In Nutting's view, it is characterized by the fact that the obliquely situated roller-like leaves of the rachis in all colonies, including large, mature specimens, bear no more than 5 autozooids. In *P. finmarchica*, which is extremely similar to *P. pacifica* and practically indistinguishable in all other external characters, the number of autozooids in mature specimens ranges from 7 to 16 per leaf.

All colonies of *Pavonaria* collected in the Gulf of Alaska and in the Aleutian trench — with the exception of five obtained at the shallowest station (170 m) — also had no more than 5 autozooids on each 117
leaf. In young colonies (total length up to 250-400 mm), the number of autozooids in one row was 2, less often 3, and this only on the distal part of the rachis, and only in the largest mature colonies with a length of over 600 mm did it reach 5.

At the abovementioned shallow station we found colonies with more numerous autozooids: in young specimens each row had 3-4 polyps, in the largest colony, there were 6, and on three distal leaves, even 7. Unfortunately, we were unable to establish the total dimensions of this colony, as it was heavily damaged during trawling and its base and upper part of the rachis were lost. This peculiarity of the shallow-water colony is explainable by a long observed principle: as a rule, representatives of a species living in shallow waters have more but relatively smaller polyps, than those living in deep water (Pax, 1936; Pasternak, 1961b).

Thus, the small number of autozooids on each leaf of a colony may be regarded as a stable morphologic character of North Pacific Pavonaria. Taken by itself, this character scarcely justifies the rank of species. Taking into account the coincidence of the remaining characters of the external structure of P. finmarchica and P. pacifica, one might assume that they belonged to the same species. However, study of transverse sections through the rachis of several specimens that were in our possession (including one taken from the least depth) showed that the ventral part of the coenosarc of P. pacifica is penetrated by a dense network of radial channels, which are entirely lacking in the soft parts of the rachis of P. finmarchica (Kölliker, 1872; Hickson, 1916). In this respect P. pacifica bears greater resemblance to a species of another Pavonariid genus — Halipteris christi—which is also characterized by ventral radial channels. The latter have also been described for the genus Osteocella, but this genus lacks spicules in the autozooids and in the coensarc of the rachis (Hickson, 1916).

Revised diagnosis of P. pacifica. Colony extended, moderately fleshy, rachis fairly long, axial polyp heavily calcified. Obliquely arranged short, roller-shaped leaves of mature colonies have a maximum of 7 autozooids. In youth, the leaves are little developed, becoming distinct only in the distal part of the rachis, where they bear 2-3 autozooids. In the ventral part of the coenosarc there is a dense network of radial channels.

Occurrence. Colonies of *P. pacifica* have been found in the Pacific Ocean along the coasts of Japan and California, in the Gulf of Alaska, at the Aleutian Islands and at Bering Island, at 130-1,950 m.

FAMILY VIRGULARIIDAE

8. *Stylatula elegans* (Danielssen, 1859)

Virgularia elegans Danielssen, 1958 [sic]: 257
Dubenia abyssicola Kören et Danielssen, 1877: 94, taf. X.
D. borealis Kören et Danielssen 1883: 9, pl. II.
Stylatula (Dubenia) elegans Jungersen, 1904: 38.

Material: Station 6120, 7 spec.; station 6134, 20 spec.

Remarks. Our specimens possess the basic characters of the genus *Stylatula* -- small leaves supported by a membrane-like protuberance that is pierced by long spicules arranged like a fan, and autozooids with calyx. The colonies consist of a long and fairly fleshy peduncle and a thin, shorter rachis, which gives rise, at more or less equal intervals, to pairs of lateral leaves which bear the autozooids. The membranous protuberances of the rachis at the lower part of each leaf are pierced by 6-10 cuneate spicules that diverge like a fan. The distal end of a spicule extending beyond the rim of the protuberance makes up about 1/3 of the 118
former's length; the basal part, submerged in the tissue of the protuberance, is inflated and has three longitudinal facets. The surface of this part of the spicule is rough and longitudinally striate. The upper, free, part is round with a smooth surface and rounded end. The length of the spicules is highly variable, from 0.8 to 2.0 mm. Apart from these skeletal corpuscles, the tissue of the protuberances also contains short,

thin, rod-shaped spicules with rounded ends. Each leaf bears three autozooids with long, thin tentacles, strengthened by an aboral ribbon of closely contiguous spicules. The high, cylindrical calyces are divided nearly to the very base. The dorsal autozooid is the largest, the ventral one, the smallest.

These characters of the Aleutian colonies coincide with the description of the widely found S. elegans. At the same time they differ sharply from the usual colonies of this species in the presence of spicules in the calyx and even in the anthocodiae of the autozooids. The spicules of the autozooids are much more massive than the small spicules of the membranous protuberances: their length is 0.20-0.25 mm, their width, 0.06-0.08 mm. The surface of the corpuscles is entirely smooth, without tubercles or longitudinal striae, their margins are rounded, in the middle there is a distinct constriction. In the autozooid tissue the spicules are arranged in two to three longitudinal strands, terminating only beneath the very crown of tentacles. In each of the strands the spicules make up one to two layers, irregularly, but in frequently alternating groups, in which they are either loosely scattered or closely contiguous.

The presence of spicules in the calyces and anthocodiae of the autozooids is a character common in Stylatula. It is true that Kükenthal and Broch (1911) described specimens of S. elegans in which small spicules from the membranous protuberances that support the leaves sometimes extended to the base of the calyx. But the spicules in the autozooids of the Aleutian specimens differed greatly from those in the membranous protuberances and must be regarded as completely independent features.

However, Bayer (1957) described colonies of Stylatula, collected along the cost of Florida at a depth of 306 m and determined by him as

S. elegans, whose calyces were also found to contain spicules grouped in longitudinal strands. At the upper margin of the leaves, where the calyces still remain undivided, the longitudinal strands are most distinct, and the spicules themselves often extend into the tissues of the leaves themselves. The remaining characters agree with the description of S. elegans (Kölliker, 1872), with the exception of a somewhat greater number of fan-like spicules in the membranous protuberances of the rachis and more numerous (3-7) autozooids. Spicules of the same type were found by Bayer in the calyces of yet another Stylatula specimen obtained at Cape Fear (USA). However, the similar colonies from Chesapeake Bay completely lacked spicules in this section, the same as the specimens from Japanese waters. Bayer is therefore inclined to consider the presence or absence of spicules in the autozooid calyces merely as an instance of individual variation.

The wide range of variation in sea feathers is long and well known. The extreme forms of variation series often differ so greatly from one another that they have frequently been described as separate species. However, among the taxonomic characters of sea feathers the presence, dimensions and shape of spicules have justifiably been regarded as the most conservative and least variable. Hickson (1916), who had an excellent understanding of the variation range of sea feathers, emphasized, e.g., that the combination of the species P. willemoesi and P. septentrionalis, respectively possessing and lacking spicules in the polypoid part of the colony, could disturb the orderliness of the entire system of pennatularians.

At present it is difficult to adopt, without reservations, either 119
one or the other viewpoint. The availability of new material could facilitate

Table 4. Dimensions of Stylatula elegans (mm)

Character	St. 6120	St. 6131
Total length of colony	56-82	110-177
Length of rachis	35-4 /sic/	72-112
Width of rachis	0.7-0.2	0.8-1.1
Length of polypoid part with mature leaves	24-28	20-41
Length of peduncle	17-38	38-60
Width of peduncle	2-24 /sic/	2.4-4
Length of bulb	4-6.5	6-12
Distance between leaves	4-5	4-7
Number of leaves	6-7	11-18
Number of autozooids per leaf	2-3	2-3

the solution of this problem. At the moment we are compelled to include our colonies conditionally in S. elegans.

The main dimensions of the colonies collected in the Aleutian trench and the Gulf of Alaska are given in Table 4.

Occurrence. Colonies of S. elegans have been found in the North Atlantic, near Iceland, northwesterly of the Hebrides, along northern Norway, the east coast of the United States, near Cuba; in the Pacific, along the coasts of Japan, the Aleutians, and in the Gulf of Alaska; at depths of 122-1,965 m.

9. Virgularia cystifera (Nutting, 1909)

Halisceptrum cystiferum, Nutting, 1909: 698.

Material: Station 6093, 1 spec.; station 6120, 1 spec. and three fragments; station 6121, 15 spec.; station 6134, 28 specimens.

Remarks. About 50 species have been described as belonging to Virgularia. However, the more information was accumulated on the variation and age changes of the Virgularia, the clearer it became that many of the species described actually represented merely eco-phenotypes or growth stages. Hickson (1916) believed that only 12 of Virgularia species could be considered well described and studied; 17 species, in his view, were described extremely poorly and were doubtful. Among the latter was V. cystifera, described by Nutting (1909) from the coast of California. Colonies of V. cystifera, according to the description, are distinguished by small leaves with 4-5 autozoids and small, nearly indistinguishable siphonozooids. The margin of the calyces is usually compressed into eight short lobes. The characteristics are also found in our own specimens, which have a long, moderately fleshy peduncle with a vesicle-like base and a thin rachis (not longer than the peduncle), which gives rise to 20-40 paired leaves. Fairly often the right or left leaf of a pair is underdeveloped or lacking, which deprives the colony of symmetry. The protuberances are so small that it looks as if the autozooids extended directly from the rachis. The leaves of typical specimens are larger, they envalop like a halfmoon the lateral surfaces of the rachis, but the originator of the species received the impression that the autozooids of V. cystifera are attached directly to the rachis.

Each leaf of the mature Aleutian colonies gives rise to 3-4 autozooids with high slightly laterally compressed calyces, which agrees with the diagnosis; however the margin of the calyces among extended 120 autozooids is even and only among the contracted ones does it become slightly wavy. Only on rare occasions is the margin of the calyx compressed into eight short lobes.

The siphonozooids of our specimens, as in the typical specimens, are small, little differentiated, very few, and are sometimes lacking altogether. They are found singly only at the base of the autozooids, nearest the dorsal side of the rachis, and in the lower part of the leaf, and even so not on all leaf pairs. Their diameter may reach 0.1 mm. In spite of some differences in leaf structure and the outlines of calyx margins, we may affirm that the Aleutian specimens are identical with the type specimens.

V. cystifera was unjustifiably counted among doubtful species, in spite of its indubitable resemblance to the widely found V. gracillima and V. cladiscus.

From V. gracillima the colonies of V. cystifera differ in their much larger autozooids, whose calyces are divided nearly to the very base, while in the former the small calyces of the autozooids are fused along more than half their length. Leaves and autozooids in V. cystifera are oriented at a slight angle to the axis of the colony, rather than perpendicularly, as in V. gracillima. The differences between V. cystifera and V. cladiscus consist in the structure and number of siphonozooids: in cystifera they are little differentiated, while in cladiscus the base of each leaf invariably bears 3-6 distinct autozooids [siphonozooids?].

The main dimensions of V. cystifera colonies collected in the Aleutian trench and the Gulf of Alaska are given in Table 5.

Occurrence. V. cystifera has been found in the Pacific along the coast of California (710-1,100 m), along the Aleutians and in the Gulf of Alaska (1,340-1,965 m).

Table 5. Dimensions of Virgularia cystifera (in mm)

Character	St. 6093	St. 6120	St. 6121	St. 6134
Total length of colony	126	29	107-144	95-193
Length of rachis	63	13	58-73	47-97
Width of rachis	0.8	0.3	0.6-0.8	0.6-1.0
Length of peduncle	54	13	46-65	45-90
Width of peduncle	2.5	1.1	1.8-2.2	2.1-3.0
Length of bulb at base	9	3	3-6	3-8
Distance between leaves	6.5	2	4.5-5.5	4-6
Length of autozooids	4-6	1-2	2.8-4.3	4-5.5
Number of leaves	16	6	12-17	10-21
Number of autozooids per leaf	3	2	4	3-4

FAMILY PENNATULIDAE

10. Pennatula phosphorea L., 1758

Synonyms see Pasternak, 1961b: 225.

Material: Station 6096, 1 spec.; station 6105, 2 spec.

Remarks. The structure and dimensions of the two colonies obtained from 2,970–2,980 m do not transcend the limits of intraspecific variation established previously for P. phosphorea (Pasternak, 1961b). The structural characteristics of the third specimen, obtained from 4,190 meters, require special consideration.

In the collections of the "Ob'" made in the Indian Ocean at depths of 1,000 and 1,360 m, there were two colonies of Pennatula similar to specimens of P. phosphorea var. antarctica obtained by the German Deep-Sea Expedition at Bouvet Island (Kükenthal, Broch, 1911), and P. indica, collected in the Banda Sea (Hickson, 1916). In his turn, while describing colonies of P. indica, Hickson noted its great similarity with specimens of P. distorta var. pacifica and particularly P. prolifera and expressed the view prëviously described deep-sea species and varieties of of Pennatula actually could turn out to be nothing more than forms of the one species P. phosphorea, and that differences between them and typical shallow-water P. phosphorea could be explained by an adaptation to deep-water habitats. An analysis of the morphology of the abovelisted forms and colonies, collected by the "Ob'," demonstrated the correctness of Hickson's hypothesis (Pasternak, 1961b): differences between shallow-water 121 specimens of *P. phorphorea* and deep-sea colonies from Davis Strait, the South Atlantic, the Malay Archipelago and the Indian Ocean agree with the character of variation due to a transition to a deep-sea ecology and demonstrated in the case of several other representatives of sea feathers. Therefore *P. prolifera*, *P. distorta* var. *pacifica*, *P. indica* and *P. phosphorea* var. *antarctica* have been placed by us among the synonyms of *P. phosphorea*, a species possessing wide geographic distribution, being highly eurybathic, and having a high degree of ecologic valence.

The third Aleutian colony of *P. phosphorea* differs notably from the others in the proportions and dimensions of individual parts and in some other respects. It was obtained from a record depth for that species, exceeding all hitherto known deep-sea occurrences by nearly 1,000 meters.

The colony consists of a peduncle, relatively longer than in other known *P. phosphorea*, and a short rachis, comprising only 1/3 of the total length of the colony. The rachis gives rise to six leaves on the left and seven leaves on right side. The leaves are long, elastic, thin, absolutely and relatively longer than in *Pennatula* from lesser depths (Table 6). They extend from the rachis at an acute angle, the longest (3rd to fifth on either side) bear only three autozooids, fewer than in most known deep-sea colonies of *P. phosphorea*. The remaining leaves have thin, cylindrical, sometimes slightly curved denticles; from the eighth leaf on, the denticles are long and pointed.

As in typical colonies, the siphonozooids are arranged in two parallel strands on either side of the dorsal surface of the rachis free of polyps; in each strand the siphonozooids are arranged in only two to three somewhat indistinct rows.

The spicules of this specimen do not differ in number and configuration from the skeletal corpuscles of the other deep-sea colonies, but they are notably larger: the length of the acicular spicules in the leaves is 0.25-0.40 mm, their width is 0.030-0.045 mm. The dimensions of the large spindle-shaped spicules supporting the leaves and sometimes extending to the surface of the terminal autozooids are 2.5-3.8 mm in length and 0.20-0.45 mm in width. The acicular spicules of the autozooids are somewhat larger than those of the leaves. The sharp denticles on the calyces of the autozooids are made up of long, large spicules with a smooth surface with longitudinal facets; their length is 1-2 mm, their width, 0.2-0.3 mm.

Thus, the colony reviewed here occupies an extreme position in the series of the gradual transition from large, shallow-water colonies with numerous and relatively small autozooids on short fleshy leaves to the small deep-sea colonies with sparse but relatively large autozooids on long and thin leaves. With the same structural plan as other deep-sea P. phorphorea, this colony has the most leaves and the relatively largest autozooids. As to the calyces, they are not only proportionately but absolutely taller than those of any other deep-sea colonies.

Occurrence. Colonies of P. phosphorea have been found along 122 the coasts of Europe from Norway to the Adriatic Sea and the Sea of Marmara (6-300 m), in the Atlantic along the coasts of Morocco (105 m), in the northwestern Atlantic (2,120-2,624 m), in the Indian Ocean, the Bay of Bengal, the Arabian Sea, near South Africa (833-1,483 m), east of Bouvet Island at 439-457 m, in the Pacific, the Sea of Okhotsk, along the coasts of Japan, in the Gulf of Alaska, along the west coast of North America, and in the Gulf of Panama (18-4,190 m).

* * *

Table 6. Dimensions of deep-sea Pennatula phosphorea (mm)

Character	Depth, in meters		
	4,140	2,980	2,970
Total length of colony	44	39	48
Length of rachis	14	17	21
Width of rachis	2.1	1.8	1.8
Length of peduncle	30	22	27
Width of peduncle	1.2	1.1	1.3
Number of leaves (maximum)	18	12	16
Width of leaves	0.7	0.8	0.8
Number of leaves on right & left	6-7	7-8	10-11
Autozooids on long leaves	3	3-4	4
Length of free part of autozooid	3.8	2.7	2.5

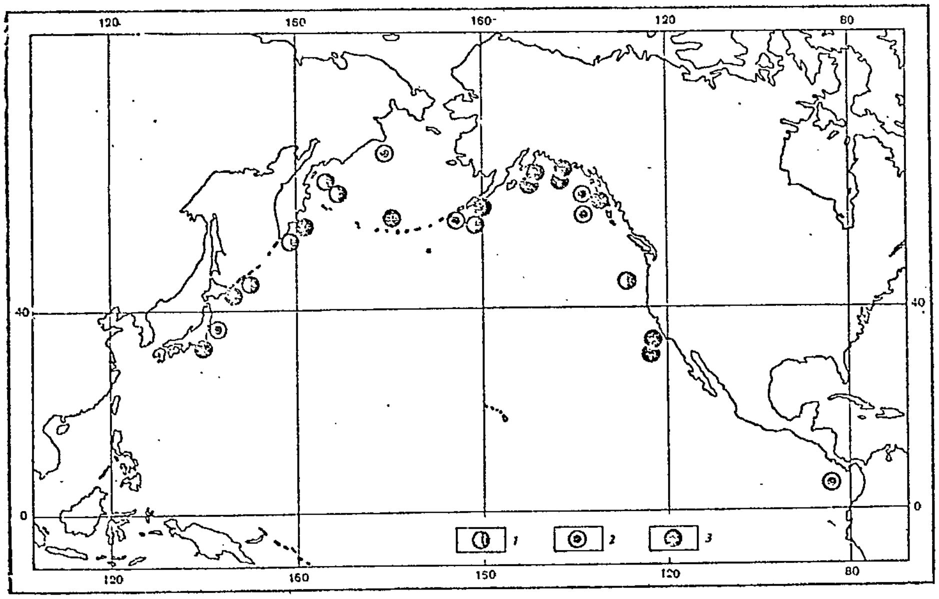

Fig. 1. Distribution of sea feather Kophobelemnon biflorum (1), K. affine (2) and Pavonaria pacifica (3).

Although the deep-sea sea feathers of the North Pacific are as yet little studied, the information accumulated up to now allows us to draw certain conclusions concerning the geographical and vertical distribution of these organisms.

Earlier, two species of Kophobelemnon (K. affine and K. biflorum) had been discovered in the North Pacific. The places where they were found coincided, to some degree, with the limits of the disconnected Japan-Oregon habitats of the shallow-water species (Pasternak, 1961a). Even then we expressed the assumption that the distribution of these species had nothing in common with amphi-Pacific range, and that the observed disconnection between the Asiatic and North American habitats was due only to lack of information concerning the area of the Aleutian trench, i.e., the channel along which there might occur an exchange of deep-sea organisms between the western and eastern part of the Pacific. We assumed that these species would be found by subsequent expeditions.

The investigations of the deep-sea fauna of the Aleutian trench and the Gulf of Alaska during Cruise 45 of the "Vityaz'" confirmed this assumption. A colony of K. biflorum was discovered at a depth of 4,100 m within the trench, and numerous specimens of K. affine were collected from depths of 1,560-1,965 m, both in the trench itself and in the Gulf of Alaska. Thus, the ranges of K. biflorum and K. affine in the Asiatic and the North American parts of the Pacific linked up in the region of the Aleutian island arc. In the trench we found numerous colonies of Pavonaria pacifica, which had also been known only from the coasts of Japan and Kamchatka in the western part of the ocean, and from the coast of California, in the east. It can now be regarded as firmly established that the geographical ranges of these three species (one abyssal and two bathyal) fringe like a narrow band the coasts of the continents and island arcs bounding the northern half of the Pacific Ocean (Fig. 1). The question therefore arises as to the possibility of existence of disconnected amphi-Pacific ranges of deep-sea organisms as a whole.

Intensive investigations of the deep-sea fauna of the ocean carried out during the last 20 years on the "Vityaz'" and other ships, and the analysis of results from earlier deep-sea expeditions have compelled us to revise our previous concepts concerning the cosmopolitan distribution of deep-sea benthonic fauna. The information concerning its distribution that has become available in recent years not only emphasizes the zoogeographical independence of the deep-sea benthonic fauna in the various parts of the ocean, it also appears to make it possible to distinguish such types of distribution as bipolar, amphiboreal, circumtropical, and amphi-Pacific, analogously to the disconnected ranges of shallow-water organisms (Birshtein, 1960; Vinogradova, 1956, 1969; Zenkevich, Birshtein, Belyayev, 1954; Zenkevich, 1958; Ekman, 1953). Such deductions, however, must be approached with a certain caution, since many deep-sea regions of the ocean are still very little known, and there are still very vew systematic revisions of the basic deep-sea benthonic groups carried out at a modern level. Therefore, the possibility of the existence of disconnected ranges of deep-sea organisms, and above all amphi-Pacific ones, seems rather doubtful. The concept of an amphi-Pacific range is based on a distribution of a species where its members are found along the coasts of Asia and North America within 30-50° latitude, but are absent in the Bering Sea and along the Aleutian island arc in the north and throughout the tropical

part of the Pacific in the south (Andriyashev, 1939). But if the absence of shallow-water benthonic and pelagic species in the breaks between amphi-Pacific ranges is easily explained by unfavorable modern hydrologic conditions, this cannot be asserted in any way of the deep-sea organisms, which live within deep water masses with their remarkably stable temperature, salinity and other factors. This applies, of course, not only to amphi-Pacific but also to other disconnected ranges of deep-sea benthonic invertebrates. Ya. A. Birshtein (1960), analyzing the distribution of deep-sea isopods, was compelled to note that the nature of the barrier hindering the migration of bipolar deep-sea species to the tropical abyssal zone remained unknown. Without doubting the existence of disconnected geographical ranges of deep-sea organisms, Birshtein attempted to explain 124
the emergence of bipolar and amphiboreal ranges in the abyssal zone of the ocean and proposed the hypothesis that the disruption of ranges of deep-sea organisms "arose among the shallow-water ancestors of the modern deep-sea organisms. While migrating to the greater depths, the derivatives of the shallow-water fauna could preserve the features of the geographical distribution that had evolved with their ancestors, living in regions of shallow ocean water." (Birshtein, 1960, p. 26). In other words, we are faced with a polytopic, parallel emergence of deep-sea species, which is in contradictinn with modern evolutionary concepts. Nonetheless, Birshtein in his next exposition (1963) continued to adhere to his interpretation. To some degree, the reasons for the latitudinal zonation in the distribution of deep-sea fauna may be sought in the biology of the organisms themselves, which are sensitive to changes in feeding conditions in the latitudinally alternating eutrophic and oligotrophic regions.

However, the eutrophic regions of the Northern and Southern hemispheres link up in the coastal areas not only at high but also at tropical latitudes, offering migration paths to bipolar elements. Such a hypothesis is even less appropriate to the amphi-Pacific ranges of deep-sea organisms, as the eutrophic conditions in the areas of disruption may be even more pronounced than in the coastal deep-sea areas of Asia and America, where they live. Therefore, in order to explain the emergence of amphi-Pacific ranges of deep-sea benthonic organisms N. G. Vinogradova (1969) was obliged to have recourse to Birshtein's theory that such ranges arose among the shallow-water ancestors, and that their deep-sea descendants preserved the characteristics of their distribution. For practical purposes, Vinogradova was also forced to admit the possibility of a parallel emergence, in the western and eastern parts of the Pacific, of the same species, derivatives of shallow-water amphi-Pacific forms.

In view of all the foregoing, Vinogradova's remark, "it is difficult to assume that they (the amphi-Pacific deep-sea species — F.P.) will be found in the North or South Pacific" (1969, p. 179) appears highly unconvincing. It is true that Vinogradova cites yet another argument in favor of the theory of amphi-Pacific ranges of deep-sea benthonic invertebrates. In her view, the acceptance of a bipolar and amphiboreal distribution of deep-sea organisms by itself compels us to recognize the possibility of an amphi-Pacific distribution as well. Unfortunately, the weakness of this argument is evident, the more so as the existence of the amphiboreal and bipolar elements of deep-sea benthonic fauna is itself just as dubious.

The lack of success in explaining the emergence of amphi-Pacific geographical ranges of deep-sea organisms, the lack of biological justification for their existence and of any genuine barrier to their migration along the Aleutian trench, as well as the fact that the very first expedition to the North Pacific resulted in the find of several species of deep-sea pennatularians -- previously found on either side of the ocean -- in the area of the classic break between the amphi-Pacific ranges are convincing evidence that amphi-Pacific ranges of deep-sea benthonic invertebrates never had any actual existence. Neither can there be any doubt that subsequent expeditions to the area of the Aleutian trench will result in finds of members of the remaining 20 species of deep-sea benthonic organisms known hitherto only from the western and eastern part of the Pacific.

Returning to the distribution of K. affine, K. biflorum and P. pacifica, we must note that the boundaries of their geographical ranges, like those of other deep-sea species, must be defined by other factors than the boundaries of shallow-water species. Recent investigations have shown 125
that the distribution of deep-sea benthos is most closely associated with the presence and accessibility of food on the ocean bottom. Evidently, this applies particularly to the fauna of deep-sea sea feathers. In any case, representatives of all genera of pennatularians, with rare exceptions, were found not far from the coasts. The coastal strip in which the sea feathers live is, as a rule, much narrower than the peripheral sections of the eutrophic regions of the ocean. The vertical range of these colonial coelenterates is very great, and if, as a result of the great steepness of the continental slope, the abyssal depths approach close to the shores of the continents, the pennatularians, being typical

representatives of the bathyal zone, easily penetrate into unfamiliar abyssal depths. Only four species of the genus Umbellula possess a wider geographical distribution, settling freely throughout the ocean basin not only in eutrophic regions but also in transitional zones between eutrophic and oligotrophic regions. Evidently, for most of the deep-sea sea feathers the main factor determining their distribution is distance from the coast. In his work on quantitative distribution patterns of benthos in the western Pacific G. M. Belyayev (1960) writes that distance from the coast may be regarded as an indicator embracing a number of factors affecting the abundance of life, such as the dynamics of bottom waters, food supply, oxygen saturation, etc. Near the coast, even at considerable depth, these factors are most effective, so that in the coastal deep-sea strip conditions arise favoring the existence of a more varied and a richer benthonic fauna than in the ocean basin. It stands to reason that it is precisely in the coastal strip that the best conditions arise for deep-sea pennatularians as well. This yields a simple explanation of their geographic ranges, which fringe as a narrow band the coasts of continents and island arcs.

As regards the distribution of K. affine, K. biflorum and P. pacifica, we have as yet no information as to the southern limits of their range. However, judging from the fact that K. affine was found west of the Isthmus of Panama, and that north of New Zealand a young colony of Kophobelemnon sp. was found bearing a structural resemblance to young specimens of K. biflorum (Pasternak, 1961a), the hypothesis suggests itself that these species also exist in the Southern Hemisphere. For the time being we may retain for these species the term "North Pacific coastal-deep-sea species," proposed and derived by us previously from the work of Ekman (1953). Such

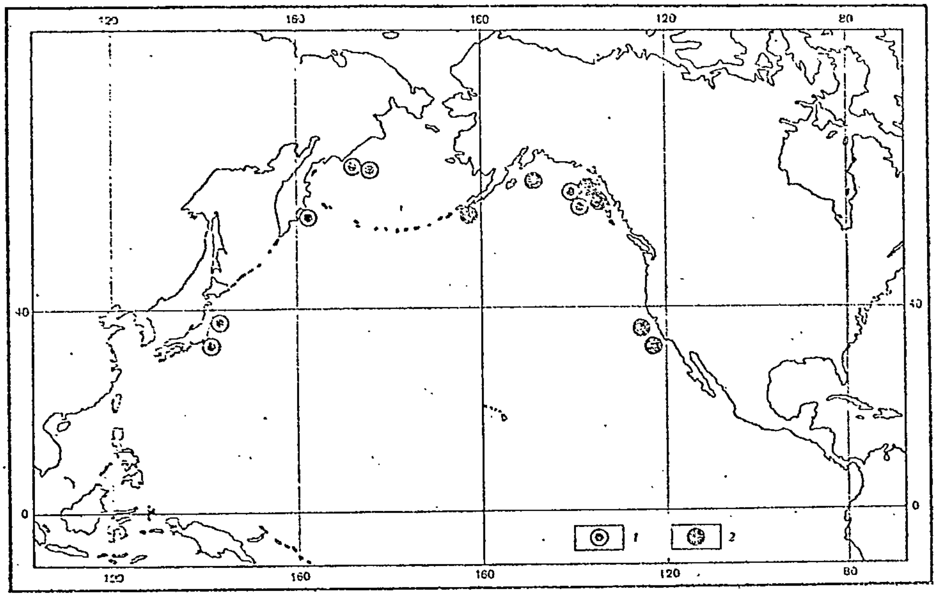

Fig. 2. Distribution of sea feathers Protoptilum orientale (1) and Virgularia cystifera (2).

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a name, it seems to us, reflects more correctly the character of the distribution of these species than a term that may reflect links between their distribution and the boundaries of the peripheral parts of eutrophic regions. In fact, the adoption of the term "eutrophic deep-sea species" could suggest a much wider geographic range of these pennatularian species than what is actually observed. It makes no sense to define them as "coastal eutrophic-deep-sea species," since all coastal areas of the continents and even of island arcs are, as a rule, characterized by eutrophic conditions.

Similar to this type of distribution of deep-sea pennatularians are the geographical ranges of two other species — Protoptilum orientale and Virgularia cystifera (Fig. 2). The first of these is found in Japanese waters at depths of 455-510 m (Nutting, 1912), along the coasts of Kamchatka and Bering Island at depths of 1,928-2,160 m, and in the northern Gulf of

Alaska at depths of 1,560–1,965 m. In the voluminous collections of sea feathers obtained along the coast of California by the "Albatross" expedi- 126 tion, P. orientale was not observed. V. cystifera, on the other hand, has been described from specimens collected near California (710–1,100 m), and during Cruise 45 of the "Vityaz'" it was found at four stations in the Gulf of Alaska and the Aleutian trench (1,340–1,960 m). In the "Vityaz'" collections in the northwestern Pacific these pennatularians were not found. In view of the geographical and vertical distribution of the two species, we may assume that the centre of emergence of P. orientale is along the coast of Japan, that of V. cystifera, in the eastern part of the Pacific, along the coast of California. Thence the species may have moved northward along the coasts of Asia and North America, until their ranges became superimposed on one another in the area of the Aleutian trench. Be that as it may, the distribution of P. orientale and V. cystifera may serve as a good example of the juncture of ranges of deep-sea benthonic invertebrates. Both these species make similar demands on their habitat: at those stations where we found numerous colonies of P. orientale we also found in many instances V. cystifera. We may assume that in the future P. orientale is bound to migrate further along the coast of North America, and V. cystifera along those of Asia. In the end, their geographical ranges will acquire the same features as those of the previously considered North Pacific coastal-deep-sea species.

The remaining species reviewed in this paper — K. stelliferum, F. quandrangularis, U. thomsoni, S. elegans, and P. phosphorea — have a very wide geographical as well as vertical range. Their discovery in the Aleutian trench and the Gulf of Alaska was not unexpected. Of all these species only S. elegans cannot be included among the pan-oceanic species, since it has not as yet been found in the Indian Ocean. The largest geographical range is that of U. thomsoni, one of the few genuinely abyssal species of sea feathers. We know of only three instances of finds of U. thomsoni in bathyal depths -- west of the coast of Morocco at depths of 2,000 and 2,125 m, and on the ocean side of the Antilles island arc, at 1,336 m. However, it is precisely in these areas that we find a rise of deep cold water, which usually leads to a change in the position of the 127 upper boundary of the range of many abyssal organisms (Pasternak, 1964, 1970). Previously, while discussing the factors determining the distribution of deep-sea pennatularians, we already noted that only a few species are capable of existing on the floor of the open ocean basins, and then only in eutrophic regions. U. thomsoni provides a good example.

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POLYCHAETE FAUNA OF THE ALEUTIAN, JAPAN AND IDZU-BONIN TRENCHES IN THE PACIFIC OCEAN

By R. Ya. Levenshtein

During Cruise 45 of the "Vityaz'" investigations were made of the benthonic fauna of the Gulf of Alaska and the Aleutian trench, and several trawls were also carried out in the Japan and Idzu-Bonin trenches. As a result of these and earlier collections we now possess an assemblage of polychaetes from 18 stations, distributed as follows by depths and trenches:

Depth, m	Aleutian trench	Japan trench	Idzu-Bonin trench
6,000-7,000	5	4	-
7,001-8,000	3	3	-
8,001-9,000	-	-	2
over 9,000	-	-	1

Thus far, very little information had been available on the polychaetes of the Aleutian, Japan and Idzu-Bonin trenches. A few data concerning polychaetes of the genera Macellicephala, Macellicephalloides, Travisia and Kesun, also obtained in the abovementioned trenches, are found in the studies by R. Ya. Levenshtein (1970a, b, 1971) and P. V. Ushakov (1971). We had previously published some data on the polychaetes of the Japan trench (1961).

Although the polychaete collection obtained during Cruise 45 has not been fully studied, the information obtained nevertheless permits us to draw certain conclusions concerning the geographic and vertical distribution of the polychaetes. Table 1 provides a list of polychaetes by stations.

In the trenches investigated we found about 30 species of polychaetes (of these, 18 were determined down to species) [sic], belonging to 26 genera and 15 families (Table 2). In the Aleutian trench we found 20, in the Japan trench 24, in the Idzu-Bonin trench 4 species. Half the species living in the Aleutian trench are also found in the Japan and in the Kurile-Kamchatka trenches. Information concerning the polychaetes of the Kurile-Kamchatka trench has been derived from the studies of Ushakov (1952, 1953, 1955, a,b, and from personal communications) and of Levenshtein (1970a, b, 1971).

By their vertical distribution, the polychaete species of the trenches may be divided into four groups: (a) eurybathic species; (b) species that are mainly bathyal but also occur in the abyssal region; (c) mainly abyssal species, also descending to the ultra-abyssal region; (d) ulta-abyssal species.

	Eurybathic	Bathyal	Abyssal	Ultra-abyssal
Aleutian trench	1	1	5	2
Japan trench	3	1	7	3
Idzu-Bonin trench	0	0	3	0

Not many eurybathic and mainly bathyal species are found in the trenches, which are inhabited mainly by abyssal and ultra-abyssal species.

Table 1. Stations at which polychaetes were collected

Station No. and date	Latitude and longitude	Depth, meters	Species and number of specimens
	Aleutian trench Алеутский желоб		
3340 1.VI.1955	53°53′,2 с. ш. 166°55′,6 в. д. e	6410—6757	*Jasmineira filatovae* Capitellidae—2 fr., Serpulidae — 1
3357 7.VI.1955	52°25′,8 с. ш. 170°53′, 9 в. д. e	7246	*Eulalia sigeformis* — 1, *Macellicephala kirkegaardi* — 4, *Kesun abyssorum* — 5, Cirratulidae—1, Capitellidae — 1, Oweniidae — 2
4120 5.XI.1958	53°37′,7 с. ш. 159°40′,9 з. д. W	6328 6296	*Jasmineira filatovae* — 4, *Onuphis* sp.—6, Pista sp.—10, Oweniidae — 1, Ampharetidae — порядочно
6085 1.V.1969	50°48′, 6 с. ш. 173°29′,0 з. д. W	6965—7000	*Macellicephala kirkegaardi* — 8, *Macellicephaloides, berkeleyi* — 2, *Kesun abyssorum* — 3, *Amphicteis gunneri* var. *japonica* — 5, *Ilyphagus* sp. — 6
6139 11.VI.1969	53°06′,8 с. ш. 163°05′,8 з. д. W	6550	*Jasmineira filatovae* — 6, *Notomastus* sp. fr., Oweniidae — fr.
6140 13.VI.1969	52°55′,2 с. ш. 163°20′,0 з. д. W	6960	*Kesun abyssorum* — 8, *Terebellides eurystethus* — 2, *Jasmineira filatovae*—10, Lumbrineris n. sp. — fr.
6144 16.VI.1969	51°42′,5 с. ш. 168°05′ з. д. W	7200	*Macellicephala kirkegaardi* — 1, *Kesun abyssorum* — 1
6145 20.VI.1969	51°09′,7 с. ш. 174°35′,5 в. д. e	7250	*Macellicephala mirabilis* — 2, *M. kirkegaardi* — 2, *Travisia profundi* — 22, *Kesun abyssorum* — 18, *Amphicteis gunneri var. japonica* — 2, *Lumbrineris* n. sp. — 1, *Ilyphagus* sp. — 1, *Ammotrypane* sp. — 1
	Японский желоб Japan trench		
3214 25.X.1854	38°10′ с. ш. 43°56′,2 в. д. e	6156—6207	*Admetella longipedata* —1, *Macellicephaloides verrucosa*—4, *Travisia profundi* — 3, *Kesun abyssorum* — 40, *Maldanella harai* — много, *Amphicteis gunneri* var. *japonica* — 1, *Lumbrineris* n. sp. — 4, *Notoproctus* sp. — 2, *Anobothrus* sp. — много Pista. sp., *Jasmineira* sp. — fr.
3227 2—3.V.1955	38°02′ с. ш. 143°57′,4 в. д. e	7181—7190	*Vitiazia dogieli* — 1, *Travisia profundi* — 1, *Terebellides eurystethus* — 1, Capitellidae — fr.
3457 21.IX.1955	41°17′, 3 с. ш. 145°50′, 2 в. д. e	6475—6571	*Macellicephala* sp. — fr., *Lumbrineris* n. sp. — 1, *Travisia profundi* — 1, *Amphicteis gunneri* var. *japonica* —70, *Jasmineira filatovae*.
3571 30.IV.1957	38°56′,7 с. ш. 143°57′,4 в. д. e	7565—7587	*Vitiazia dogieli* — 1, Nereidae — 10. *Lumbrineris* n. sp. — 10, *Ilyphagus* sp. — fr, *Kesun fuscus* — 3, *Ammotrypane* sp. — 2. *Notomastus* sp. — 100, *Amphicteis gunneri* var. *japonica* — 1, *Terebellides eurystethus* — 20
3593 22.V.1957	40°54′,9 с. ш. 144°53′ в. д. e	6380	Maldanidae — fr., *Amphicteis mederi* — 5, *Jasmineira filatovae* — 15, *Jasmineira* sp.
6151 28.VI.1969	37°41′,5 с. ш. 143°54′,3 в. д. e	7370	*Macellicephala mirabilis* — 3, *Lumbrineris* n. sp. — 10, *Ilyphagus* sp. — 1, *Kesun abyssorum* — 9, *Ammotrypane* sp. — 6, *Notomastus* sp. — 25 fr., *Amphicteis gunneri* var. *japonica* — 8, *Terebellides eurystethus* — 10

Table 1, cont.

6152 28.VI.1969	37°00′ с. ш. 143°23′ в. д. e	6600—6700	*Macellicephala zenkevitchi* — 1, *Ceratocephale loveni* — 2, *Lumbrineris* n. sp. — 10, *Scalibregmidae* — 3, *Ilyphagus* sp. — 3, *Travisia profundi* — 40, *Kesun abyssorum* — 11, *Notomastus* sp. — 2, *Amphicteis gunneri* var. *japonica* — 6, *Jasmineira filatovae* — 1
	Idzu-Bonin trench Идзу-Бонинский желоб		
3494 9.X.1955	29°09′,3 с. ш. 142°53′, 1 в. д. e	9715—9735	*Macellicephala* sp. — fr., *Kesun abyssorum* — 1, *Jasmineira filatovae* — 1, *J.* sp. — 1, Serpulidae — 1
3514 21.X.1955	27°59′,3 с. ш. 143°15′,5 в. д. e	8530—8540	*Jasmineira* sp. — 1
6153a 1—2.VII.1969	34°32′,5 с. ш. 142°06′ в. д. e	8800—8830	*Micronephthys abranchiata* — 1, *Kesun abyssorum* — 1

Note: All samples were obtained with a Sigsby trawl, with the exception of St. 3357 ("Okean" bottom grab) and 3593 ("Galatea" trawl).

The group of eurybathic species is represented by *Maldanella harai*, *Amphicteis gunneri* var. *japonica* and *A. mederi*. They are all found in the upper horizons of the ultra-abyssal zone of the Japan trench, and *A. gunneri* var. *japonica* is also found in the Aleutian trench. The species *Maldanella harai* is found widely in the World Ocean and lives at widely differing depths. Thus, in the Pacific along the coasts of Japan it has been found in the sublittoral zone (100-146 m), in the Sea of Okhotsk on the continental slope (220-591 m), in the Kermadec trench in the upper ultra-abyssal zone (6,620-6,720 m). In the Indian Ocean this species was noted in the bathyal zone (1,154-2,110 m), in the Atlantic, in the abyssal zone (2,690-4,700 m). Thus, inhabiting a wide range of depths, *M. harai* is more commonly found in the deep sea. *A. gunneri* var. *japonica* is also found from the sublittoral to the abyssal region (Far Eastern seas, 33-3,330 m; along the Pacific coasts of Japan, 12-150 m); this marks its first known occurrence in the ultra-abyssal region. A. mederi occurs in the Far Eastern seas, the Kurile-Kamchatka trench and, according to our data, is also found in the Japan trench (6,380 m).

The group of mainly bathyal species includes Eulalia sigeformis and Ceratocephale loveni. E. sigeformis was found for the first time in the ultra-abyssal region (Aleutian trench, 7,246 m); heretofore this species had been known to occur only in the bathyal region of the Bering Sea, the Sea of Okhotsk and the Sea of Japan (443-645 m).

C. loveni has also been found for the first time in the ultra-abyssal zone (Japan trench, 6,600 m); previously it was known from the Sea of Okhotsk and the Bering Sea (200-4,400 m). It is found widely in the North Atlantic, also mainly in the bathyal region, though it has also been found there at depths of 5,023 m (Hartman, Fauchald, 1971). Most numerous in all the trenches is the group of mainly abyssal species, of which there are eight. Of these, five were found in the Aleutian trench, and seven in the Japan trench. All species (three) known to occur in the Idzu-Bonin trench belong to this group. Most of the members of this group are found widely in the World Ocean (Macellicephala mirabilis, Admetella longipedata, Travisia profundi, Kesun abyssorum), and only the territories of Kesun fuscus, Jasmineira filatovae and Terebellides eurystethus are limited to the Pacific. This may explain the similarity of the species representing this group in the Aleutian and the Japan trenches. Both trenches contain M. mirabilis, T. profundi, K. abyssorum, J. filatovae, T. eurystethus; two of them -- K. abyssorum and J. filatovae -- are also found in the Idzu- 132
Bonin trench. The latter contains Micronephthys abranchiata, found previously in the Kermadec trench. Only in the Japan trench did we find A. longi-

Table 2. Occurrences of polychaetes in the Aleutian, Kurile-Kamchatka, Japan, and Idzu-Bonin trenches

Species	Occurrences in the Pacific Ocean					Occurrences in other oceans
	A	KK	Jap	I-B	Elsewhere	
Fam. Phyllodocidae						
Eulalia sigeformis Annenkova	+	-	-	-	Sea of Japan, Okhotsk, Bering	-
Vitiazia dogieli Uschakov	-	+	+	-	-	-
Fam. Aphroditidae						
Macellicephala mirabilis McInt.	+	+	+	?	Sea of Okhotsk, East. Kamchatka, New Zealand	Arctic, Atlantic, Antarctica
M. zenkevitchi Uschakov	-	+	+	-	-	-
M. kirkegaardi Uschakov	+	-	-	-	-	-
Macellicephaloides verrucosa Usch.	-	+	+	-	-	-
M. berkeleyi Levenstein	+	-	-	-	-	-
Admetella longipedata McInt.	-	+	+	-	-	Indian and Atlantic Oc.
Fam. Nereidae						
Ceratocephale loveni Malmgren	-	-	+	-	Bering Sea, S. of Okhotsk	North Atlantic
Nereis sp.	-	-	+	-	-	-

Table 2. cont.

Fam. Nephthyidae						
Micronephthys abranchiata Ehlers	-	-	-	+	Kermadec trench	Antarctica
Fam. Eunicidae						
Onuphis sp.nov.	+	-	-	-	-	-
Lumbrineris sp. nov.	+	+	+	-	-	-
Fam. Cirratulidae						
Gen.? sp.?	+	-	-	-	-	-
Fam. Chloraemidae						
Ilyphagus sp. nov.	+	+	+	-	-	-
Fam. Ophellidae						
Travisia profundi Chamb.	+	+	+	-	Bering Sea, Banda Sea, coast of Peru	Coast of Angola, Antarctic basin
Kesun fuscus Chamberlin	-	-	+	-	North and Central Pac.	
K. abyssorum Monro	+	+	+	+	Kermadec trench	Atlantic and Indian oceans, Antarctica
Ammotrypane sp.	+	-	+	-	-	-
Fam. Capitellidae						
Notomastus sp.	+	+	+	-	-	-

Table 2, cont.

Fam. Maldanidae						
Maldanella harai (Izuka)	-	-	+	-	Sea of Okhotsk, coast of Japan, Kermadec trench	Indian and Atlantic oceans
Notoproctus sp.	+	-	+	-	-	-
Fam. Oweniidae						
Gen.? sp.?	+	-	-	-	-	-
Fam. Ampharetidae						
Amphicteis gunneri var. japonica McIntosh	+	+	+	-	Bering Sea, S. of Okhotsk, S. of Japan, Japanese coast	-
A.mederi Annenkova	+	+	+	-	Bering Sea, Sea of Okhotsk, Sea of Japan	-
Anobothrus sp.	-	+	+	-	-	-
Gen.? sp.?	+	-	+	-		
Fam. Terebellidae						
Pista sp.	+	-	+	-	-	-
Terebellides eurystethus Chamb.	+	+	+	-	East Pacific, Kermadec tr.	-
Fam. Sabellidae						
Jasmineira filatovae Levenstein	+	+	+	+	North Pacific	
J. sp.	-	-	+	+		
Fam. Serpulidae						
Gen.? sp.?	+	-	-	+	-	-

pedata and K. fuscus, which also belong to the group of mainly abyssal species.

A substantial role in the polychaete fauna of the Aleutian and Japan trenches is being played by ultra-abyssal species. There are five of them; two of these— Macellicephala kirkegaardi and Macellicephaloides berkeleyi — are thus far known only from the Aleutian trench; three — Vitiazia dogieli, Macellicephala zenkevitchi, and Macellicephaloides verrucosa — have been found in the Japan and Kurile-Kamchatka trenches. No ultra-abyssal species at all were found in the Idzu-Bonin trench, possibly because of the small number of stations carried out there.

In geographical terms, the polychaetes inhabiting the trenches fall into the following groups: (a) Pacific, (b) Pacific-Atlantic, (c) Indian-Pacific, (d) Panoceanic.

	Pacific	Pacific-Atlantic	Indian-Pacific	Panoceanic
Aleutian trench	5	0	1?	3
Japan trench	8	1	0	5
Idzu-Bonin trench	1	0	1?	1

Most numerous in the trenches are species found only in the Pacific Ocean and panoceanic ones. The former group embraces 10 species, i.e., more than half of all species of polychaetes inhabiting the trenches. 133 A more detailed analysis reveals their heterogeneity: four of the species are typical inhabitants of trenches: Vitiazia dogieli, Macellicephala zenkevitchi and Macellicephaloides verrucosa, which are found in the Japan and the Kurile-Kamchatka trenches, and Macellicephaloides berkeleyi, which is found in the Aleutian trench. Three species — Kesun fuscus, Terebellides eurystethus and Jasmineira filatovae — live not only in the trenches but also in the ocean basin. Three species — Eulalia sigeformis, Amphicteis mederi and A. gunneri var. japonica — are Asiatic, North Pacific species that live in the Far Eastern seas and adjacent parts of the Pacific. The only Pacific-Atlantic species, Ceratocephale loveni, was found in the Japan trench. This species occurs widely in the North Atlantic, and in the Pacific it was known from the bathyal region of the Bering Sea and the Sea of Okhotsk.

In the group of Indian-Pacific species we are tentatively including Macellicephala kirkegaardi and Micronephthys abranchiata. The former was described by Ushakov (1971) from the Aleutian trench; in the view of that investigator, that species also ought to include the specimens of M. abyssicola (Kirkegaard, 1956, non Fauvel, 1915) found by the "Galatea" expedition in the Java and Kermadec trenches and in the Banda Sea (Kirkegaard, 1956). M. abranchiata was described from the Indian Ocean sector of Antarctica from a depth of 385 m (Ehlers, 1913), and subsequently found by us in the Kermadec and Idzu-Bonin trenches.

A group of species occurring widely in the World Ocean consists of Admetella longipedata, Macellicephala mirabilis, Kesun abyssorum, Travisia profundi and Maldanella harai. All of them, except M. harai, are mainly abyssal species occurring in the Pacific, Atlantic, and Indian oceans and at Antarctica. All five species are found in the Japan and Kurile-Kamchatka trenches; M. mirabilis, T. profundi and K. abyssorum are also found in the Aleutian trench, and the last-named, in the Idzu-Bonin trench as well.

Evident is the similarity of the polychaete fauna of the Aleutian, Kurile-Kamchatka and Japan trenches. All of these trenches represent a single geomorphological complex. They are typical trenches of island arcs, having steep slopes and a flat bottom that consists of an accumulative plain. The bottom morphology of all trenches of this type is similar (Udintsev, 1962). The similarity of physical-geographical conditions -- bottom morphology, character and distribution of bottom sediments (Bezrukov, 1955, 1957; Bezrukov, Petelin, 1962; Gershanovich et al., 1964), similar temperature and salinity readings (Moroshkin, 1955; Dobrovol'skii, Leont'yeva, 1960; Plakhotnik, 1964; Shurunov, 1964) -- apparently create in them the same types of ecological conditions, in spite of inherent variety.

The Idzu-Bonin trench, on the other hand, resembles in the character of its sediments the southern trenches -- the Marianas and the Ryukyu trenches (Bezrukov, Petelin, 1962).

Typical of deep-sea trenches is the quantitative abundance of benthonic fauna -- its biomass in many trenches is considerably greater than at the lesser depths of the adjacent ocean basins. This results from the proximity of the trenches to the continental slope and the intensive sedimentation (Bezrukov et al., 1961; Romankevich, 1962), so that the benthos of the trenches, particularly those situated in the productive parts of the ocean, is more abundantly supplied with food than that of the ocean basin.

The abundant development of life in the trenches is also favored by the stable temperature and salinity and an adequate oxygen saturation of the water. The richest fauna is found in the Kurile-Kamchatka, Aleutian and Japan trenches (Belyayev, 1966; Filatova, 1969). The numbers of polychaetes in the trawl catches were fairly high: up to 40 specimens of *Travisia profundi* and *Kesun abyssorum* were caught in the Aleutian and Japan trenches; up to 122 specimens of *Notomastus* sp. were caught in the Japan trench; numerous also were *Maldanella harai* and *Anobothrus* sp. Considerably sparser is the fauna of the Idzu-Bonin trench, which is situated in a zone of low productivity.

The degree of endemism of the polychaete fauna in each of the 134
trenches is low. The Aleutian trench has only one endemic species — *Macellicephaloides berkeleyi*. Three ultra-abyssal species found in the Japan trench — *Vitiazia dogieli*, *Macellicephala zenkevitchi* and *Macellicephaloides verrucosa* — also occur in the Kurile-Kamchatka trench and may be termed endemic to the two trenches. No endemic species were discovered in the Idzu-Bonin trench. Data on some other groups of burying benthonic fauna confirm this judgment. Thus, among abyssal sipunculids inhabiting the Kurile-Kamchatka trench not a single endemic species was found, and all of them have a wide geographic range (Murina, 1971).

The same picture confronts us if we consider the occurrence of new species in the trenches. Of eight new species which can thus far be regarded as ultra-abyssal, as they are known only from trenches, only one species, *Onuphis* sp. nov., has been found only in the Aleutian trench; three species — *Lumbrineris* sp. nov., *Ilyphagus* sp. nov., and *Notomastus* sp. [nov.], — inhabit the Aleutian, Kurile-Kamchatka and Japan trenches; *Ammotrypane* sp., *Pista* sp. and *Melinnexis* sp. have been found in the Aleutian and Japan trenches, and *Anobothrys* sp. has been found in the Kurile-Kamchatka and Japan trenches.

In the Idzu-Bonin trench we found only one species absent in the trenches and the basin of the North Pacific: *Micronephthys abrachiata*,* for which this trench seems to represent the northern habitat boundary. This species was previously known from the Indian Ocean sector of Antarctica (Ehlers, 1913) and the Kermadec trench (Levenshtein, 1962). The similarity of the fauna of the Kurile-Kamchatka and Japan trenches, and a certain difference between their fauna and that of the Idzu-Bonin trench, is also confirmed by data on bivalves (Filatova, 1971).

It is of interest that no species have been found in the Aleutian trench that are at home on the eastern shores of the Pacific, even though the investigations of Cruise 45 turned up polychaetes in the basin and the continental slope of the Gulf of Alaska that are known from the abyssal region off California and Peru (*Onuphis pallida*, *O. lepta*).

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SCALPELLIDAE (CIRRIPEDIA) OF THE GULF OF ALASKA

By G. B. Zevina

The barnacle fauna of the bathyal region of the Gulf of Alaska has been little studied. In Pilsbry's monograph (1907), which gives a good description of American pedunculate barnacles, there is no mention of species from that region. Later on, Henry (1940a) and Cornwall (1930, 1955) studied collections of barnacles from the North Pacific, but from more southerly areas. The small VNIRO collections from the Gulf of Alaska were previously studied by this writer (Zevina, 1970).

During Cruise 45 of the "Vityaz'" in the Aleutian trench and in the Gulf of Alaska, we collected 34 specimens of barnacles belonging to 6 species of the genus Scalpellum (Fig. 1). One of these species turned out to be new.

Scalpellum regium W. Thomson, 1873

Synonyms see Zevina 1970:263.

Material: Station 6088, 53°58'5 north lat., 157°37' west long., depth 5,740 m, 2 spec.; station 6094, 57°44' lat., 148°37' long., depth 2,400 m, 2 spec.

Dimensions of the largest individual from station 6094: length of capitulum, 55; length of peduncle, 40 mm; width of capitulum, 33 mm; width of peduncle, 22 mm. This is one of the largest known specimens.

Occurrence. The species lives in the Atlantic Ocean between 35° and 43° north lat., 10° and 63° west long.; it is found in the Indian Ocean, in the waters of the Indo-Malay Archipelago, in the Pacific from the coasts of Australia and New Zealand to the Kuriles. It had not hitherto been found on the east coast of the Pacific.

Vertical distribution range: 1,507-6,135 m.

Scalpellum levinsoni Zevina 1970

Zevina, 1970:265, Fig. 12, 12.

Material: Station 6111, 56°17' north lat., 137°51' west* long., depth 2,880 m, 5 spec.; station 6117, 56°12' north lat., 139°12' west long., depth 3,350-3,370 m, 2 spec.

Occurrence. The species had previously been found in the Pacific along the east coast of Kamchatka and in the southwestern Bering Sea at depths of 3,660-4,070 m. The find in the northeastern Pacific expands this territory. Depths of habitat — 2,880-4,070 m.

Scalpellum vegae Nilsson-Cantell, 1926

Synonyms see Zevina, 1970:253

Material: Station 6,090 m, 57°58' north lat., 149°10' west long., depth 455 m, 1 spec.; station 6089, 57°01' north lat., 149°01' west long., depth 170 m, 8 spec.; station 6130, 53°47' north lat., 169°51' west long., depth 210-176 m, 7 spec.

Occurrence. Sea of Okhotsk and Bering Sea, at the Kommandorskiye and Kurile islands, Gulf of Alaska, coast of Canada, depth 127-515 m. 137

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* Longitudes are repeatedly given as "east," obviously in error. — TRANSL.

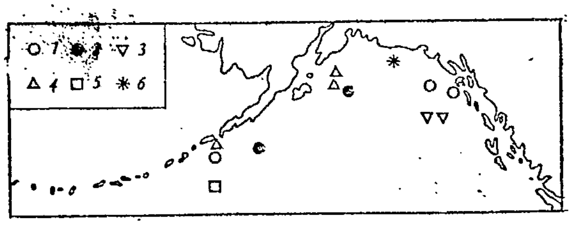

Fig. 1. Finds of Scalpellidae in the Gulf of Alaska. 1 -- S. alascensis; 2 -- S. regium; 3 -- S. levinsoni; 4 -- S. vegae; 5 -- S. vitreum; 6 -- S. columbianum.

Scalpellum vitreum Hoek, 1883

Synonyms see Newman, Ross 1971:87

Material: Station 6143, 51°31' north, 163°10' west, depth 4,820 m, 1 spec.

Occurrence. Throughout the world. The species has been found in the Sea of Okhotsk, along the coasts of Japan, the Kuriles, Kamchatka, the Indo-Malayan Archipelago, in the western part of the Indian Ocean, the northwestern Atlantic (33°58' north, 75°24 west) and along the south coast of Greenland (58°15' north, 48°36' west) and in the Antarctic (63°54' south, 83°03' west). Depth of the habitat is 74-6,096 m. The "Vityaz'" collection marks the first find in the northeastern Pacific.

Scalpellum columbianum Pilsbry, 1909

Pilsbry, 1909: 367, Figs. 1-2; Cornwall, 1930: 215, Fig. 1; 1955: 20, Fig. 15; Henry, 1940: 36, Fig. 5.

Material: Station 6100, 59°14' north, 141°49'7 west, depth 573-534 m, 1 spec.

Occurrence. The species has been found along the coast of British Columbia at depths of 60-90 m. Our find was made much farther north and at greater depth.

Remarks. The species resembles S. lydiae Tarasov et Zevina, which lives in the Sea of Okhotsk at depths of 168-441 m. S. columbianum differs in having a narrower central-lateral plate and a narrower and better-proportioned capitulum. Apparently, these are two vicarious species.

Scalpellum alascensis n. sp.

Material: Station 6132, 53°46' north, 163°41' west, depth 1,100-900 m, 2 spec.; station 6122, 56°45'5 north, 136°02' west, depth 1,100-1,180 m, 2 spec. (incl. holotype); station 6127, 55°20'8 north, 134°50' west, depth 1,310-1,370 m, 1 spec.

Description. Scalpellum with flat, broad capitulum narrowing toward the top, top slightly curved. Plates white, fully calcified, covered with a very thin, slighly yellowish cuticle without hairs.

The tergum is large, triangular, with slightly curved top, the surface of the plate has noticeable longitudinal and less noticeable transverse striae.

The scutum is large, slightly convex in the middle and depressed parallel to the tergal margin; the top is beak-shaped and extends to the margin of the tergum, the carinal side is depressed in the upper part, in- 138
serted into which is the top of the upper lateral plate; the carina-basal angle is rounded.

The carina is evenly curved, its lateral side narrows in a downward direction, the operculum is flat, bordered with convex crests.

The upper lateral plate is narrow, pentagonal, with a pointed top from which extend two distinct crests and several much less distinct small crests.

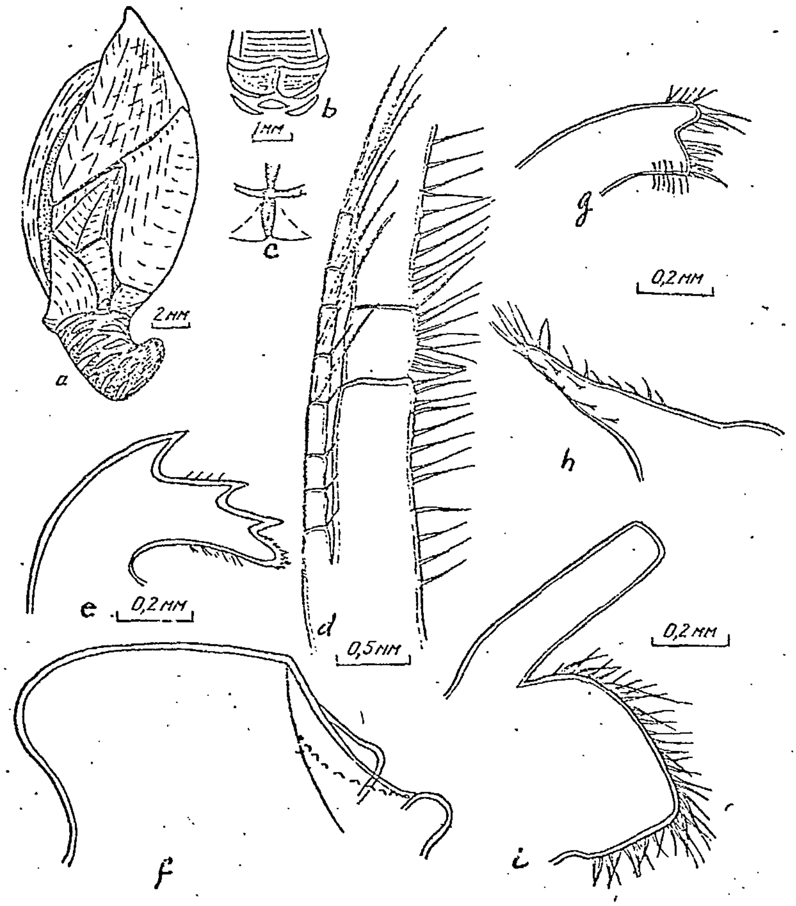

Fig. 2. Scalpellum alascensis sp. nov. a -- general view, from side; b -- carino-lateral plates from dorsal side; c -- rostrum; d -- tail appendage; e -- mandible; f -- labrum; g -- maxilla I; h -- tentacle; i -- maxilla I.

The rostrolateral plate has a round umbilicus raised somewhat above the basi-carinal angle; the umbilicus projects slightly over the margin of the carina. On the carinal side, both plates are joined by a straight suture, each of them, on this side, looks like a denticle with a umbilicus at the top; the lateral side of the plate is concave.

The central lateral plate has the shape of an irregular hourglass, with a considerably larger upper part; the umbilicus is located in the narrowest part.

The rostral plate is quadrangular, from the umbilicus to the opposite corner there extends a distinct straight crest or ridge.

The rostrum is narrow, indistinct beneath the cuticle, and extends to the middle of the rostro-lateral plates.

The peduncle is small, narrow, and covered with sparse, elong- 139
ated scales.

Dimensions of the holotype: length of capitulum, 16 mm; width, 8 mm; length of peduncle, 4 mm; width, 3 mm. Dimensions of the paratype: length of capitulum 23 mm; width, 11 mm; length of peduncle, 5 mm; width, 3.5 mm.

Parts of the mouth: Labrum with heavily convex anterior part and a row of small, rounded denticles. The palpi are triangular, covered with strong, rather short, finely pinnate setae. The mandible has three pointed teeth and a fairly wide, rounded lower angle, which bears 7-8 denticles. The Maxilla I has a broad and deep notch almost in the centre of the anterior margin. The maxilla II is heart-shaped, covered with finely pinnate setae; the maxillar lobe is long, cylindrical.

Number of cirri segments: first pair, 10-12; second pair, 21-24; third pair, 21-22, fourth pair, 26-26; fifth pair, 27-28; sixth pair, 29-30.

The first pair of cirri has unequal rami; the segments of the inner ramus are broad, the setae finely pinnate. The remaining pairs of cirri are thin, covered with strong, finely pinnate setae. The sixth pair has on the anterior side 3-4 pairs of setae at the posterior upper angle 2-3 setae.

The tail appendages have eight segments, the upper segments are covered with long setae and are covered with small denticles, the lower segments have short, strong setae.

Two males are covered with obliquely set rows of spines.

The species resembles S. proximum Pilsbry which lives near California, but it differs in its distinct transverse striae on the plates, the curved central lateral plate, the larger number of segments in the tail appendages.

In addition, the species resembles S. laccadivicum Annandale, occurring from the Indian Ocean to southern Japan, but in that species the central lateral plate is wider in its upper part, while the lower part is considerably narrower; furthermore, the carino-lateral plate has a pointed, greatly protruding lower carinal angle, and the setae on the tail appendages have coarser denticles.

Discussion

Of the six species found, one (S. alascensis) turned out to be new. It is similar to two tropical species, one of which lives in the Indian and the western part of the Pacific Ocean, and the other along the coast of California. S. columbianum, it seems, is found only in the northeastern Pacific, in the northwestern Pacific it is replaced by the very similar S. lydiae. S. levinsoni is found in the northernmost Pacific; it may be that it will also be found in the eastern Bering Sea. The same habitat, but a more extensive one, belongs to S. vegae, which penetrates much farther south than S. levinsoni, and makes its home in shallows. Two species (S. vitreum and S. regium) are world-wide or nearly world-wide and have a very large vertical range. They live mostly in the ocean basin, but are also found on the slope and even in the lower sublittoral region.

Only two of the six species are found in the Kurile-Kamchatka region. Both live at relatively shallow depths (*S. columbianum* at 60-573 m, *S. alascensis* at 900-1,370 m), and are sparse (1-2 specimens per station). Another shallow-water species, *S. vegae*, is more numerous, up to 8 specimens per station. It seems to be better adapted to cold water than *S. columbianum*, for which the Gulf of Alaska is most likely the northern habitat boundary.

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TANAIDACEA (CRUSTACEA, MALACOSTRACA) COLLECTED BY THE "VITYAZ'" IN THE ALEUTIAN TRENCH AND THE GULF OF ALASKA

By R. K. Kudinova-Pasternak

During Cruise 45 of the "Vityaz'" we collected a considerable quantity of Tanaidacea, in particular from bathyal depths, a zone that had been insufficiently studied in respect of benthonic fauna, including the Tanaidacea.

This paper gives the results of an analysis of the tanaids collected at 27 stations (see table).

The analysis revealed 33 species from 12 genera belonging to three families; we are describing one new genus and nine new species.

In our figures we are using the following designations: A_I-A_{II} -- first and second antenna; Md -- mandibles: Md(r) right, Md(l) left; Mx_I-Mx_{II} -- first and second maxilla; Mxp -- maxilliped; Epi Mxp -- epignath of maxilliped; Lbr -- labrum; Lb -- labium; P_I-P_{VII} -- first to seventh peraeopods; Pl_I-Pl_V -- first to fifth pleopods; Pt -- pleotelson; U -- uropod; Car -- carapax.

Systematic Part

SUBORDER MONOKONOPHORA

FAMILY APSEUDIDAE

K. Lang (1949) united the genera Apseudes Leach 1814 and Leiopus Beddard 1886 into a single genus Apseudes, but later on he (1968) again proposed to regard them as separate genera. An analysis of the diagnoses shows that the differences between Apseudes and Leiopus consist only in the fact that the former has sexual dimorphism, and the latter has none. In our view, the differences cited are insufficient for separating the genera, the more so as in practice it is usually impossible to use such characters, as tanaid males are caught much less frequently than females, and if a catch contains only females it will be quite impossible to determine to which of the two genera the specimens belong.

It is even more difficult to concur with the creation of the new family Leiopidae (Lang 1970), which differs from the Apseudidae in the presence on the caudal-distal margin of the maxillipeds of a seta of peculiar shape -- with a leaf-like expansion at the end and covered with small spines. In addition, Lang notes that among members of the Apseudidae sexual dimorphism never appears in the structure of the mandibles, whereas in the Leiopidae there are genera having sexual dimorphism in the mandibles and other genera without such dimorphism (i.e., not differing in this character from the Apseudidae).

List of stations of "Vityaz'" at which Tanaidacea were collected

(Д = "Okean-50" bottom grab; T = Sigsby trawl)

Station No.	Coordinates		Depth, m	Equipment used for catching	
	N. Lat.	W. Long.			
6089	58°02′	149°02′	180	Д	
6092	57°53′	149°00′	1090	Д	
6093	57°51′	148°57′	1540—1340	Т	
6095	57°38′	148°35′	3200	Д	
	57°37′	148°36′	3240—3300	Т	
6099	59°18′	141°59′	290	Д	
6100	59°14′	142°00′	563	Д	
6104	59°03′	141°58′	2088	Т	
6105	58°55′	142°03′	2970	Д	
			2980—2970	Т	
6106	58°16′	142°34′	3620	Д, проба № 1	sample No. 1
			3610	Д, проба № 2	sample No. 2
			3620	Т, проба № 1	
			3610	Т, проба № 2	
6107	57°38′	143°12′	3800	Т, проба № 1	
	57°37′	143°06′	3800	Д	
6109	56°14′	139°44′	3450	Д	
	56°13′	139°43′	3460	Т	
6117	56°12′	139°12′	3350—3370	Т	
	56°10′	139°13′	3350	Д	
6118	56°28′	136°54′	2340	Т	
6120	56°40′	136°24′	1953	Т	
6122	56°42′	136°02′	770	Д, проба № 1	
6124	55°38′	134°18′	180	Д, проба № 1	
6127	55°21′	134°50′	1110	Д, проба № 2	
6132	55°48′	163°29′	1040	Д, проба № 1	
	53°43′	163°39′	1550	Д, проба № 2	
6132	53°49′	163°30′	1360—1319	Т, проба № 1	
	53°46′	163°39′	880—800	Т, проба № 2	
	53°46′	163°41′	1100—900—830	Т, проба № 3	
6134	53°43′	163°33′	1950	Д	
	53°43′	163°36′	1740—1690	Т	
6135	53°30′	163°22′	3080	Д	
6136	53°25′	163°28′	4260	Д	
6138	53°11′	163°12′	5595—5660	Т	
	53°15′	163°57′	5050	Д	
6139	53°08′	163°07′	6520	Д	
6141	52°55′	162°52′	5960	Д	
6142	52°16′	163°34′	5000	Д	
6143	51°40′	163°00′	4860	Д	

Genus *Apseudes* Leach, 1814

1. *Apseudes vitjazi* Kudinova-Pasternak, 1970

Kudinova-Pasternak, 1970: 342-343, Fig. 1, 2.

Material: Station 6138, bottom grab, 1 female, length 8.4 mm.

Distribution: The species has previously been found in the Kurile-Kamchatka trench at a depth of 5,096 m.

2. *Apseudes zenkevitchi* Kudinova-Pasternak, 1966

Kudinova-Pasternak, 1966: 518-521, Fig. 1-2.

Material: Station 6134, bottom grab, 2 spec. at the manca stage, length 5.8 and 6.3 mm; station 6135, fragment of specimen at manca stage.

Distribution. The species has previously been found in the northwestern Pacific (40°20' north, 175°45 east) at 6,065 m.

3. *Apseudes bicornis* sp. nov.

(Fig. 1, 2, 3)

Material: Station 6106, trawl No. 2; 4 females with a length of 12.8 mm (with marsupium); 12.3; 12.2; 12.2 (with rudimentary oostegites) and 2 males with a length of 12.9 and 11.8 mm; trawl No. 1: 1 female with a length of 13.2 mm, 3 males with a length of 10.3, 10.9 and 12.2 mm and 3 stages of female with a length of 5.6, 7.4 and 8.7 mm; bottom grab, sample No. 2: 1 male, length 11 mm, and a defective specimen at the female stage, 9 mm; station 6117, bottom grab: 7 females, length 9.8, 11.1, 12.7, 13.0, 14.3, 14.7 and 15.1 mm (holotype) (except for the first, all with oostegites); 7 fragments of females, 2 males with a length of 10.6 and 13.7 mm (paratype), 7 spec. at the manca stage with a length of 7.0-8.2 mm; trawl 3: females with a length of 10.1, 14.3 and 14.5 mm (the latter two with marsupium), 1 fragment of female, 6 males with length of 11.9, 12.2, 12.8, 12.8, 13.3 and 14.2 mm.

Description. The female has a length of 15.1 mm. The body is extended, its length exceeds by a factor of 11.4 its greatest width. The carapax resembles that of A. vitjazi, but its length is considerably greater than its width, while the frontal margin is straight with small protuberances. In the anterior, narrower part of the carapax there are two massive protuberances on the sides that resemble horns (hence the name of the species). The 2nd thoracic segment (the first free segment) is the shortest, with very wide lateral growths directed sideways and somewhat upward. The length of the 2nd to 7nth thoracic segments exceeds their width. The lateral spines of the anterior part of the 3rd to seventh thoracic segments are directed horizontally towards the sides. In the posterior part of the thoracic segments there are distinct protrusions for the attachment of the peraeopods. The length of the 3rd thoracic segment is much less than that of the seventh, the fourth segment equals the length of the seventh, the fifth and sixth are the longest; the sixth is slightly longer than the fifth. The thoracic segments are rather thick, and the sternal side of the segments is convex, rounded.

The pleonites decrease in length from the first to the fifth, their length is equal to that of the seventh, sixth and half the fifth thoracic segments taken together. The pleotelson is cylindrical, its shape resembles that of A. vitjazi, but it has a more rounded distal margin.

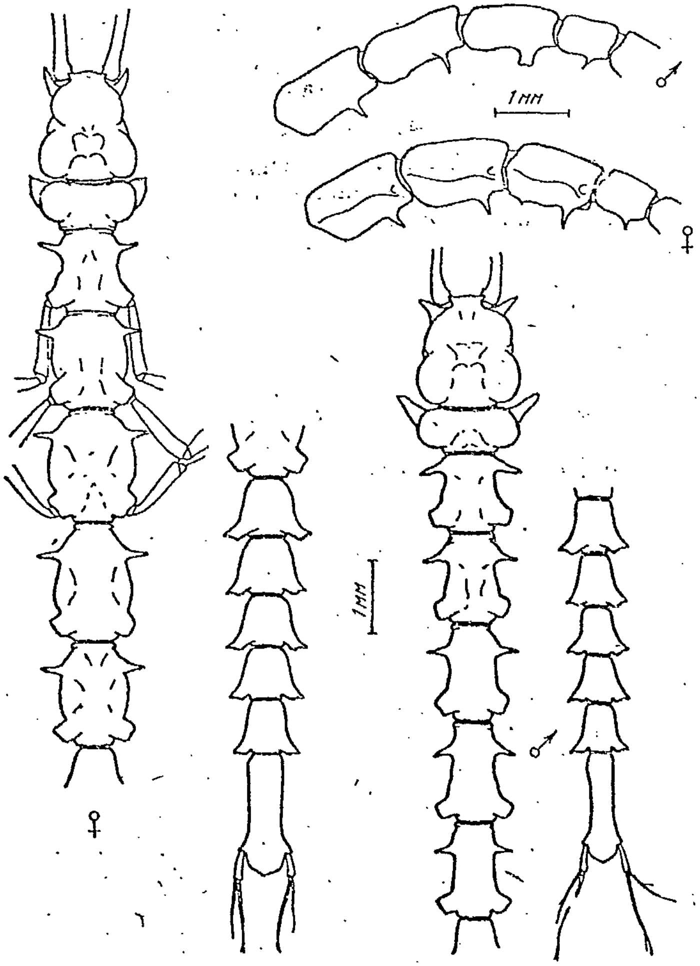

Fig. 1. Apseudes bicornis sp. nov. Female with a length of 15.1 mm (holotype) and male with a length of 13.7, dorsal and lateral views.

The first antenna has a long stem; the length of its three joints exceeds that of the external 8-jointed branch of the flagellum, the interior branch has three joints, terminating with a long, thin seta. On the first and second joints of the stem there are sensory setae. The second antenna has flagella with 9 joints, the squama is shorter 144 than the first two joints of the flagellum, with three setae on the distal end, of which one is very long and ciliate. There are three sensory setae on the third joint of the flagellum and two very long ones on the fifth joint.

The labrum has three protuberances on the frontal part -- the middle one is very small and the lateral ones are larger. There are fine cilia along the frontal margin and long ones along the sides.

The pars incisiva of both mandibles has six teeth. The pars mobilis of the left mandible has six teeth, the spine bundle contains divided and simple setae.

The lobes of the labium have thin, hair-like setae, particularly long at the distal margin, and terminate in one long and thin seta.

First maxilla: interior endite with five setae, of which three are ciliate and two are simple and longer; exterior endite with 10 setae on the distal margin and two setae below it. Palpi with eight setae, which are ciliate only on the distal part. Second maxilla: immobile endite with setae of various structure (Fig. 2).

Maxilliped: second joint of the base with hairs. First 145 joint of the palpi with two spinous setae. Armature of the endite shown in Fig. 3. Epignath with two rounded lobes, one of which is densely ciliate. Fine, hair-like setae also grow on the external margins of the epignath and on its terminal spine, where they are particularly long.

The first peraeopod (claw-bearing limb). Basipodite lacks a denticulate protuberance, but has four small, spine-like spicules. The exopodite has four ciliate setae. The carpopodite has five setae, the

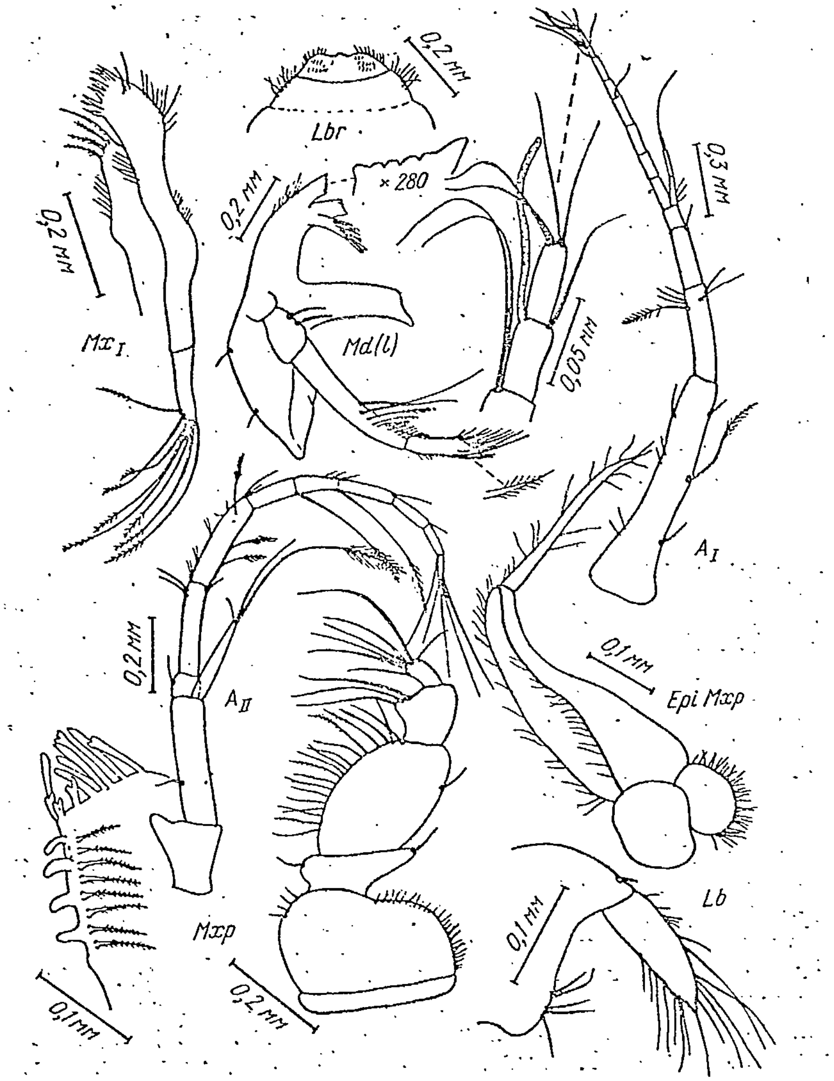

Fig. 2. Apseudes bicornis sp. nov. Holotype, structural details.

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propus is broad, with small setae. The finger of the claw has a large tooth situated nearer the base; the armature of the rest of it is shown in Fig. 3. The dactylus has three setae situated nearer its distal part, and a row of spinous spicules on the inner surface.

The second peraeopod is adapted for digging, with a widened carpopodite and propodite. The carpopodite is shorter than the meropodite.

The peraeopods of the third and fourth pairs are similar. The armature of the peraeopods of the sixth and seventh pairs is shown in Fig. 3. The peraeopod of the fifth pair differs from that of the sixth pair in that its carpopodite has nine rather than seven spicules on its distal end.

The pleopods have small coxopodites and long basipodites with 146 one ciliate seta. The two-jointed exopodite and the single-jointed endopodite have very long ciliate setae.

The uropods have a protopodite that bears on the inner side a seta; the exopodite has five and the endopodite eight joints.

The male has a length of 13.7 mm. Unlike the female, its body exceeds by only a factor of 9.8 its greatest width. The width of the anterior part of the carapax is greater than in the female. The length of the second thoracic segment is 2.4 times less than its width (in the female, 2 times less). The lateral protuberances of the second thoracic segment are longer and narrower. The protuberances of the third thoracic segment are directed toward the sides and somewhat downward. The fourth to seventh thoracic segments of the male are narrower than in the female. All thoracic segments are flatter on the ventral side than in the female, which can easily be discerned in a lateral view. The propus of the peraeopod of the third pair in the male differs from that of the female in having a crest-like spicule.

Variability. In the 14.3-mm-long female (station 6117) the claws of the first peraeopod differ greatly in size -- the left one is quite small. The claws of two specimens at the manca stage (station 6106) differ in that one of them (length 7.4 mm) has an immobile finger with a tooth, while the other (5.6 mm) has no such tooth. Among adult specimens

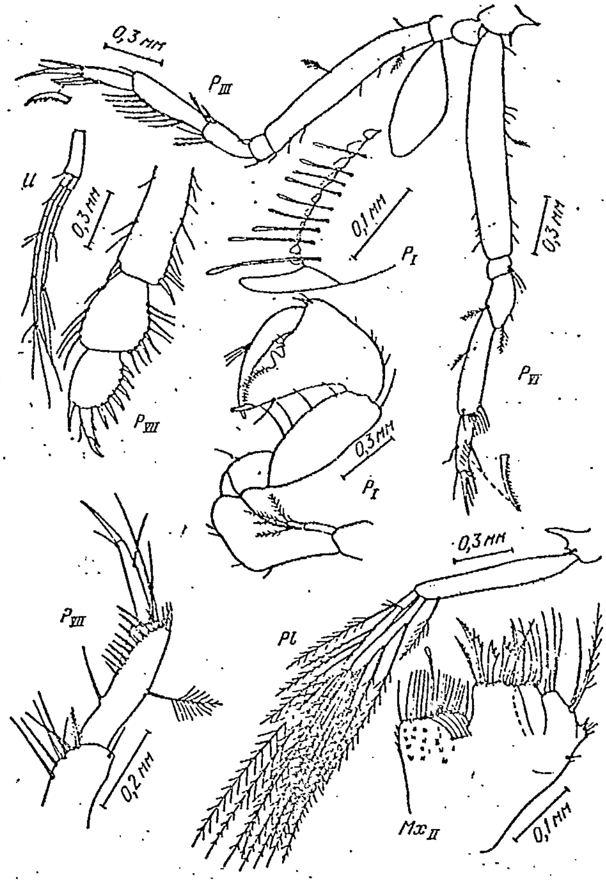

Fig. 3. Apseudes bicornis sp. nov. Holotype, structural details.

the shape and size of the tooth on the immobile finger of the claw also vary.

Remarks. The new species is similar to A. vitjazi Kudinova-Pasternak, 1970, but differs distinctly in the structure of the carapax, the shape of the thoracic segments, the structure of the first peraeopod and other characters.

Genus Carpoapseudes Lang, 1968.

4. Carpoapseudes serratispinosus Lang, 1968

Lang: 1968: 63-72, Figs. 27-33.

Material: Station 6134, trawl: two females (with marsupium, length 12.7 mm and with rudimentary oostegites, length 11.0 mm); station 6132, bottom grab, sample No. 1: 59 females with a length of 10-13.2 mm; 37 males, length 8-13 mm; 84 specimens at manca stage, length 5-9 mm; bottom grab, sample No. 2: 1 female with marsupium, length 11.5 mm; 1 male, length 12.4 mm; trawl, sample No. 1: 2 females with marsupiums, length 11.5 and 11.8 mm; 3 males, length 11.5 and 12 mm, third defective; trawl, sample No. 2: 1 female, length 9 mm; 1 male, length 10.2 mm; trawl, sample No. 3: 144 females, length 9.4-11.3 mm; 161 males, length 10.1-12.5 mm; 3 specimens at manca stage, length 4.8, 5.5 and 5.7 mm, and 3 hermaphrodite individuals, length 8.9, 10.2 and 10.8 mm; station 6105, trawl: 3 females, length 11.3, 12.0 and 12.2 mm (the two latter with rudimentary oostegites); 4 males, length 10.3, 10.7, 11.0 and 11.1 mm; station 6106, trawl: 1 female, length 12.3 mm, with rudimentary oostegites; station 6092, bottom grab: 1 male, length 8.6 mm.

Remarks. 1. In the female from station 6132, length 11.5 mm, there are large orange-colored ova in the marsupium (21).

2. In the diagnosis of Carpoapseudes K. Lang (1968: 62) writes that the spicular protuberances along the front of the respiratory chambers are lacking. Among our specimens, there are some without such protuberances or with small, barely noticeable ones, and others with fully developed protuberances. It appears that the lack of protuberances

along the front of the respiratory chambers cannot serve as a diagnostic criterion of the genus.

3. The number of joints in the flagella of the first and second antennae varies: on the first antenna there are 15 to 19, and on the second antenna, 10 to 12.

4. In the specimens available to Lang the uropods were broken off, and it is therefore appropriate to indicate the number of joints in both branches: the exopodite consists of eight, the endopodite of 24 joints. In our collection there is one female in which the uropod branches consist of 9 and 25 joints.

5. Among the numerous specimens from station 6132 there were 3 hermaphrodite individuals, having, on the one hand, claws of the male type and rudimentary oostegites and, on the other, the typically female genital cone on the ventral side of the seventh thoracic segment, directed obliquely forward.

Distribution. The species had previously been found along the west coast of Central America at a depth of 3,570 m and in the Gulf of Panama at a depth of 875 m (Lang, 1968).

SUBORDER DIKONOPHORA 148

FAMILY NEOTANAIDAE

Genus Neotanais Beddard, 1886

5. Neotanais serratispinosus (Norman et Stebbing, 1886)

Synonyms see Kudinova-Pasternak, 1965a: 75

Material: Station 6138, trawl: 1 female, length 13 mm, with rudimentary oostegites, 1 male, length 13.4 mm; station 6107, trawl, sample No. 1: 1 male, length 15.5 mm; station 6139, bottom grab: 1 female, length 10.7 mm.

Remarks. The left endopodite of the uropods of the male from station 6138 has 9, the right endopodite 8 joints.

Distribution. Widely found eurybathic species. Found in the North Atlantic at 677-3,375 m (Norman, Stebbing, 1886; Hansen, 1913), in the Kermadec trench at 7,150 m (Wolff, 1956), in the Bougainville trench at 7,657 m (Kudinova-Pasternak, 1965a), and in the Kurile-Kamchatka trench at 4,895 and 5,240 m (Kudinova-Pasternak, 1970).

6. Neotanais triangulocephalus sp. nov.

(Fig. 4, 5)

Material: Station 6136, bottom grab: 2 females, length 5.0 and 9.5 mm (holotype) and four specimens at manca stage, length 2.9-3.1 mm.

Description. The body is relatively short, its length is only six times the greatest width (at the level of the second thoracic segment). The carapax has the typical triangular shape, greatly broadening in the proximal part, with a very small, obtuse rostrum. The length of the carapax exceeds the length of the second and third thoracic segments together. Along the lateral margins of the anterior part of the carapax there are keels, on its upper surface there are distinct oblique furrows. The second thoracic segment (the first free segment) is wider and shorter than the others, its width is three times greater than its length and equals the width of the proximal part of the carapax. The third and fourth thoracic segments are nearly identical, their width exceeds their length, the fourth segment is somewhat longer than the third and seventh, but shorter than the nearly square fifth and sixth. All thoracic segments are somewhat wider where the peraeopods are attached. The pleonites are of identical shape and length and decrease slightly in width from the first to the fifth. The pleotelson is somewhat narrower than the last pleonite. The first antennae are thin and differ from those of other species of the genus in having a very long first joint (its length is 6.5 times greater than its width). The second antennae are as in N. serratispinosus. The mandibles are broad, strongly convex in such a way that inside there is a large band for the attachment of the muscles. The pars incisiva of the mandibles has one obtuse tooth. The processus molaris is massive, with denticles on the distal end. The lacinia mobilis of the left mandible is broad, with two denticles, one of which is larger than the other, the distal part of the lacinia is curved in such a way that the denticles are situated in different planes. Of two spicules on the left mandible only the interior one has spines on the distal part and setae on the proximal. Of three spicules on the right mandible the upper is simple, massive, the middle one is simple and thinner, the interior spicule bears small spines on its lower margin.

The first peraeopod has a very broad propus and a massive immobile finger on the claw with five denticles inclined toward the claw. The inner surface of both fingers, both claws and the denticles of the immobile finger are brown. There are distinct keels along the lower margin of the immobile finger and along the upper margin of the propus. The second peraeopod resembles that of N. serratispinosus, but 149
differs in the lesser serration of the spicules and in the fact that

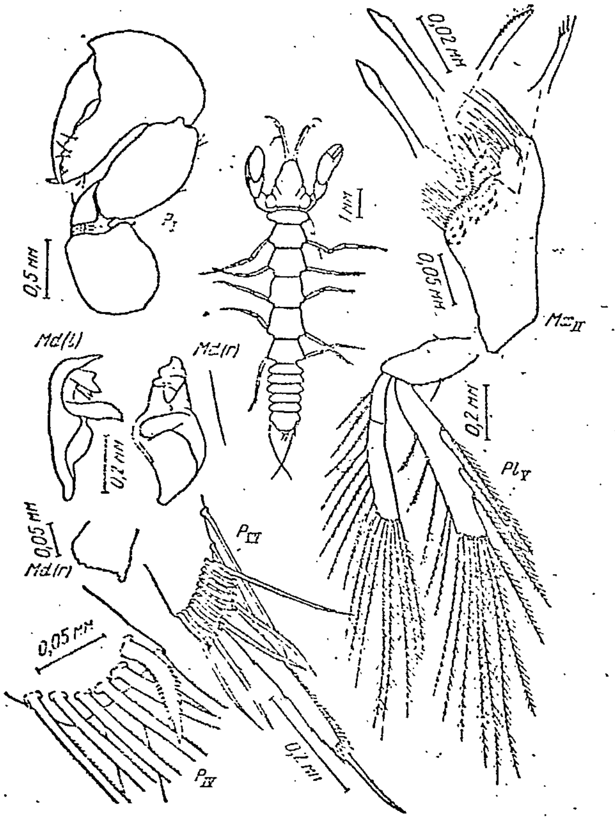

Fig. 4. Neotanais triangularis sp. nov.
Female, length 9.5 mm
(holotype).

the carpopodite bears on the inner side 8 spicules, and at the terminus one simple spicule. The propodite of the second peraeopod has 11 serrate spicules on the inner side and two, also serrate, spicules at the terminal end. The crest-like spicule is more massive than in serratispinosus and has not six but ten to eleven denticles. The spicules of the third and fourth peraeopod are slightly serrate, those of the fifth to seventh pair of peraeopods are merely fringed with setae; the dactyli of the fifth to seventh pair have spines. The propodite of the seventh peraeopod has 12 terminally arranged short spicules.

The pleopods are distinguished by unusually (for Neotanais females) long and narrow branches, their length is 6.5-7 times greater than their width. Both branches have very long, densely ciliate setae, whose length exceeds that of the branches and which form a peculiar "tail" protruding from beneath the pleotelson.

The uropods are long and thin, with two branches, their length equals that of the pleon. The endopodite has 9 joints, the seventh and eighth joint each have one very long seta, the ninth joint has four. The exopodite has two joints, the distal joint is twice as long as the proximal one and wider, it has two very long setae.

Remarks. N. triangulocephalis is characterized by a broad carapax whose shape resembles a triangle, which is reflected in the name of the species, a narrow second thoracic segment, the shape of the other thoracic segments, a very long first joint of the first antenna, the shape of the first peraeopod, the absence of serrate spicules on the 150 last three pairs of peraeopods, long branches and setae on the pleopods.

Distribution. In addition to the collections of Cruise 45, the species has also been found in other collections of the "Vityaz'" -- south of the Gulf of California (station 4267, 21°34' north, 110°32' west, depth 3,282 m) and along New Guinea (station 3980, 3°41 south, 146°21' east, depth 2,127 m).

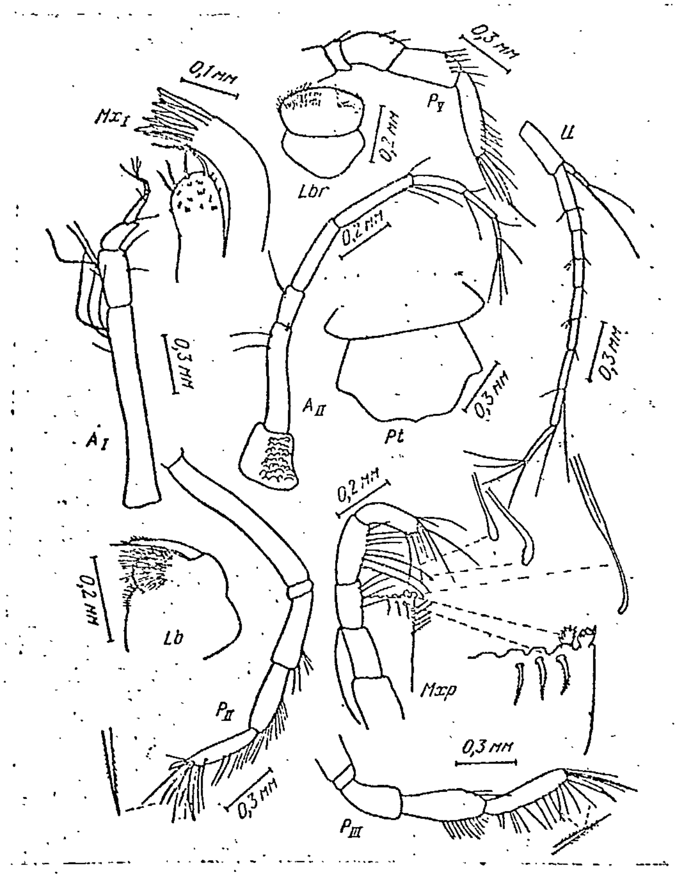

Fig. 5. Neotanais triangulocephalus sp. nov. Holotype, structural details.

7. Neotanais zenkevitchi sp. nov.

(Fig. 6, 7)

Material: Station 6109, trawl: 2 females, length 23.5 mm with rudimentary oostegites (holotype) and 17.5 mm (paratype).

Description. The length of the body is 6.7 times the greatest width. The crusts are heavily calcified. The carapax has a small rostrum and resembles in shape N. longimanus (Wolff, 1956a), but is wider, its length is only 1.2 times its width and is equal to the total length of the second, third and half the fourth thoracic segment. In the anterior part of the carapax there are distinct lateral keels, on whose lower side there are 13 setae per keel. Behind and somewhat below this row there is yet another seta (as in N. deflexirostris Lang, 1968: 136, Fig. 79)

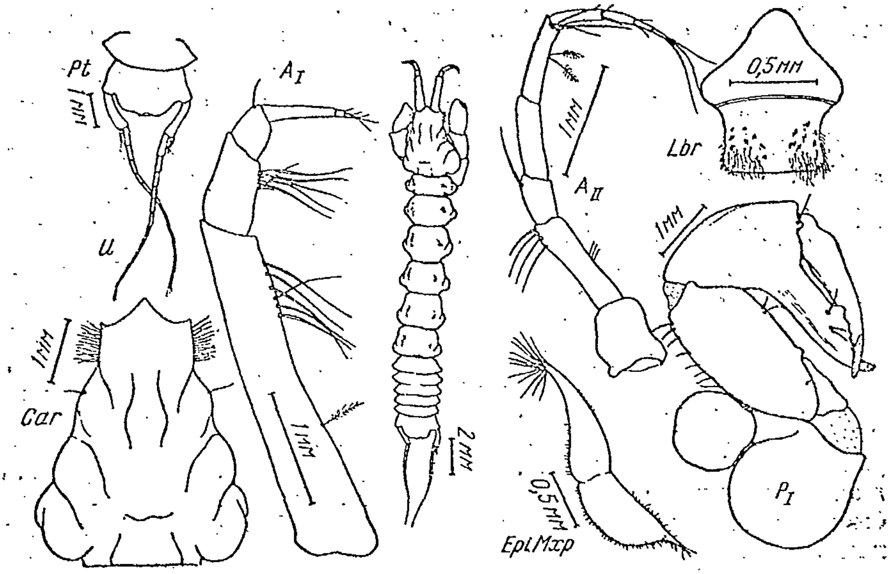

Fig. Рис. 6. *Neotanais zenkevitchi* sp. n.
Самка длиной 23,7 *мм* (голотип) Female, length 23.7 mm (holotype).

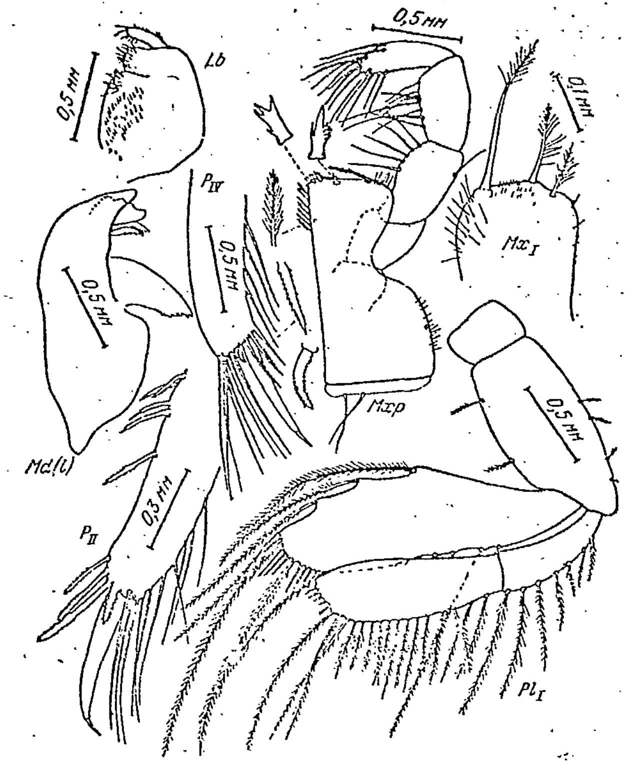

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Fig. Рис. 7. *Neotanais zenkevitchi* sp. n.
Голотип, детали строения Holotype, structural details.

The width of the thoracic segments is greater than their length, which increases from the second to the fourth; the fifth and sixth segments are of the same length and somewhat shorter than the fourth; the seventh segment is longer than the second, but shorter than the sixth. 152
The shape of the thoracic segments is shown in Fig. 6, they are all rounded on the ventral side, while on the dorsal side they have depressions on either side of the centre line. The length of the pleon equals the total length of the seventh, sixth and half the fifth thoracic segments. All pleonites have greatly protruding, acute lateral margins and low ventral tubercles; the first and fifth are slightly longer than the rest. The pleotelson has distinct protuberances for the attachment of the uropods. The width of the pleotelson is 1.8 times greater than its length and equals the width of the two last pleonites.

The first antenna has a long first joint, which is nearly four times that of the second; on its outer side it has seven simple setae and (nearer the base) one ciliate seta (sensory). The second joint is twice as long as the third. The first joint of the flagellum is three times as long as the three remaining joints taken together. The second antenna is nearly of the same length as the first, its first joint is nearly 1.5 times shorter than the second, which is twice as long as the third. The fifth joint is longer than the fourth and has two ciliate setae. The length of the last four joints decreases from the sixth to the ninth. The labrum resembles that of N. deflexirostris, but has long setae. The pars incisiva of both mandibles lacks teeth. The lacinia mobilis of the left mandible has four rounded denticles.

The proximal spicules of the mandibles are ciliate on both sides. The first maxilla (right) has an external endite, the ten spicules of which are brown; the external endite of the first left maxilla has only two spicules (apparently, a deformity). The interior endite has three ciliate setae, the second maxilla is as in deflexirostris. The armature and shape of the labium, maxillipeds and epignath are shown in Figs. 6 and 7.

The first peraeopod resembles that of deflexirostris, with the same caudal keel on the inner sternal surface of the immobile finger, but it differs in a narrower basipodite and also in that the finger has on its inner side only four rounded tubercles, while the dactylus and its claw are not so long. The second to fourth peraeopod are very similar, the ratio between the joints is as in deflexirostris, but the armature differs in the presence of serrate spicules, situated as shown in Fig. 7. On the basipodite of the fourth peraeopod there are sensory setae. The fifth and sixth peraeopod are broken off.

The ratio of the joints of the seventh peraeopod is the same as in deflexirostris; the distal end of the propus has a "collar" of 13 ciliate spicules; the serration of the spicules is smaller than on the peraeopods of the second to fourth pairs. The pleopods have a short coxopodite, whose length is nearly four times less than the length of the basipodite. The endopodite is somewhat longer than the exopodite, with three long ciliate setae on the inner margin and with numerous, also ciliate, setae along the distal and outer margins. The first joint of the exopodite is 1.7 times smaller than the second. The basipodites of the pleopods of the first and second pair each have two ciliate setae, the third and fourth pair each have four; the first joint of the exopodite of the first and second pleopod pair has seven setae on the outer side, the fourth and fifth pair has nine. The second joint of the exopodite of all pleopods has numerous ciliate setae attached to the outer and distal margins. Thus the number of setae on the various pleopods may differ and can hardly be regarded as a reliable taxonomic character.

The uropods are longer than the pleotelson, the exopodite is shorter than the first joint of the endopodite; the second joint of the endopodite has two setae. The endopodite has 12 joints.

Remarks. The species is similar to N. longimanus and N. deflexirostris, but it is easily distinguished from the former in the structure of the rostrum, the first peraeopod and a number of other characters, and from the latter in the not very protruding oral parts, and from either species in the shorter immobile finger of the first peraeopod and the presence of serrate spicules on the remaining peraeopods.

The species is named after my teacher, Academician Lev 153
Alexandrovich Zenkevich.

Distribution. In addition to Cruise 45 of the "Vityaz'," the species has been found by us in the collections of the scientific ship "Akademik Kurchatov" in the eastern Pacific (station 227, 6°00'-5°54' south, 84°53' west, depth 4,100-4,050 m).

8. Neotanais barfoedi Wolff, 1956

Wolff, 1956a: 44-45.

Material: Station 6105, bottom grab: 2 females, length 6.0 and 6.6 mm; trawl: 2 females, length 3.8 and 6.7 mm, 1 male, length 5.4 mm; station 6095, trawl: 1 female, length 6.7 mm, and manca stage, length 2.1 mm.

Remarks. The female from station 6105 with a length of 6.0 mm and the female from station 6095 with a length of 4.7 mm have an eight-jointed endopodite in the uropods, while the female from station 6105 with a length of 6.7 mm has a seven-jointed endopodite. In the remaining specimens the endopodite consists of nine joints, which agrees with the description of Wolff (1956a).

Distribution. The species had previously been found in the Kermadec trench at 2,640 and 2,470 m.

FAMILY PARATANAIDAE

Genus *Typhlotanais* G. O. Sars 1880

9. *Typhlotanais compactus* Kudinova-Pasternak 1966

Kudinova-Pasternak 1966:525-28, Fig. 8.

Material: Station 6136, bottom grab: 1 female, length 1.6 mm; station 6132, bottom grab, sample No. 2: 1 female, length 1.6 mm.

Distribution. The species had previously been found in the northwestern Pacific (40°20' north, 175°45' east) at 6,065 m, and in the Kurile-Kamchatka trench at 4,895-6,135 m (Kudinova-Pasternak 1970).

10. *Typhlotanais mucronatus* Hansen 1913

Hansen, 1913: 42-44, Pl. II, Fig. 3a-3f.

Material: Station 6109, bottom grab: 3 females, each with a length of 3.2 mm.

Distribution. The species had previously been found in the North Atlantic at 1,620-1,836 m (Hansen 1913) and in the Kurile-Kamchatka trench at 4,840-6,675 m (Kudinova-Pasternak, 1970).

11. Typhlotanais magnificus Kudinova-Pasternak 1970

Kudinova-Pasternak 1970:349-351, Fig. 5.

Material: Station 6106, trawl, sample No. 2: 1 female, length 8 mm.

Distribution. The species had previously been found in the Kurile-Kamchatka trench at 4,895 m.

12. Typhlotanais grandis Hansen 1913

Hansen, 1913: 54-55, Pl. V, Fig. 7a-7e.

Material: Station 6107, trawl: Female, length 5.9 mm, another defective. Both females were found in ooze tubes.

Distribution. The species was previously known from the North Atlantic at 1,264 m (Hansen, 1913), from the basin of the northwestern Pacific, at 6,065 m (Kudinova-Pasternak, 1966), and from the Kurile-Kamchatka trench, at 4,895-5,240 m (Kudinova-Pasternak 1970).

13. Typhlotanais rectus Kudinova-Pasternak 1966 154

Kudinova-Pasternak 1966:525, Fig. 6, 7.

Material: Station 6106, trawl No. 2: 2 females, length 9.3 and 10.6 mm.

Distribution. The species had previously been found in the northwestern Pacific (24°02' north, 167°24' east) at 6,051 m and in the

Kurile-Kamchatka trench at 4,895 m (Kudinova-Pasternak 1966, 1970).

Genus Leptognathia G. O. Sars 1880

14. Leptognathia armata Hansen, 1913

Hansen 1913:82-83, Pl. VIII, Fig. 3a-3f.

Material: Station 6139, bottom grab: 1 female, length 2.1 mm; station 6132, sample No. 2: 2 females, length 2.4 and 2.9 mm; station 6106, bottom grab, sample No. 2: 1 female, length 3.3 mm.

Distribution: The species was found in the North Atlantic at 2,625-3,375 m (Hansen, 1913), north of Alaska (Menzies, Mohr 1962), at 530-1,540 m, in the Bougainville trench at 7,974-8,006 m (Kudinova-Pasternak, 1965a) and in the Kurile-Kamchatka trench at 3,385-4,895 m (Kudinova-Pasternak 1970).

15. Leptognathia rectifrons sp. nov.

(Fig. 8, 9)

Material. Station 6122, bottom grab, sample No. 1: 1 female, length 2.8 mm (holotype); station 6100: 5 females, length 2.0, 2.5, 2.6, 3.1 and 3.4 mm.

Description. The body is elongated, its length is 9.3 times the greatest width. The carapax is elongated, its length is 1.3 times the width and equals the combined length of second and half the third thoracic segments. The carapax lacks a rostrum, its anterior margin is cut off straight (hence the name of the species). The second to fifth thoracic segments are as in L. parabrevimanu Lang, 1968; the sixth and seventh thoracic segments are short, the sixth segment is considerably shorter than the fifth and the seventh is shorter than the second.

The length of the pleon equals the combined length of the second and third thoracic segments. As in parabrevimanu, the first and fifth pleonite are of the same length and somewhat longer than the rest, but, unlike the abovenamed species, the second, third and fourth pleonites are somewhat wider than the first and fifth. The shape of the pleotelson resembles the pleotelson of parabrevimanu, but at the end of the pleotelson there is a very small protuberance, while in parabrevimanu the end of the pleotelson is rounded. Also, in parabrevimanu the lateral margins of the pleotelson are straight, while in our species the sides are typically depressed and the proximal part is wider than the distal one. There are no setae.

The first antenna resembles that of L. brevimanu (Lilljeborg), with a short first joint, whose length is slightly less than that of the remaining joints taken together; in parabrevimanu the first joint is 1.3 times longer than the rest. The ratio and shape of the remaining joints are as in parabrevimanu. The armature is shown in Fig. 8.

The second antenna , the labrum and labium are as in parabrevimanu.

The mandibles have processus molaris that narrow down greatly toward the distal ends and are directed obliquely downward; at their end there are four long, fine denticles. Pars incisiva of both mandibles and lacinia mobilis of the left mandible are without denticles.

The first maxilla has a corona of 11 simple spicules, one of which is very small. The palpi have two smooth setae. Maxillipeds: Basis completely fused with the following joints (as in parabrevimanu). Behind 155

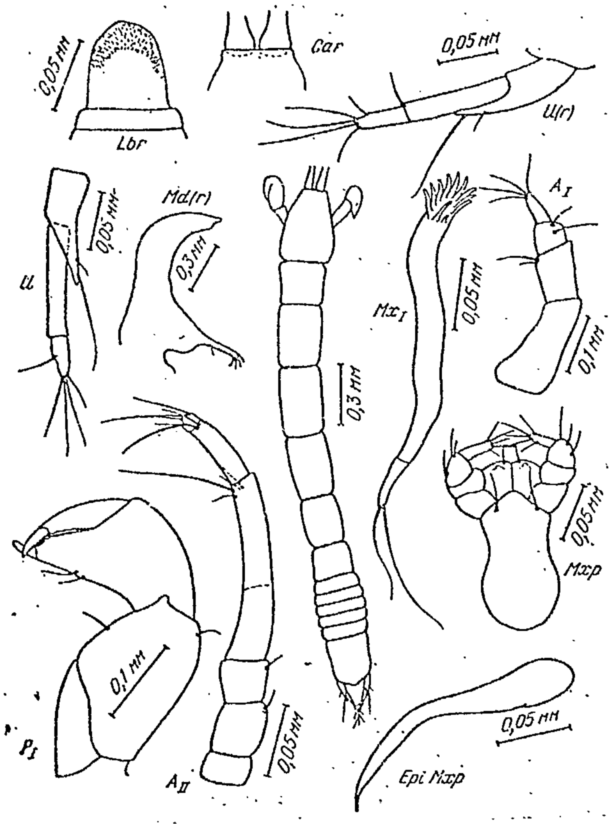

Fig. 8. Leptognathia rectifrons sp. nov.
Female, length 2.8 mm (holotype).

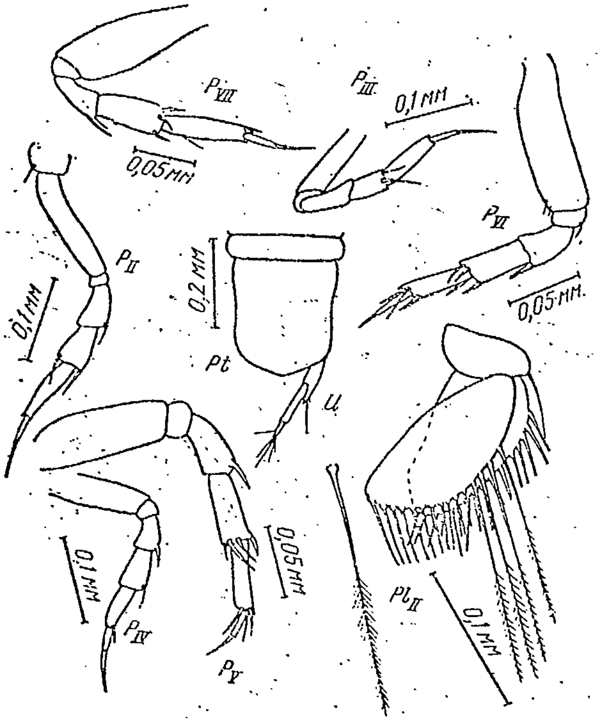

Fig. 9. Leptognathia rectifrons sp. nov.
Holotype, structural details.

each of the palpi there is a single caudal seta. The epignath is as in parabrevimanu, sickle-shaped at the end. The first peraeopod differs from that in parabrevimanu in the armature of the claw fingers and the lack of a row of fine hairs on the propus. The shape and ratios of the joints of the second to fourth pairs of peraeopods resemble those of brevimanu. As in brevimanu, and unlike parabrevimanu, the surface of the merus, carpus and propus is entirely smooth, without rows of small hairs. The fifth to seventh peraeopods differ from both species in having narrower basipodites.

The exopodite of the pleopods is somewhat longer than the endopodite. Both branches bear along the outer and distal margins ciliate setae, which are longer than in parabrevimanu. The basipodite has one smooth seta.

The protopodite of the uropods, as in parabrevimanu, is completely fused with the exopodite and has the appearance of a long, triangular protuberance with a very long subterminal and a short terminal seta.

The exopodite is two-jointed and is distinguished by the lack of ciliate setae and a longer distal joint (the joint ratio is as in brevimanu).

Remarks. The new species resembles L. brevimanu and L. parabrevimanu. It is easily distinguished from either species in the lack of a rostrum and the straight frontal margin of the carapax, the structure of the pleotelson, the length ratios of the thoracic segments and the "uninflated" basipodites of the last three peraeopod pairs.

16. Leptognathia brevimanu (Lilljeborg, 1864)

Lilljeborg, 1864: 22, Fig. 1e.

Material: Station 6127: 1 female, length 3.7 mm; station 6124, 3 females, length 2.4, 2.5 and 3.0 mm; station 6100: 3 females, length 1.6, 3.5 and 3.6 mm, and 3 fragments.

Distribution. The species has been found in the North Atlantic from the coast of Sweden and Norway to the Mediterranean at 24-450 m (Stephensen, 1948; Greve, 1965a, b, 1966).

17. Leptognathia longiremis (Lilljeborg, 1864)

Lilljeborg, 1864: 19, Fig. 1e.

Material: Station 6139: 1 female, length 2.1 mm.

Distribution. West coast of Sweden (Lilljeborg, 1864; Lang, 1957), coast of Norway (Greve, 1965a, 1966, 1968), at 120-475 m. In addition, it has been found in the Kermadec trench at 8,928-9,174 m (Kudinova-Pasternak, 1972).

18. Leptognathia gracilis (Kröyer, 1842)

Kröyer, 1842: 182. Detailed synonyms in Lang 1957.

Material: Station 6136: 1 female, length 5.8 mm; station 6132, bottom grab, sample No. 2: 3 females, length 3.1, 3.8 and 4.6 mm; station 6135: 1 female, length 3.2 mm; station 6093: fragment; station 6120, bottom grab: 2 females, length 3.0 and 3.9 mm; station 6124: 1 female, length 2.6 mm; station 6095, bottom grab: fragment of female.

Distribution. Eurybathic species occurring widely in the North Atlantic at 9-906 m (Hansen, 1913, Greve 1965a, b, 1966), it has also been found on the north coast of Alaska (near Cape Barrow) at 531-1,486 m (Lang, 1957), in the Kara Sea at 91 m, at Spitsbergen and in the Kurile-Kamchatka trench at 4,915-6,675 m (Kudinova-Pasternak 1970).

19. *Leptognathia dentifera* G. O. Sars 1896

Sars 1896:30, Pl. XIV, Fig. 2.

Material: Station 6142: 2 females, length 1.5 and 2.3 mm.

Distribution. The species is known from the coast of Norway from Tromsö to the Skagerrak (Sars 1896, Greve 1964, 1965a, b, 1966) and from the Kurile-Kamchatka trench at 4,895-6,225 m (Kudinova-Pasternak 1970).

20. *Leptognathia forcifera* Lang 1968

Lang 1968:170-174, Fig. 105-107.

Material: Station 6132, bottom grab, sample No. 2: 1 female, length 2.0 mm; station 6134, bottom grab: 1 female, length 1.8 mm; station 6089: 2 females, length 3.0 and 3.4 mm.

Distribution. The species had previously been found along the west coast of Central America at 3,570 m.

21. *Leptoghathia zenkevitchi* Kudinova-Pasternak 1970

Kudinova-Pasternak 1970:360-61, Fig. 13.

Material: Station 6132, bottom grab, sample No. 2: 1 female, length 2 mm; station 6135: 1 female, length 2.6 mm.

Distribution. The species had previously been described from the Kurile-Kamchatka trench at 4,945 m (Kudinova-Pasternak 1970).

22. Leptognathia zezinae sp. nov.

(Fig. 10)

Material: Station 6107, bottom grab: 1 female, length 2.4 mm (holotype).

Description. Body elongated, its length is 7 times its greatest width. Carapax of rounded-ovate shape, without rostrum, length 1.3 times the width and equal to the total length of the first two thoracic segments. The second thoracic segment widens in the distal part, its length is less than that of the third segment. The third to seventh segments have rounded lateral margins. The third segment is somewhat longer that the fourth, the fourth, fifth and sixth have approximately the same length, the seventh is the shortest. The pleon is relatively long, its length being equal to the total length of the three last thoracic segments. All five pleonites are identical, the length of each of them equals half the length of the seventh thoracic segment. The pleotelson is narrow in its proximal part and widens distally, terminating in a small triangular protuberance. The length of the pleotelson is nearly twice that of a pleonite.

First antenna: The first joint is twice as long as the second, the third is shorter than the second, the fourth equals the second. The second antenna has short first and second joints; the third and fifth have the same length, the fourth equals the total length of the fifth and sixth. The pars incisiva of the right mandible has two denticles separated by a depression; the left mandible has, in addition to these denticles, a third one, which is very long. The lacinia mobilis has no denticles. The processus molaris is curved, its distal end points downward and has five long denticles. The first maxilla has only eight spicules (K. Lang 158 holds that among members of Leptognathia there are always 11 spicules). The palpi have two terminal setae.

The basis of the maxilliped is fused with the corresponding joint of the other side. The armature of the maxillipeds is shown in Fig. 10.

First peraeopod: The immobile finger of the claw has one obtuse tooth having the shape of a tubercle and situated right behind the talon. The structure of the second to fourth peraeopod pairs is similar, as is that of the fifth to seventh pairs.

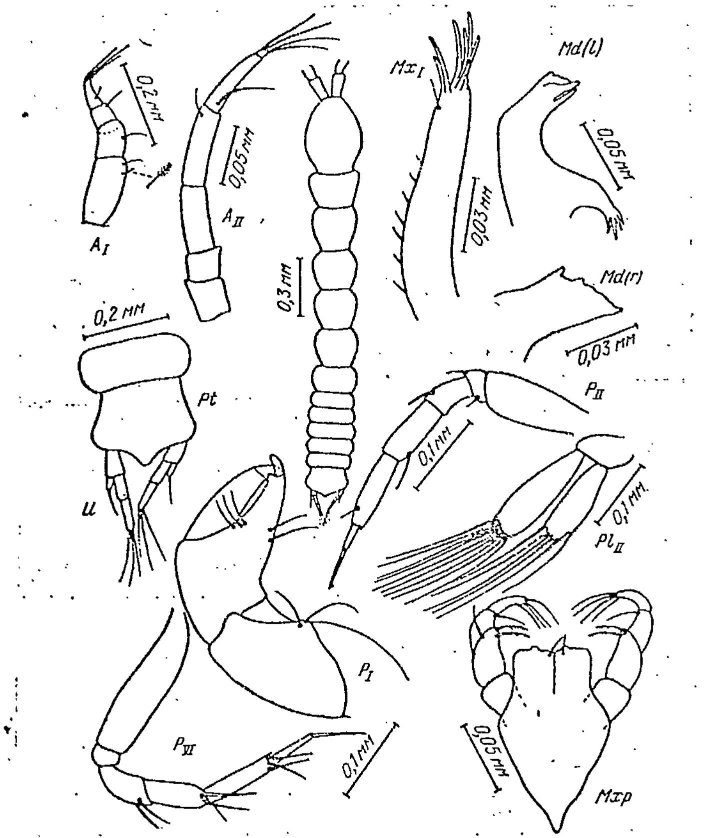

Fig. 10. Leptognathia zezinae
sp. nov.
Female, length 2.4 mm,
holotype.

The exopodite of the pleopods exceeds the length of the endopodite. Both branches of the pleopods are equipped with long, simple setae.

The uropods are biramous, the endopodite is two-jointed with three setae, the exopodite is single-jointed and terminates with a seta.

Remarks. The species differs from other species of the genus in the shape of the pleotelson and the structure of the mandibles.

The species is named after my friend the brachiopod specialist O. N. Zezina.

Genus Filitanais gen. nov.

Diagnosis. Very long body (in the only species described here the length of the body is 14 times that of its greatest width), ventrally flat. The pleon is relatively long (longer than among the Leptognathia, but shorter than in the Strongylura), and consists of five identical pleonites of an unusual, nearly round shape. In the species described
here the pleotelson resembles the shape of the pleonites, but has a 159
small terminal protuberance.

The first and second pairs of antennae and maxillipeds are as in Leptognathia. The mandibles are not known. The first maxilla has a corona of seven spicules. The pleopods are biramous, both branches have short setae, the exopodite is two-jointed. The uropods are biramous.

Type species: Filitanais moskalevi sp. nov.

Remarks. Filitanais gen. nov. resembles in many respects Leptognathia, but differs in the structure of the pleonites, the first maxilla with seven (rather than 11) spicules, the two-jointed exopodite of the

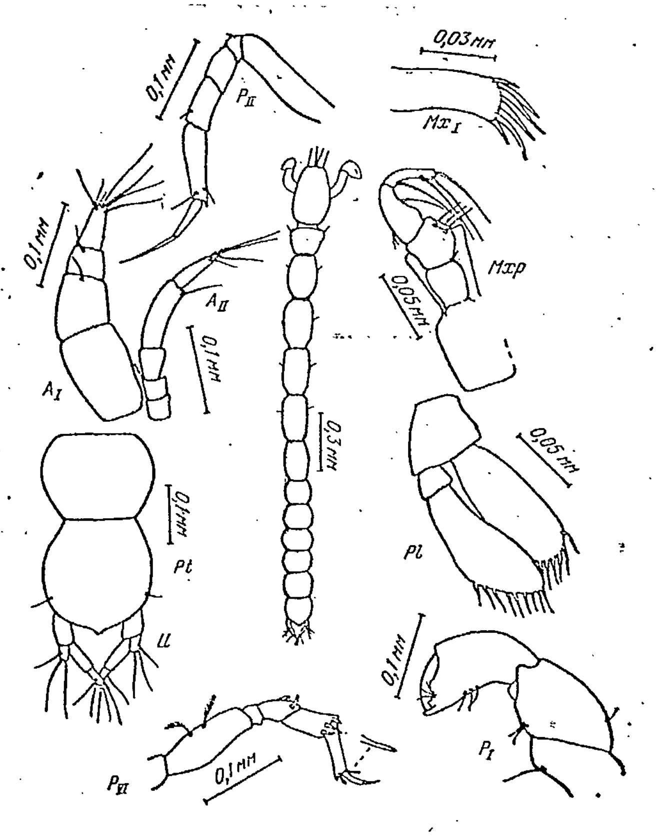

Fig. 11. Filitanais moskalevi gen. et sp. nov. Female, length 2.8 mm (holotype).

pleopods. In some features the new genus resembles Strongylura, e.g., the structure of the peraeopods, particulary the first, and the relatively long pleon; it differs from Strongylura in its flattened venter, the structure of the pleotelson, pleopods and uropods, and the shorter pleon.

23. Filitanais moskalevi gen. et sp. nov.

(Fig. 11)

Material: Station 6109, bottom grab: female, length 2.8 mm (holotype).

Description. The body is very long, string-like, its length is 14 times its greatest width. The carapax is ovate with a tiny rostrum, its length is 1.7 times its width. The second thoracic segment is the shortest, its length equals that of the pleotelson, the anterior part of the segment is much wider than the posterior. All other segments are long. The lateral sides of the second to fourth segments have a single seta on either side. The five pleonites are of unusual, almost round shape. The shape of the pleotelson resembles that of the pleonite, but it has a small terminal protuberance; on the lateral sides of the pleotelson, nearer the distal end, there are two setae.

The first antenna has four joints, the first having the same length as the second and third combined; the fourth equals half the length of the first. The second antenna has six joints, with the first three short, the fourth and fifth long, and the sixth very short. Mandibles were not observed (they were apparently lost). The first maxilla has a corona of seven spicules. The maxillipeds are of the same type as in Leptognathia, the armature of the four-jointed palpi is shown in Fig. 11.

The first peraeopod resembles that of Strongylura cylindrata, but the structure of the interior side of the immobile finger of the claw differs in the presence of two protuberances. The second peraeopod is characterized by a very long dactylus and its claw. The peraeopods of the third and fourth pair are like the second pair, but have shorter dactyli and their claws. The fifth to seventh peraeopod pairs are similar in structure; their mero-, carpo- and propodites have thick spicules with blunt, rounded ends, and the basipodites have two ciliate setae.

The pleopods are biramous; the two-jointed exopodite is somewhat longer than the single-jointed endopodite; both branches bear a few short, simple setae. The uropods are biramous, they are shorter than the pleotelson; the exopodite is single-jointed, equipped with three setae, the endopodite is two-jointed, its proximal joint is longer than the distal one, which bears four setae.

The species is named after my friend, the limpet specialist L. I. Moskalev.

Genus Strongylura G. O. Sars 1882

24. Strongylura cylindrata G. O. Sars 1882

Sars, 1882:53; 1896:36, Pl. XVI, Fig. 1; Hansen 1913:116-118, Pl. XII, Fig. 1a-1h.

Material: Station 6143, bottom grab: 1 female, length 3 mm; station 6117, bottom grab: 1 male, length 3.4 mm; station 6111, bottom grab: fragment of male.

Distribution. The species is known from the North Atlantic from 90-3,104 m (Sars 1882, 1896; Greve 1965) and from the Kurile-Kamchatka trench at 4,895-6,710 m (Kudinova-Pasternak 1970).

25. Strongylura larviformis sp. nov.

(Fig. 12)

Material: Station 6142, bottom grab: female, length 2.4 mm (holotype).

Description. The body is elongated, no shorter than S. cylindrata, its length is 8 times its greatest width (in cylindrata 9 times). The width of the pleonites increases from the first to the fifth. The pleotelson is broader than the last pleonite, heavily inflated, so that it resembles the larvae of insects with inflated venter (reflected in the

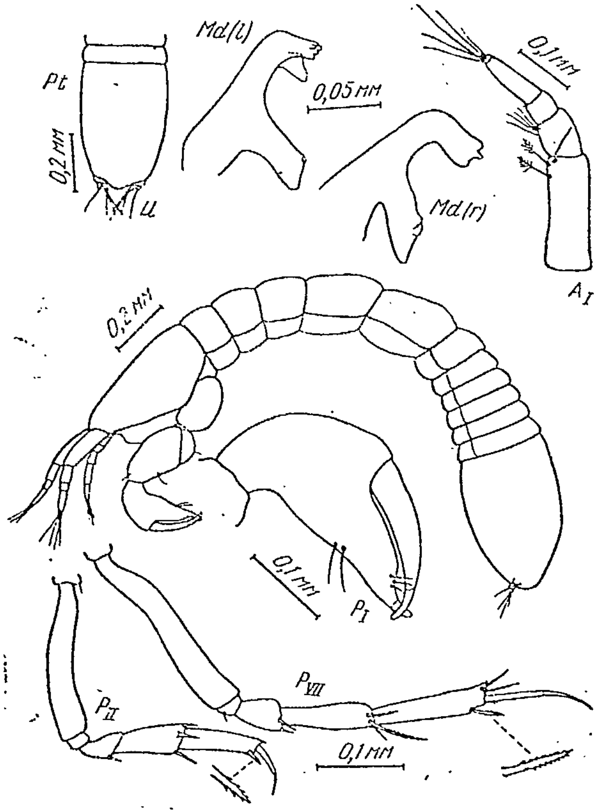

Fig. 12. Strongylura larviformis sp. nov.
Female, length 2.4 mm
(holotype)

name of the species). The structure of the carapace and the thoracic segments is as in cylindrata.

The first antennae are distinguished by the button-shaped fifth joint, the first joint is 2.5 times as long as the second and has two sensory setae and one simple seta. The second joint is longer than the third and bears four fine setae. The fourth joint is long, it is fully half the length of the first joint. The second antennae and the labrum are as in cylindrata. The mandibles have cutting edges with denticles, 161
of which there are five on the left mandible and only one on the right. The processus molaris is massive. The lacinia mobilis, unlike that in cylindrata, lacks the row of small denticles. The first maxilla and the maxilliped are as in cylindrata.

The first peraeopod resembles that of cylindrata, but differs in the presence of a depression on the inner side of the immobile finger of the claw near the talon and the lack of denticulation thereon.

The second to seventh peraeopod resemble those of cylindrata and have setae with cilia and even spines; this applies particularly to the last three pairs.

Pleopods are lacking. Uropods are as in cylindrata.

Remarks. The new species undoubtedly resembles S. cylindrata, but it differs in the structure of the first antenna, mandibles and the immobile finger of the claw, as well as pleonites that increase in width from the first to the fifth and a heavily inflated pleotelson. An inflated pleon has been described by Vanhöffen (1914) in male S. antarctica, but there the greatest width occurs not in the pleotelson but in the second pleonite; from then on, toward the end of the pleotelson, the width of the body decreases gradually. Among the females of S. antarctica the pleon has the usual structure and is not inflated. The structure of the first antenna and the claw of the first peraeopod in our species is different than in antarctica.

Genus Paranarthrura Hansen 1913 162

26. Paranarthrura zevinae Kudinova-Pasternak 1970

Kudinova-Pasternak 1970:368-369, Fig. 19.

Material: Station 6136, 2 females, length 2.1 and 2.2 mm; station 6106, bottom grab: 1 female, length 3.4 mm.

Distribution. The species had previously been found in the Kurile-Kamchatka trench at 4,895-5,240 m.

27. Paranarthrura insignis Hansen 1913

Hansen 1913: 122-124, Pl. XII, Fig. 3a-3m.

Material: Station 6142: 1 female, length 2.9 mm; station 6136, 2 females, length 2.3 and 2.7 mm; station 6105, trawl: 1 female, length 3 mm and one fragment; station 6118, 1 female, length 4.4 mm; station 6135: 1 female, length 5.2 mm; station 6095, bottom grab: 1 female, length 2.2 mm.

Remarks. In the female from station 6118 the immobile finger of the claw has one large tooth and two smaller ones, while in the other specimens there is only one large tooth, as is appropriate in this species.

Distribution. The species has been found in the North Atlantic at depths of 579-2,172 m (Hansen 1913).

28. Paranarthrura vitjazi Kudinova-Pasternak 1970

Kudinova-Pasternak 1970: 366-368, Fig. 17-18.

Material: Station 6135, male, length 2.1 mm.

Distribution. The species had previously been noted in the Kurile-Kamchatka trench, at 4,945 and 5,240 m (Kudinova-Pasternak 1970).

Genus Arthrura Kudinova-Pasternak 1967

29. Arthrura shiinoi sp. nov.

(Fig. 13)

Material: Station 6109, bottom grab: 1 female, length 4.5 mm (holotype).

Description. Body elongated, length 6.6 times the greatest width at the carapax level. Carapax wide in the middle, narrowing toward the distal end. The shape of the thoracic segments resembles that of A. andriashevi (see Kudinova-Pasternak 1967), but the second (first free) segment is longer and widens more toward the anterior margin. The second to fourth segments each have two setae; on the second segment these are attached to the anterior side, on the other segments, to the anterior-lateral side. The length of the pleon equals the combined length of the seventh, sixth, and half the fifth thoracic segments. On the ventral side the pleonites have medial conical tubercles. The first and second pleonites have the same width, from the second to the fifth the width of the pleonites gradually decreases. The pleotelson is somewhat wider than the last pleonite, with rounded lateral sides and distinct obtuse terminal protuberance. The width of the pleotelson is somewhat greater than its length, which equals the combined length of the fifth, fourth, third and half the second pleonite.

The first antenna has four joints, as in andriashevi, but without the cluster of setae at the base of the first joint. The second antenna has six joints, the first of them is very small, nearly square, the second 163
is nearly twice as long as the first, with a typical protuberance in the distal part, which serves as the base of a spine. The third joint is somewhat longer than the first, with a seta, the fourth is long, its length exceeds the combined length of the first three joints, in the middle of the fourth joint there is a sensory seta and in the distal part there are three simple setae; the fifth joint is nearly four times shorter than the fourth, the sixth joint is very small, with a cluster

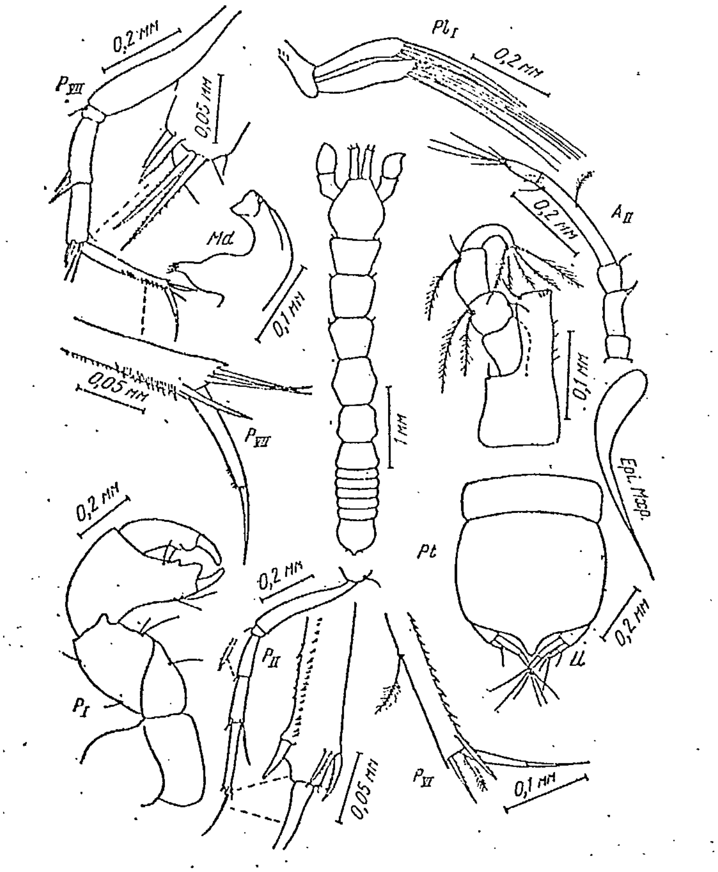

Fig. 13. Arthrura shiinoi sp. n. Female, length 4.5 mm (holotype).

five setae at the end. The mandibles have a distinct processus molaris, with four denticles at the end. The pars incisiva has four small teeth. The margin of the lacinia mobilis of the left mandible is smooth. The first maxilla is as in andriashevi, with a corona of seven spicules. The palpi of the maxillipeds have heavily ciliate setae, on the outer side of the endite there is a caudal seta. The epignath has the shape of a sickle.

The first peraeopod is distinguished by a short carpopodite and a broad "hand." The immobile finger of the claw has on its inner side two obtusely rounded teeth, at the base of the talon there is a very large tooth, and behind it a small one. On the inner side of the dactylus there are two low protuberances. The first to fourth peraeopods are similar in structure, the coxopodite has a seta, the basipodite is very long, the meropodite of the second and third pair has one seta with small spines along the sides, the peraeopod of the fourth pair has four setae, the carpopodite has one short and one long spicule, the armature of the propus is shown in Fig. 13; typically it has three spinous subterminal spicules, two of which, in turn, have small spines and two longitudinal rows of spines along the joint. The fifth to seventh peraeopods are also 164 similar. Their armature is shown in Fig. 13. Typical are longitudinal rows of spines along the propus. On the basipodite of the fifth peraeopod and on the propus of the sixth there are sensory setae.

The pleopods are biramous, on the base there are three small setae, both branches are equipped with very long setae whose length exceeds that of the branches themselves.

The uropods have a two-jointed exopodite and endopodite; the latter's length exceeds that of the former. The distal joint of the endopodite is much shorter than the proximal, while both joints of the outer branch are approximately of the same length.

Remarks. This species is the second of the genus *Arthrura*, which differs from the similar *Paranarthrura* in the presence of a well-developed processus molaris on the mandibles, the width of the pleonites and the structure of the first maxilla with a corona of seven spicules.

It seems that the genus *Arthrura* should embrace also *P. monacanthus* which was described by Vanhöffen (1914), as I have learned from an oral communication of O. G. Kusakin that the specimens of *P. monacanthus* preserved in the Zoological Institute of the Academy of Sciences of the USSR in Leningrad have well-developed processus molaris on the mandibles.

The new species *A. shiinoi* is easily distinguished from *A.*

andriashevi in the structure of the carapax, the pleotelson, the first peraeopod, the pleopods, the uropods and a number of other characters. The species is named after the Japanese carcinologist Prof. S. M. Shiino.

Genus Agathotanais Hansen 1913

30. Agathotanais splendidus Kudinova-Pasternak 1970

Kudinova-Pasternak 1970: 370, Fig. 20.

Material: Station 6111: 1 defective female.

Distribution. The species is known from the Kurile-Kamchatka trench at 5,441 m (Kudinova-Pasternak 1970).

Genus Pseudotanais G. O. Sars 1880

31. Pseudotanais vitjazi Kudinova-Pasternak 1966

Kudinova-Pasternak 1966: 532-534, Fig. 12.

Material: Station 6136: two females, length 1.6 and 1.7 mm.

Distribution. The species had previuosly been found in the basin of the Pacific (40°20' north, 175°45' east) at 6,065 m, in the Kurile-Kamchatka trench at 4,895-5,420 m (Kudinova-Pasternak 1966, 1970) and in the Japan trench at 7,370 m.

32. Pseudotanais forcipatus (Lilljeborg 1864)

Lilljeborg, 1864: 16.

Material: Station 6099, two females, length 1.0 and 1.3 mm.

Distribution. The species is widely distributed in boreal and arctic waters: along the coasts of northern Scotland, Denmark, along the entire coast of Norway, in the Barents Sea, at Franz Josef Land at depths of 6-364 m (Hansen 1913; Greve 1965).

33. Pseudotanais inflatus sp. nov.

(Fig. 14)

Material: Station 6106, trawl No. 2: female, length 2.4 mm (holotype).

Description. Body short, length only 2.9 times greatest width at the fifth thoracic segment. Carapax triangular, somewhat depressed 165 laterally in the distal part. The thoracic segments increase in length from the second to the fifth, and decrease from the fifth to the seventh. The fifth and sixth segments are the widest and longest, so that the body appears inflated in the centre (hence the name of the species). The second thoracic segment is very narrow, its width is less than that of the base of the carapax. The third segment has the same width as the fourth. The length of the fifth segment is equal to the combined length of the five pleonites, the length of the sixth is somewhat less. The length of the seventh segment equals that of the first three pleonites. The pleonites decrease in width from the first to the fifth; the first pleonite is longer than the rest.

The width of the pleotelson is less than the width of the last pleonite, but somewhat more than two times longer that its own width. Terminally the pleotelson has a small, obtuse protuberance.

The first antenna has a long first joint, exceeding in length the two others. The third joint is slightly longer than the second. The second antenna has a very narrow first joint. The second joint widens in

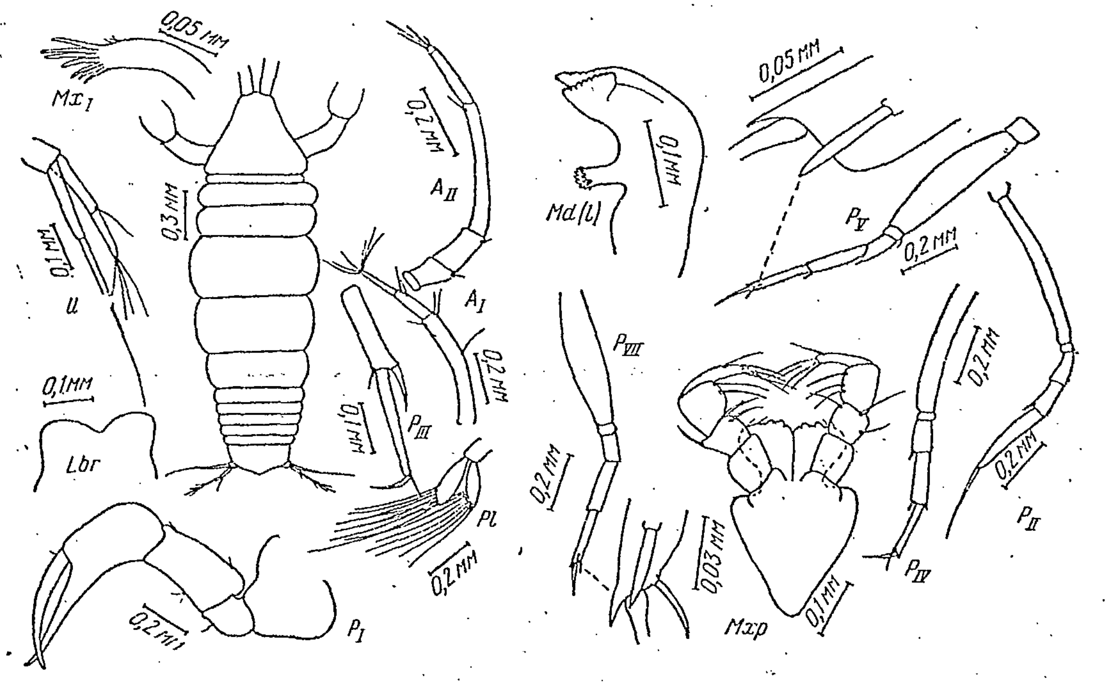

Fig. 14. Pseudotanais inflatus sp. nov. Female, length 2.4 mm (holotype) and structural details

the distal part, the third is rectangular and longer than the second, the fourth is very long, nearly twice as long as the combined fifth and sixth, the length of the fifth equals the combined length of the third and half the second, the sixth is small, button-shaped. The pars incisiva of the mandibles has six low denticles, the processus molaris have many denticles. The lacinia mobilis has a row of 11 teeth. The labium has a notch in the middle. The first maxilla has a corona of seven spicules and three setae on the outer margin.

The armature of the maxillipeds is shown in Fig. 14.

The first peraeopod has a very long "hand," with long claw fingers; the immobile finger has on its outer side, near the base, a seta. The armature of the other peraeopods is shown in Fig. 14. The second peraeopod is characterized by a very long dactylus with a long talon. The third peraeopod has a long spinous terminal spicule on the carpopodite. The fifth to seventh peraeopods have a very powerful knife-like subterminal spicule on the propodite.

The pleopods are biramous, with setae which are 2-3 times 166 as long as the branches bearing them. The uropods are biramous, both branches are two-jointed. The proximal joint of the exopodite is longer than the distal one, which has a very long seta at the end. The proximal joint of the endopodite is also longer than the distal one, which terminates in a cluster of four setae.

Remarks. The new species resembles P. abyssi Hansen 1913, but differs in the structure of the carapax, a wider third thoracic segment, which in our species is as wide as the second one, while it is narrower in abyssi. The uropods are distinguished by a longer exopodite and by the fact that its proximal joint is longer than the distal one, while in abyssi both joints have the same length.

Genus Cryptocope G. O. Sars 1880

33. Cryptocope arctica Hansen 1887

Hansen, 1887a: 209, Tabl. XXI, Fig. 4; 1887b: 180, Tabl. VII, Fig. 1-1c; Richardson, 1905: 16-17, Fig. 19-20.

Material: Station 6134, bottom grab: 1 female, length 2.4 mm, and 13 specimens at the manca stage, length 1.0-1.2 mm. The female and the young individuals were found in a ooze tube.

Distribution. The species had previously been known from the North Atlantic at depths of 18-2,626 m (Hansen, 1913), from the coast of Spitsbergen, Novaya Zemlya (183 m) and the Kara Sea (8-165 m). It has also been found in the Kurile-Kamchatka trench at 4,895-5,240 m (Kudinova-Pasternak 1970).

Conclusions

1. We have found a great similarity between the Tanaidacea of the Aleutian trench and the Gulf of Alaska, on the one hand, and of the Kurile-Kamchatka trench, on the other. Of 33 species found in the region studied, 17, or 51.5%, are also found in the Kurile-Kamchatka trench. Many species are also found in the North Atlantic (12, or 37%). Neotanais triangulocephalus is found in the Aleutian trench and along the coasts of New Guinea. The apparent bipolar distribution of this species is most likely due to insufficient study of the tanaids.

It seems that the same type of habitat or territory belongs to N. zenkevitchi, Carpoapseudes serratispinosus and Leptognathia forcifera. All three species were found by us in the Gulf of Alaska; N. zenkevitchi, in addition, was found in the Aleutian trench and in the eastern Pacific (6°00' to 5°54' south, 84°50' to 84°53' west), and C. serratispinosus and L. forcifera were also found in the area of Acapulco, Mexico, and in the Gulf of Panama (Lang 1968). It is possible that future collections will reveal these species in the intervening region, and their disrupted territories will become continuous, stretching along the west coast of North America and the northwest coast of South America.

2. The greatest numbers and the greatest biomass were found at Station 6132 in the upper bathyal region. Bottom-grab sample No. 1

(depth 1,040 m) contained 180 individuals of Carpoapseudes serratispinosus, which amounted to a biomass of 0.448 g/m^2. Trawl catch No. 3 at the same station turned up 311 specimens of this species.

3. Usually, tanaid males are much rarer than females. But in bottom-grab sample No. 1 at station 6132 we found 37 males and 59 females of C. serratispinosus, and in trawl catch No. 3 from the same station the number of males even exceeded that of the females (161 males against 144 females). It may be that this phenomenon is due to a sex shift, and that the material was obtained at the moment when many or even most of the individuals happened to be in the male phase.

Among the 311 specimens of C. serratispinosus from the trawl 167 catch we found three hermaphrodite individuals which possessed both the characters of the female (structure of first peraeopod, four pairs of rudimentary oostegites extending from the bases of the second to fourth peraeopods), and the typically male genital cone on the venter of the seventh peraeonite. The presence of rudimentary oostegites coupled with that of a well-developed genital cone of the male probably indicates hermaphroditism of the protogynous type, rather than protandry. In the case of C. serratispinosus, hermaphroditism is noted for the first time; in the case of other species it has been noted by a number of investigators (Lang, 1953, 1958; Forsman, 1956; Wolff, 1956a, b; Kudinova-Pasternak, 1965b.

4. Doubt is being expressed in the appropriateness of re-establishing the genus Leiopus Beddard (Lang, 1968), which had previously been combined with the genus Apseudes Leach (Lang, 1949). There is even less reason, in our view, for establishing the family Leiopidae (Lang, 1970),

which differs from the Apseudidae only in the fact that it has on the interior caudal-distal margin of the maxillipeds a seta of peculiar shape, which is wide at the end and bears spines.

5. We have described a new genus — _Filitanais_ — and nine new species.

6. It appears that _Paranarthrura monacanthus_ Vanhöffen belongs to _Arthrura_ rather than _Paranarthrura_.*

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* K. Lang (Arch. f. Zool., B. 23, N. 6, 1971) placed _P. monacanthus_ Vanhöffen 1914 in his newly described genus _Libanius_.

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PELAGIC AMPHIPODS OF THE GENUS VIBILIA MILNE-EDWARDS (HYPERIIDEA, VIBILIIDAE) FROM THE SOUTH-EASTERN PACIFIC

By T. N. Semenova

The pelagic amphipods of the family Vibiliidae belong to one of the least studied groups of crustaceans of the marine zooplankton. They have experienced the same fate as some other groups of Hyperiidea, distributed widely in the surface waters of the tropical zones of the World Ocean (e.g., Hyperia). Having already been known in the past century, often from incomplete and inexact descriptions accompanied by imperfect figures or without figures, they were subsequently often described anew or re-described under various names by numerous investigators, sometimes from single or accidental finds in various parts of the ocean. As a result, the systematics of the family Vibiliidae which is actually not very large (three genera, about 30 species) turned out to be confused, and the assemblage of synonyms was quite complex. A contributing factor was the great ontogenetic variation and indistinct sexual dimorphism among most species. The most extensive genus (about 25 species) of this family is Vibilia Milne-Edwards, 1830. The second genus, Vibiloides Chevreux 1905, is monotypic: its only species V. albertii is known from only two finds in the tropical Atlantic and, it seems, lives in deep water. The genus Cyllopus Dana 1852 (with a few species) differs greatly from the first two genera in a number of typical features, which caused Bovallius (1889) and, after him, several other investigators to elevate it into the rank of the family Cyllopodidae. Its distribution is confined mainly to the surface waters of the Antarctic.

This paper deals with organisms belonging to Vibilia and collected in the southeastern Pacific by the TINRO ships "Lira" in 1965-66 and "Professor Deryugin" in 1968 and kindly made available to us for study by A. F. Volkov. Samples were taken with the self-closing model of the multi-depth pelagic trawl of the Isaacs-Kidd type from horizons of 100, 50, 25, and 0 meters during darkness. We also reviewed specimens obtained by the ship "Akademik Kurchatov" in the same area of the Pacific with a ring trawl, an ichthyo-plankton net and a non-closing Isaacs-Kidd trawl.

Vibilia were found at 33 stations (Fig. 1a). Altogether, we determined 1,018 specimens, which we assigned to 11 species: robusta, gibbosa, propinqua, antarctica, viatrix, stebbingi, armata, chuni, pyripes, cultripes and longicarpus.

Until now, we knew of nine Vibilia species from the southeastern Pacific, mainly through the work of A. L. Behning (1912, 1913), which was based on materials from the "Albatross" expedition. All of these species were among our own collection. In addition, we found two more species not 170 previously known from that area — V. gibbosa and V. robusta.* We are providing information on each of the species encountered.

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* A. F. Volkov (1970), who analyzed net collections made by the "Lira" in the same area, mentions robusta in his list of species, but is not sure of his determination. In any case, the "Lira" collections give the first evidence that this species lives in the waters of the eastern Pacific.

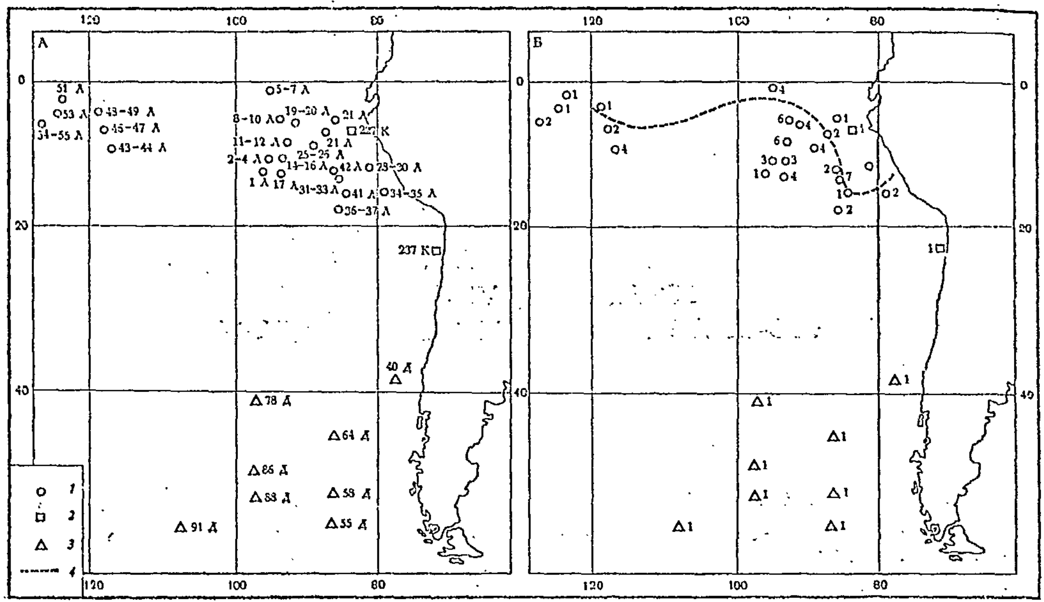

Fig. 1. Location of stations (A) and number of Vibilia species found at each station (B). Stations: 1 -- "Lira," 2 -- "Akademik Kurchatov," 3 -- "Professor Deryugin," 4 -- location of southern subtropical divergence (after V. A. Burkov, 1968).

Vibilia robusta Bovallius 1887

V. robusta -- Bovallius 1887:34; Behning 1912:213, 215; Stephensen, 1918:37-38.

At stations 25 and 26 "L" the catch included 6 females and 3 males (11.2 and 19.4 mm). The two largest females had embryos in the marsupial chamber, a female of 15.7 mm had ova. The specimens caught fully accord with the description of Stephensen (1918). All individuals were found in one catch at 37 m; no members of the species were found at the neighboring stations. This is a fairly common phenomenon in the distribution of pelagic amphipods, as the organisms are most often found in separate schools or with accumulations of macroplankton -- in the case of Vibiliidae, with salpas.

This species is known from the Atlantic, where it lives in the tropics and spreads to temperate waters, both northward and southward; from the Indian Ocean (Stephensen 1918), the Indian sector of the Subantarctic and from the Tasman Sea (Barnard 1930; Hurley 1960). V. robusta had not hitherto been found in the basin of the Pacific.

Vibilia gibbosa Bovallius 1887 171

V. gibbosa -- Bovallius 1887:53; Vosseler 1901:119; Behning 1912:213, 215; 1913:529; Stephensen 1918:36-37.

Station 2-4"L": female, 7.6 mm; station 11-12"L": 2 females, 7.5 and 7.7 mm; station 17"L": 11 females, 5.7-6.9 mm,and three males, 6.3-6.4 mm; station 28-30"L": female, 6.7 mm; station 31-33"L": 4 females 5.5-5.6 mm, five males, 5.6-6.5 mm and one juvenile, 4.7 mm; station 43-44"L": male, 5.3 mm, and juvenile, 4.6 mm.

We included in this species 30 individuals, although they do differ in some structural details from the type specimen described by Bovallius. These differences concern above all the telson, which is regularly rounded in the largest individuals, and transverse-oval in the younger ones. Most investigators (Bovallius 1887; Vosseler 1901; Chevreux 1925) described gibbosa as having a triangular telson. However, Stephensen (1918) notes that the individuals studied by him had a rounded telson, and in his figure the urosoma is very similar to the urosoma of the specimens in our collections. Apart from the telson, our specimens also differ in the length of the carpal protuberance on the second peraeopod and the somewhat different proportions of the joints of the seventh peraeopod, in particular in a shorter and broader second joint (Fig. 2). There are small differences in the peraeopodal setae.

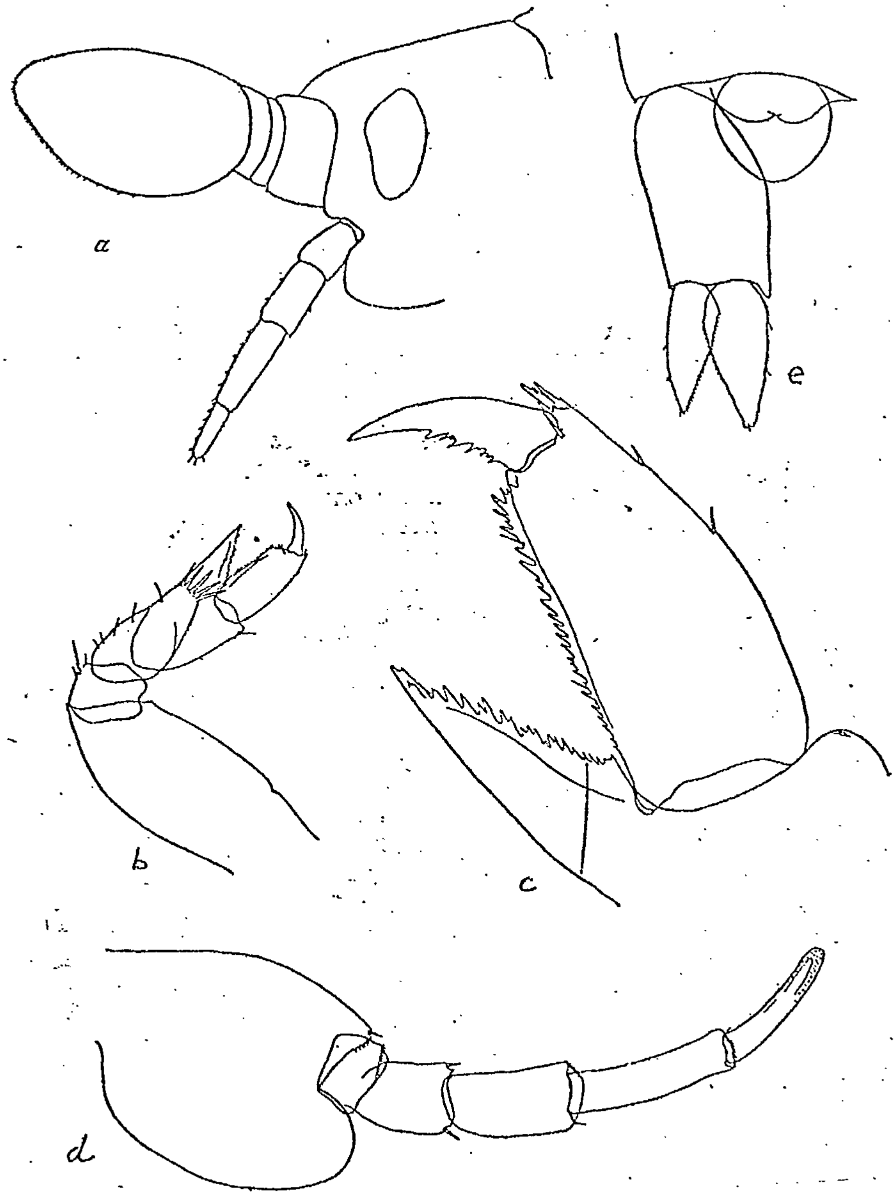

Fig. 2. Vibilia gibbosa Bovallius. Form with rounded telson (female, length 7.5 mm). a –– head with antennae; b –– second peraeopod, c –– chela of second peraeopod, d –– seventh peraeopod, e –– third uropod and telson.

Unfortunately, we know very little concerning the character and range of variation in the Vibiliidae, and it is difficult to correctly assess these differences. In any case, ontogenetic variation is excluded in the telson, as it is usually rounder in young individuals than in adults. In our case, as in that of Stephensen, fully adult individuals (including females with ova) had a round telson when measuring over 7 mm, while the specimens of other investigators contained individuals of lesser size (5-6 mm) with a triangular telson. The shape of the telson of adult Vibilia is widely used in the systematics of the genus as a specific character.

The possibility is not excluded that under the name V. gibbosa two similar forms have been intermingled, but at present we clearly do not possess sufficient information in order to resolve this matter.

V. gibbosa is distributed widely in the Atlantic and the Mediterranean, but always in small numbers. It had not been known until now in the Indian Ocean and in the South Pacific.

The scientific literature contains indications that the species was found in the waters of Japan (Irie 1957, 1959), and there is one unsubstantiated find along the coast of California (Hurley 1956), consisting of two very young specimens that were tentatively included in this species.

Vibilia antarctica Stebbing 1888

V. antarctica -- Stebbing 1888:1290; Behning 1913:530;
Vibilia sp. (II) -- Stebbing 1888: 1293.

Station 8-10"L": juvenile, 4.0 mm; station 11-12"L": male, 8 mm; station 14-16"L": female, 5.5 mm, male, 9.5 mm; station 19-20"L": female with ova, 7.5 mm; station 28-30"L": 8 females, 6.9-9.0 mm, 6 males, 5.6-9.0 mm, 3 juveniles, 4.3-5.0 mm; station 31-33"L": female, 7.6 mm, juvenile, 4.8 mm.

The species was described by Stebbing (1888) from Antarctic waters and has a circumpolar distribution, although it may spread with cold currents into the lower latitudes (Behning, 1925; Hurley, 1960; Vinogradov, 1962). In our region, antarctica undoubtedly owes its appearance to the powerful Peru Current which carries waters from the Subantarctic along the coast of America to the equator. The species had earlier been noted here by Behning (1912) and Hurley (1958).

Vibilia stebbingi Behning et Woltereck 1912 172

V. stebbingi -- Behning, Woltereck 1912:5; Behning 1913:217; 1925:485; Stephensen 1918:40; Hurley 1955:125.

The catches contained five specimens of this widely distributed species: Station 5-7"L": male, 4.4 mm; station 24"L": male, 4.6 mm; station 25-26"L": females, 4.8, 5.0 and 5.5 mm, the lastnamed with embryos in the marsupial chamber.

In appearance and dimensions these specimens are closer to the description of Behning than to the larger Antarctic form described by Hurley (1955) from New Zealand waters.

The species is known from the tropics of the Atlantic and Pacific and is widely distributed in the Antarctic waters of the Indian Ocean sector (Hurley 1955, 1956, 1960; Barnard 1930; Vinogradov 1962). 173

Vibilia viatrix Bovallius 1887

V. viatrix -- Bovallius 1887:63; Behning 1912:213, 217; Stephensen 1918:41-43;
V. viator -- Stebbing 1888:1286;
V. hirondellei -- Chevreux 1900:126;
V. californica -- Holmes 1908:490.

Station 31-33"L": 114 females, 97 males and 7 juveniles (4.4-8.1 mm); station 34-35"L": 4 females, 5.8-6.2 mm, 5 males, 5.1-6.6 mm; station 43-44"L": male, 4.3 mm; statinn 46-47"L": female, 5.2 mm, male, 5.1 mm, juvenile, 4.1 mm; station 54-55"L": female, 5.0 mm; station 40"D": 7 females, 5.7-6.4 mm. Many females had ova or embryos in their marsupial chambers.

The species has been found both in the tropical part of our region and at 40° south, approximately in the area of the Subantarctic convergence. It seems that in some instances viatrix may form noticeable accumulations, as was the case at one of the stations, where three catches brought up 218 specimens, with 121 specimens in a single catch. For Vibilia, which are not generally numerous, this is a significant number. In our own collections only V. armata exceeded the number of this catch.

V. viatrix has a circumtropical distribution in all oceans and in the Mediterranean (Stephensen 1918), it is often found in salpa bands (Chevreux 1925). In the South Atlantic it is found north of the Antarctic convergence (Vosseler 1901).

Vibilia propinqua Stebbing 1888

V. propinqua -- Stebbing 1888:1279; Vosseler 1901:124; Behning 1912: 213, 218; Stephensen 1918:43-46;
Vibilia sp. (I) -- Stebbing 1888: 1285;
V. milnei -- Stebbing 1888:1284.

Station 8-10"L": 2 females, 8.5 and 9.5 mm, 2 males, 8.8 and 9.3 mm; station 11-12"L": 2 females, 8.2 and 9.2 mm, 3 males, 8.0-9.5 mm; station 14-16"L": 8 females, 8.2-10.5 mm, two of them with ova, male, 9.4 mm; station 19-20"L": 3 males, 9.3-10.0 mm; station 25-26"L": 6 females, 7.1-10.0 mm, two with ova, one with embryos, male, 9.0 mm; station 28-30"L": 9 females, 10.0-12.3 mm, two with embryos, one with ova, 2 males, 9.6 and 10.1 mm; station 31-33"L": 39 females, 29 males and 5 juveniles (4.6-11.8 mm); station 42"L": female 10.0 mm, 2 males, 8.5 and 9.2 mm; station 43-44"L": female, 6.8 mm, male, 8.0 mm; station 51"L", female, 5.5 mm.

V. propinqua is fairly common in the tropics of the Atlantic, Indian and Pacific oceans (Behning 1912; Stephensen 1918; Hurley 1958), and may range far into high latitudes, particulary in the Southern Hemisphere: it has been found at 69° south in the Indian Ocean sector of the Antarctic (Walker 1909) as well as south of New Zealand (Hurley 1960).

Vibilia armata Bovallius 1887

V. armata -- Bovallius 1887:69; Behning 1912:213, 220; 1925:491-94; Stephensen 1918:46-52;
V. gracilis -- Bovallius 1887:65;
V. gracilienta -- Bovallius 1887:67;
V. erratica -- Chevreux 1892: 32.

This is the most numerous Vibilia in the region studied.

It was found at most stations (frequency of occurrence 74%); in one of the catches (Station 43-44"L") there were 245 specimens. Altogether, the catches brought up 242 males and 321 females (dimensions 4.2-8.5 mm), many females had ova or embryos in the marsupial chamber. Along with viatrix and propinqua, armata makes up the basic Vibiliidae "background" typical of the southeastern Pacific, which was joined at the various stations by one or the other of the remaining species. V. armata was 174 found both at low latitudes and south of the Subantarctic convergence, right up to 55° south, but in the latter case the numbers were small.

V. armata is not only the most numerous but also the most widely distributed Vibilia: it occurs in all the oceans, in the North Atlantic it ranges to 53° north (Stephensen 1918), in the North Pacific, to the latitude of Japan (Irie 1957, 1959), and the area west of California (Hurley 1956). It is known from the waters of the Subantarctic, but it does not usually range south of the Antarctic convergence (Vinogradov 1962; Hurley 1969).

Vibilia cultripes Vosseler 1901

V. cultripes -- Vosseler 1901:121; Behning 1913:533; 1925:495-96; Stephensen 1918:54-55.

Station 11-12"L": male, 14.6 mm; station 19-20"L": female, 14.6 mm with embryos; station 53"L": female, 7.7 mm, with ova.

The species has been found in the Atlantic and the Indian oceans and in the Mediterranean. Our finds are located somewhat to the east of the only previous occurrence in the Pacific, noted by Behning (1912). Apparently the species has a circum-tropical distribution. In their morphology, our specimens accord well with Vosseler's description.

Vibilia longicarpus Behning 1913

V. longicarpus -- Behning 1913:530-33.

Station 2-4"L": females 9.5 and 8.0 mm; station 5-7"L": male, 9.2 mm; station 8-10"L": female 9.5 mm, 2 males 9.3 and 10.2 mm; station 11-12"L": 2 females 9.3 and 9.8 mm, 3 males, 8.7-10.3 mm; station 17"L": female with embryos, 8.2 mm, 2 males, 9.2 mm.

V. longicarpus was described by Behning from catches of the "Albatross" made approximately in the same area of the Pacific as our own catches. After Behning, the species was not noted by any investigator in any part of the World Ocean. The individuals from the material collected by the "Lira" agree well with Behning's description and figures, which we considered it necessary to complement by adding morphological details of longicarpus not figured by the author of the species (Fig. 3).

It seems to us that Behning incorrectly compares longicarpus to pyripes, when in fact it is much more similar to another species, namely cultripes, a rather typical large Vibilia. In a cursory examination, cultripes and longicarpus appear so similar that they may be confused, and only a careful review of the morphology shows that they are different species. The large, stocky body with a compact chitin, the proportions of the head, the large (both in males and females), intensively pigmented eyes, the shape of the flagellum of the first antenna, the strong limbs, the powerful seventh peraeopod with small distal protuberances on the fifth and sixth joint, the structure of the urosoma -- these are the characters linking the two species. At the same time the differences in the structure of the maxillipeds, the chela of the second peraeopod and the shape of the terminal joint of the seventh peraeopod, along with other smaller

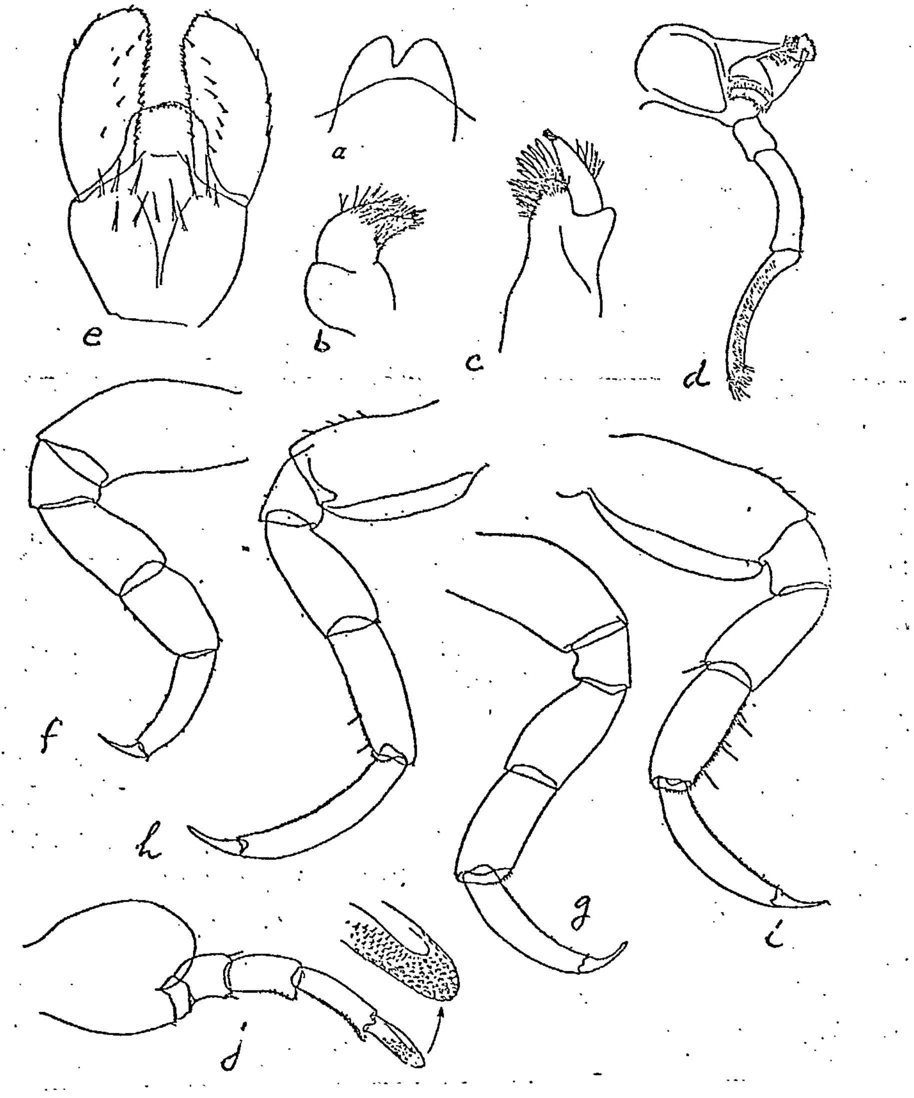

Fig. 3. Vibilia longicarpus Behning.

a -- labrum, b -- first maxilla; c -- second maxilla, d -- mandible; e -- maxillipeds, f-j -- third to seventh peraeopods.

characters, make it impossible to confuse them.

V. pyripes resembles the two abovenamed species mainly in the structure of the urosoma, but it differs greatly both in its external appearance and in the shape of the first antenna and the seventh peraeopod. In comparing the criteria it would be more correct, in our view, to place longicarpus alongside cultripes, rather than include it in the pyripes group.

Thus far the species has been found only in the tropical waters of the southeastern Pacific. Such a habitat is not entirely common among the Vibilia, which in most cases have a very wide range. Of species with 175 a similarly limited range we can name only V. caeca Bulycheva, which is known from the northwestern Pacific.

Vibilia pyripes Bovallius 1887

V. pyripes — Bovallius 1887: 71; Behning 1912:213, 221; 1925:495-96; Stephensen 1918:52-53.

Station 5-7"L":male, 5.9 mm; station 8-10"L": 3 females, 5.3-6.0 mm, one with ova; station 17"L": male, 4.7 mm; station 31-33"L": female, 6.4 mm.

A widely distributed but always sparse species, occurring in the Atlantic, Indian and Pacific oceans, mainly in the tropical region, but also known from the Southern Ocean: north of the Antarctic convergence in the Atlantic sector and south of New Zealand (Vinogradov 1962; Barnard 1930; Hurley 1956, 1969).

Vibilia chuni Behning et Woltereck 1912

V. chuni -- Behning, Woltereck 1912:8; Behning 1925:495-98;
V. hodgsoni -- Stewart 1913:248.

Station 5-7"L": male, 4.5 mm; station 8-10"L": 5 females, 4.0-5.6 mm, three with embryos, male, 5.0 mm; station 14-16"L": female, 6.0 mm; station 28-30"L": 2 males, 6.0 and 7.4 mm; station 31-33"L": 3 males, 3.8-5.4 mm; station 36-37"L": female, 4.0 mm; station 54-55"L": male, 6.0 mm.

The species is distributed in the tropical regions of the Atlantic, Indian and Pacific, always very sparse. In the region under study, it was known from a single find by Behning (1912).

* * *

The greatest number of Vibilia was found in the region of the southern tropical divergence -- in the waters with a southern east-subtropical structure (Burkov et al., 1971). In the same region we also noted the greatest numbers of individual species. This is understandable: The development of a rich pelagic fauna in that region is being fostered both by an influx of biogens through upwelling and by the mixing of tropical waters with those of the Peru current, rich in life, which in these latitudes veers from the coast of America toward the west.

The collections analyzed have expanded our understanding of the ranges of the individual Vibilia species, which had not hitherto been known in this area (V. gibbosa, V. robusta) or had been known from single finds (V. cultripes, V. longicarpus, V. chuni).

The discovery of adult females with ova or embryos in the marsupial chamber, as well as of young individuals shows that all of species found may normally procreate in these waters, i.e., the region of the Pacific studied by us is part of their main habitat.

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PANTOPODS FROM THE NORTHEASTERN PACIFIC

By Ye. P. Turpayeva

This paper deals with information on pantopods obtained during Cruise 45 of the "Vityaz'" in the Gulf of Alaska and the Aleutian trench at 16 stations. We have also used data obtained during preceding cruises of the "Vityaz'" (1949-58) at 8 stations in waters adjacent to the Gulf of Alaska. The collections were made at 180-4,860 meters (Table 1). They were found to contain 11 pantopod species, belonging to 6 genera and 5 families.

FAMILY NYMPHONIDAE WILSON

Genus _Nymphon_ Fabricius 1794

Nymphon procerum Hoek 1881

N. procerum Hoek 1881:39-40; Fage 1951:95-97; Turpayeva 1971:276-77;
N. profundum Hilton 1942a:3; Hedgpeth 1949:270;
N. noctum Hilton 1942a:3; Hedgpeth 1949:271.

Material: Station 6105, 2 spec; 6106, 2 spec.; 6111, 2 spec.; 6117, 1 spec.; 6143, 1 spec.

Remarks. In the specimen from station 6105 the seventh leg joint is nearly 1.5 times longer than the eighth. In the remaining specimens the proportions of the body[*] and limbs is the same as in _N. procerum_ from the Kurile-Kamchatka trench, however, unlike the latter, some of our specimens (station 6105, 6106, 6111) have fairly dense setae on the long leg joints. Some of the setae are very short and form a dense cover, others are long,

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[*] "Tulovishche" can be translated as body, torso, trunk, etc. It may be identical with prosoma. -- TRANSL.

equal to or slightly greater than the diameter of the joint, and are fairly sparse.

Distribution. Northern and southern temperate zones of the Pacific and northern Atlantic at 2,450-6,156 m.

Nymphon pixellae Scott 1912

N. pixellae Scott 1912:206-09; Hilton 1942b: 279-80; Stock 1955:216-17;
N. solitarium Exline 1936:414-16; Hedgpeth 1939:458-62.

Material: Station 6124, 4 spec. (1 male with cocoons).

Remarks. The structure of the body and limbs of *N. pixellae* resembles that of the arctic-boreal form *N. longitarse* Kröyer. The principal distinction between the two species resides in the structure of the marginal spines of the third leg: in *longitarse*, as among most North Atlantic species of *Nymphon*, the marginal spines have one pair of large basal denticles and a finely denticulate lamina, while in *pixellae* these denticles on the eighth to tenth joints of the third leg have 8-9 pairs of lateral denticles of medium size, on the seventh joint there are two pairs of large basal denticles and a small lamina with medium-sized 179
denticles on the distal part of the spine. V. M. Shimkevich (1930) regards *Nymphon* species with coarsely denticulate marginal spines as indigenous Pacific forms.

The elongation of the neck and the seventh leg joint, typical of *longitarse*, is even more distinct in *pixellae*: while in *longitarse* the length of the neck equals 35-40% of the total length of the first segment, and the seventh leg joint is twice the length of the eighth, in *pixellae* the neck makes up 45-50% of the length of the first segment

Table 1. List of "Vityaz'" stations at which pantopods were collected

Station No.	Date	Depth, m	Coordinates	
			North lat.	Longitude
26	15. VIII 1949	1128—1240	50°40′	149°14′ вост. east
976	4. XI 1951	3820	56°51′	174°03′9 »
2078	11. V 1953	1070	44°09′	148°38′ »
3353	5. VI 1955	1600	53°53′5	169°15′5 »
3578	11. V 1957	1641	38°25′	142°53′3 »
4177	4. XII 1958	650	44°51′7	126°04′ зап. west
4265	13. I 1959	3315—3340	24°57′6	113°24′8 »
6089	6. V 1969	180	58°02′	149°02′4 »
6099	10. V 1969	292	59°18′	141°58′8 »
6100	11. V 1969	573—534	59°14′8	141°59′7 »
6101		798—756	59°16′8	142°00′8 »
6105	12. V 1969	2970	58°55′	142°03′ »
6106	13. V. 1969	3620	58°15′5	142°33′6 "
6111	16. V. 1969	2890	56°16′5	137°58′6 "
6117	18. V. 1969	3350—3370	56°12′	139°12′1 "
6118	19. V. 1969	2340	56°27′8	136°54′ "
6120	20. V. 1969	1923	56°39′8	136°24′ "
6124	22. V. 1969	180	55°38′2	134°17′ "
6126		532	55°22′5	134°47′ "
6127		1100	55°20′5	134°49′5 "
6131	5. VI. 1969	540—700	53°47′5	163°51′ "
6132—I	6. VI. 1969	880—800	53°45′5	163°38′ "
6132—II	»	1100—830	53°46′	163°41′ "
6143	15. VI. 1969	4860	51°40′	163°00′ "

and the seventh leg joint is 2.5-3 times longer than the eighth.

Distribution. West coast of North America from Canada to Southern California, Gulf of California; depth 50-2,000 m.

Nymphon mixtum Kröyer 1845

Sars 1891:68-71; Lozina-Lozinskii 1935:39-41.

Material: Statinn 6099, 1 spec.

Remarks. This specimen differs from the type in several characters that cause it to resemble other members of the variable group N. grossipes-brevirostre. The eye tubercle is high, conical, pointed, with lateral tubercles and humeri; the eighth joint of the walking legs makes up 60-65% of the length of the seventh; the large claw makes up about 60% of the length of the eighth joint, the small claws equal 60% of the length of the large claw. These are characters typical of N. mixtum tuberculatum Losina-Losinsky. A certain shortening of the eighth leg joint as against that of the Norwegian specimens is also observable in the specimens collected along the Atlantic coast of North America (Hoek 1881: 44, Plate III, Fig. 9-12). Our specimen also differs in that the second and third joints of the palpus are of equal length, as in N. heterospinum Hedgpeth, while the fourth joint is half the length of the fifth, which is typical of N. sluiteri Hoek. On the sole or underside of the eighth leg joint there are 2-3 spines, equal to or somewhat longer than the thickness of the joint. These spines are situated on the proximal part of the sole, whereas in the distal part the spines are about half as long -- a character that creates a similarity with N. grossipes var. longidactylus Losina-Losinsky and N. heterospinum Hedgpeth.

Distribution. Arctic-boreal species. The typical form N. mixtum lives in southern, relatively warm regions of the Barents Sea, in the North Atlantic and the North Pacific at 18-760 m. In the northern part of the Barents Sea, the Kara Sea and the Sea of Okhotsk the typical form is absent and is replaced by a subspecies — N. mixtum tuberculare Losina-Losinsky. The statement by Ohshima (1936) that N. mixtum had been found in the Sea of Japan is, in the view of Hedgpeth (1949) erroneous.

Nymphon dissimilis Hedgpeth 1949

Hedgpeth 1949:262-63.

Material: Station 6132-I, 1 spec.

Remarks. Our specimen is somewhat larger than the holotype: the length of its body is 8.5 mm, the proboscis measures 3.0 mm, the abdomen, 1.2 mm; the seventh leg joint is by 25% shorter than the eighth (in the type specimen, it is half the length). The spines on the eighth leg joint are somewhat shorter than in Hedgpeth's figure.

Distribution. Pacific, Aleutian Islands (Near and Rat islands), at 800-1,910 m.

Genus Heteronymphon Gordon 1932

Heteronymphon bioculatum Turpaeva, 1956

Turpayeva, 1956: 67-72; 1971:280.

Material: Station 6101, 2 spec. (1 male with cocoons); 6105, 1 spec.; 6127, 2 spec. (female and male with cocoons).

Remarks. The specimen from station 6105 is large (length of body 3.2 mm) with a solid, thick chitin, the eyes are almost unnoticeable, the limbs are covered with fine setae, which are densest on the long leg joints. In the specimen from station 6101 the chitin is thin, the eyes are clearly observable, the legs are almost bare of setae. The male from station 6127 has elongated cocoons on the third limb; it differs from the type in its somewhat curved eighth leg joint and a shorter small terminal claw, whose length equals half the eighth joint.

Distribution. Sea of Okhotsk and Bering Sea, Kurile-Kamchatka 181
and Aleutian trenches, Gulf of Alaska, 800-3,940 m.

Heteronymphon birsteini (Turpaeva 1955)

Turpayeva 1955:322-24; 1956:67-72.

Material: Station 2078, 5 spec. (incl. holotype); 3353, 1 spec.

Distribution. The species has been found only twice in the "Vityaz'" collections: in the Kurile-Kamchatka and the Aleutian trenches at 1,060-1,600 m.

Heteronymphon sp.

Material: Station 4177, 1 spec. Young specimen, not determinable. It marks the first find of a member of Heteronymphon along the coast of North America.

FAMILY PALLENIDAE WILSON

Genus Pallenopsis Wilson 1881

Pallenopsis longiseta Turpaeva 1958

Turpayeva 1958:359-61.

Material: Station 26, 1 spec.; 976, 1 spec.; 4265, 1 spec.

Distribution. The species has been found in the Sea of Okhotsk and the Bering Sea and the subtropical zone of the Pacific at 60 miles from the coast of Mexico at 1,228-3,820 m.

FAMILY AMMOTHEIDAE DOHRN

Genus Ascorhynchus Sars 1877

Ascorhynchus japonicus Ives 1892

Loman 1911:5; Ohshima, Kishida 1947:292; Utinomi 1971:333.

Material: Station 26, 1 spec; 3578, 3 spec.; 6120, 2 spec. (1 juvenile).

Distribution. North Pacific (from coast of Japan to Gulf of Alaska) and Sea of Okhotsk, 53-1,920 m.

FAMILY PHOXICHILIDIIDAE SARS

Genus Anoplodactylus Wilson 1878

Anoplodactylus typhlops Sars 1888

Fig. 1

Sars 1888, 1891:29-30; Möbius 1901:53; Carpenter 1905:5; Stephensen 1933:44-45; 1936:29-30; 1937:1-13; Hedgpeth 1948:228-29; Stock 1955: 235-36.

Material: Station 6105, 2 spec. (male and female); 6106, 1 spec. (male); 6118, 1 spec. (male).

In the pantopod literature available to us there are descriptions only of females of this species. We are providing a description of the male caught at station 6118.

Description. The body is well-proportioned, bare, the segments are not completely fused, sutures are observable only between the first

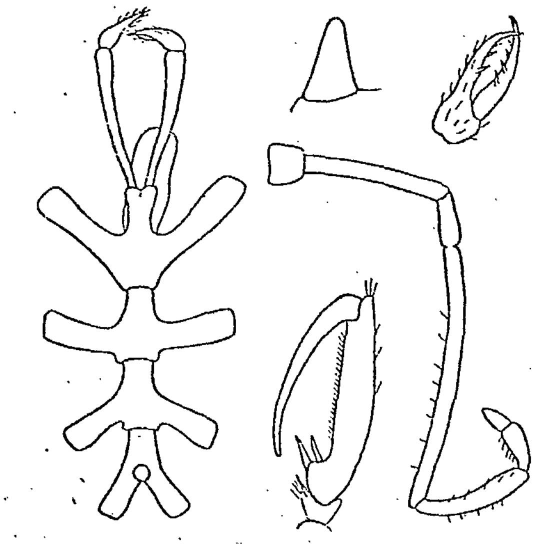

Fig. 1. Anoplodactylus typhlops G.O. Sars. 1 -- general view from dorsal side; 2 -- abdomen; 3 -- second joint of second limb; 4 -- third limb; 5 -- seventh and eighth leg joints.*

and second and second and third segments. The eye segment is drawn out over the base of the proboscis into a narrow protuberance, whose length amounts to 1/3 the length of the segment. The transverse processes are longest on the anterior segment, becoming gradually shorter on the following segments, and are divided by wide intervals. The proboscis is some- 182
what longer than the eye segment, it is rounded at the end, somewhat widened in the middle and has a constriction at the boundary of the second third of its length. The eye tubercle is low, reduced, situated at the forehead margin, eyes are lacking. The abdomen is short, obtusely conical, directed vertically upward. The first limb pair is two-jointed. The thin first joint is somewhat longer than the proboscis, slightly widened in the distal part; the second joint is half the first; the fingers,

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* Identifying numbers omitted in drawing. -- TRANSL.

curved at the interior margin, have 3-5 large denticles, the dactylus is twice as large as the basal part. On the distal part of the first and on the second joint there are short setae.

The third limb pair is nearly 1½ times longer than the body, thin. The third joint is the longest, equal to nearly half the length of the limb, slightly curved and has in the proximal part an annular inflation, which is a vestige of the fusion of two joints. The second and fourth joints have almost the same length, the fifth is narrow in the proximal part and wide in the distal one, the sixth is short, wedge-shaped. The third and fourth joints have short, simple setae along their entire length, the fourth has, in additinn, very fine hair-like setae arranged in a band on the side of the joint opposite to the row of setae. The legs are nearly five times longer than the body, thin. The first and third joint are of the same length, the second is three times longer than each of them, the fourth is nearly 1½ times the combined length of the first three. The fifth and sixth joint have the same length and are somewhat longer than the fourth, the sixth is noticeably thinner than the fifth, the seventh is short, wedge-shaped, and has a cluster of setae at the top, in the lower part there are several spines, one of which 183
is usually larger than the rest. The eighth joint nearly equals the second, it is curved in the proximal part and straight in the distal, it has a small heel with three large spines, two of which are placed together, while the third, largest, is unpaired and situated in the proximal part of the heel. The sole is straight and bears one row of small, nearly identical spines. The large claw is long, by 1/5 shorter than the eighth joint, slightly curved. The small claws are rudimentary.

Dimensions (in mm)

Body	3.15	3rd limb	5.0
First segment	1.05	1st joint	0.25
Second segment	0.75	2nd joint	1.00
3rd & 4th segments	1.35	3rd joint	2.30
Proboscis	1.4	4th joint	0.85
Abdomen	0.3	5th joint	0.35
Transverse processes		6th joint	0.25
1st pair	1.0	1st leg	14.9
2nd pair	0.85	1st joint	0.5
3rd pair	0.7	2nd joint	1.5
4th pair	0.5	3rd joint	0.5
1st limb	2.25	4th joint	3.5
1st joint	1.5	5th joint	3.7
2nd joint	0.75	6th joint	3.7
		7th joint	0.1
		8th joint	1.4
		Large claw	1.1

On the long joints of the legs and on the upper side of the eighth joint there are sparse setae.

In the female from station 6105 the third pair of limbs is lacking, the abdomen is cylindrical as in the holotype, the males from stations 6106 and 6105 are identical to the female from 6105.

Distribution. North Atlantic (Norway, Ireland), Caribbean Sea, 180-1,060 m, Gulf of Alaska, 2,340-3,620 m.

FAMILY COLOSSENDEIDAE HOEK

Genus Hedgpethia gen. nov.

Diagnosis. Body elongated, consisting of four unfused segments. The first segment is the longest, exceeding the second more than $1\frac{1}{2}$ times. The transverse processes are separated by intervals not exceeding the diameter of the processes. The proboscis is massive, considerably longer than the body, very wide in the middle, sometimes there is a short neck. The abdomen is very small, located almost ventrally and directly vertically downward. The first limb is lacking, the second and third limbs have 10 joints.

The type species is Colossendeis articulata Loman 1908.

Remarks. This genus embraces four pantopod species which were previously placed in the genus Colossendeis: H. articulata (Loman), H. dofleini (Loman), H. californica (Hedgpeth) and H. brevitarsis (Losina-Losinsky). All these species differ from members of Colossendeis in the complete separation of the body into segments, the fusiform proboscis, the small size and ventral location of the abdomen. These differences caused Stock (1958) to transfer these species from Colossendeis to Rhopalorhynchus.

While recognizing the complete appropriateness of excluding this group of species from Colossendeis I cannot, however, agree to adding them to Rhopalorhynchus. All members of Rhopalorhynchus have on the dorsal side of the proboscis a tooth-like protuberance, a character that previously served as a criterion for segregating Rhopalorhynchus and Colossendeis. Members of Hedgpethia lack this protuberance. The proboscis in Hedgpethia is much more massive and longer than in Rhopalorhynchus. The neck of the proboscis, which in Rhopalorhynchus makes up ½ to ¼ of its length, is in Hedgpethia either very small (not over 1/10 of the length), or lacking altogether (Table 2).

The Hedgpethia species also lack the elongated central part of the second and third body segments typical of Rhopalorhynchus members, so that the length of the first segment represents only ¼ to ½ the length of the second.

Hedgpethia also differs from Rhopalorhynchus in its distribution, as was noted by Stock (1958), who divided the genus Rhopalorhynchus into two sections -- kroeyeri and articulatum. Hedgpethia's habitat is located in the North Pacific, while that of Rhopalorhynchus is located mainly in the Indian-West Pacific.

Hedgpethia articulata (Loman, 1908)

(Fig. 2)

Colossendeis articulata Loman 1908:22, Pl. VI, Fig. 66-73.

Material: Station 6106, 1 spec. (female).

Remarks. The general structure of this specimen, the reduction of the eye tubercle, the length and shape of the proboscis and the abdomen, the structure of the limbs lead us to place it in the species H. articulata, described from the Banda Sea. A substantial difference from the holotype consists in the presence of a false claw at the distal end of the tenth joint of the third limb. The claw is made up of a relatively large mobile talon, twice as large as the flat lanceolate spines of the joint, and of

(Text cont. on p. 352)

Table 2. Dimensions and proportions of parts of Rhopalorhynchus (Stock 1958) and Hedgpethia (by holotypes)

Species		Length, mm		Length ratios, %		
		Body	Probosc	Prob./ Body	Neck/ fusiform part of probosc.	1st/ 2nd segm.
Rh. kroeyeri	♂	5,40	4,73	87	76	30
»	♀	6,23	5,44	87	55	39
Rh. lomani	♂	6,70	5,2	78	62	38
»	♀	5,74	6,86	120	50	50
Rh. sibogae	♂	6,80	6,67	98	72	31
»	♀	7,27	6,80	94	46	40
Rh. pedunculatum	♂	3,70	3,50	92	105	25
»	♀	4,04	4,47	110	148	28
Rh. clavipes		5,40	5,00	92	71	41
Rh. gracillimum		3,71	3,87	104	57	52
Rh. mortenseni		7,27	7,06	97	71	31
H. articulata		2,90	5,20	180	—	157
H. dofleini		4,00	6,00	150	10	160
H. californica		3,75	5,50	147	8	160
H. brevitarsis		8,00	13,5	169	—	168

Table for determining species of the genus Hedgpethia

1(2) Eye tubercle low, eyes not developed; proboscis in distal third cylindrical and constricted almost to half its maximum diameter........................ H. articulata.

2(1) Eye tubercle high, eyes developed; proboscis in the distal third broad and narrowing conically............3

3(4) On the distal joints of the third limb there is one row of marginal spines, the tenth joint of the third limb has only one underdeveloped terminal talon. Soles of seventh and eighth joints of the legs are bare.........H. dofleini

4(3) On the distal joints of the third limb the marginal spines are arranged in several rows, on the tenth joint of the third limb there is a distinct small claw. The soles of the seventh and eighth joints of the legs are covered with small setae..5

5(6) The proboscis, in its central and distal parts, is cylindrical; the seventh leg joint is half the length of the slightly curved eighth joint; the large claw is less than half the length of the eighth leg joint.....H. brevitarsis

6(5) The proboscis is fusiform, the seventh leg joint is equal to or slightly longer than the eighth; the large claw is more than half the length of the eighth joint..H. californica.

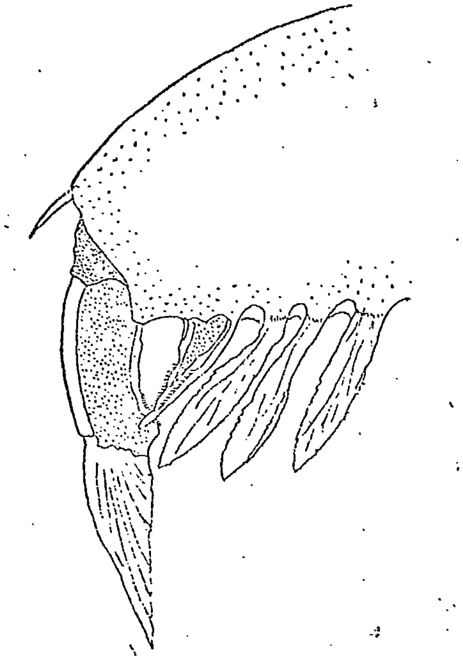

Fig. 2. Hedgpethia articulata (Loman)
Distal part and terminal talon on tenth joint of third limb.

an opposite immobile short wedge-shaped spine. The mobile talon consists of a massive basal part and and equally long distal part, having the appearance of a thin, transparent lamina with a slightly serrate inner margin. The inner margin of the talon is concave, which increases the gap within the claw, and, where it meets the immobile spine, it has a row of very small denticles. Two analogous rows of denticles are located in the distal half of the immobile spine, along the innner margin. Such a false claw on the tenth joint of the third limb is also present among the other species of the genus, except for H. dofleini. That it was not noted in the original description of C. articulata is apparently due to lack of attention.

Our specimen is somewhat smaller than the holotype, its abdomen is proportionately longer, it is directed obliquely downward, the legs and the second limb are shorter, while the third limb is longer than in Loman's specimen. There are also differences in the proportions of the leg joints: in the holotype the fourth and sixth joints are of the same length, and the fifth is nearly 1½ times longer than either; in our specimen the fourth joint is only 1/10 shorter than the fifth and nearly 1½ times longer than the sixth. Also, in the holotype the sixth joint of the second limb is longer by 1/5 than the fourth, while in our specimen they are the same.

Dimensions of *H. articulata* (in mm)

	"Vityaz'" spec. (fem.)	Holotype (male)
Body	2.9	3.5
Proboscis	5.2	6.25
Abdomen	0.35	0.2
2nd limb	11.25	9.0
3rd limb	9.1	10.0
Leg of 3rd pair	22.0	37.0
4th joint	6.5	8.3
5th joint	7.25	11.8
6th joint	4.7	8.3

Distribution. Banda Sea, depth 1,944 m; Gulf of Alaska, depth 3,610 m.

Hedgpethia californica (Hedgpeth 1939)

Colossendeis californica Hedgpeth 1939:458; Hilton 1943:4.
C. chitinosa Hilton 1943:4; Hedgpeth 1949:301; Stock 1954:161;
    Utinomi 1955:34, 1971:337; Lozina-Lozinskii, Turpayeva,
    1958:23.
C. bicornis Lozina-Lozinskii, Turpayeva 1958:27.

Material: Station 6089, 1 spec.; 6099, 7 spec.; 6100, 1 spec.; 6126, 2 spec.

Remarks. The scientific literature indicates great similarity among *Colossendeis californica*, *C. chitinosa* and *C. bicornis* (Hedgpeth 1949; Lozina-Lozinskii, Turpayeva 1958). The "Vityaz'" collections turned up forms transitional among these "species." A revision of our old material (Lozina-Lozinskii, Turpayeva 1958) and study of the collections from Cruise 45 of the "Vityaz'" lead to the conclusion that these three forms should be regarded as subspecies of a single fairly variable species *H. californica*.

Description. Body smooth, elongated-oval, fully segmented. The first three segments widen at the posterior margin and have on the dorsal side chitinous inflations in shape of rolls of drums, often with a small conical tubercle in the centre. The first segment is the longest, 1½ times as long as the second, the length of the following segments decreases toward the posterior end of the body. The first segment forms a short and broad neck that widens anteriorly; at the frontal margin, above the base of the proboscis there is a small notch. In some specimens one may observe on either side of the notch two usually small tubercles. The eye tubercle is high, with an elongated, conical top, it varies in shape and is located in the anterior half of the first segment, at the boundary of the first third or fourth of the latter's length. The height of the eye tubercle in various specimens makes up 50 to 100% of the length of the first segment. The eyes are pigmented (sometimes slightly), are situated below the centre of the eye tubercle, and are usually convex. The anterior eye pair is often larger than the posterior. The transverse processes are shorter than the width of the body, and are divided by intervals whose width is less than or equal to the diameter of the processes. The proboscis is massive, $1\frac{1}{2}$ to 2 times longer than the body, fusiform, curved downward, in the proximal part with a well-developed neck, whose length may attain 1/5 the length of the proboscis. At the boundary between the first and second third of the length of the proboscis there is an annular constriction, in some specimens highly indistinct. The 187 abdomen is very small, ventral, directed vertically downward. The first limb is lacking, the second limb is ten-jointed, by 1/3 to $\frac{1}{2}$ longer than the proboscis, with a few setae on the last joints. The third joint is the longest, the fifth equals 30 to nearly 60% of the third joint, the seventh joint is usually shorter than the eighth, the ninth is longer than or equal to the tenth. The third limb is ten-jointed, two to three times longer than the body. The fourth joint is as long as , or slightly longer than, the sixth. The terminal joints are curved into a spiral and bear on the inner margin several rows of long lanceolate marginal spines. The tenth joint has a small claw formed of a massive terminal talon and an opposite large spine, whose margin, on the talon side, is finely serrate. The terminal talon makes up 1/5 to 1/3 the length of the tenth joint. The legs are 6-8 times longer than the body, thin and bare. The first three joints are short, the second is the longest of the three, the third is usually somewhat longer than the first, the fourth is 1.3 to 2 times longer than the body, the fifth is somewhat longer but nearly half as thin [sic] as the fourth, the sixth is somewhat shorter than the fourth. On the soles of the seventh and eighth joints there is a row of small setae of the same length. The main talon is slightly curved, its length is 50-100% the length of the eighth leg joint.

Analogously to many widely distributed pantopod species, this species is subject to considerable variation. Variation affects the general dimensions of the animal, the shape of the body, the ratios of the lengths of the various parts, the height and shape of the eye tubercle, the sizes of the tubercles at the frontal margin, etc. Study of variation in H. californica confirms its division into three subspecies: californica californica, c. chitiosa, and c. bicornis (Table 3).

The subspecies californica californica is characterized by a relatively large body, very long legs (nearly 8 times the body) and a relatively low eye tubercle with protruding eyes situated in the central part of the first body segment. The proboscis has a barely discernible constriction; the fifth joint of the second limb is half the length of the third; the small talon on the third limb is nearly twice as along as the immobile spine and attains 1/3 the length of the tenth joint, the immobile spine on the inner margin of the claw is very finely serrate; the fourth, fifth and sixth joints of the legs are very long, each being nearly twice the length of the body; the terminal little talon of the walking legs is approximately half the length of the eighth joint. Some specimens have distinct small tubercles at the frontal margin of the first segment.

H. c. californica is somewhat smaller than c. chitinosa, has relatively shorter legs (six times the length of the body). The eye tubercle is located near the frontal margin, very high, attaining the length of the first body segment, with a greatly elongated, sharp point, the proboscis has a distinct annular constriction; the fifth joint of the second limb has one third the length of the third; the talon on the third limb is short, equalling approximately 1/5 the tenth joint and exceeds only slightly the length of the immobile spine; the latter is finely serrate on the inner side; the fourth to sixth joints of the legs are less than twice as long as the body; the terminal talon of the walking legs equals the eighth joint.

H. c. bicornis is similar in its dimensions to c. californica, its eye tubercle is nearer the frontal margin than in c. chitinosa at the boundary of the first quarter of the length of the first segment, of the same shape, but higher; the proboscis has a distinct annular constriction; the fifth joint of the second limb is half the length of the third; the talon on the third limb is 3.5 times shorter than the tenth joint, the immobile spine is only a little shorter than the terminal talon, with distinct serration on the inner margin; the fourth to sixth joints of the legs average 1½ times less that the body; the main talon of the walking legs is usually equal to or somewhat shorter than the eighth joint. At the frontal margin of the first segment there are usually distinct tubercles.

The "Vityaz'" collections and those kindly made available by the TINRO expedition contain typical representatives of c. chitinosa and c. bicornis, as well as forms that may be regarded as transitions among the three subspecies of H. californica. 189 Thus, in the specimens of c. bicornis described by us (Lozina-Lozinskii, Turpayeva 1958) from the area of the Kurile Islands, the main talon of the legs is little more than half as long as the eighth joint -- a character causing them to resemble c. chitinosa. Among the specimens of c. californica collected in the Gulf of Alaska (station 6100, 6126) the fifth joint of the second limb is only half the length of the third; in this character they resemble c. chitinosa, but they differ in the height and location of the eye tubercle and the length of the main leg talon. In the specimen of c. chitinosa described by Stock (1954) from the Korean Strait the terminal talon of the third limb is short, as in c. californica.

In the collections of Utinomi (1955) there are also specimens that deviate from the type. The talon of the third limb, judging from his figure, is very short, the main talon of the legs is nearly equal to the eighth joint, but the eye tubercle is relatively low, the same as in specimens of c. chitinosa from the

Table 3. Size of body and ratios of parts among subspecies of Hedgpethia californica (Hedgpeth)

	Length ratios (%)								
	Number of specimens	Body length, mm	Proboscis/body	1st segment/body	Distance from forehead to eye tubercle/1st segment	Fifth/third joint of 2nd limb	Seventh/eighth leg joint	Main talon/8th leg joint	Height of eye tubercle/1st segment (in brackets — number of spec.)
H. c. chitinosa									
Bering Sea	8	5,0±0,81	160±11,0	37,1±4,3	33,7±3,2	50,5±3,9	105,7±6,7	55,0±6,0	73,2 (1)
Gulf of Alaska	7	4,1±0,55	144±20,2	37,9±1,2	35,2±4,2	54,0±4,2	106,7±7,9	61,1±6,3	57,1±11,0 (7)
Aleutian trench	1	5,2	157	42,3	36,4	50,0	—	—	50,0 (1)
Komandor Islands	3	4,7	166	33,3	33,3	56,8	107,5	67,7	—
Kurile-Kamchatka tr.	5	5,5±0,55	180±19,2	39,2±2,8	35,5±3,4	50,0±3,3	116,9±11,0	52,7±6,5	47,8±5,3 (5)
Average, subsp.	24	4,9±0,7	160±18,3	37,5±3,8	34,3±3,4	52,3±4,4	108,0±8,5	58,4±8,4	52,8±10,8 (4)
H. c. californica									
California (holotype)	1	3,75	147	33,3	—	33,8	112,5	93,6	100 (1)
Gulf of Alaska	3	2,9	149	39,0	27,5	56,7	99,0	80,2	98,7 (3)
H. c. bicornis									
S. of Okhotsk (holo.)	1	4,3	142	39,5	25,0	57,1	106,0	100	77,0 (1)
" " " (para.)	11	3,8±0,74	165±8,2	36,8±4,5	21,2±4,5	58,9±5,6	102,5±9,3	97,8±5,5	80,0 (3)
Kurile Islands	3	3,1	163	44,1	—	55,4	99,7	56,7	—

Bering Sea and the area of the Kuriles, the fifth joint of the second limb is half the third joint, the tubercles on the frontal margin seem to be lacking (they are noted neither in the text nor shown in the figure).

The ancestral form of this species may well have been *H. c. chitinosa*. As it migrated and adapted to new environments, two new subspecies originated in different regions, which differed from the basic form in similar morphological changes: a decrease in size, a more compact body, shortening of limbs, shift of the eye tubercle toward the frontal margin, increase in the distal constriction of the proboscis, reduction of the terminal little talon on the third limb, elongation of the main talon of the walking legs.

Distribution. *H. californica* lives in the North Pacific from the coast of California to the Japanese Islands, in the Bering Sea, the Sea of Okhotsk and the Sea of Japan. In the main part of this extensive habitat -- in the Bering Sea and in the Pacific from Japan to the Gulf of Alaska -- we find the subspecies *c. chitinosa*. The subspecies *c. bicornis* has been noted only in the Sea of Okhotsk, and *c. californica* along the Pacific coast of North America. The species is relatively eurybathic, it lives in the sublittoral zone and the upper bathyal zone (to 20-785 m). The Sea of Okhotsk subspecies has been observed at 64-1,000 m.

Conclusion

The collection of pantopods gathered in the Gulf of Alaska and adjacent parts of the Pacific consists of eurybathic forms that live on the continental slope and the ocean basin. Here we find sublittoral-bathyal forms -- *Nymphon mixtum*, *N. pixellae*, *Ascorhynchus japonicus*, *Hedgpethia californica*; bathyal forms: *Nymphon dissimilis* and *Heteronymphon birsteini*; bathyal-abyssal forms: *Heteronymphon bioculatum*, *Pallenopsis longiseta* and *Anoplodactylus typhlops*; the abyssal species *Hedgpethia articulata* and *Nymphon procerum*, which penetrates to the upper horizon of the ultra-abyssal zone.

Most of these species are found only in the North Pacific. Some of them live from Japan to the Gulf of Alaska: *Heteronymphon bioculatum*, *Ascorhynchus japonicus*, *Hedgpethia californica chitinosa*. *Heteronymphon birsteini* has thus far been found only in the Kurile-Kamchatka and Aleutian trenches, *Hedgpethia articulata* has been found in the Banda Sea and in the Gulf of Alaska. Other species -- *Nymphon pixellae* and *Hedgpethia californica californica* -- are known only in the northeastern Pacific from Canada to Southern California. *Nymphon dissimilis* has been found only in the area of the Aleutians, and *Pallenopsis longiseta* has been found in the Sea of Okhotsk and the Bering Sea and the subtropical waters of the Pacific near California.

Three species are also found outside the Pacific. The 190
deep-sea *Nymphon procerum*, described from the South Pacific (near Chile), occurring widely in the northern trenches, is

also found in the central part of the North Atlantic at 4,600 m (Fage 1951). The shallow-water N. mixtum, known from the boreal region of the Atlantic and forming in the arctic seas and the Sea of Okhotsk a special, apparently cold-loving subspecies is represented in the collections from the Gulf of Alaska by a specimen that is morphologically nearer the boreal form than the cold-loving subspecies. Anoplodactylus typhlops, which is widely found in in the Atlantic (from Norway to the Caribbean) in the sublittoral and upper bathyal zone, has been found for the first time in the Pacific, where it descends to the abyssal zone.

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COMPOSITION AND DISTRIBUTION OF BRACHIOPODS AMONG THE BENTHOS OF THE GULF OF ALASKA

By O. N. Zezina

Until very recently, the brachiopods of the Gulf of Alaska were known only from occasional finds made by American expeditions along the coasts of the Alaska Peninsula, the Shumagin Islands, Kodiak Island, the Alexander Archipelago and the Queen Charlotte Islands (Dall 1877, 1920; Taylor 1895; Hertlein, Grant 1944; Eyerdam 1960-61). In these studies we find information as to the discovery of six species along the west coast of North America from Unimak Island to the Queen Charlotte Islands: Hemithyris psittacea, Terebratulina unguicula, Terebratalia transversa, Laqueus californianus, L. vancouveriensis, Diestothyris frontalis.

The paucity of the finds (until the activities of the Soviet expeditions the brachiopods of the Gulf of Alaska were known from only nine stations occupied only near the shores) made it impossible to form an assessment as to the spatial distribution of these organisms in that region.

During the expeditions of the All-Union Scientific Research Institute for Marine Fisheries and Oceanography (VNIRO) on the ships "Pervenets" (1960-6;), "SRT 4454" (1961), "Orlik" (1961-62) and "Zhemchug" (1962), as well as during the joint expedition of the Institute of Oceanography of the

Academy of Sciences of the USSR and the Pacific Institute for Fisheries and Oceanography (TINRO) in 1969 on the "Vityaz'" (Cruise 45) and the "Ekvator" (Cruise 3), brachiopods were collected from 82 stations in the Gulf of Alaska (Fig. 1) in 90 samples taken by bottom grab, trawl, and bottom drag at depths ranging from 16 to 3,460 meters. As a result of these activities the brachiopod fauna of the Gulf of Alaska turned out to be one of the best studied in the World Ocean.

The collection analyzed by me consists of 652 specimens collected live, 133 empty shells and over 200 valves. It includes members of eight species, of which three are new for the regional fauna (_Neorhynchia strebeli_, _Frieleia halli_, _Terebratulina kiiensis_). The analyzed material, in combination with previously published data, makes it possible to provide a description of the composition and distribution of brachiopods in the Gulf of Alaska, to trace the succession of species with increasing depth on the continental shelf and slope, as well as to cite certain data on the quantitative distribution of brachiopods and assess their role in benthonic biocenoses.

I should like to take this opportunity to express my thanks to the members of VNIRO V. V. Shevtsov and V. N. Semenov, who made available to me brachiopods collected by them in 1960-62, as well as the staff member of the Biological Station of the Fisheries Service of Canada at Nanaimo, Dr. D. B. Quayle, who kindly made available to me brachiopod specimens collected along the Queen Charlotte Islands and Vancouver Island.

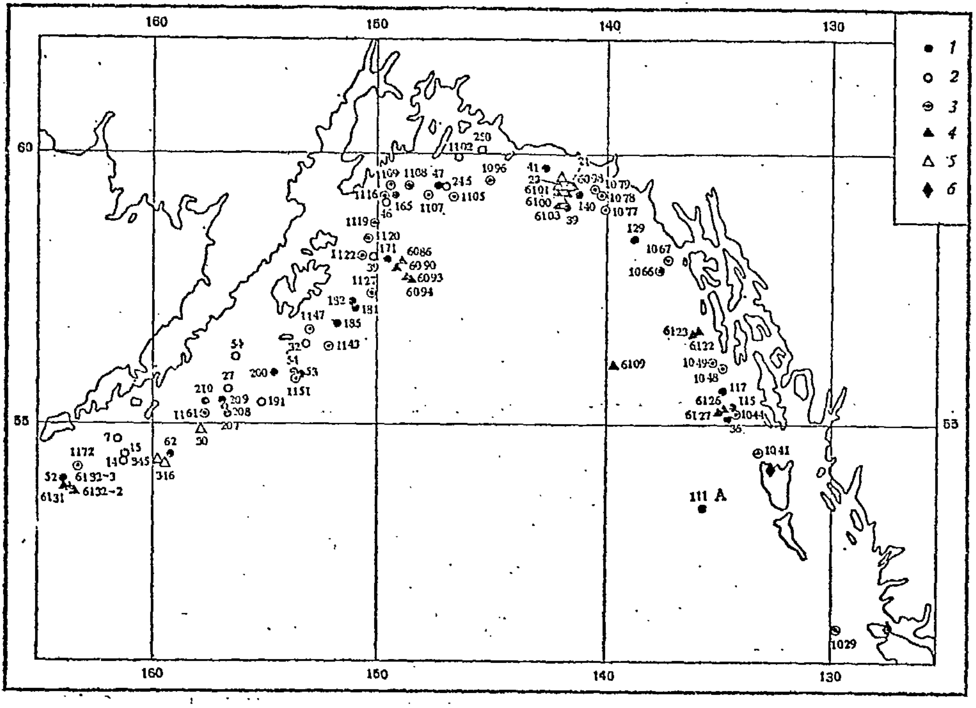

Fig. 1. Location of stations with brachiopod finds in the Gulf of Alaska. 1 -- "Pervenets" 1960, 1961; 2 -- "SRT-4454, 1961, and "Orlik," 1961, 1962; 3 -- "Zhemchug," 1962; 4 -- "Vityaz'" 1969; 5 -- "Ekvator" 1969; 6 -- Fisheries Service of Canada, 1963-64.

Systematic Composition and Distribution of Species

According to currently accepted classification of brachiopod (Williams, Rowell et al., 1965), the species found in the Gulf of Alaska occupy the following position in the system:

Type Brachiopoda

Class Articulata

Superfamily Rhynchonellacea

Family Basiliolidae Cooper 1959

Genus *Neorhynchia* Thomson 1915

1. *Neorhynchia strebeli* (Dall 1908)

Family Hemithyrididae Rzhonsnitskaya 1956

Genus *Hemithyris* Orbigny 1847

2. *Hemithyris psittacea* (Chemnitz 1785)

Family Frieleiidae Cooper 1959

Genus *Frieleia* Dall 1895

3. *Frieleia halli* Dall 1895

Superfamily Terebratellacea

Family Cancellothyrididae Thomson 1926

Genus *Terebratulina* Orbigny 1847

4. *Terebratulina unguicula* (Carpenter 1864)

5. *Terebratulina kiiensis* (Dall et Pilsbry 1891)

Family Dallinidae Beecher 1893

Genus *Terebratalia* Beecher 1893

6. *Terebratalia transversa* (Sowerby 1846)

6a. *Terebratalia transversa caurina* (Gould 1850) 194

Genus *Diestothyris* Thomson 1916

7. *Diestothyris frontalis* (Middendorff 1849)*

Family Laqueidae Hatai 1965

Genus *Laqueus* Dall 1870

8. *Laqueus californianus* (Koch 1848)

9. *Laqueus vancouveriensis* Davidson 1887

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* This species, which occurs in the North Pacific from the Bay of Peter the Great and the Sangar Strait to British Columbia at 0-435 m, has been known to occur in the region under study at the Shumagin Islands (Dall 1920). It is not present in our material from the Gulf of Alaska.

1. Neorhynchia strebeli (Dall 1908)

Hemithyris strebeli Dall 1908:441-42
Neorhynchia strebeli Dall 1920:290; Hertlein, Grant 1944:57, Pl. 20, Figs. 8-15; Cooper 1959:35, Pl. 2, Figs.12-23; Muir-Wood 1961:Pl. 7, Figs. 6-8.

Occurrence of holotype: "Albatross," station 4721, 8°07'05" south, 104°10'05" west, depth 3,811 m.

Material. "Vityaz'": 6109, T* (3,460 m, 2 spec.).

Distribution. Until now the species was known from five deep-sea stations of the "Challenger," "Albatross," and "Iltenin," in the southeastern Pacific and in the Coral Sea. Depth of habitat 2,560-3,950 m.

Remarks. The find of N. strebeli in the Gulf of Alaska has considerably expanded our notion concerning the habitat of this deep-sea species, which turned out to be living in the Pacific Ocean basin not only in the Southern but also in the Northern Hemisphere.

2. Hemithyris psittacea (Chemnitz 1785)

Anomia rostrum psittaci Chemnitz 1785:106, Pl. 78, Fig. 713a-c (fide Hertlein, Grant 1944).
Anomia psittacea Gmelin 1790:3348 (fide Hertlein, Grant 1944).
Terebratula psittacea Lamarck 1819:248 (fide Hertlein, Grant 1944).
Rhynchonella psittacea Davidson 1887:163-68, Pl. 24, Fig. 1-8.
Hemithyris psittacea Dall 1920:284-86; Hatai 1940:197-203, Pl. 6, Fig. 64-67, 72-73, 77-78; Wesenberg-Lund 1941:15, 16; Hertlein, Grant 1944:46-53, Pl. 3, Fig. 12-13; Konzhukova 1957:71-73, Pl. 9, Fig. 13-16; Cooper 1959:Pl. 3B, Fig. 12-21, Pl. 4E, Fig. 9-12; Zezina 1970a:436.

Occurrence of holotype. Davis Strait, coast of West Greenland.

Material. "Zhemchug," 1172 B (54 m, 1 spec.).

Distribution. The species has a north-circumpolar habitat.

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* Here and infra, T means trawl, B means bottom grab.

The southern limits of its territory, in the Atlantic Ocean, run from the Gulf of Maine to the northeast of England, and, in the Pacific, from the coast of Kyushu Island (Japan) to the state of Oregon. In the Sea of Japan the species is known from La Perouse Strait to the Noto Peninsula. Depth of habitat 2-1,242 m.

Remarks. The shell of our specimen has very fine, smoothed, radial striation and is nearly black. These characters cause it to resemble *Hemithyris woodwardi* (Adams 1863), which has a perfectly smooth, black shell and is found along the east coast of Japan from 40° to 30° north at depths of 23-269 m. Some investigators (Davidson, 1886; Hatai, 1940; Hertlein, Grant, 1944) regard *H. woodwardi* as a warm-water subspecies of *H. psittacea*.

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3. *Frieleia halli* Dall 1895

Dall 1895:714-16, Pl. 24, Fig. 6, 9-13; 1920:292-93; Thomson 1927:157-58, Fig. 28a, b; Hatai 1940:219-22, text fig. 21; Hertlein, Grant 1944:58-59, Pl. 4, Fig. 6-7; Zezina 1970a: 436-37.

Occurrence of holotype. Cortes Bank along the coast of California, depth 1,799 m.

Material. "Pervenets," 1961: 53/227 B (376m, 1 spec.); "Zhemchug," 1029 B (517 m, 1 shell), 1048 B (310 m, 2 spec., 1 shell), 1096 B (215 m, 2 shells); "Vityaz'" 6089 B (180 m, 2 spec., 4 shell, 8 valves), 6089 T (170 m, 2 shells), 6090 T (455 m, 3 spec, 6 shells, 13 valves), 6090 B (465 m, 8 valves), 6093 T (1,540-1,340 m, 1 valve), 6094 T (2,400 m, 1 valve), 6099 T (292 m, 1 spec., 3 valves), 6100 T (573-534 m, 3 shells) 6100 B (563 m, 1 valve), 6101 T (798-756 m, 2 shells), 6101 B (755 m, 1 valve), 6122 T (1,100-1,180 m, 9 spec., 8 shells, 67 valves), 6122 B (770 m, 1 shell, 5 valves), 6132 B (650 m, 1 spec., 7 valves) 6126 T (560 m, 4 spec.), 6127 T (1,340-1,370 m, 3 spec., 27 valves), 6127 B (1,100 m, 9 valves), 6131 T (310-700 m, 1 shell, 1 valve), 6132, 2T (880-800 m, 1 valve), 6132 3T (1,100-830 m, 50 spec., 33 shells, 71 valves).

Distribution. The species has a North Pacific habitat, bounded on the north by the continental slope of the Bering Sea basin. In the south, it extends along the coasts of Asia to the island of Honshu, and along the coast of North America to San Diego. This is the first find in the Gulf of Alaska. Depth of habitat 38-2,393 m.

4. *Terebratulina unguicula* (Carpenter 1864)

Terebratula unguiculus Carpenter 1864:607 (fide Hertlein, Grant 1944.
Terebratula unguicula Carpenter 1865:201, Fig. 1-4 (fide Hertlein, Grant 1944.
Terebratulina unguicula Dall 1873:177; 1877:156; 1920:300-301; Hertlein, Grant 1944:79-81, Pl. 5, Fig. 9-10, Pl. 6, Fig. 6-7, Pl. 17, Fig. 9, 13-14, 18-19; Konzhukova 1957:19-22.
Terebratulina caputserpentis var. *unguicula* Davidson 1886:25-26, Pl. 5, Fig. 38-40.
Terebratulina caputserpentis unguicula Dall 1895:719-20, Pl. 32, Fig. 2, 5.

Occurrence of holotype. At Vancouver Island, depth not given.

Material. "Pervenets" 1960: 52 B (77 m, 2 spec.), 111A B (112 m, 1 shell), 115 B (182 m, 4 spec.), 117 B (181 m, 1 spec.), 129 B 95 m, 3 shells), 140 B (212 m, 1 spec.), 165 B (135 m,1 spec.), 182 B (136 m, 1 spec.); "Pervenets" 1961: 36 B (260 m, 1 spec.), 39 B (298 m, 1 spec.), 41/206 B (209 m, 1 spec.), 62/238 B (196 m, 2 spec.), "SRT-4454": 7 B (113 m, 1 spec.) 14 B (292 m, 6 spec.), 32 B (95 m, 3 spec.), 46 B (177 m, 2 spec.), 54 B (210 m, 1 spec.); "Zhemchug": (1044 B (245 m, 2 spec.), 1048 B (310 m, 2 spec.), 1049 B (188 m, 1 shell), 1079 B (178 m, 13 spec.), 1105 B (205-290 m, 4 spec., in 2 samples), 1107 B (182 m, 6 spec.), 1119 B (148 M, 2 spec., 1 shell), 1143 B (68 m, 1 spec.), 1151 B (83 m, 1 shell); "Vityaz'": 6089 B (180 m, 1 valve), 6098 B (200 m, 4 spec., 2 shells, 3 valves), 6098 T (200 m, 181 spec., 23 shells), 6099 T (292 m, 5 spec., 2 valves), 6100 T (573-534 m, 2 spec.), 6103 T (1,500 m, 1 valve); "Ekvator": 21 T (220-190 m, 1 spec.), 30 T (120 m, 5 spec.), 345 T (200 m, 2 spec.), 346 T (540-500 m, 30 spec.).

Distribution. The species has a North Pacific habitat and is known from the Avachinskii Bay (Kamchatka) and the Pribilof Islands (57°10' north, 170°00' west) southward to the Korea Strait and the coast of California (Todos Santos Bay, San Lucas Cape). Depth of habitat 25-1,247 m.

Remarks. The species differs from Terebratulina kiiensis in the elongation of the shell along the longitudinal axis and the uniformity of the radial crests on the valve. The morphological differences between the North Pacific T. unguicula and the North Atlantic T. retusa are as yet insufficiently studied.

5. Terebratulina kiiensis Dall et Pilsbry 1891

Terebratulina unguicula var. (?) kiiensis Dall et Pilsbry 1891:18, Pl. 1, Fig. 4-5 (fide Hertlein, Grant 1944).
Terebratulina kiiensis Dall 1895:720, Pl. 32, Fig. 8-9; 1920:307; Hatai 1940:235-37, Pl. 7, Fig. 18-21; Hertlein, Grant 1944:71-73, Pl. 6, Fig. 10, 13; Zezina 1970a:443-446, Fig. 9-10.

Occurrence of holotype. Coast of Kii Province, Japan, depth not given.

Material. "Vityaz'": 6122 T (1,100-1,180 m, 2 spec., 1 shell), 6126 T (560 m, 3 spec.), 6127 T (1,340-1,370 m, 2 spec.), 6132-3 T (1,100-830 m, 28 spec., 2 shells).

Distribution. The species has a North Pacific habitat and is known from Bower's Bank (Bering Sea) to the coast of Kii Province (Japan) and San Nicolas Island (California, 33° north). This is the first find in Gulf of Alaska. Depth of habitat 64-1,258 m and 4,550-4,640 m.

Remarks. The rounded shape of the shell and the uneven height of the radial crests makes it possible to distinguish T. kiiensis from T. unguicula at all growth stages.

6. Terebratalia transversa (Sowerby 1846)

Terebratula transversa Sowerby 1846:94 (fide Hertlein, Grant 1944).
Terebratella transversa Dall 1873:185; 1877:157; Davidson 1887:79-81, Pl. 16, Fig. 6-9.
Magasella radiata Dall 1877:159; 1889:Pl. 6, Fig. 1; Davidson 1887:101, Pl. 18, Fig. 1.
Terebratalia transversa -- Dall 1920:339; Thomson 1927:245; Hertlein, Grant 1944:135-138, Pl. 8, Fig. 10, 15-16, Pl. 9, Fig. 1-7; Paine 1969:337-343.

Occurrence of holotype. Unknown.

Material. "Pervenets": 209 B (97 m, 1 spec.),; "SRT-4454": 27 B (97 m, 1 spec.); "Zhemchug": 1147 B (68 m, 1 spec.), 1172 B (54 m, 1 spec.).

Distribution. The species is known from the Pacific coast of North America from the Shumagin Islands (55°north, 160° west) to Santo Tomas, Lower California (31°30' north, 116°25' west). Depth of habitat 15-1,504 m.

Remarks. The specimens of the type subspecies *T. transversa transversa* studied by us have smooth valves with traces of smoothed radial striae and umbo. The young specimen from station 1172 in the free-swimming* stage (length of shell 4 mm) has distinct radial crests with an arc-like profile, corresponding to the description of *Magasella radiata*.

6a. *Terebratalia transversa caurina* (Gould 1850)

Terebratula transversa caurina Gould, 1850: 347 (fide Hertlein, Grant, 1944).

Terebratula caurina — Gould, 1856; pl. 44, fig. 582 a—d (fide Hertlein, Grant, 1944); Dall, 1870: 119, pl. 6, figs. 1—3.

Terebratella transversa var. *caurina* — Davidson, 1887, pl. 16, figs. 10—12.

Terebratella transversa var. *occidentalis* — Davidson, 1887, pl. 16, figs. 14, 14a.

Terebratella transversa — Dall, 1892, pl. 4, figs. 6—7 (подписи на таблице ошибочно отнесены к fig. 8—9). (captions erroneously referred to fig. 8-9.)

Terebratalia transversa var. *caurina* — Dall, 1895, figs. 12—13.

Terebratalia caurina — Thomson, 1927: 246.

Terebratalia caurina rubescens — Dall, 1910: 96; 1920: 341.

Terebratalia transversa caurina — Hertlein, Grant, 1944: 138—143, pl. 8, figs. 11—14, pl. 15, figs. 7, 12—13, 15—16.

Occurrence of holotype. Puget Sound, depth not given.

Material. Collections of Fisheries Service of Canada (1963): station 153 and 154, Queen Charlotte Islands (Naden Harbour), 16 m, 1 spec., 2 shells.

Distribution. The subspecies is known from the Pacific coast

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* Conjectural translation of "ishmeniform." -- TRANSL.

North America from Kodiak Island to Santo Tomas, California Peninsula. Depth of habitat from line of syzygial low-water to 90 m.

Remarks. The specimens studied by us have a transversely extended shell, closing anteriorly after the sulcate type. The radial striae, with a triangular section, are distinct from the umbo to the margins. The subspecies *T. t. caurina* is usually considered as having a shallow-water habitat as compared with the type subspecies. Our material confirms this view. A number of studies (Davidson 1887; Hertlein, Grant 1944; Paine 1969) note the existence of forms with transitional characters. Descriptions of such forms, however, are lacking, and the segregation of the subspecies is presently based only on specimens with characters that are highly distinct.

8. *Laqueus californianus* (Koch 1848)

Terebratula californiana Koch 1848:38, Pl. 2b, Figs. 21-23 (fide Hertlein, Grant 1944).
Terebratula kochii Küster 1848:39, Pl. 2d, Fig. 1-3 (fide Davidson 1887).
Laqueus californicus Davidson 1887: 112, Pl. 18, Fig. 6-9; Dall 1920: 348-50; Kozhukova 1957:38-54, Pl. 6, Fig. 1-12; Pl. 7, Fig. 1-12.
Laqueus erythraeus Dall 1920:350; Hertlein, Grant, 1944:147, Pl. 21, Fig. 1-7.
Laqueus japonicus Yabe, Hatai, 1934:663, Fig. 19-21, 26; Hatai, 1940: 365, Pl. 5, Fig. 10-19; 23-25.
Laqueus californianus Hertlein, Grant 1944: 144-147, Pl. 13, Fig. 5, 8, 14, text fig. 31; Zezina 1970a:449.

Occurrence of holotype. Coast of California, depth not given.

Material. "Ekvator," station 4-7, multi-depth Isaacs-Kidd trawl, depth 100 m, 2 spec.

Distribution. The species has a North Pacific habitat and is known from Cape Navarin on the Bering Sea southward along the Asiatic coast to Peter the Great Bay, Sangar Strait and Sagami Gulf, and along the American coast to San Diego. Depth of habitat 45-1,600 m.

Remarks. The only whole specimen of this species among the material studied (the second specimen was squashed) has a shell length of 35 mm. The maximum width equals 88% of the length. The specimen is adult, but not old. The brachial valve is covered with an even, thin layer of sponge, except for the part where the shell rested on the substrate.

9. *Laqueus vancouveriensis* Davidson 1887

Laqueus californicus var. *vancouveriensis* Davidson, 1887: 113, pl. 18, figs. 10—13.
Megerlia jeffreysi Dall, 1877: 158 (ex parte); — Davidson, 1887, pl. 19, figs. 8—10 (Non *Frenula jeffreysi* Dall, 1871: 55).
Laqueus jeffreysi — Dall, 1895: 726.
Ladueus californicus vancouveriensis—Dall, 1920: 348.
Laqueus vancouveriensis — Hertlein, Grant, 1944: 147—151, pl. 17, figs. 15—17, pl. 18, figs. 15—21, textfig. 32.

Occurrence of holotype. At Vancouver Island, depth not given.

Material. "Pervenets" 1960: 129 B (95 m, 1 spec.), 171 B (142 m, 1 spec.), 181 B (215 m, 2 spec.), 182 B (136 m, 5 spec.), 185 B (80 m, 2 shells), 200 B (116 m, 2 spec., 1 shell), 207 B (257 m, 1 spec.), 208 B (127 m, 1 spec.), 209 B (97 m, 3 spec.), 210 B (82 m, 1 spec.); "Pervenets" 1961: 47/212 D (127 m, 2 spec.), 54/228 B (177 m, 3 spec.), 62/238 B (196 m, 1 spec.); "SRT-4454": 15 B (101 m, 1 spec.), 27 B (97m, 5 spec, 1 shell), 39 B (132 m, 1 spec.), 46 B (177 m, 1 shell); "Orlik": 1961: 191 B (85 m, 3 spec.), 245 B (208 m, 3 spec.), 250 B (100 m, 1 spec.); 1962: 1102 B (74 M, 2 spec.); "Zhemchug": 1041 B (105 m, 6 shells), 1049 B (188 m, 4 spec., 2 shells), 1066 B (195 m, 2 spec.), 1067 B (135 m, 5 spec.), 1077 B (127 m, 1 spec.), 1078 B (125 m, 2 shells), 1108 B (89 m, 6 spec., 1 shell), 1109 B (100 m, 3 spec., 1 shell), 1116 B (127 m, 2 spec.), 1120 B (76 m, 198
2 spec.), 1122/64 B (102 m, 1 shell), 1127 B (235 m, 1 spec.), 1143 B

(68 m, 2 spec., 1 shell), 1147 B (68 m, 5 spec.), 1151 B (83 m, 2 spec.), 1161 B (78 m, 1 spec.); "Vityaz'": 6089 B (180 m, 1 spec.), 6089 T (170 m, 1 spec., 4 shells, 7 valves), 6098 T (200 m, 66 spec., 17 shells), 6100 T (573-534 m, 1 spec.); "Ekvator": 21 T (220-190 m, 55 spec.), 23 T 195-100 m, 11 spec.), 345 T (200 m, 8 spec.), 346 T (540-500 m, 1 spec.); collection of Fisheries Service of Canada (1963): station 63-8 at Vancouver Island (59 m, 1 spec., 1 shell).

Distribution. Along the Pacific coasts of North America from the Alaska Peninsula to the state of Washington. Depth of habitat 5-540 m.

Remarks. The find of a live specimen of Laqueus vancouveriensis at the "Ekvator" station 346 (500-540 m) has expanded the known habitat of this species in a vertical sense: previously it was known to occur only to a depth of 253 m. Among our collections of L. vancouveriensis with age characteristics, the most common specimens have a length of 28-29 mm. The maximum length of individuals of this species is 32.6 mm ("Orlik," station 1102). The width of adult individuals makes up 79-97% of their

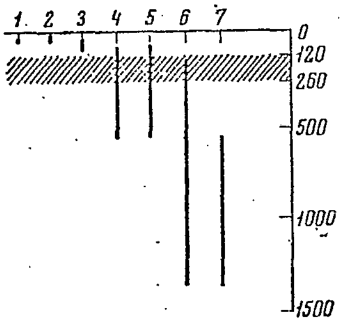

Fig. 2. Vertical distribution of brachiopods on the continental shelf and slope of the Gulf of Alaska.
1 — Hemithyris psittacea; 2 — Terebratalia transversa caurina; 3 — T. t. transversa; 4 — Laqueus vancouveriensis; 5 — Terebratulina unguicula; 6 — Frieleia halli; 7 — Terebratulina kiiensis. Hatching indicates location of shelf edge. (Gershanovich, Kotenev, Novikov, 1964).

length, and only in one specimen does the width exceed the length (104% -- "Orlik", station 191). The shell color varies throughout the entire gamut from green and brown to yellow and pink. The first description of the species (Davidson 1887) derives from one of the extreme variants characterized by the narrowest shell of a greenish tinge. The variations in width and color discovered among our collections exclude these criteria as means of diagnosis for differentiating vancouveriensis and californianus, leaving as the only criterion of the former the maximum dimensions of adult individuals. This circumstance supports the assumption (Davidson 1887; Dall 1920) that vancouveriensis may represent a depressed form of californianus. As the circumstances of the co-existence of the two forms in the Gulf of Alaska are not yet clear, we are, in this paper, treating them as separate species.

* * *

Vertical Distribution of Species and Biogeographical Characteristics of the Region

In the Gulf of Alaska, live brachiopods are found on the continental shelf and slope at depths of 16-1,370 m, as well as in the ocean basin at 3,460 m ("Vityaz'" station 6109). Shells and valves of species inhabiting the slope are found to depths of 2,400 m. Thus, brachiopods are found in the Gulf of Alaska at practically all depths from sublittoral to bathyal.

The vertical distribution of individual species (Fig. 2) shows that with increase in depth there occurs a regular change in the brachiopod fauna. Relatively stenobathic species living only on the shelf are replaced by more eurybathic ones that descend to the bathyal region, and later on by deep-sea endemic species. In terms of depth distribution, the species inhabiting the Gulf of Alaska may be divided into three groups:

(1) Species inhabiting only the continental shelf (Hemithyris psittacea, Terebratalia transversa).

(2) Species inhabiting the lower part of the shelf, its outer margin and the upper slope, the "dumping ground of the deep" (Terebratulina unguicula, Laqueus californianus, L. vancouveriensis).

(3) Species inhabiting the continental slope or margin (Frieleia halli, Terebratulina kiiensis).

(4) A species inhabiting the ocean basin (Neorhynchia strebeli).

As we have noted previously (Zezina 1970a, b), the shelf margin and the "dumping ground of the deep", which correspond to the lower sublittoral zone and the transitional horizon, are the most favorable region for brachiopod life. In some parts of the seas and oceans brachiopods inhabit only this zone. On the average, the largest number of modern brachiopod species have been found in the World Ocean in a range corresponding to the average depth of the outer shelf margin. This situation also applies in the Gulf of Alaska.

A peculiarity of the gulf is the absence in the lower sublittoral zone of some North Pacific species which one might have expected to find there. Thus, our collection contains no specimens of the widely occurring boreal species Diestothyris frontalis. This may be due to the small number of shallow stations occupied. It is not excluded, however, that the Gulf of Alaska is unfavorable for this species, and it is either present in small numbers only, or its habitat is disrupted there.

The north-circumpolar Hemithyris psittacea, one of the coldest-water brachiopod species, is known to inhabit a great vertical range in the Northern Hemisphere. Among our own collections it was found only once, at 54 m, and, it seems, does not penetrate any deeper in the Gulf of Alaska. The specimen in question has a smooth, highly colored shell, similar to the shell of the more warm-water species H. woodwardi. This shows that the waters of the Gulf of Alaska are somewhat too warm for such a cold-water species as psittacea. At the same time, its southern habitat boundary along the American coast of the Pacific runs at the latitute of the City of Astoria (Oregon), and the Gulf of Alaska is far from being the limit of its territory -- yet it is, apparently, a relatively unfavorable region. The relatively warm water of the gulf may be the reason why we do not find along the Pacific coast of North America another north-circumpolar brachiopod species, Glaciarcula spitzbergensis (Davidson), occurring in the boreal waters of the Pacific along the coast of Asia and in the North Atlantic.

In the Gulf of Alaska we were unable to trace any biogeographic boundaries in the brachiopod fauna associated with latitudinal zonation. The species observed here occur in waters of polar, subpolar and subtropical structure, forming North Pacific and north-circumpolar faunal elements.

A special place is occupied by the species Terebratalia transversa and Laqueus vancouveriensis, which are common along the coasts of North America but which had not hitherto been found west of the Shumagin Islands (55° north, 160° west).* In the same area, at the tip of the

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* This may partly be the result of lack of knowledge of brachiopods along the Aleutian island chain.

Alaska Peninsula near Unimak Island we know (Konshukova 1957; Zezina 1970a) of the easternmost finds of North Pacific brachiopods Chismatocentrum sakhalinensis and Terebratalia tisimana, which belong to the Asian shores. This leads us to regard the eastern part of the Aleutian chain 200 as the boundary between two North Pacific brachiopod faunas: Asiatic and American. The correlation coefficient of the two faunas, according to Preston (1962) is fairly high, 0.57, which allows us to view the zoogeographic differences of the adjacent territories — following the method of N. G. Vinogradova (1969) — as having the rank of provinces.

The segregation of the Asiatic and North American brachiopod faunas in the eastern part of the Aleutian chain distinguishes them from a number of other organisms, for whom the Asiatic-American biogeographic boundary runs west of the Aleutians (Gur'yanova 1964). The broad, deep straits in the western part of the Aleutian chain apparently represent a geomorphological barrier for many shallow-water benthonic invertebrates. An analysis of the distribution of brachiopods in the North Pacific shows that for them this barrier is not insurmountable. This may be due both to the eurybathic adaptation of some species (F. halli, T. unguicula, T. kiiensis, L. californianus), and to the broad migration possibilities of all brachiopod species in the larval stage. The existence of a boundary of species habitats in the eastern part of the Aleutian chain cannot be explained in geomorphological terms and can be due only to hydrological differences or the hydrological segregation of the water of the Gulf of Alaska and that of the straits in the Aleutian chain.

According to V. S. Arsen'yev, L. I. Galerkin and V. V. Leont'yeva (1973), "the water transfer in the Alaska current is accompanied by a substantial transformation of the surface and, in particular, intermediate water masses," the temperature in the core of the cold intermediate layer in the Gulf of Alaska is 2° higher than in the eastern Aleutian trench. The current system in the northeastern Pacific (Favorite 1967) produces a separate water circulation that touches the coasts of British Columbia and the Gulf of Alaska and reaches to the Shumagin Islands and Unimak Island. Small, independent whirls are formed around the islands of the Aleutian chain (Arsen'yev 1967). Such a dynamics of the waters results in the segregation of water masses along various parts of the coast line and this, it seems, serves as the biotopic basis for the segregation of the habitats of brachiopod species along the Aleutian Islands and the Alaska Peninsula.

Some Quantitative Assessments and the Role of Brachiopods in Benthonic Communities

Quantitative accounts of brachiopods in bottom-grab and trawl samples show that these organisms occupy an important place in the benthos of the Gulf of Alaska. In the lower sublittoral, upper bathyal and intervening horizons, in biocenoses dominated by sestonophages, brachiopods are numerous, varied, and are sometimes numbered among the leading (or index) forms.

Most numerous in the benthos of the Gulf of Alaska is Terebratulina unguicula, which at a depth of 178 m ("Zhemchug," 1962, station 1079) was found in amounts of 44 specimens per square meter. The other most common and numerous brachiopod species in the gulf (Terebratalia transversa, Laqueus vancouveriensis), even while they are index forms of biocenoses at depths of 70-310 m, do not occur at more than 16-24 specimens per square meter ("Vityaz'" station 6089, 6098; "Pervenets" stations 115, 182, 209, 62/238; "SRT-4454" station 14;"Zhemchug" stations 1048, 1049, 1067, 1107, 1108, 1119, 1147).

One of the most deep-sea brachiopod species in the Gulf of Alaska, Frieleia halli, is found as a rule in 4 to 8 specimens per square meter and is never as numerous as the other species.

The greatest quantity of brachiopods in trawl samples was obtained at 200 m ("Vityaz'" station 6098) and 830-1,180 m ("Vityaz'" stations 6122, 6132-3). In the first instance it was an accumulation of Terebratulina unguicula (181 live individuals in the catch) and Laqueus vancouveriensis (65 live individuals); in the second, of Frieleia halli (up to 50 live individuals) and Terebratulina kiiensis (up to 28 live individuals and many empty shells). 201

In the number of brachiopods the Gulf of Alaska is comparable to the continental coast of the Sea of Japan north of Cape Povorotnyi. There, as has been shown by the investigations of the "Vityaz'" in 1950, Terebratalia tisimana and Laqueus californianus also play a leading role in the benthonic biocenoses at depths of 80-140 m, attaining quantities of 40-44 spec./m^2.

These values, however, are small compared with those observed along northern Norway (Filatova 1938) and the entrance to Shelikhov Bay ("Vityaz'" collections of 1952). In that area of the Barents Sea, Macandrevia cranium is the index form of the biocenosis at 150-350 m, attaining quantities of 400 spec./m^2. At the entrance to Shelikhov Bay at a depth of 120 m, Diestothyris frontalis, according to our own calculations, reaches the same numbers.

The circumstances leading to the formation of massive populations of brachiopods are as yet not fully understood. We know, however, that essential prerequisites for such populations are the presence of a suitable substrate as well as a sufficient amount of suspended food. In the boreal zone the greatest accumulations of articulate brachiopods, as may be seen from data cited, are observed at eulittoral depths, where the brachiopods make up a substantial portion of the sestonophagous belt along the outer edge of the continental margin.

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A NEW FASCIOLARIID (MOLLUSCA, NEOGASTROPODA) FROM THE LOWER ABYSSAL REGION OF THE NORTH PACIFIC *

By V. Ya. Lus

We know of only two species of molluscs of the family Fasciolariidae dwelling in the abyssal region of the World Ocean: Fusus rufocaudatus (Dall 1896) and Troschelia (Thalassoplanes) morchi Dall 1908. Individuals of the former species were found at depths of 2,323 and 3,437 m in the Pacific along the coasts of Guatemala and Peru, and, of the latter, at 4,503 m in the central Pacific (Dall 1896, 1908). In this paper we are describing an abyssal fasciolariid belonging to a new genus and new species and being classified within a new subfamily Brevisiphoninae, owing mainly to the extremely short siphonal process which is not typical of the family as a whole. Individuals of this species were collected from the "Vityaz'" within a narrow depth range in the lower abyssal region: 5,500-6,300 m on the basin of the northwestern Pacific (five stations) and on the boundary between ocean basin and the southern slope of the eastern Aleutian trench (one station).

All figures, with the exception of Fig. 1(6), illustrate the holotype.

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* Owing to the scientific obscurity of this mollusc, I have had to rely in some cases on literal or commonsense translations of anatomical terms. -- TRANSL.

FAMILY FASCIOLARIIDAE

The diagnosis of the family Fasciolariidae given by Thiele (1929) is in need of a substantial correction: the salivary-gland ducts do not pass through the pharyngeal ring. This was noted by Marcus and Marcus (1962) in the instance of Leucozonia nana (Gmelin 1791) and is confirmed by our description of the new abyssal species Brevisiphonia circumreta, in which both the salivary glands and their ducts are located far behind the peri-pharyngeal nerve ring (along the sides of the posterior half of the proboscis) and, naturally, cannot penetrate it (Fig. 3(1), in which, for the sake of clarity, the salivary glands have been moved slightly apart -- the left one upward, the right one downward). As regards the second controversial taxonomic character -- the location of the eyes among the Fasciolariidae -- we cannot ally ourselves either with the affirmation of Thiele that the eyes are located at the base of the tentacles, or of Marcus and Marcus, that the eyes are located at the level of half the tentacles, as in our own species the organs of sight are wholly reduced.

SUBFAMILY BREVISIPHONINAE Lus, subfam. nov.

Diagnosis. Shell from ovate to oval shape, of moderate size, with very short siphonal process and a broad, open channel. The periostracum is well developed. The lid or operculum is shaped like a talon, with a terminal core (testicle?). The mantle is short. The siphon is small, massive, broad. The central dental lamina of the radula is small, the lateral laminae are large, broad, convex, with numerous more or less equal denticles, without small, intervening denticles. The salivary glands are large and are located along the sides of the posterior part of the proboscis; their ducts are short, bent double, and do not reach the peripharyngeal nerve ring. The central nervous system is of the oligomeric type, with a very large peripharyngeal ring. Type genus: Brevisiphonia Lus.

Genus Brevisiphonia Lus, gen. nov.

Diagnosis. The shell is of ovate to oval shape, thin-walled, with more or less convex, rounded and evenly growing whorls. The coil is somewhat raised, the last whorl is the largest. The aperture is large, with a wide oval shape. The labrum is evenly and broadly rounded, it goes over imperceptibly into the siphonal process and, in a manner of speaking, terminates at the column of the shell; the margin of the labrum is sharp, without complications; the inner surface of the labrum has no folds. The column may have some slight callosity. The spiral and axial costae on the shell form a very fine but distinct reticulate ornamentation. The periostracum is well developed, of a coriaceous type, layered. The operculum is narrow and long, talon-shaped, with an apical core. The foot is small, elongated, with a deep anterior pedal furrow and a small protruding papilla on the posterior end. The head tentacles are long. The central lamina of the radula is oval, with one denticle, the lateral laminae are as in Lathyris Montfort. The genotype is the only known species Brevisiphonia circumreta Lus.

Differential diagnosis. Brevisiphonia resembles Lathyris Montfort 1810 (=Latirus) and, in particular, the subgenus Leucozonia Gray 1847 (Thiele 1929). Distinguishing features of Brevisiphonia are: the shell has very thin walls and is more egg-shaped; the aperture is broadly oval, with inner folds, with a greatly foreshortened siphonal process and a broad, open channel; the operculum is narrow, long, shaped like a talon; the tentacles are somewhat elongated; at the posterior end of the foot there is a small papilla.

Brevisiphonia circumreta Lus sp. nov.

(Fig. 1-3).

Material. 13 live and 1 dead specimens of this species were collected at five stations in the North Pacific and at yet another station a fragment was found of a shell of an adult mollusc (Table 1). All molluscs were brought up by Sigsby-Gorbunov trawls.

The soft parts of all molluscs, with the exception of the holotype, turned out to be in very poor condition.

The holotype is being kept in the type collection of the Institute of Oceanography of the Academy of Sciences of the USSR, under designation VI-28-3.

Description (based on male holotype). The shell (Fig. 1(1-6) is oval-ovate in shape, with very thin walls (thickness in the centre of the labrum 0.2 mm), brittle and semitransparent, with $3\frac{1}{4}$ whorls divided by a deep, slightly compressed suture; the whorls are evenly rounded, inflated, regularly turned around the sutures. The coil is raised, but

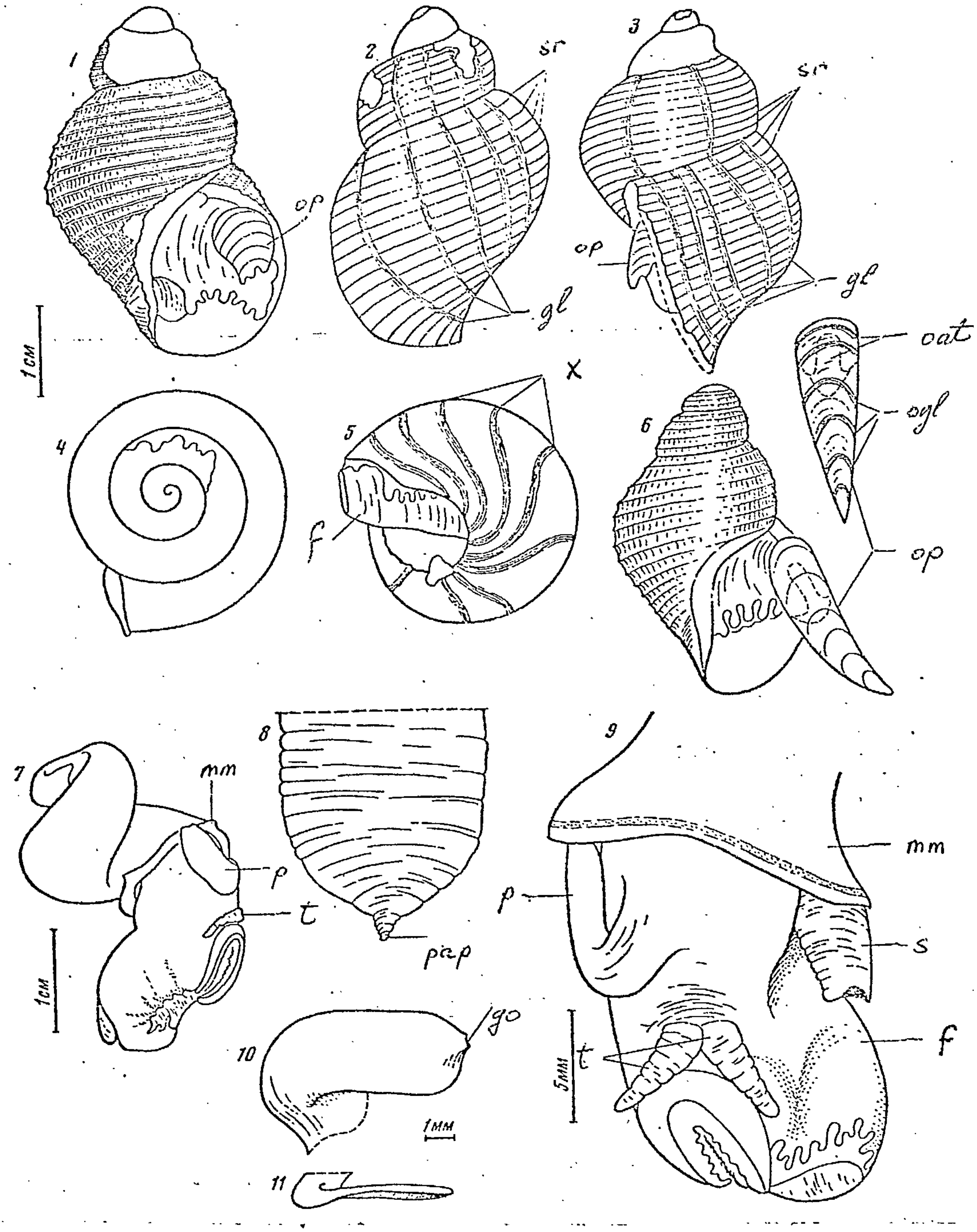

Fig. 1. Caption on page 392.

Caption for Fig. 1. Brevisiphonia circumreta gen. et sp. nov.

1-6 -- view of shell: 1-5 holotype (2-5 -- schematic); 6 -- paratype from station 3156; 7 -- general view of soft body of mollusc, from right side; 8 -- posterior end of foot, top view; 9 -- anterior part of body of mollusc; 10, 11 -- penis (lateral and top views); mm -- mantle margin; op -- operculum; gl -- concentrations of growth lines of shell; ogl -- opercular growth lines; oat -- attachment of operculum to the foot; f -- foot ; p -- penis; pap -- papilla at posterior end of foot; go -- outer genital opening of male; sr -- spiral ribs on shell; s -- siphon; t -- head tentacles; x -- not identified in caption.

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not high, with gradually and evenly growing whorls (Fig. 1(4). The upper whorls have no periostracum, are heavily eroded, with evident traces of secondary deposition of calcium carbonate. The first whorl of the embryonic shell is destroyed. The last whorl is very large and makes up 4/5 of the 206 entire shell. The base of the shell is convex, narrowing evenly toward the siphonal process. The walls of the shell are milky-white in color. The periostracum is light olive in color, on whose background one clearly sees 16 darker, brown, axially arranged bands of varying width (Fig. 1 (2, 3, 5, gl). They may represent interruptions in the growth of the shell. The periostracum is dense, rather coriaceous than pelliculate, layered, opaque, closely adhering to the surface of the shell, although it is apparently easily destroyed (it was preserved only on the last $1\frac{1}{2}$ whorls, but even there damaged in many places). Lifting up along the growth lines, the periostracum forms very low, regularly and closely spaced laminae, which give it a silky appearance. These protuberances of the periostracum were

"Vityaz'" stations at which Brevisiphonia circumreta Lus was collected

Station	Date	North lat.	East long.	Depth, m.	Bottom	Number of spec.
3156	28.9.54	39°57'	165°08'	5,525	Red clay with slight admixture of small pebbles, concretions, sand	1 juv.
3162	1.10.54	43°15'	157°48'	5,502	Id., without concretions	Shell fragment
3206	19.10.54	30°53'	153°09'	5,988-98	Brown ooze with pumice	1
3232	5.5.55	33°18'	149°46'	6,096	Brown ooze with very little pumice pebbles	3 + 2 juv.
3363	10-11. 6.55	48°15'	169°39'	6,272-82	Ooze? Much pumice pebbles	2 + 2 juven. + 1 shell
6088	4.5.69	53°58'	157°36'W.	5,740	Fine clayey ooze with little pumice pebbles and volcanic tuff	1 : holotype, male

preserved only on the dorsal side of the last whorl.

The shell ornamentation is very fine and represented by both axial and spiral costae or striae which form a regular reticulation covering the entire surface of the shell. The spiral ornamentation predominates. When viewing the shell with the unaided eye, one sees clearly the distinct thread-like spiral costae, while the axial ones appears as closely spaced and fine striation that runs nearly parallel to the shell axis. Under magnification the shell ornamentation looks as follows. The spiral costae are well shaped, low, rounded, with a blunted top; on the last whorl they are faintly blurred, their width is 0.15-0.20 mm. The number of spiral costae reaches 18 on the dorsal side of the last whorl, eleven at its start (over the parietal angle), and nine on the penultimate whorl. The width of the intervals between the costae depends on the height and width of the whorls on which they are located, and varies from 0.7 to 1.1 mm (at the widest part of the last whorl) and 0.4 mm near the siphonal process. On the periphery of the last whorl, in the centre of the intervals, secondary costae make their appearance; they have the same width as the primary costae, but are indistinct. The axial ornamentation is also represented by very low, narrow and flat belt-like costae, arranged very evenly, with intervals of 0.20-0.25 mm. Within one millimeter of shell surface there are four axial costae. At the intersection of the 207 spiral and axial costae uneven nodes are formed, while the cells of the reticulation have the shape of parallelograms drawn out in the direction of the axis; the height of the parallelogram is twice its width; it is rectangular on the periphery of the whorls and has biased angles near the sutures and at the base of the shell.

The aperture is wide, rounded-oval, slightly angular at the bottom where it merges with the margins of the broad siphonal channel. The width of the aperture is about 2/3 its height. The interior surface of the aperture is slightly shiny, of grayish-white color, with bright white spots marking "pits" on the outside of the shell, transmitting the uneven brown color of the periostracum bands. The entire inner surface of the aperture is covered with microscopic "pock marks," which dim the glitter of its shiny layer. The parietal angle is obtuse, about 110°, rounded. The labrum is broad and evenly rounded, with complicating features, it goes over smoothly into the siphonal process, without a bottom notch. The margin of the aperture is not inflated and not turned out, it is sharp; in profile it is slightly S-shaped and somewhat twisted, forming a 15° angle with the shell axis. The lower end of the labrum protrudes slightly beyond the end of the column. The inner lip is narrow. The margin of the inner and parietal lip form a smooth, slightly concave, arched line. Both lips are covered with a thin layer of transparent, fine glaze, through which in the parietal part one can easily discern the spiral and axial costae, along with their relief, so that in this place the surface has a slightly wavy character. The folds on the column, which are typical of the Fasciolariidae, are lacking, but there is an indistinct fold running parallel to the margin of the column and very near it. The column is short, slightly curved; it has a slight callosity.

Along the outer boundaries of the parietal and inner lips there runs a narrow "eroded" furrow, which lacks a periostracum. The siphonal process is very short, its channel is very wide and open (the length of the channel is about 0.5 mm, its width 4.5 mm). The distal margin of the siphonal process forms an angle of 100° with the shell axis.

The height of the holotype shell is 34 mm, its width is 24 mm, the height of the last whorl is 28 mm (82% of the entire height of the shell), the length of the aperture is 19 mm, its width is 13 mm. The weight of the soft body of the mollusc is 2.71 grams, that of the empty shell 0.77 grams (22.1% of the total weight).

The largest specimen is the holotype.

The operculum (Fig. 1(op) of the holotype is more than half broken off. It is bright brown in color, semitransparent, at the place of attachment to the opercular foot noticeably inflated. In the paratypes the operculum is extremely narrow and long, of a typical talon-like shape, and usually protrudes beyond the aperture (Fig. 1(6, op).

On the lower surface of the apical part, not attached to the foot, (which makes up about 2/3 of the entire operculum) there are distinct inflations in the shape of rolls which run along the lateral margins and act as supporting struts.

Remarks. All shells of B. circumreta in our possession have small numbers of whorls, and, regardless of age (size) of the molluscs, the number of whorls is the same, from 3 to 3¼, owing to the gradual destruction of the uninhabited apical whorls.

The embryonic shell was preserved (without the original little shells and part of the first whorls) in four young specimens from stations 3232 and 3363. It is large and somewhat blunt, dome-shaped, pinkish-white in color. The first remaining whorls are three times wider than high, and smooth. The first ornaments to appear on the shell surface are the axial costae in the shape of fine grooves starting near the upper suture and becoming narrower toward the lower suture (this kind of ornamentation occupies about half the whorl), after that one notes on the periphery of the whorl the first spiral costa, which is gradually joined on both sides by the remaining spiral costae, and beginning with the third whorl there is already a distinct juvenile reticulate ornamentation with equilateral rectangular cells made up of well-developed axial and spiral costae. Among adults these cells become narrower and higher.

The shells of the molluscs from the northwestern Pacific and the region of the Hawaiian Ridge (with the exception of the youngest specimens) differ from the holotype (from the south slope of the Aleutian trench) in being less wide and having a somewhat more elongated oval shape, the labrum is slightly inflated on the periphery, and the aperture is just a little narrower (Fig. 1(6)).

Shells of medium size (height 20-25 mm) show some resemblance in their shape with the antarctic species Bathydomus calathiscus (Watson 1886). In these individuals, there are well preserved raised laminae on the periostracum on the last whorls, while on the first whorls, covered with a juvenile reticulation, the periostracum is always lacking.

Soft body of the mollusc (Fig. 1 (7-11); 2(3). It is very difficult to extract the mollusc from the shell owing to the existence of a specialized feature, resembling a button, on the very narrow columellar muscle, which, as it were "buttons" the body of the mollusc to the column (Fig. 3(6) but.)

The mantle is very short, its margin is inflated and rounded. The siphon is fairly large, expanded at the base (Fig. 1(9)s); its walls are little inflated. The head is barely discernible on the trunk. The head tentacles are of elongated-conical form, round, and rounded at the ends; there are no basal processes. Organs of sight are lacking. The foot is moderate size, elongated, with a very deep anterior pedal furrow (it is filled with abundant semitransparent mucus) and a small, protruding papilla at the posterior rounded end.

Anatomy. The mantle cavity (Fig. 2(1)) is small, short. The organs of the mantle complex are large, their anterior ends are located near the margin of the mantle fold. The osphradium is thick, olive in color, in the shape of a broad oval, with a thick (0.4 mm) steeply curved axis. The petals of the osphradium are inflated, solid, with still wider rounded margins, along whose periphery there runs a fine filmy crest. On the half of the osphradium turned toward the siphon the petals are round, with a beak-like process on the apical margin of the crest; they all differ in size and alternate irregularly by size, which gives to the entire osphradium an unkempt appearance (Fig. 3 (3,4) shows two adjacent petals of different size from the middle of the row); on the opposite half of the osphradium the petals have an elongated shape (Fig. 3(5)), the largest are located in the middle of the row, toward the ends of the organ they decrease gradually. There is a distinct pattern of golden-brown punctate pigmentation in the petals; the band running along the free margin of the lamina is more deeply colored. The ctenidium is also very large and long. B. circumreta is characterized by an unusual structure of the ctenidium lamellae. Each lamella consists of two organically linked parts: a proximal, larger part, which is the usual ctenidial lamina and has a triangular shape, and a marginal band, fairly broad, that surrounds it and resembles in consistency a semitransparent distended gelatinous mass. These gelatinous peripheral margins of the ctenidial lamellae, touching one another, form

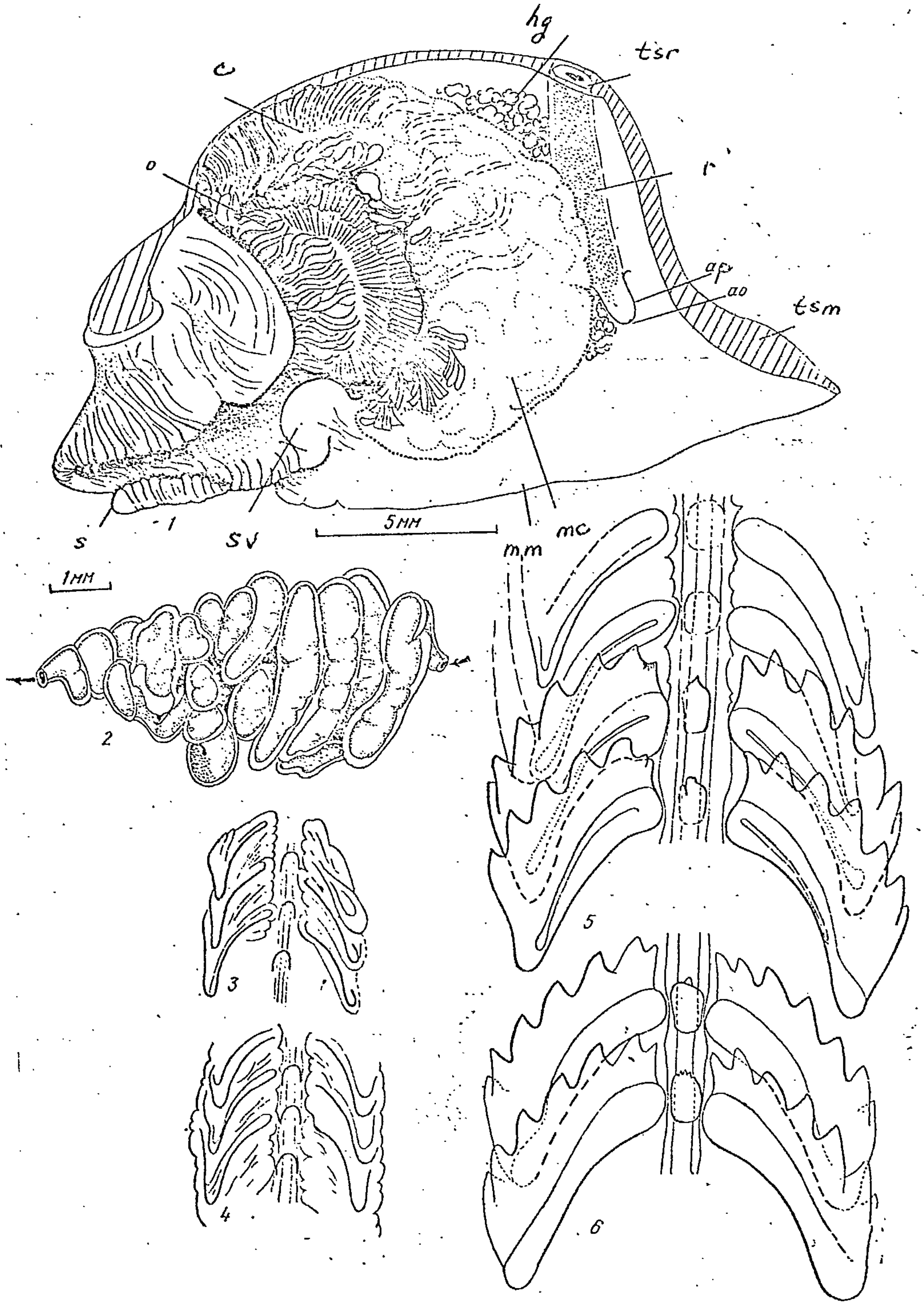

Рис. 2. *Brevisiphonia circumreta* gen. et sp. nov.

(Caption on p. 401)

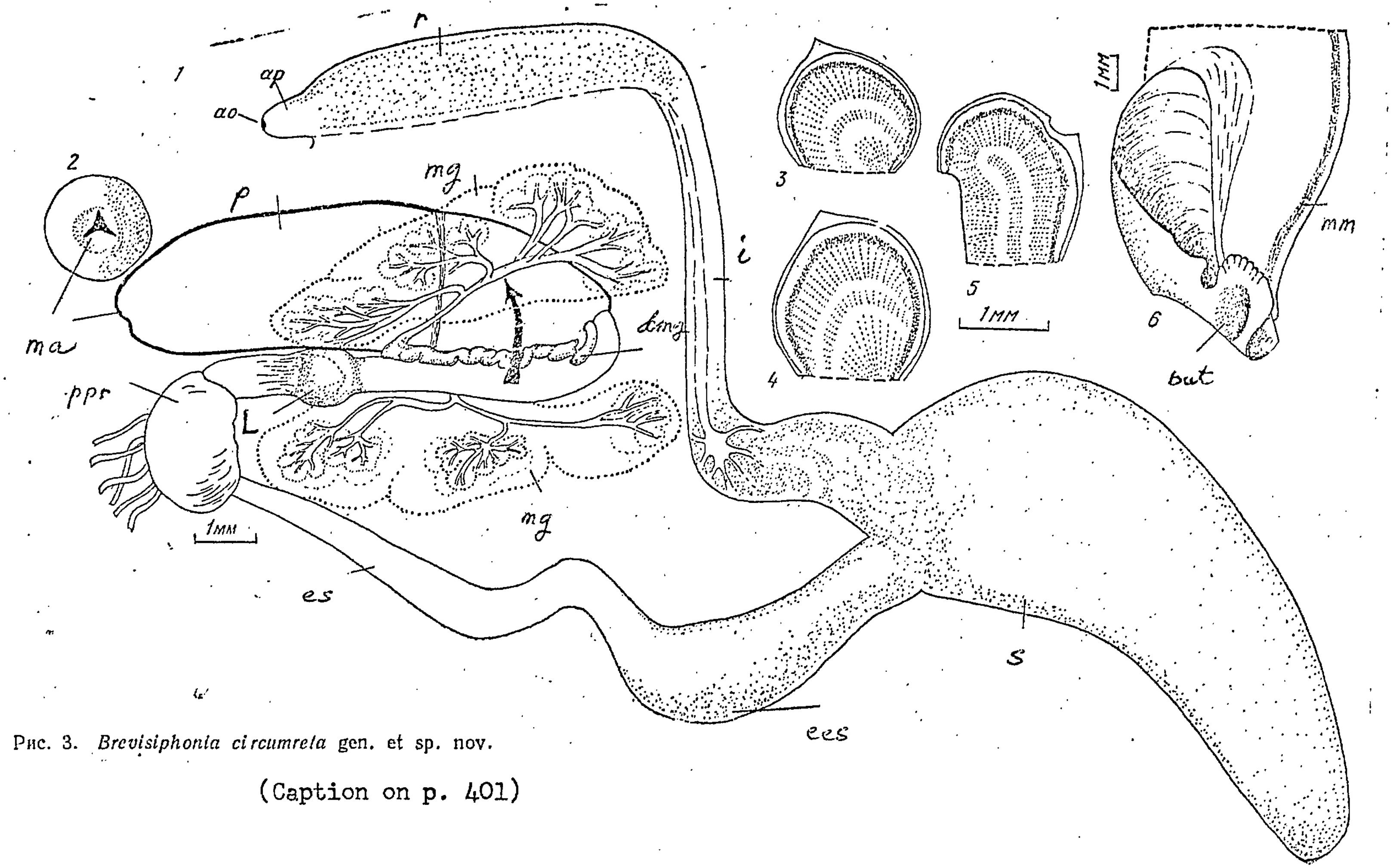

Рис. 3. *Brevisiphonia circumreta* gen. et sp. nov.

(Caption on p. 401)

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Caption for Fig. 2.

1 -- detached mantle with complex of mantle organs, view from interior; 2 -- twisted part of spermiduct; 3-6 -- changes in the rows of radular teeth during ontogeny (explanations in the text; (6) shows the 43rd and 44th central rows of the radula); ao -- anal opening; ap -- anal papilla; hg -- hypobranchial gland; c -- ctenidium; sv -- siphon valve; mm -- mantle margin; o -- osphradium; r -- rectum; tsr -- transverse section of rectum; s -- siphon; tsm -- transverse section of mantle wall; mc -- mucous "cover" of ctenidium.

Caption for Fig. 3.

1 -- digestive system (scattered dots on the surface of the posterior part of the esophagus, stomach and rectum are the translucent dark blue microelements of the blood); 2 -- proboscis and mouth aperture, frontal view; 3-5 -- ctenidial lamellae from central part of ctenidium: adjacent unequal lamellae from left (3-4) and right (5) halves of the organ; 6 -- columellar muscle. ao -- anal opening; ap -- anal papilla; L -- Leiblein "pharynx"; s -- stomach; mm -- mantle margin; but -- "button" of columellar muscle; ppr -- peripharyngeal nerve ring; r -- rectum; es -- esophagus; ma -- mouth aperture; ees -- expanded posterior part of esophagus; mg -- mucous glands (for the sake of illustration, the left gland has been moved slightly upward, as indicated by the arrow, and the right gland downward); dmg -- duct of left mucous gland; i -- intestine; p -- proboscis.

something in the nature of a cover enveloping the entire ctenidium, with the exception of the very posterior. The proximal part of the ctenidial lamellae is pigmented with dark-olive dots forming a pattern 211
resembling reticulation; along the very margin of the gelatinous part of the lamella there runs a more delicate and paler pigmented band. The hypobranchial gland is narrow; its excretions, in the shape of opaque, white flakes, are few. The anal papilla is large, rounded at the end. The lips surrounding the outer excretory opening of the kidney form a large, round tubercle that occupies about half the posterior wall of the mantle cavity.

Digestive system (Fig. 3 (1, 2). The moutn opening has the shape of a star with three points. The proboscis is small, slightly expanded. The salivary glands are very large, elongated-expanded, lobed, white, semitransparent, of a gelatinous consistency. Located along the sides of the proboscis, they cover its entire posterior half, the start of the anterior section of the esophagus and their own ducts, which are folded in half (Fig. 3 (1, mg, dmg)).

The ducts of the salivary glands are short, thick, slightly winding; they extend from the anterior end of the glands, forward, without reaching the Leiblein "pharynx," make a turn of 180° and continue to the end of the proboscis, where they penetrate it. The Leiblein "pharynx" is pear-shaped, displaced anteriorly and located between the peripharyngeal nerve ring and the salivary glands with their ducts. A Leiblein gland is lacking. The posterior part of the esophagus is slightly extended, its interior longitudinal folds, about 10 in number, are prominent, rounded. The stomach has thick walls and, in its shape, resembles the air bladder of fishes; the intake and outlet openings are very close together and situated in the anterior part of the stomach. The radula (Fig. 2 (3-6)) is on the whole structured in a way that is typical of the Fasciolariidae. On the broad lateral laminae there are seven more or less equal denticles, but on the central laminae, oval in outline, there are not three denticles, as is common to the family, but rather a single, small one. However, on the central laminae of the radula of the holotype there are sometimes additional denticles, which is not observable in the specimen from station 3232. The stages in the formation of the dental laminae are shown in Fig. 2 (3-6). In the formation of the lateral teeth, the first to appear are blade-like transparent films with wavy edges (Fig. 2 (3)), which then become less noticeable, but at that time their basal anterior margins become much thicker (Fig. 2 (4)), and, finally, the first fully formed teeth make their appearance (Fig. 2 (5)). The central dental laminae appear first in the shape of semicircular processes which gradually change into oval laminae.

The central nervous system is of the oligomeric type. The peripharyngeal nerve ring (Fig. 3 (1, ppr)) is extremely powerful, the ganglia are very close together, the opening for the esophagus is very narrow; the ganglion ring occupies more than half of the small trunk sinus.

The nerves extending from the ganglia are also very thick, particularly the pedal ones.

Genital system of the male. The testis is large, bean-shaped, tubular in structure, and is easily distinguished from the liver. The winding part of the vesicula seminalis (Fig. 2 (2)) is multilamellar; the tube of the vesicula seminalis is nodular and is located in a clearly visible filmy sleeve, when straightened its length exceeds 40 mm. The penis (Fig. 1 (10, 11) is very small, heavily flattened in the dorsal-ventral direction, of simple configuration; the genital opening is located on a barely perceptible protuberance.

Distribution. Brevisiphonia circumreta is a typically stenobathic, lower-abyssal species. It is found at depths of 5,502-6,282 m, on the basin of the northwestern Pacific, north of the Hawaiian Ridge, and on the south slope of the Aleutian trench (30°53' to 53°58' north, 212 149°46' east to 157°36' west) on clayey ooze with pebbles, mainly of pumice.

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TYPES OF HABITATS OF CEPHALOPODS IN THE NORTH PACIFIC

By K. N. Nesis

This paper analyzes the distribution of cephalopods in the non-tropical regions of the North Pacific, from the Bering Sea to southern Japan and Lower or Baja California inclusive. Attention will be directed mainly to the distribution of pelagic squids (suborder Oegopsida), Vampyrotheutis (order Vampyromorpha), and pelagic octopuses (suborder Incirrata, superfamilies Bolitaenoidea and Argonautoidea) -- primarily because they are widely distributed and are more closely associated with the main oceanic water masses than the neritic squids, cuttlefishes and octopuses, and, secondarily, because the study precisely of the pelagic cephalopods is the teuthological problem that is presently receiving the most intense scrutiny. Of the cephalopods inhabiting inshore waters, we are giving more detailed attention to neritic squids, (suborder Myopsida) and cuttlefishes (order Sepiida). Benthonic octopuses (suborder Cirrata and superfamily Octopodoidea of the suborder Incirrata), whose systematics are still chaotic, are only given cursory attention.

Studies of cephalopods in the North Pacific have been carried on since the mid-19th century, and in respect of this part of the ocean we already possess extensive data (Akimushkin 1957, 1963; Kondakov 1941;

Shevtsov 1969; Berry 1912; Mercer 1968; Nishimura 1968; Okutani 1966, 1967, 1968a, 1969; Okutani, McGowan 1969; Pearcy 1965; Sasaki 1920, 1929; Taki 1963, 1964; Young 1972; and many others). Nonetheless, it is only recently that the basic outlines of the cephalopod fauna in the North Pacific have begun to be understood. The depths of the oceans still hold many surprises in store for the taxonomists. Only during the last ten years we have seen described from this region a new family, five new genera and subgenera, 36 new species and subspecies of cephalopods, and several more new species have been determined but as yet not described (my own data and communications of M. Okiyama, T. Okutani and R. Young). As regards the distribution of pelagic cephalopods in the North Pacific, there are still far more questions than answers, not least because up to now investigations have been carried on mainly near the coasts of the Soviet Far East, Japan, Canada, and the United States, while only a few samples have been collected from the open sea. If, in the present paper, I am attempting to integrate available data on the distribution of the cephalopods of the North Pacific, it is because this is the best means of learning where gaps exist in our knowledge.

The basis for this paper was provided by the collections of the expeditions of the Institute of Oceanography of the Academy of Sciences of the USSR on the "Vityaz'" — mainly during Cruise 29 (October 1958 to March 1959), Cruise 39 (July to September 1966), and Cruise 45 (May to July 1969), on the oceanographic ship "Baikal" (Cruise 3, August to October 1967), and the joint expeditions of the Oceanographic Institute and the Pacific Institute of Fisheries and Oceanography (TINRO) on the vessels "Ekvator" (June to August 1969) and "SRTM-8-453" (August to October 1970), as well as all of the scientific literature available to me, only a small 214 part of which is listed in the bibliography. Some new information obtained during the analysis of the material is given in notes attached to to Tables 1 and 2.

Cephalopod molluscs have been caught near the surface, with a dip net, a Japanese squid rig, a jigger (at night with illumination); in the open sea, with the multi-depth Isaacs-Kidd trawl, with a KhKS net (catches from 1,000 to 0 meters), and a Sigsby trawl during its return to the surface; from the bottom, with a Sigsby trawl and a commercial benthonic otter trawl.

The information was collected by members of the Oceanographic Institute V. E. Bekker, V. M. Makushko, N. V. Parin, G. N. Pokhil'skii, V. M. Chuvasov and Yu. N. Shcherbachev, and members of TINRO and commercial exploration A. I. Vyaznikov, V. V. Fedorov and G. A. Shevtsov. R. E. Young kindly made it possible for me to become acquainted with his extensive study on the taxonomy and distribution of Californian cephalopods (R. E. Young 1972) before publication. To all of these investigators I give a heartfelt thanks.

The basic material for further consideration is assembled in tables showing the distribution of all pelagic cephalopods, neritic squids and cuttlefishes registered in the non-tropical waters of the North Pacific and maps showing the habitats of species (naturally, we are providing only a few of these). In assigning habitats to various types we have followed the principles accepted for zoogeographical investigations of benthonic molluscs (Golikov, Kusakin, 1962; Golikov, 1963). Among boreal species I place those that are found from the Bering Sea to Japan and California; among north-boreal (upper boreal) species, those occurring from the Bering Sea to the Sea of Okhotsk (or the coldest parts of the Sea of Japan), the central Kuriles and British Columbia; among south-boreal (lower boreal) species, those occurring either along the coasts of the Soviet Primor'ye region, Hokkaido, Sakhalin, the southern Kuriles, or in the Washington-Oregon region. Subtropical species are those that occur either in the Yellow Sea, along the south coast of Korea and the southern part of Honshu, or along Southern California. Tropical species are those that occur in equatorial and central waters; most of them are listed among the subtropical species, as they are not given any special name; some of them occur northward as far as the boreal waters, and these I call tropical-boreal. Species that do not range into the subtropical regions (tropical species properly speaking), let alone those that are not found even in the central waters (equatorial species), are absent in the part of the North Pacific under consideration here, and are analyzed only in a cursory manner in this paper.

1. Pelagic Cephalopods

A complete list of pelagic cephalopods with data concerning their distribution as of 1 October 1972 is given in Table 1. It contains 76 species and subspecies of Oegopsida squids, one species of *Vampyroteuthis* and ten species of pelagic octopuses.

Based on an analysis of Table 1, we can distinguish seven types of distribution of cephalopods in the North Pacific: A: species distributed

(Text cont. on page 420)

Table 1. Distribution and zoogeographical characteristics of pelagic cephalopods in the non-tropical waters of the North Pacific

(NP -- North Pacific; NWP -- North-West Pacific; NEP -- North-East Pacific; IWP -- Indian-West Pacific; IP -- Indian-Pacific; AIP -- Atlantic-Indian-Pacific; A -- Atlantic; P -- Pacific; I -- Indian Ocean; EP -- East Pacific; bor -- boreal; n-bor -- north boreal; s-bor -- south boreal; s-bor-sub -- south-boreal-subtropical; sub -- subtropical; trop -- tropical; trop-bor -- tropical ranging into boreal waters. Geographical designations in brackets with a question mark denote finds of cephalopod beaks in the stomachs of whales.

Species	Zoogeographical range	Habitat boundaries	
		Northern	Southern
		Order Teuthida, Suborder Oegopsida	
Gonatus berryi Naef	NP bor	Bering Sea, G. of Alaska	NE Honshu, N Lower California
Gonatus onyx Young	NP bor	Bering Sea, G. of Alaska	NE Honshu, Lower California
Gonatus californiensis Young[1]	NEP s-bor-sub?	N California	S Lower California, ? Gulf of Panama.
Gonatus pyros Young	NEP (NP?) bor	Bering Sea	N Lower California
Gonatus n. sp. (type gamma Okutani)	NP bor	Bering Sea, G. of Alaska	E Hokkaido
Gonatus tinro Nesis	NP bor	Bering Sea, G. of Alaska	Southern Kuriles
Berryteuthis magister (Berry)	NP bor	Anadyr Peninsula, Gulf of Alaska	Korea Strait, N California
Berryteuthis anonychus (Pearcy et Voss)	NEP bor	British Columbia	Central California

Table 1, cont.

Gonatopsis octopedatus Sasaki	NP bor	Bering Sea, G. of Alaska	Sado Is., SE of Hokkaido
Gonatopsis japonicus Okiyama	NWP n-bor?	Northwestern and central parts of the Sea of Japan	
Gonatopsis borealis Sasaki	NP bor	Bering Sea, G. of Alaska	N Sea of Japan, SE Hokkaido, Lower California
Gonatopsis makko Okutani et Nemoto	NP n-bor?	Bering Sea, G. of Alaska	?S of Aleutian Islands
Gontopsis okutani Nesis	NP n-bor	Bering Sea, Aleutians	S Kuriles, Sea of Japan
Enoploteuthis chuni Ishikawa	NWP s-bor-sub	Central Honshu, Kuro Shio	Amami and Idzu islands
Enoploteuthis theragrae Taki	NWP s-bor-sub?	Sado Is.	S Sea of Japan
Abratia andamanica Goodrich s.l. (possibly coll. species)	IWP trop	S Honshu, Kuro Shio, Hawaii	Indonesia, Polynesia
Abralia japonica Ishikawa	NWP sub?	Gulf of Toyama	
Abraliopsis felis McGowan et Okutani	NEP s-bor-sub	Washington State	Lower California
Abraliopsis falco Young[1]	EP trop	Hawaii, Low. California	Indonesia, Peru
Watasenia scintillans (Berry)	NWP s-bor-sub	S Kuriles	Korea Strait, Shikoku Is.

Table 1. cont.

Pyroteuthis addolux Young[1]	NEP sub?	S. California	Lower California
Pterygioteuthis giardi Fischer	AIP	S Honshu, Kuro Shio, S California	SE Australia, N Chile
Pterygioteuthis gemmata Chun (=*P. microlampas* Berry)	AIP:A trop, P antiequat.	Hawaii, S California	Central Chile
Ancistrocheirus alessandrini (Verany)	AIP trop	Kyushu, Kuro Shio, ? Lower California	Indonesia, Polynesia
Octopoteuthis ex gr. *sicula* Rüppell (incl. *O. nielseni* Robson)	AIP trop-bor?	NE Honshu, Cocos Is.	Melanesia, N Chile
Octopoteuthis deletron Young[1]	EP anti-equat.?	British Columbia	N Peru
Taningia danae Joubin (=*Cucioteuthis unguilata* pt.)	AIP trop(-bor?)	Boso Pen., Kuro Shio[2], Hawaii,(Bering Sea?)	Easter Is.?
Onychoteuthis banksi borealijaponicus Okada	NP s-bor-sub	Bering Sea (forage), Centr. Hokkaido, Kuro Shio, California (spawning)	S Japan, Lower California
Onykia carribea Lesueur	AIP trop	Cent. Honshu, Kuro Shio, California[3]	Indonesia, Polynesia
Onykia japonica Taki[4]	NWP sub?	S coast of Shikoku Is.	

Table 1, cont.

Moroteuthis robusta (Verrill)	NP bor	Bering Sea	Sangar Strait, California
Moroteuthis lonnbergi Ishikawa & Wakiya	IWP trop?	Centr. Honshu	S Honshu
Ctenopteryx sicula (Verany) s.l. (collect. species)	AIP trop	Centr. Honshu, Kuro Shio, Low. California	SE Australia, Easter Is. region, Peru
Brachioteuthis riisei (Steenstrup) (collective species)	AIP trop-bor	Kuro Shio, S California	Tasmania, Chile
Histioteuthis dofleini (Pfeffer)	AIP trop-bor	Aleutian Islands	S Pacific at 40° south
Histioteuthis corona berryi N. Voss	NEP sub?	California Current	
Histioteuthis corona inermis (Taki)	NWP sub?	S Honshu	Shikoku Is.
Histioteuthis meleagroteuthis (Chun)	AIP trop-bor	Kuriles, Oregon (Bering Sea?)	New Zealand
Histioteuthis heteropsis (Berry)	EP trop	Central California	Central Chile
Bathyteuthis berryi Roper	NEP sub	S California	Lower California
Neoteuthis sp.[1]	?	ib.	ib.

Table 1, cont.

Psychroteuthis sp. (=*Architeuthis* sp. sp. juv. Iwai 1956)	?		Bonin Islands
Architeuthis japonica Pfeffer (=*A. martensi* Hilgendorf?)	NWP bor-sub	Bering Sea	S Honshu, California*
Todarodes pacificus Steenstrup	NWP s-bor-sub	Central Sea of Okhotsk, Kronotskii Gulf (Komandorskiye Is.?) (forage) , S. Kuriles (breeding)	Senkaku Islands, Syangan
Hyaloteuthis pelagica (Bosc)	AIP trop	Khatidzyo Is., N of Hawaii	Melanesia, Galapagos Is.
Ommastrephes "bartrami" (Lesueur)	AIP:P-n-sub; I:s-sub; A:anti-equat.	Komandorskiye Is. (forage) , Central Honshu (spawning) British Columbia	S of Kyushu, Low. California
Symplectoteuthis luminosa Sasaki	P bi-central n- and s-sub) I?	South Kurile Strait, California	S of Kyushyu, Lower California, Kermadec Islands and New Caledonia
Symplectoteuthis oualaniensis (Lesson)	IP trop	Centr. Honshu, Lower California, S Honshu	NE Australia, W of Peru
Ornithoteuthis volatilis (Sasaki)	IWP trop?	S Honshu	New Caledonia

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* Preceded by the qualifying letter "g", whose significance is unclear. — TRANSL.

Table 1, cont.

Dosidicus gigas (d'Orb.)	EP trop-sub	S California (forage), Gulf of Panama (spawning)	Central Chile
Thysanoteuthis rhombus (Troschel)	AIP trop	Sangar Strait	Melanesia, Polynesia
Chiroteuthis calyx Young[1] (=*C. veranyi* Akimushkin non Fer.)	NP bor	N Kuriles, Gulf of Alaska[5] (Bering Sea?)	S Kuriles, Lower California
Chiroteuthis imperator (=*C. picteti* Joubin?)	IWP (AIWP?) trop	S Honshu, Kuro Shio	Indonesia
Ch. (Tankaia) borealis Sasaki[4]	?	east of Hokkaido	
Valbyteuthis danae Joubin	EP trop	S California	Chile
Valbyteuthis oligobessa Young[1]	EP trop?	S California	Lower California, ? Micronesia
Mastigoteuthis cordiformis Chun	IWP (AIWP?) trop	S Honshu	Indonesia
Mastigoteuthis latipinna (Sasaki)	NWP sub?	Sagami Bay	
Mastigoteuthis ex gr. *grimaldii* youbin incl. *pyrodes* Young[1]	NP bor-trop?	S Kuriles, Oregon	Idzu Islands, Lower California
Promachoteuthis megaptera Hoyle	?	Japan trench south of Boso Peninsula.	
Grimalditeuthis bonplandi (Verany)	AIP trop?	S California	?

Table 1, cont.

Cranchia scabra Leach	AIP trop	Central Honshu, Kuro Shio, Oregon	Melanesia, Galapagos Is.
Liocranchia reinhardti (Steenstrup)	AIP trop	Central Honshu, Kuro Shio	SE Australia, Chile
Liocranchia valdiviae Chun	AIP trop	S Honshu, Kuro Shio	Polynesia
Leachia (Pyrgopsis) pacifica (Issel)	AIP trop	N Honshu, Kuro Shio, California	Chile, Polynesia
Taonius pavo (Lesueur)[7]	AIP trop-bor	along southeastern Kamchatka	
Belonella pacifica borealis Nesis	NP bor	Bering Sea, G. of Alaska	S Kuriles, S California
Belonella pacifica pacifica Nesis	P trop	Kyushu	Philippines, Lion Is.
Galiteuthis phyllura Berry	NP bor	Bering Sea, G. of Alaska	N Honshu, Lower California
Galiteuthis pacifica (Robson)	P trop	S California, Philippine Sea	N Chile, ?New Caledonia
Sandalops melancholicus	AIWP trop	Kuro Shio	Melanesia
Megalocranchia (?) tagoi (Sasaki)[4]	?	Suruga Bay	
Megalocranchia (?) elongata (Sasaki)[4]	?	Sagami Bay	
Helicranchia pfefferi Massy	AP trop	Central Honshu[8] California	Polynesia, N Chile

Table 1, cont.

Corynomma oceanica (Goodrich)	IP trop	Kuro Shio	?Polynesia, Galapagos Is.
Bathothauma lyromma Chun	AIP trop	S Honshu, Kuro Shio	Melanesia, Chile

Order Vampyromorpha

Vampyroteuthis infernalis Chun	AIP trop-bor	S Honshu, Oregon	S New Zealand, Centr. Chile

Order Octopoda, Suborder Incirrata, Superfamily Bolitaenoidea

Japetella diaphana Hoyle (=*J. heathi* Berry)	AIP trop-bor	S Kuriles, G. of Alaska	E Australia, Chile
Eledonella pygmaea Verrill	AIP trop	Centr. Honshu, ?S California	S New Zealand, Chile
Idioctopus gracilipes Taki	?	Region of Boso Peninsula	
Amphitretus pelagicus Hoyle	IP trop	Centr. Honshu, Kuro Shio, (Kuriles?)	Tasmania, Galapagos Is.

Superfamily Argonautoidea

Alloposus mollis Verrill	AIP trop-bor	N Honshu, S California, (Bering Sea? G. of Alaska?)	Indonesia, Galapagos Is.
Argonauta argo L. (= *A. pacifica* Dall)	AIP trop	S Hokkaido, S California	SE Australia, New Zealand, Galapagos Islands

Table 1, concluded

Argonauta hians Solander	AIP trop	Sangar Strait, Gulf of California	E Australia, New Zealand, N Chile
Argonauta boettgeri Maltzan	AIP trop	Centr. Honshu, Gulf of California	E Australia, New Zealand
Tremoctopus gracilis (=*T. lucifer* Akimushkin, *T. violaceus* pt.)	IP (AIP) trop	S Kuriles, Hawaii	New Zealand, Peru
Ocythoe tuberculata Rafinesque	AIP trop	Sado Is., Central Honshu, Oregon, ?Sangar Strait	Polynesia

NOTES TO TABLE 1, see page 418.

Notes to Table 1.

1. The species is figured in Roper, Young 1969.

2. A larva of Taningia danae with a mantle length of 26 mm was caught at Kuro Shio at 38°52' north, 160°24' east, at 320 meters.

3. Onykia caribbaea was found in California at 30°55' north, 122°45' west and south of Cape San Lucas at 20°00' north, 110°02' west. The squids were caught at the surface. These are the first finds of the species in the northeastern Pacific.

4. The taxonomic position of this species is unclear.

5. Chiroteuthis calyx Young, which was wrongly identified with Ch. veranyi (Akimushkin 1963; Okutani, McGowan 1969), has been found south of the Alaska Peninsula at 54°43'3 north, 157°41'5 west and 53°50' north, 163°27' west and is known from the Kuriles, Oregon and California. Evidently it has a continuous habitat in the North Pacific from Alaska to the Southern Kuriles and Lower California.

6. This species was caught east of Honshu (34°40'2 north, 141°51'5 east) and southeast of Iturup (43°58' north, 149°42'2 east). It is probable that M. flammea, which Okutani (1967) cites as a Japanese species, belongs to this same species.

7. The name Taonius pavo has been applied to several different forms of squids. The genuine T. pavo has only been found once in the Pacific, in the stomach of a sperm whale caught southeast of Kamchatka (Iwai 1956). "T. pavo" of M. Sasaki and G. Voss (Sasaki 1920, 1929; G.Voss 1963) and "T.pavo" of I. I. Akimushkin (1957, 1963) are two different subspecies of the same species Belonella pacifica Nesis. The first, according to our data, occurs in the equatorial waters of the Pacific, and the

second in subarctic waters. The Antarctic "T. pavo" of Chun 1910 probably also belongs to Belonella.

8. Helicocranchia pfefferi Massy (= H. beebei Robson) was caught east of Honshu (36°24' north, 141°55' east), and has also been found in the equatorial part of the ocean (1°57'8 north, 172°33'8 west; 6°23' north, 135°36' east).

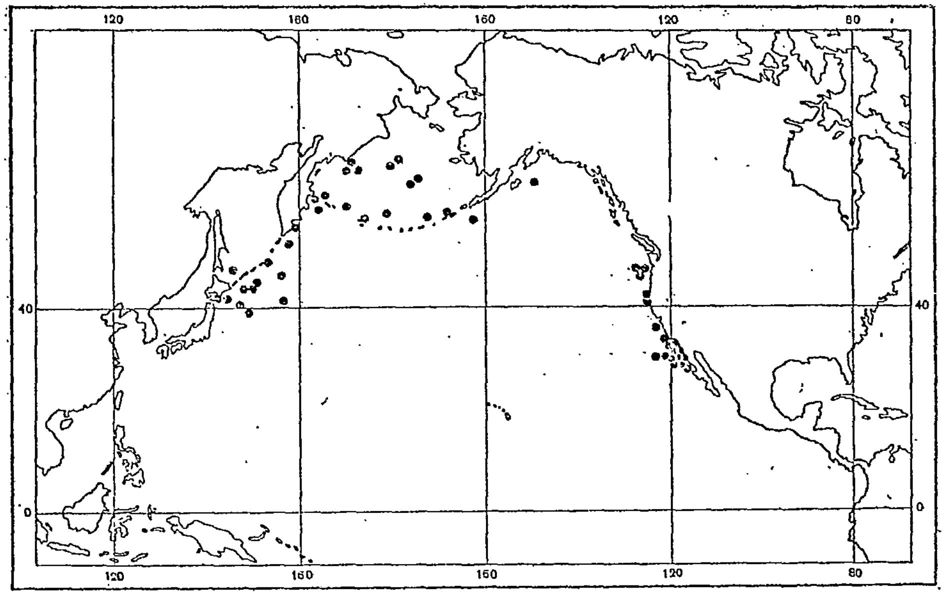

Fig. 1. Distribution of Galiteuthis phyllura: an example of a boreal species

in zonal patterns and found both in the western and the eastern half of the ocean -- (1) occurring in the boreal zone (subarctic waters); (2) in the subtropical (transitional) zone; (3) in the tropical zone. B: species distributed only in the western or eastern part of the ocean -- (4) in the non-tropical zone of the northwestern Pacific, (5), idem, northeastern Pacific; (6) in the tropical zone of the western Pacific, (7) idem, eastern Pacific.

The first group embraces 14 species. Mainly, these are 219
broadly boreal species, such as Gonatus berryi, Gonatus onyx, Berryteuthis magister, Gonatopsis borealis, Moroteuthis robusta, Chiroteuthis calyx, Belonella pacifica borealis, Galiteuthis phyllura etc. Some are north boreal (Gonatus tinro, Gonatopsis okutani, possibly Gonatopsis makko, etc.).

A typical example of such a species is Galiteuthis phyllura (G. armata of Sasaki and Akimushkin). Larvae and juveniles of G. phyllura (it follows from our studies that Crystalloteuthis beringiana Sasaki
are the larval stages of G. phyllura) have been caught east of the Southern 220
Kuriles, in the Central Basin of the Bering Sea, along the Aleutians, in the Gulf of Alaska and along California; adult individuals have been caught in the Bering Sea. The squids turned up at depths of 400-1,000 meters and in total catches from depths of 2,400-6,500 meters to the surface, only the larva has been caught from a depth of 200 m. This species ranges throughout the North Pacific from the Bering Sea to north

of Honshu and Lower California (Fig. 1)*.

The basic zone in which boreal species occur is the subarctic waters. There the species of this group are very numerous, they predominate completely over all other pelagic cephalopods and play an important role in the food chains of the pelagic zone. Nearly all of them are adapted for living both on the bottom and in the water stratum; B. magister and M. robusta are more closely tied to the bottom than the other species, their habitat embraces in the shape of an arc the boreal zone from the north. The northern boundary of all species of this group is the continental slope of the Bering Sea and the Gulf of Alaska, their southern boundary varies for different species. Along the Southern Kuriles and in the Gulf of Alaska we find all species of this group, along the Pacific coast of Hokkaido and California we find more than half, while only a few range as far as southern Honshu and Lower California. Along southern Honshu and Lower California there stretches the zone of dispersion of larvae of Gonatus spp. -- in the deep waters of northern origin occasional larvae penetrate to Japan and the Idzu Islands (34° north), and along Lower California, to 22° north (Okutani 1969; McGowan 1969). Of the broadly boreal species, the deep-sea Chiroteuthis, Belonella, and

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* Our maps are based both on our own and on published data (Fig. 1-12); we have also used some data of G. P. Bulgakova (Fig. 5), A. N. Vovk (Fig. 4), G. V. Zuyev (Fig. 4) and material from the Zoological Institute of the Academy of Sciences of the USSR (Fig. 11). All published sources used in the compilation of the maps are cited in the Bibliography.

Galiteuthis fail to penetrate to the Sea of Japan, and it seems that this is also true of Moroteuthis robusta, although it occurs in the sublittoral zone. Gonatus sp. ex gr. fabricii and Gonatopsis borealis are found only in the cold waters of the northern and northwestern parts of the Sea of Japan, Gonatopsis octopedatus occurs only at depth,and only B. magister ranges widely across the entire sea.

In the second group we can reliably include Symplectoteuthis luminosa and, with reservations, three other forms: Onychoteuthis banksi borealijaponicus (taking into account only its breeding grounds), Ommastrephes "bartrami" and the North Pacific Pterygioteuthis gemmata (the northern boundary of this species in the Pacific runs farther south than that of the three preceding squids). The distribution of these species will have to be discussed in greater detail.

The epipelagic squid Symplectoteuthis (Eucleoteuthis) luminosa has a disrupted habitat of the subtropical type ("peripheral-bicentral," according to K. V. Beklemishev 1969). In the North Pacific this species has been found along northeastern Honshu, in the Kuro Shio (39°43'8 north, 159°07'8 east; 39°00' north, 158°00' east; 38°36'8 north, 160°03'8 east), north and northeast of Hawaii (28°02' north, 157°30' west; 35°06'8 north, 137°53' west),in the California Current (31°54' north, 123°45' west; 30°57' north, 123°41'4 west). It is also known along the southern and eastern coasts of Japan, the Southern Kuriles and in the California Current /sic/ (Akimushkin 1963; Okutani 1967; Sasaki 1929; Young 1972), and, in the South Pacific, at New Caledonia and Kermadec Island (Berry 1916; Rancurel 1970). It is said to occur in the northern Indian Ocean (Filippova 1968), though the precise locality is not given. The habitat of S. luminosa (Fig. 2) is a narrow band stretching along the northern,

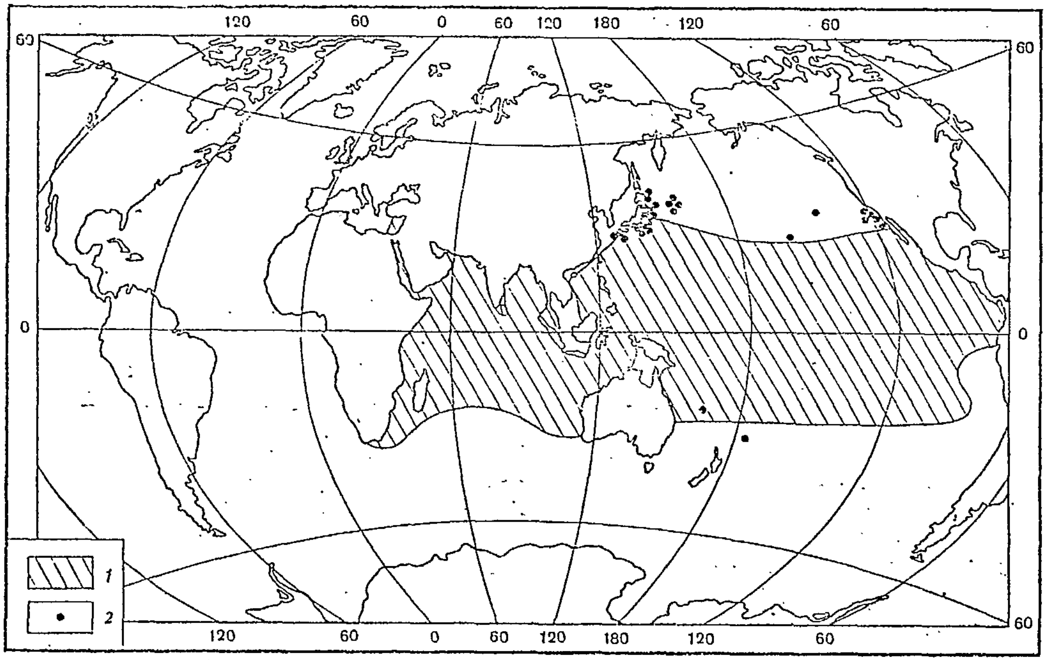

Рис. 2. Распространение индотихоокеанского тропического вида *Symplectoteuthis oualaniensis* (*1*) и субтропического *S. luminosa* (*2*)

Fig. 2. Distribution of the Indian-Pacific tropical species Symplectoteuthis oualaniensis (1) and the subtropical S. luminosa (2)

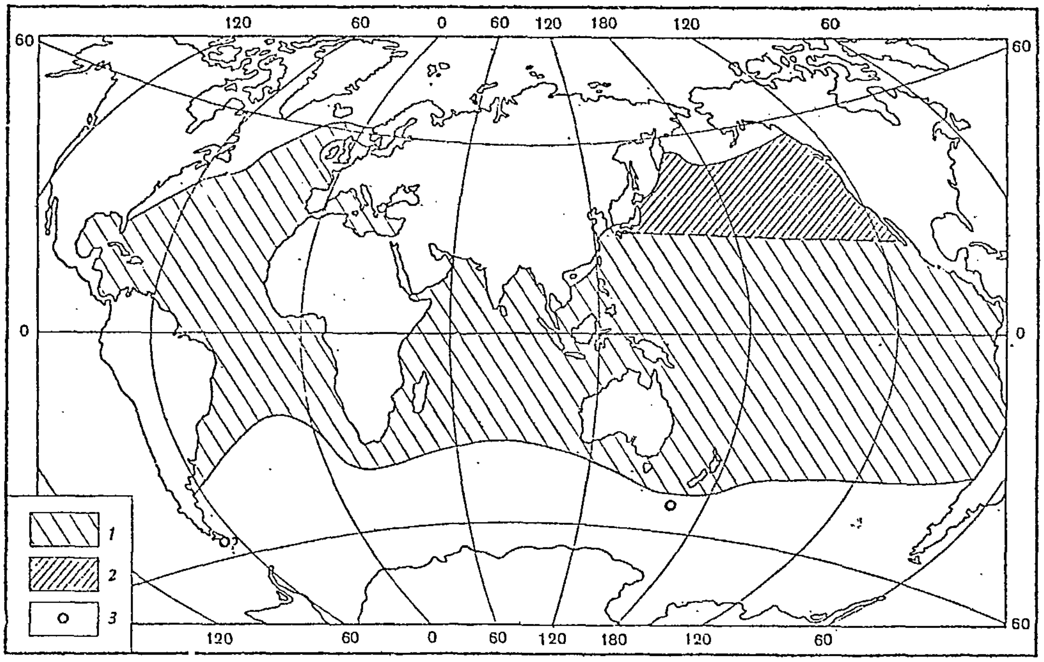

Рис. 3. Распространение космополитического вида *Onychoteuthis banski*

1 — *O. banksi banksi*, *2* — *O. banksi borealijaponicus*, *3* — нотальная форма *O. banksi*

Fig. 3. Distribution of the cosmopolitan species Onychoteuthis banksi 1 -- O. banksi; 2 -- O. banksi borealijaponicus; 3 -- notalian form of O. banksi

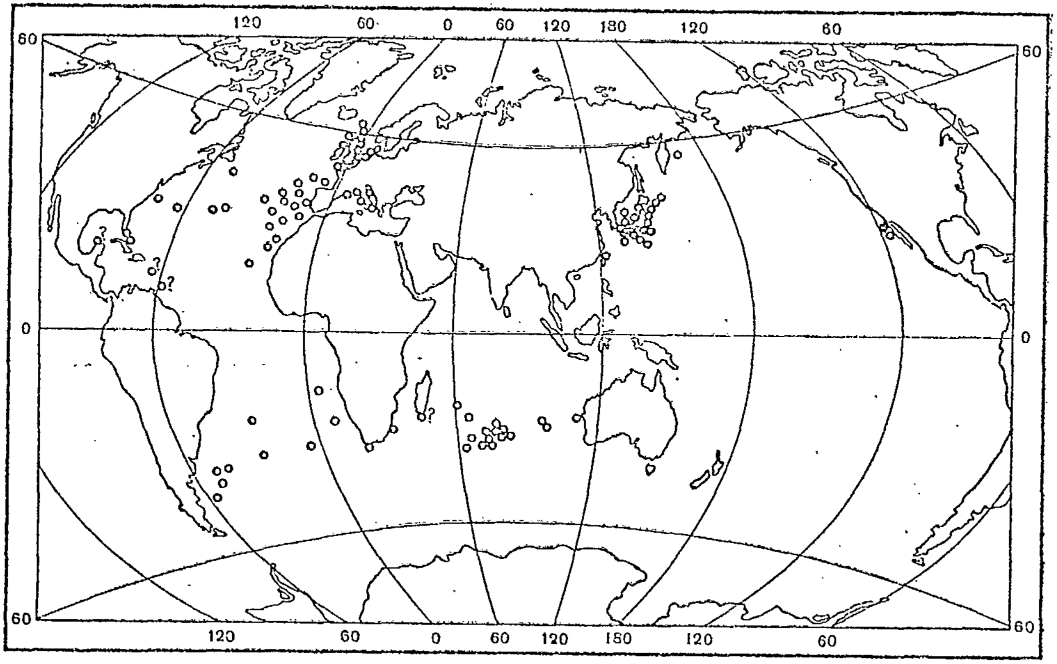

Рис. 4. Распространение комплекса *Ommastrephes «bartrami»* в Атлантическом (включая *O. caroli*), Индийском и Тихом океанах

Fig. 4. Distribution of the Ommastrephes "bartrami" complex in the Atlantic (including O. caroli) Indian and Pacific.

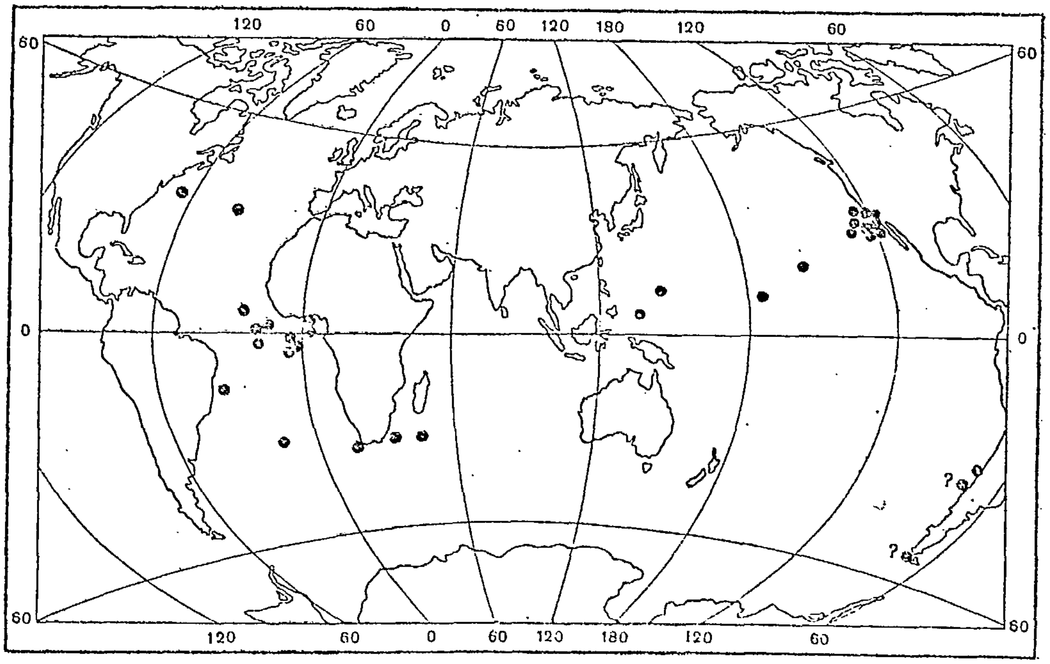

Рис. 5. Распространение *Pterygioteuthis gemmata*

Fig. 5. Distribution of Pterygioteuthis gemmata.

and possibly also along the southwestern, margin of the habitat of the broadly-equatorial squid Symplectoteuthis (S.) oualaniensis. The distinct segregation of the habitats of these two similar species suggests a competitive exclusion: the larger S. oualaniensis displaces the small 222 S. luminosa from the warm parts of the ocean, as it is itself displaced from the Peru Current by a still larger and more formidable competitor -- the Peruvian-Chilean giant squid Dosidicus gigas (Nesis 1970).

Onychoteuthis banksi is regarded as the most widely occurring squid species of the World Ocean (Clarke 1966): from the Bering Sea to Cape Horn (Fig. 3). The North Pacific form of O. banksi was distinguished as a special species O. borealijaponicus (Okada 1927; Young 1972). This form is found along the Pacific coasts of Honshu and Hokkaido, along the Kuriles (only on the Pacific side; in the Sea of Okhotsk it occurs only exceptionally), the Aleutians, British Columbia, Oregon and California. Our collections contain squids from the regions east of Honshu and Hokkaido, southeast of Shikotan, Iturup, Urup, Simushir, south of the Aleutian Islands and from Dixon Entrance. The southern boundary of the habitat of the northern form is uncertain, in the equatorial waters of the Pacific and in the region of the Hawaiian Islands , according to our data, one finds only the typical O. banksi, and in the Kuro Shio east of Honshu, individuals having the characteristics of both forms.

Although the main habitat of the northern form is situated in subarctic waters, where boreal species live, it cannot be considered a boreal form. Along northeastern Honshu, Hokkaido, the Kuriles and Aleutians one finds only foraging squids. They keep near the surface and are easily caught with light. In subarctic waters these squids attain large sizes -- the length of the mantle in females is up to 35.5 cm (Hunter 1965), commonly 20-30 cm; the males are smaller, usually 16-25 cm (Shevtsov 1969); our own data). These squids breed much farther south than their foraging areas, in the waters of the Kuro Shio system and south and east of Honshu. The main breeding period occurs in winter, from December to March (Shevtsov 1969; Okutani 1968a, 1969). In the California Current they breed mainly in spring and summer (Okutani, McGowan 1969), which indicates a segregation of the western and eastern Pacific populations of the northern form. In the tropical waters of all three oceans, where the typical O. banksi is abundant, we know of no squids of this species measuring more than 16 cm (Clarke 1966; Pfeffer 1912). Among the numerous O. banksi obtained in tropical waters by the "Vityaz'" and the "Kurchatov" there was not a single specimen exceeding 14 cm. In the stomachs of tunas and lancet fishes no O. banksi were found larger than 11-13 cm (Bouxin, Legendre 1936; Rees, Maul 1956; G. Voss 1967, and many others), although, while consuming other squid species, these fishes easily manage much larger individuals. When measuring 15-16 cm, the O. banksi males already possess spermatophores, but their penis does not yet attain the dimensions typical of sexually mature squids, while the females are completely immature. It may be that the tropical O. banksi, during the foraging and maturation period, descends to the ocean depths and does not rise to the surface at all, differing sharply in this respect from the North Pacific form. On the basis of our present knowledge I believe it to be possible to describe O. banksi borealijaponicus as a south-boreal-subtropical subspecies of the cosmopolitan species O. banksi. As regards the squids from the southern periphery of the habitat of O. banksi, the sparse data now in our possession merely allow us to postulate that there, too, exists a special notalian form that differs from the tropical one.

Ommastrephes bartrami was also regarded until recently as a cosmopolitan species, occurring extremely widely in the World Ocean (Akimushkin 1963). An analysis of modern data suggests that this name covers two to three different forms and, possibly, none of these should be called O. bartrami. Unfortunately no distinct taxonomic characters have as yet been established allowing us to distinguish these forms (Clarke 1966; Filippova 1968; Young 1972). In the Pacific, O. "bartrami" is known re- 224
liably from the Komandorskiye Islands, east of the South Kuriles, along the Pacific coast of Japan from Hokkaido to Kyushu, in the open regions of the central and southern Sea of Japan, at Taiwan and Lower California (Fig. 4) (Berry 1912; Nishimura 1968; Okutani 1967; Sasaki 1929; Young 1972). A statement by N. N. Kondakov (1941) that O. bartrami was caught at Paramushir Island is in error: his figure shows a young Gonatopsis borealis.

O. "bartrami" is often caught in commercial quantities east of Hokkaido and the Southern Kuriles and always keeps to waters with a high temperature, usually not below 16°; its habitat is seaward of the habitat of Todarodes pacificus (Murata, Araya 1970; G. A. Shevtsov, personal communication; our own data). O. "bartrami" breeds near Japan in the waters of the Kuro Shio system (Okutani 1968a, 1970), near Hokkaido and the Kuriles the catches bring up only large but as yet not sexually mature squids -- this is a typical foraging migration. It is probable that the region of the Komandorskiye Islands is also visited by O.

"bartrami" only during the foraging period in the chase after prey. On the other hand, in the equatorial and central waters of the Pacific the species is absent — in any case, the rich collections of the "Vityaz'" and the "Akademik Kurchatov" contain no specimens. Apparently, the North Pacific *O. "bartrami"* is a north-subtropical species.

In the Indian Ocean, on the other hand, *O. "bartrami"* lives only in the southern part of the ocean (Fig. 4), in southern subtropical waters (Filippova 1968; our own data). In the Atlantic, *O. bartrami* (including *O. caroli*) (Fig. 4) is found mainly in the system of the Gulf Stream and the Canada Current, ranging in the north to Bermuda and the coast of Europe (Shetland Islands, North Sea), it occurs occasionally in the Mediterranean, is common in the South Atlantic between 26 and 44 degrees south, i.e., it is mainly a subtropical (antiequatorial) species that extends into tropical waters. A feature common to all three *O. "bartrami"* is that they have a strictly pelagic lifestyle and very rarely enter coastal waters.

Pterygioteuthus gemmata (=*P. microlampas* Berry) occurs in the North Pacific (Fig. 5) mainly in the central waters — at Hawaii and at California (Berry 1914; Young 1972). Our collections contain individuals from the California Current (31°26' north, 122°57' west; 31°10' north, 123°10' west; 29°43' north, 122°33' west), from the Philippine Sea (13°31' north, 139°58' east; 6°23' north, 135°36' east), and from the area southwest of the Hawaiian Islands (13°00' north, 176°04' west). Not a single specimen has been found in the equatorial waters of the Indian and Pacific oceans, although the area has been visited by many expeditions, and the collections of the Oceanographic Institute contain much material from those waters. The species reappears in the south-western Indian Ocean (G. Voss 1967) and in Chilean waters (our own data). Thus, the species is antiequatorial in the Pacific and south-subtropical in the Indian Ocean. In the Atlantic, on the contrary, P. gemmata has a continuous habitat, and occurs both in equatorial and in central waters (Clarke 1966; Young 1972; our own data).

The third group -- tropical species* with a wide distribution -- embraces 33 species or 38 per cent of the fauna (including habitats with a question mark). Of this number, 26-27 species occur in the Atlantic, Indian and Pacific oceans, 3-4 in the Indian and Pacific, one species in the Atlantic and Pacific, and two are so far known only from the Pacific. Twenty-four species occur only in the tropics, nine range into boreal (and some also into notalian) waters. It seems probable that a large part of the species that penetrate into boreal waters do not breed there but only forage. In any case, their larvae are absent in the sub-arctic waters of the Pacific, or are found only rarely (Shevtsov 1969; Okutani 1966, 1967, 1970).

Tropical and tropical-boreal species are characterized by a gradual reduction of fauna as one moves from south to north (a "shingle-like overlapping of habitats"). The first to disappear are the equatorial 225
species, which do not penetrate into the ocean regions considered in this paper. Such are, for example, Abraliopsis affinis, Bathyteuthis bacidifera,

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* The original has "waters" rather than "species"; but in Russian the two words differ in only one letter. -- TRANSL.

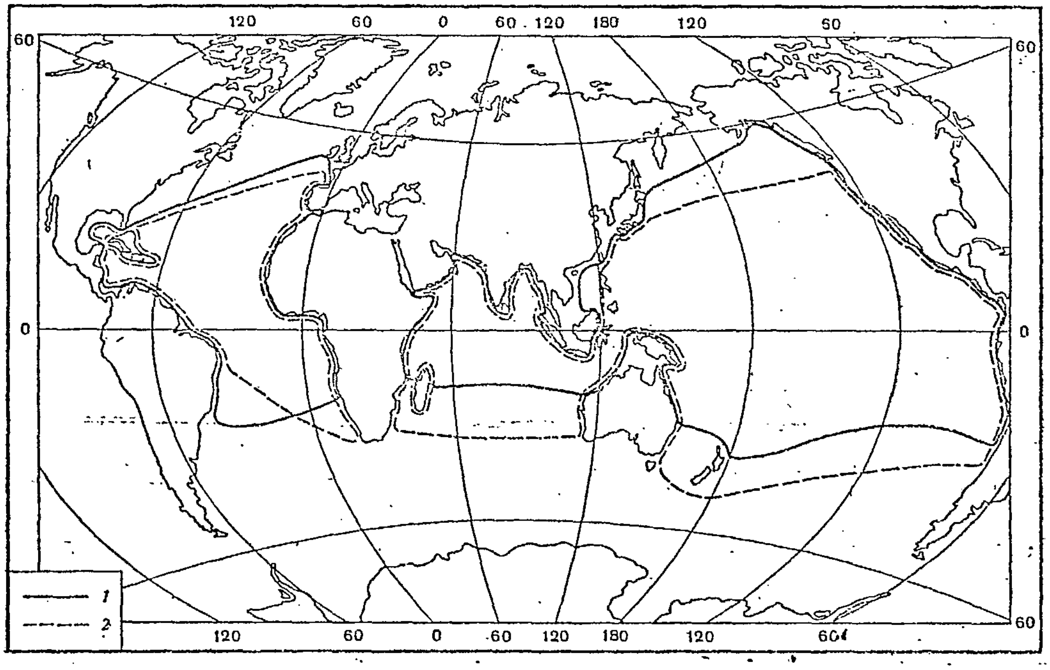

Fig. 6. Distribution of the tropical-boreal cosmopolitan species Japetella diaphana (1) and Vampyroteuthis infernalis (2).

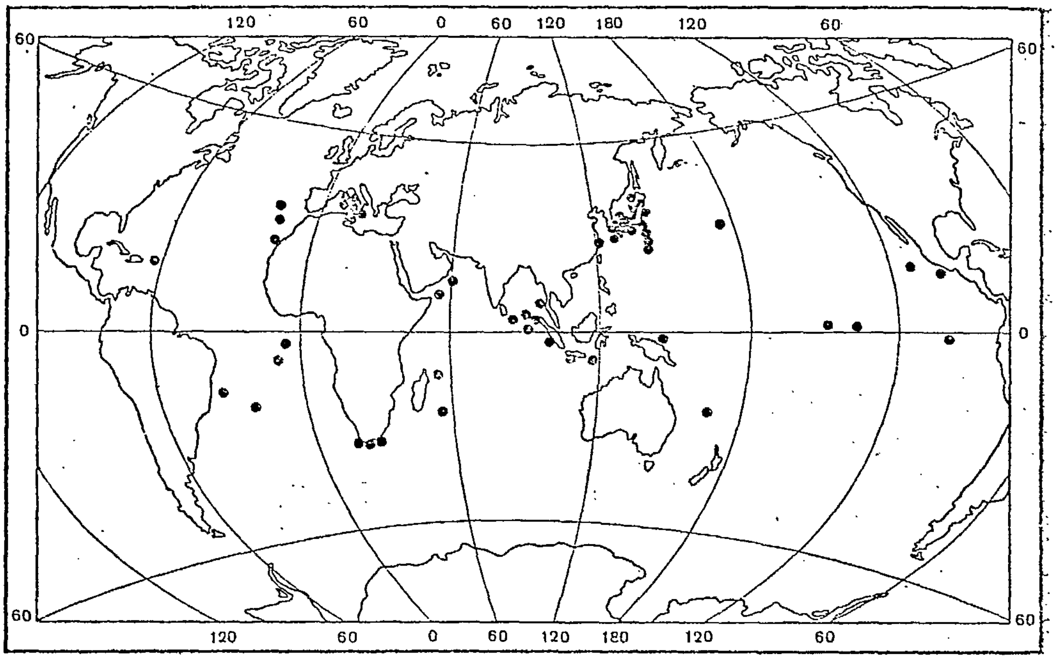

Fig. 7. Distribution of the tropical cosmopolitan species Thysanoteuthis rhombus.

Vitreledonella richardi. Such species as Pterygioteuthis giardi, Symplectoteuthis oualaniensis (see Fig. 2), Amphitretus pelagicus disappear in southern Japan. The main mass of tropical species extends no further than the Boso Peninsula and southern California, but some of the most eurythermic ones -- mainly bathypelagic and meso-bathypelagic species -- range farther north. For example, Vampyroteuthis infernalis (Fig. 6) ranges as far as Oregon, Japetella diaphana to the Gulf of Alaska, Histioteuthis dofleini, to the Aleutian Islands.

The distribution of J. diaphana (Fig. 6) requires special attention. Our collection contains Japetella from the region of the Kuro Shio (40° north, 164°40' east), from waters southeast of the Kuriles and south of the Aleutians, from the Gulf of Alaska, from the area west of the Alexander Archipelago and west of Oregon (40°34' north, 133°37' west), caught in horizontal catches at depths of 100-1,000 m, mainly at 400-1,000 m, and in vertical catches from depths of 1,000-7,000 m. The Japetella in the North Pacific are being identified as Japetella heathi (Berry), but in comparing the North Pacific individuals with typical J. diaphana from tropical waters I was unable to find distinct differences. J. diaphana is a widely occurring tropical species whose habitat is commonly regarded as being bounded by the 10° isotherm at a depth of 200 meters (Thore 1949). But in the North Pacific this species extends much farther north, to the northern part of the Gulf of Alaska; it is known along British Columbia, Oregon and California (Mercer 1968; Pearcy 1965; Young 1972). In the Western Subarctic Circulation, in the Bering Sea and the Sea of Okhotsk J. diaphana is absent. Our collections contain individuals of all sizes -- from larvae with a mantle length of 6-10 mm to sexually mature females with a mantle length of 75, 90 and 100 mm; most individuals measured under 30 mm, representing two-thirds of all catches. This argues 226 for a normal breeding of *Japetella* in the Alaska Circulation. Large females of *Japetella* caught in the Gulf of Alaska and at the Alaska Peninsula are larger than the biggest individuals from other parts of the World Ocean* (Thore 1949; our own data). It is possible that the North Pacific *J. diaphana* deserves to be recognized as a special subspecies *J. diaphana heathi*, but at this moment we cannot definitely indicate how it differs from the individuals from tropical waters.

A few tropical species -- *Hyaloteuthis pelagica*, *Thysanoteuthis rhombus* (Fig. 7), *Liocranchia reinhardti*, *Amphitretus pelagicus* -- are fairly widely distributed in the western Pacific but are absent in the California and the Peru currents. Their habitats in the east are narrower than in the west. Such a type of habitat Beklemishev (1969) terms "equatorial-west-central."

The role of warm currents in the distribution of tropical species is well observable in the Sea of Japan. Many epipelagic species -- *Thysanoteuthis rhombus* (Fig. 7), *Tremoctopus gracilis*, *Ocythoe tuberculata*, *Argonauta* spp. -- in the eastern part of the sea range with the waters of the Tsushima Current to southern Hokkaido, while on the Pacific coast

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* The basic measurements of the largest female *J. diaphana* from the Gulf of Alaska are: total length, 22 cm, length of mantle to centre of eyes, 10 cm; width of mantle, 7.7 cm; width of head, 5.0 cm; length of arms in mm (l -- left, r -- right): 1st pair, l 80, r 73; 2nd pair, l 75, r 71+; 3rd pair, l 98, r 105; 4th pair, l 84, r 83; depth of umbrella sectors, mm: A -- 30, B -- 27, C -- 24, D -- 24, E -- 23; eye diameter 18 mm; diameter of largest sucker, 5 mm.

they are found north of the Boso Peninsula.

Very few of the cosmopolitan species have been carefully studied, but in respect of those species that were analyzed in detail it has been shown that individuals from different oceans (e.g., Atlantic and Pacific) have more or less distinct morphological differences, even though they do not amount to the rank of species (Pickford 1949; Roper 1969; Young 1972).

The following two groups embrace species that are unable to 227 overcome the eastern Pacific faunistic barrier. These are neritic-pelagic or nekto-benthonic animals. They are either closely linked with the bottom -- permanently or only during spawning -- or they live in the highly productive waters above the shelf margin, submarine ridges, etc., usually, both one and the other.

The fourth group of species are endemic to the northwestern Pacific (ten species). Among them we find a complete assemblage of species from the north-boreal _Gonatopsis japonicus_ (found thus far only in the cold northwestern part of the Sea of Japan) to the subtropical _Enoploteuthis chuni_, which is found in large numbers only along southern Japan; there is a predominance of subtropical (4) and south-boreal-subtropical species (4). Typical of this group are two extremely abundant species of squids -- _Todarodes pacificus_ and _Watasenia scintillans_ (both have even been depicted on Japanese postage stamps, and the former on the postage stamps of North Korea). Both species are south-boreal-subtropical neritic-pelagic (Fig. 8). They breed mainly along southern Japan, _W. scintillans_ along the coast of Honshu northward to the Gulf of Toyama and the area of Kashima-nada, _T. pacificus_ along all Japanese

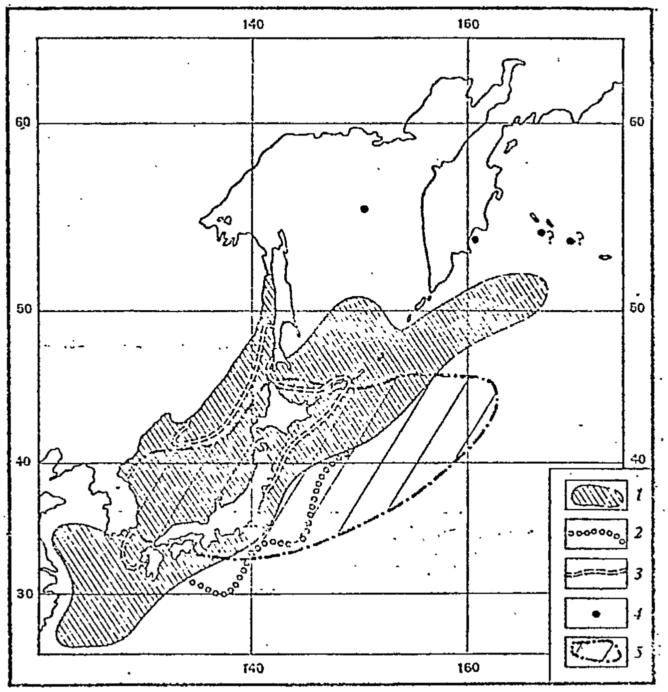

Fig. 8. Distribution of south-boreal-subtropical species in the northwestern Pacific -- Todarodes pacificus (1-4) and Watasenia scintillans (5). 1 -- established and presumed habitat of young and adult squids; 2 -- limits of the transportation of larvae by the Kuro Shio current; 3 -- boundaries of the main fisheries areas; 4 -- finds of adult squids outside the main habitat.

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coasts, but the main breeding grounds are located to the south and southwest of Kyushu. T. pacificus accomplishes very far-ranging foraging migrations, thousands of kilometers from its breeding grounds, as far as the Komandorskiye Islands, after which it returns to spawn along the coast (this species deposits benthonic eggs). Its confinement to neritic waters is the reason why T. pacificus does not cross the ocean; the extremely rare finds of the species along the coast of British Columbia merely confirm this restriction. We do not know the reason for the close link with the neritic zone of the luminescent squid W. scintillans

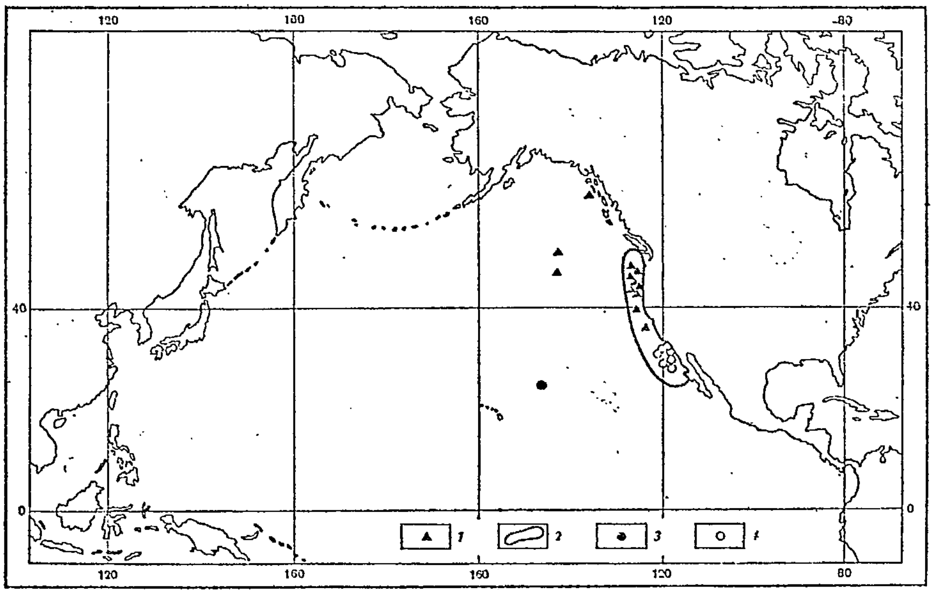

Fig. 9. Distribution of pelagic endemic squids of the northeastern Pacific -- *Berryteuthis anonychus* (1), *Abraliopsis felis* (2, 3) and *Bathyteuthis berryi* (4).

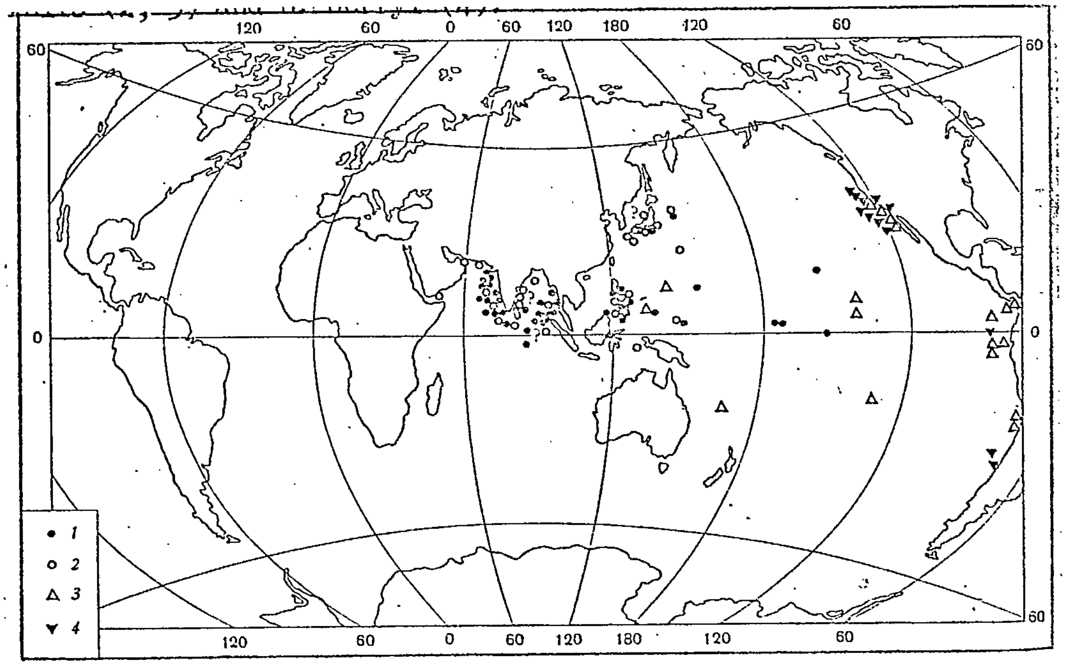

Fig. 10. Distribution of Indian-West Pacific (1, 2), Pacific (3) and East Pacific (4) tropical species -- *Abralia andamanica* s.l. (1), *Chiroteuthis imperator* (2), *Galiteuthis pacifica* (3) and *Histioteuthis heteropsis* (5).

-- after all, it is a relatively deep-sea species, its eggs are pelagic, and its nearest relatives -- the species of *Abraliopsis* -- live in the open ocean -- but the luminescent squids sometimes spawn literally along the shoreline. It is probable that inshore spawning helps to prevent the eggs from being carried by ocean currents outside the areas of the highly 229
productive inshore waters to which *Watasenia* is adapted.

Species endemic in the northeastern Pacific (group 5) are purely pelagic and not tied to the bottom. There are six or seven -- one or two boreal, two south-boreal-subtropical and three subtropical species. The boreal species *Berryteuthis anonychus* is distributed from the southern Gulf of Alaska to California, westward to about 150° west (Fig. 9). The base of its habitat is probably located in the neutral region between the Alaska and the California currents (Beklemishev 1969). The remaining species live exclusively or mainly in the system of the California Current. Example: *Abraliopsis felis* and *Bathyteuthis berryi* (Fig. 9).

The sixth and seventh groups embrace six Indian-West Pacific (three of these may possibly occur in the Atlantic) and six (some doubtful) East Pacific species (five tropical, one possibly antiequatorial). The base of the habitat of one of the East Pacific species -- *Dosidicus gigas* -- is in the Peru Current; into the California region these squids penetrate only in some years -- years of mass invasions. Some species of these groups (Fig. 10) are neritic-pelagic (*Abralia andamanica* in the western ocean, *Histioteuthis heteropsis*, in the eastern), others are tied to the bottom (*Chiroteuthis imperator*, *Mastigoteuthis cordiformis*); they are incapable of overcoming the East Pacific faunistic barrier.

Thus, of 87 species and subspecies, 45 (52%) occur only or mainly in the tropics, 18 (20%) only or mainly in boreal waters, 17 (20%) in subtropical waters or in south-boreal waters as well; the habitats of seven species (8%) are unclear. Species occurring both in the western and eastern parts of the Pacific number 51, 16 are found only in the west and 13 only in the east; 29 species occur in three oceans, 11 in two and 40 only in the Pacific Ocean.

Having analyzed the basic distribution patterns of pelagic cephalopods in the North Pacific we can now proceed to the conclusion that the great variety of habitats may be divided into five basic types: Indian-West Pacific and panoceanic tropical or cosmopolitan species; East Pacific tropical species; boreal Pacific (including those boreal species that occur only in the western or eastern Pacific); Japanese south-boreal + subtropical; Californian south-boreal + subtropical. Evidently, these five types of habitats correspond to five centres of species formation -- Indian-Pacific tropical; East Pacific; boreal Pacific; Japanese; and Californian. The subtropical species of the "second group" reviewed above probably arose from Indian-West Pacific or still more widely occurring but tropical ancestors. The tropical centre gave rise to 43 species of those reviewed here, the East Pacific to six, the boreal to 17, the Japanese to 9 and the Californian centre to five.

If we analyze the southern boundaries of the habitats of all 17 boreal species and the northern boundaries of all 45 tropical species, we find that 75% of the boreal species occur at the Southern Kuriles and along northern British Columbia, 50% occur in the Sangar Strait (east side) and along southern California, 25% occur near northern Honshu (both sides) and the northern part of Lower California. Of the tropical species, 75% penetrate northward to the southern coast of Honshu, the Kuro Shio east of Honshu and the southern part of Lower California, 50% range to central Honshu (on the Pacific coast) and southern California, 25% to the Korea and Sangar straits and northern California.

The habitats of the subtropical and south-boreal-subtropical species are naturally situated precisely in the zone of overlap of tropical and boreal species.

2. Neritic Squids and Cuttlefishes 231

The neritic benthonic-nektonic (nektobenthonic) cephalopods -- squids of the suborder Myopsida (family Loliginidae) and cuttlefishes of the order Sepiida (excluding Spirulidae) -- possess substantially different types of habitats (Table 2).

They live only on the continental shelf -- only some Sepiolidae are capable of living in the bathyal region as well. The open ocean is inaccessible to them. The centre of origin and primary diffusion of these groups is the tropical Indian-West Pacific. Typical of the Sepiida and Myopsida are (a) abundance of genera and species in the tropics of the western Pacific; (b) a great impoverishment of the fauna of the tropics of the eastern Pacific and its complete taxonomic segregation from the western Pacific; (c) a very rapid drop in the number of species from south to north; (d) extreme paucity of endemic boreal fauna; (e) the

Table 2. Distribution and zoogeographical characteristics of neritic squids and cuttlefishes in the non-tropical waters of the North Pacific

(EP — Eastern Pacific; IWP — Indian-West Pacific; NWP — North West Pacific; NEP — North East Pacific; IM — Indian-Malayan. bor — boreal; sub — subtropical; trop — tropical; s-bor-sub — south-boreal-subtropical; s-bor— south-boreal; trop-s-bor — tropical ranging into south boreal waters.)

Species	Zoogeographical range	Habitat boundaries	
		northern	southern
	Order Teuthida, Suborder Myopsida		
Loliolopsis diomedeae (Hoyle)	EP trop	Northern Gulf of California	Peru
Lolliguncula panamensis Berry	EP trop	ibid.	Ecuador
Sepioteuthis lessoniana Lesson	IWP trop	S Hokkaido, Hawaii	N Australia, Fiji
Doryteuthis bleekeri (Keferstein)	NWP s-bor-sub	NE Hokkaido	S Kyushu, E China
Doryteuthis kensaki (Wakiya et Ishikawa)	NWP sub	Centr. Honshu	Kyushu
Loligo edulis Hoyle	IWP trop-s-bor	Sangar Strait, Centr. Honshu	Philippines
Loligo chinensis Gray[1]	NWP sub	Centr. Honshu	China
Loligo budo Wakiya & Ishikawa	NWP sub	S Honshu	Kyushu
Loligo japonica Hoyle	NWP s-bor-sub	Centr. Hokkaido	Kyushu, E China
Loligo beka Sasaki	IM trop	S Honshu	Hainan
Loligo aspera Ortmann[1]	NWP sub	south of the coast of Shikoku	

Table 2, cont.

Loligo kobiensis Hoyle	IM trop	S Honshu	Malaysia
Loligo gotoi Sasaki	NWP sub	S Honshu	Kyushu, ? Gulf of Tonkin
Loligo tagoi Sasaki	NWP sub	Shikoku	Syangan
Loligo yokoyae Ishikawa	NWP sub	south coast of Shikoku	
Loligo uyii Wakiya & Ishikawa	NWP sub	S Honshu	S Kyushu
Loligo opalescens Berry	NEP s-bor-sub	Dixon Entrance	S Lower California, ? Peru

Order Sepiida

Sepia lycidas Gray	IM trop	S Honshu	Sarawak
Sepia pharaonis Ehrenberg	IWP trop	S Honshu	N Australia
Sepia esculenta Hoyle	IM trop	Central Honshu	Syangan, Philippines, ?Singapore
Sepia latimanus Quoy & Gaimard	IM trop	S Honshu	Tasmania, New Caledonia, Fiji
Sepia madokai Adam	NWP sub	S Honshu	S Kyushu
Sepia appellofi Wülker	NWP sub	S Honshu	S Kyushu
Sepia pardalis Sasaki	NWP sub	Central Honshu	Kyushu
Sepia lorigera Wülker	NWP sub	S Honshu	Shikoku
Sepia longipes Sasaki	NWP sub	Central Honshu	S Sea of Japan

Table 2, cont.

Sepia kobiensis Hoyle	IWP trop?	S Hokkaido	Syangan, ?Indonesia
Sepia andreana Steenstrup	IWP s-bor-sub	S Hokkaido	Syangan
Sepia erostrata Sasaki	NWP sub	Sagami Bay	
Sepia tokioensis Ortmann	NWP sub	Sangar Strait	Kyushu
Sepia misakiensis Wülker	NWP sub	S Honshu	Osumi Islands
Sepia carinata Sasaki	NWP sub	Sagami Bay	
Sepia tenuipes Sasaki	NWP sub	Central Honshu	Shikoku
Sepia peterseni Appellöf	NWP sub	S Honshu	S Kyushu
Sepia (Metasepia) tullbergi Appellöf	NWP sub	S Honshu	Sangan
Sepiella japonica Sasaki	NWP sub	Pos'yet Bay, Centr. Honshu	Philippines
Sepiadarium kochii nipponianum Berry	NWP sub	Central Honshu	Kyushu
Rossia pacifica Berry	NP bor	Olyutorskii Penin., Gulf of Alaska	Tsushima Strait, S Honshu, S California
Rossia mollicella Sasaki	NWB s-bor	Sangar Strait[2], Peter the Great Bay	Kii Peninsula
Rossia bipapillata Sasaki	IM trop	S Honshu	Philippines
Sepiolina nipponensis (Berry)	IM trop	S Honshu	Philippines

Table 2, cont.

Euprymna morsei (Verrill)	IM trop-s-bor	NW Hokkaido	Indonesia
Euprymna berryi Sasaki	IWP trop-s-bor	S Hokkaido	Philippines, ?Indonesia
Inioteuthis japonica Verrill	IM trop	Central Honshu	Hainan
Sepiola birostrata Sasaki	NWP s-bor-sub	S Sakhalin, Iturup	Kyushu, N China
Sepiola parva Sasaki	NWP sub?	Tokyo Bay	
Idiosepius pygmaeus paradoxus Ortmann	NWP sub	S Hokkaido	Shikoku, N China

NOTES. 1. Taxonomic position unclear.

2. The northern boundary, according to our data, is at 41°45'3 north, 141°25'2 east, depth 269-291 m.

existence of a large centre of species formation in the subtropical waters of Japan, whereas no such centre exists near California; (f) the absence of species in the North Pacific that also occur in the Atlantic.

In the Japanese waters (Sasaki 1929; Okutani 1967) we know of 30 species of Sepiida and 14 species of Myopsida. Of these 44 species, 14 are Indian-West Pacific or Indian-Malayan tropical species, one is a boreal species, and 29 are endemic in the northwestern Pacific; of the 232
latter, 24 species are subtropical (e.g., *Sepiella inermis*: Fig. 11), four are south-boreal-subtropical (e.g., *Sepiola birostrata*: Fig. 11), and one is south-boreal bathyal (*Rossia mollicella*).

The boreal *Rossia pacifica* is the only species occurring in both the western and eastern Pacific. It ranges from the Bering Sea to the Korea Strait, eastern Honshu and California, in its northern habitat it is eurybathic, in the south it is found only in the lower sublittoral and the upper bathyal zones, avoiding the shallows. Of the other 43 species only 11 extend northward to the Sangar Strait, 8 (19%) extend to southern Hokkaido, and only one species -- *Sepiola birostrata* (Fig. 11) -- ranges to southern Sakhalin and the Southern Kuriles.

For the sake of comparison I shall note that of the pelagic cephalopods occurring near Japan (again excluding the boreal species), those extending to Hokkaido represent 23%, and those extending to the Southern Kuriles, 21%.

The previously mentioned *R. pacifica* is the only Sepiida species found in the northeastern Pacific. South of California -- the southern boundary of its habitat -- the entire order Sepiida (also including the Spirulidae) is entirely absent, and it is only near southern Chile that we begin to find *Semirossia patagonica*, which lives in the southwestern

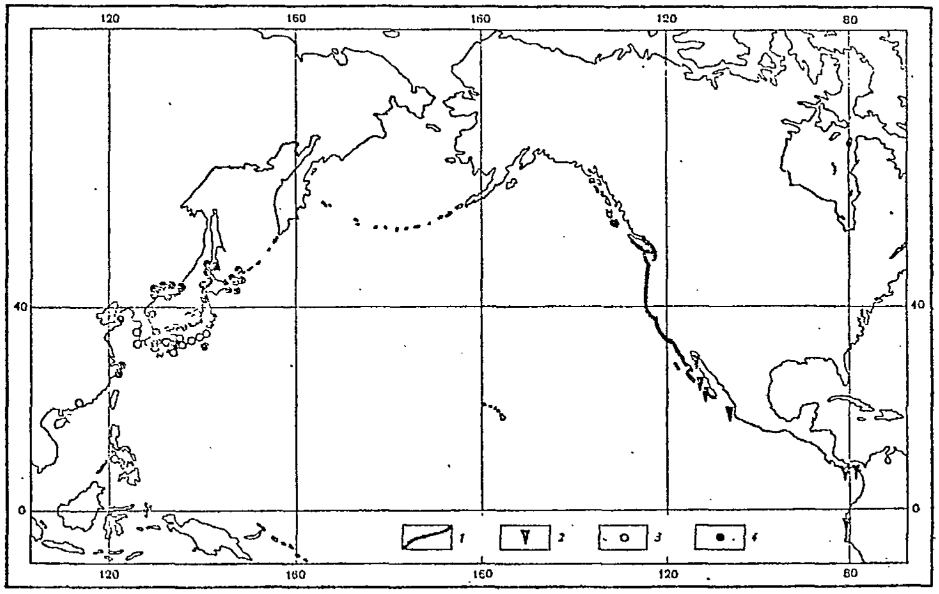

Fig. 11. Distribution of neritic squids and cuttlefishes endemic in the northeastern (1, 2), northwestern (3, 4) Pacific: Loligo opalescens (1), Lolliguncula panamensis (2), Sepiella japonica (3) and Sepiola birostrata (4).

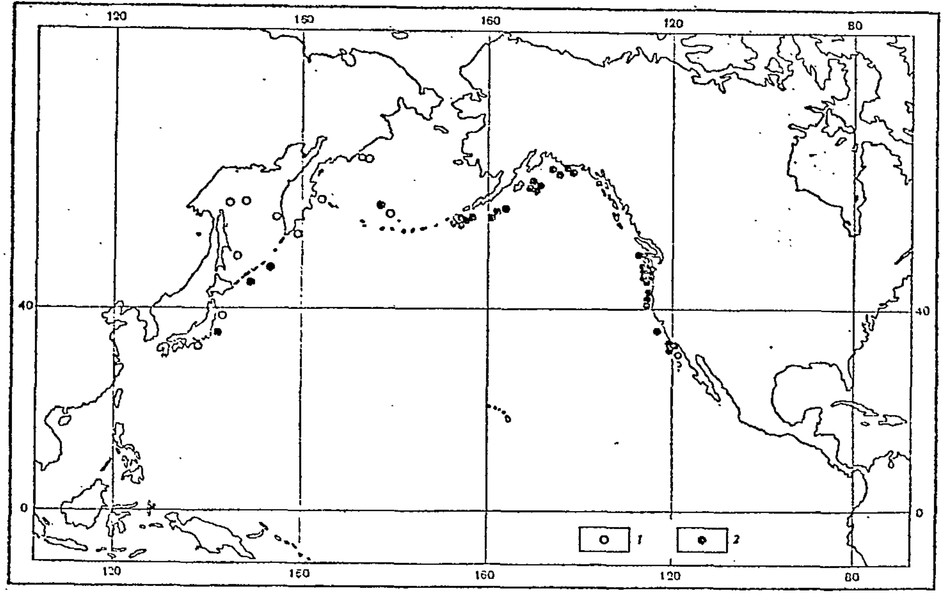

Fig. 12. Distribution of boreal benthonic octopuses Grimpoteuthis albatrossi (1) and Opisthoteuthis californiana (2).

Atlantic. The Myopsida fauna in the eastern Pacific is much poorer than in the western, there are only four species: one south-boreal-subtropical (Loligo opalescens: Fig. 11), two tropical (e.g., Lolliguncula panamensis: Fig. 11) and one notalian-south-subtropical (Loligo gahi).

Curiously, not one of the Sepiolidae species in the Pacific extends to the arctic waters, and not one of the Sepiidae and Loliginidae species is found in the north boreal zone. In the Atlantic, the picture is somewhat different: in the north boreal zone we find Sepia officinalis (though fairly rarely) and five Loliginidae species; in the western, near-Atlantic, part of the Arctic we know of three species of Rossia, one of 233
which even lives in the High Arctic, namely R. moelleri, which ranges eastward to the Laptev Sea and westward to Amundsen Gulf.

3. Benthonic Octopuses

The taxonomy of the benthonic octopuses is too confused, and our own knowledge of the North Pacific octopuses is not reliable enough to permit the compilation of the same kind of table as for the squids, cuttlefishes and pelagic octopuses. The benthonic octopuses are less closely tied to the continental shelf than the cuttlefishes and the Loliginidae, many of them live in a great depth range, others live only in the deep sea. The deep-sea inhabitants are adapted to cold water and, presumably, would be capable of migrating from one side of the ocean to the other through the subarctic regions. For this reason, many of the distribution patterns applying to the neritic squids and cuttlefishes do not apply to the benthonic octopuses.

The octopus fauna in the Japanese waters is just as rich, varied and highly endemic as that of the neritic squids and cuttlefishes, but the number of octopus species does not drop off as rapidly from south to north as in Myopsida and Sepiida. The fauna of benthonic octopuses in the eastern Pacific is also much poorer than in the western part of the ocean, but along California there exist several endemic subtropical *Octopus* species. The boreal octopus fauna is fairly rich, it includes only eurybathic and mainly bathyal species — *Grimpoteuthis albatrossi* (Fig. 12), *Opisthoteuthis californiana* (Fig. 12), *Benthoctopus profundorum*, *B. hokkaidensis*, *Bathypolypus salebrosus*, *Octopus dofleini* (from the littoral to the bathyal region), *O. leioderma* — whereas the endemic subtropical octopus fauna, Japanese and Californian, is made up mainly of inshore, littoral and upper-sublittoral species.

The boreal species range southward to Central Honshu and (at least four species) to southern California. For most of them, the northern boundary runs in the northern Bering Sea, but *Octopus leioderma* occurs 234
in Bering Strait, *B. profundorum* in the Chuckchee Sea, and *B. hokkaidensis*, at Cape Barrow (Akimushkin 1963; Berry 1912; McGinitie 1959; Sasaki 1929; Talmadge 1967). The giant North Pacific octopus *Octopus dofleini*, the largest in the world, is represented by three distinctly separate subspecies: *O. d. apollyon* (= *O. gilbertianus*), from the Bering Sea to the Northern Kuriles and the Gulf of Alaska; *O. d. dofleini* from the Southern Kuriles and southern Sakhalin to the Korea Strait, the Laotung Peninsula and central Honshu; and *O. d. martini*, from British Columbia to California (Pickford 1964).

Benthoctopus and *Bathypolypus* occur also in the near-Atlantic part of the Arctic, but Octopus is wholly absent not only in the Arctic but also in the north-boreal zone of the Atlantic: the farthest northern limits of O. vulgaris and the entire genus Octopus in the Atlantic run along a line Long Island-Bermuda-Irish Sea-southern North Sea.

There is one amphi-Pacific octopus -- the south-boreal eurybathic O. californicus (Akimushkin 1963). Among the endemic species of the northwestern part of the ocean there are not only numerous subtropical species, but also south-boreal ones (O. conispadiceus, O. araneoides), broadly south-boreal (O. longispadiceus, O. yendoi), even north-boreal (O. ochotensis) (Akimushkin 1963; Kondakov 1941; Berry 1912; Sasaki 1929; Taki 1963). Among the endemic species of the Northeast Pacific not a single one is thus far known to occur north of California.

Two species of shallow-water tropical octopuses occur in the Atlantic, Indian and western part of the Pacific oceans -- Octopus vulgaris and O. macropus; the former also occurs along the west coast of Central and South America. All other species have more or less narrow habitats: no tropical species, such as might occur near Japan or California, are found among the shallow-water benthonic octopuses.

4. General Distribution Features of North Pacific Cephalopods

The general distribution features of cephalopods in the North Pacific may be outlined as follows.

1. Most species are of tropical origin. Among the tropical species of pelagic cephalopods, predominance belongs to the cosmopolitan ones, less often to Indian-Pacific; Indian-West Pacific and East Pacific

tropical species are few in number. There are equatorial and equatorial-west-central species, although generally the differences between the equatorial and central fauna are small. On the whole, the tropical fauna is homogenous. Typical of those cosmopolitan species that have received sufficient study is that between the Atlantic and Pacific (and sometimes also Indian Ocean) individuals there are morphological distinctions, which, to be sure, do not amount to species distinctions.

Quite different is the situation in respect of neritic and benthonic cephalopods: here the Indian-West Pacific and East Pacific tropical faunas are fully separate, the former is extraordinarily rich in species, the latter extremely poor (with the complete absence of entire large groups, e.g., the orders Nautilida and Sepiida).

2. North of the tropics there arose a large centre of species formation in the subtropical waters of southern Japan. Here arose the endemic genera Watasenia and Sasakinella, many endemic subtropical and south-boreal-subtropical species; a much weaker centre of species formation is located in the Californian waters (only endemic species and subspecies). The subtropical faunas of the Japanese and Californian waters are entirely different -- there are very few pelagic subtropical species, and even 235
these are antitropical or antiequatorial (i.e., they did not necessarily originate in the northern subtropics).

3. The boreal fauna is not rich, but very characteristic; there are the endemic genera Berryteuthis and Gonatopsis, many endemic species; the boreal waters of the North Pacific gave rise to the family Gonatidae. The boreal fauna is made up only of the groups Oegopsida (three times fewer boreal species and tropical ones), Cirrata and Octopodoidea; the order

Sepiida contains only one such species, the Vampyromorpha, Bolitaenoidea and Argonautoidea not a single one. Most of the boreal species occur throughout the subarctic Pacific, but there are separate West and East Pacific boreal species.

4. Only very few Pacific cephalopods -- apparently only three eurybathic octopuses -- penetrate into the Arctic; not a single arctic species occurs in the Pacific. Of the Atlantic-Arctic cephalopod species Gonatus fabricii is of Pacific origin.

An analysis of the distribution of cephalopods allows us to establish the following zoogeographical boundaries (north to south, Fig. 13):

A. The boundary of arctic and boreal faunas -- for benthonic species, the area south of St. Lawrence Island (tentatively): the northern boundary of Rossia pacifica and Berryteuthis magister; for pelagic species, the north slope of the Bering Sea (southern margin of the Bering Sea shelf).

B. The boundary of the north-boreal and south-boreal faunas is the Tatarskii Strait, the southern Sea of Okhotsk (Cape Aniva-- Chirip Peninsula or Friza Strait), British Columbia (between Dixon Entrance and Puget Sound): in the west this is the northern boundary of Sepiola birostrata, Watasenia scintillans and commercial accumulations of Todarodes pacificus, in the east, the northern boundary of Loligo opalescens and Abraliopsis felis. In the open sea this boundary, judging from available data, is not observable.

C. The boundary of the south-boreal and subtropical faunas, the basic zoogeographical dividing line in the northern part of the ocean, runs through the Yellow Sea (Bohai Strait?), the southern Sea of Japan, Boso Peninsula, the subarctic convergence (northern polar front), California (approximately the area of Cape Conception). On either side of this somewhat tentative boundary there is a zone of mixed boreal and tropical fauna. This zone widens along the margins, where modified waters develop -- east of the Korean Peninsula, nearly the entire west and east coast of Honshu, southwestern Hokkaido, the west coast of the United States, northern Lower California -- and narrows in the centre, in the open ocean, where hydrological gradients are great. The centre of the transitional zone is the basic biotope of Symplectoteuthis luminosa and some inshore species.

D. The boundary between the subtropical and properly tropical fauna runs from the Bay of Tonkin, the area of Hainan, Taiwan, Ryukyu, Idzu, the northern boundary of the Hawaiian region, the extreme south of Lower California. This is the northern limit of some equatorial species and, in inshore waters, of narrowly tropical Indian-West Pacific and East Pacific species, and the southern boundary of subtropical (Japanese and Californian) species.

A comparison of the distribution patterns of cephalopods with those of other marine invertebrates and fishes (Ekman 1953; Gur'yanova 1964) confirms that these, too, are governed by the general principles of marine zoogeography. Any group of multicellular marine organisms that possesses a fair number of genera and species exhibits the same basic distribution patterns. Having analyzed the extensive literature on the benthonic organisms and fishes of the continental shelf and the upper bathyal zone I became convinced of the reliability of systems of latitudinal zones established from the distribution of cephalopods: a High Arctic Zone (absent in the Pacific), and Low Arctic Zone, a North Boreal Zone, 236

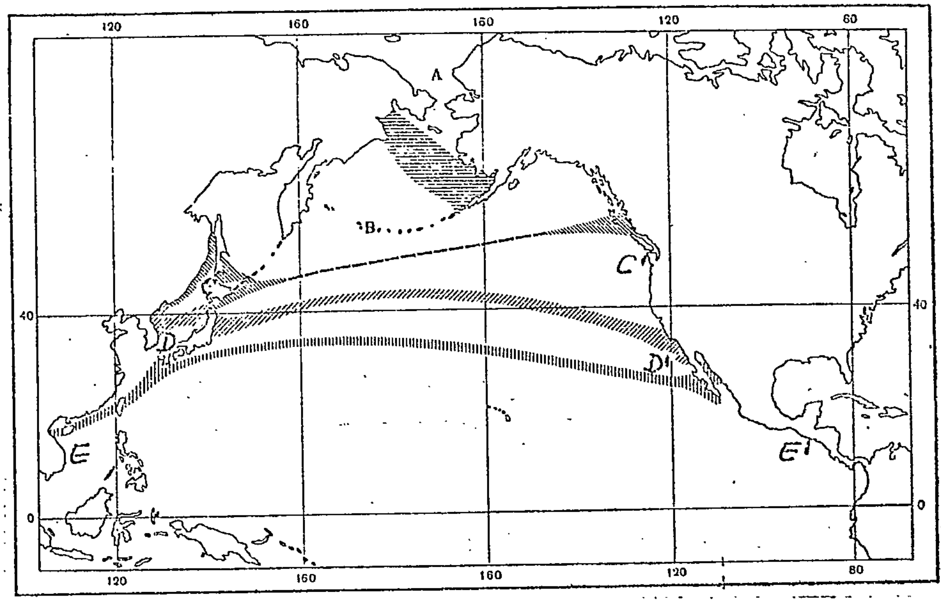

Fig. 13. Zoogeographical regions of the North Pacific, on the basis of cephalopod fauna. A -- Arctic region; B-C -- Boreal region (subregions: B -- Aleutian-Kamchatkan north-boreal; C -- North Japanese (Ainu)south-boreal), D-E -- Tropical region (subregions: D -- South Japanese (Sino-Japanese) subtropical; D' -- Californian subtropical, E -- Indian-West Pacific tropical, E' -- East Pacific tropical). Transitional zones are hatched.

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a South Boreal Zone, a Northern Subtropical Zone, and a Tropical Zone.

Zoogeographical zones of the first rank divide the Arctic, Boreal and Tropical (in the broad sense) faunas, second-rank boundaries split each of these zones into two.

The location of the above zoogeographical boundaries in inshore areas coincides very well with the location of boundaries run on the basis of the benthonic fauna of the continental shelf and upper bathyal region (map compiled by us). The same kind of scheme and approximately the same boundaries of latitudinal zones result from the study of pelagic fishes (Parin 1968; Rass, 1967). From the study of all groups of pelagic fishes there results a distinct boundary between boreal and tropical fauna and a mixture zone, which coincides with the boundary and the mixture zone of the cephalopods. The boundary between the north-boreal and south-boreal zones run on the basis of cephalopod distribution coincides with the northern limit of tuna and sunfish, while the boundary between the subtropical and properly tropical faunas coincides with the boundary of the subtropical and properly tropical flying fishes, with the southern boundary of the saury and the northern boundary of the breeding of tropical tuna fishes (Parin 1968; Rass, 1967). Many similar examples can be cited.

There is much less agreement between our scheme with that of the distribution of pelagic plankton (Beklemishev 1969). The boundary between the northern and southern zone of the Pacific subregion of the arctic-boreal region, in Beklemishev, runs approximately in the same area as our boundary between the north- and south-boreal zones, while the southern boundary of the transitional zone coincides roughly with our boundary between the south-boreal and subtropical zones. But the northern boundary of the transitional zone, after Beklemishev, fails to coincide with any substantial boundary of cephalopod distribution, while the cephalopod 237
boundary of the subtropical and tropical zones lacks any analogy with the planktonic zoogeographical boundaries.

Summing up all of the above data on the distribution of cephalopods in the North Pacific, we may propose the following zoogeographical classification of this part of the World Ocean, a classification in which I deliberately employ only two neutral terms -- "region" and "subregion."*

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* The author has transliterated the English (or German) words "region" and "subregion." The Russian words normally used for these concepts are "oblast'" and "podoblast'" -- vide infra. -- TRANSL.

To distinguish zoogeographical sections of the generally accepted rank -- "oblast'," "podoblast'," province, on the basis of only one group and, more so, in one part of the ocean, is impossible, it can be done only with the use of as many high-rank taxons as possible (Beklemishev 1969), on a global scale, otherwise we shall not see the wood for the trees.

1. Arctic region (no further subdivision considered).
2. Boreal region,(Aleutian-Kamchatkan north-boreal, North Japanese (Ainu) south-boreal and Oregon south-boreal subregions.
3. Tropical region -- South Japanese (Sino-Japanese) subtropical, Californian subtropical, Indian-West Pacific tropical and East Pacific tropical subregions.

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A NEW DEEP-SEA SPECIES OF SEA URCHINS OF THE GENUS ECHINOCREPIS AND THE DISTRIBUTION OF THE FAMILY POURTALESIIDAE (ECHINOIDEA, MERIDOSTERNINA)

By A. N. Mironov

Pourtalesiidae sea urchins are easily recognized by the deep furrow in the anterior part of the test on the lower side. Typical of each genus of this family are its own, sometimes fairly odd test outlines: ungulate in Echinocrepis, ovate in Spatagocystis, cuneate in Cystocrepis, bottle-shaped in Pourtalesia and, finally, in Ceratophysa, Helgocystis and Echinosigra the test is to varying degrees divided into an anterior part, a neck, the body itself and a posterior part (rostrum). Considerable variation within the family is also exhibited by other important taxonomic characters: the structure of the lower part of the test, the structural type of the apical system, the shape of the blades of the pedicellariae.

According to commonly accepted classifications (Mortensen 1950; Wagner, Durham 1966), the family Pourtalesiidae embraces 16 species belonging to seven genera (8 species of Pourtalesia, two species each of Ceratophysa and Echinosigra, and one species in each of the other, above-named genera). For Ceratophysa rosea Lambert & Thiery (1924), the subgenus Rodocystis was being proposed, but it was not adopted by subsequent investigators, mainly because the species was not sufficiently well known, as it has been studied only from a few fragments. On the basis of material in our possession, we consider it necessary to assign to

Rodocystis the rank of a separate genus of the Pourtalesiidae.

The genus Echinocrepis included up to now a single species, E. cuneata Agassiz 1879, known from two specimens caught by the "Challenger" near Crozet Island (46°16' south, 48°27' east, 2,912 meters). According to Clark (1925), only one of these specimens was preserved in the British Museum. Furthermore, the German deep-sea expedition on the "Valdivia" found near the Antarctic (63°16' south, 57°51' east, 4,636 m) fragments determined by Döderlein (1906) as ?Echinocrepis sp. During the "Vityaz'" expeditions, sea urchins of this genus were found at nine stations in the North Pacific. All specimens collected belong to the new species E. rostrata.

ORDER SPATANGOIDA

SUBORDER MERIDOSTERNINA

FAMILY POURTALESIIDAE

Genus Echinocrepis Agassiz 1879

Echinocrepis rostrata Mironova, sp. nov. Fig. 1, 2, Pl. 1

Material: Two nearly whole and seven heavily damaged specimens, with test having a length of 86-106 mm, fragments of at least 35 specimens, from nine trawl samples (Table 1).

Holotype. Specimen from station 4213, length of test 86.5 mm, width 82.5 mm, height 64.5 mm; oral and aboral sides partly damaged; preservation of spine cover poor; preserved in a dry state in the Institute of Oceanography of the Academy of Sciences of the USSR (Plate, 5, 6).

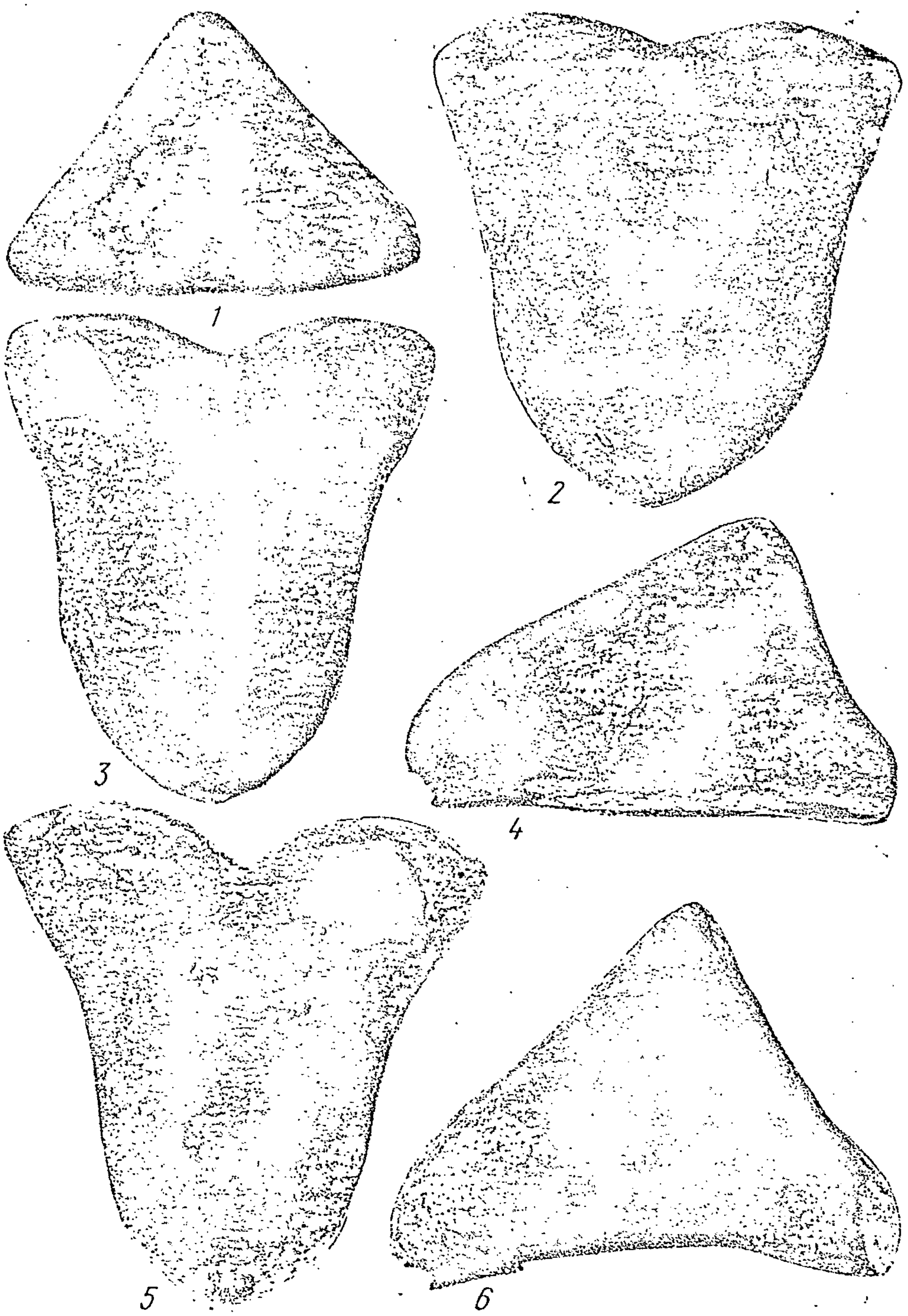

Таблица 1. *Echinocrepis rostrata* sp. nov.

Виды панциря: спереди (*1*), сверху (*2*), снизу (*3, 5*) и сбоку (*4, 6*). Длина панцирей: 94 *мм* (*1, 3, 4*; ст. 5634); 100 *мм* (*2*; ст. 5634) и 86,5 *мм* (*5, 6*; ст. 4213, голотип)

Plate 1. Tests: view from front (1), top (2), bottom (3, 5) and side (4, 6). Length of tests: 94 mm (1, 3, 4, station 5634); 100 mm (2, station 5634), and 86.5 (5, 6, station 4213, holotype).

Table 1. "Vityaz'" stations at which Echinocrepis rostrata was collected

Station	Coordinates		Depth, m	Number of specim.	State of preservation
	North Lat.	Longit.			
3359	51°30′	172°04′ в.E	5020	6	2 heavily damaged, + fragments
4147	49°35′	133°57′ з.W	3470	1	Fragments
4158	46°57′	143°59′ з.W	4661—4665	3	"
4213	34°54′	123°56′ з.W	4200—4231	3	Damaged oral side
4265	24°58′	113°25′ з.W	3315—3340	1	Fragments
5605	46°10′	153°07′ в.E	4915—4985	2	"
5634	44°17′	149°33′ в.E	4690—4720	⩾23	1 whole, 1 without oral side, + fragm.
6107	57°38′	143°12′ з.W	3800	⩾5	Fragments
6109	56°13′	139°43′ з.W	3460	1	Heavily damaged

Table 2. Test sizes (mm) of the best-preserved specimens of Echinocrepis rostrata

Measured features	Station				
	3359	4213	5634	5634	6109
Length	104	86,5	100	93	107
Width	96	82,5	92	81	100
Height	61	64,5	58	57,0	74,5
Ratio of width to length	0,92	0,95	0,92	0,87	0,93
Ratio of height to length	0,59	0,74	0,58	0,60	0,70

Diagnosis. Large, high, conical sea urchins with small subanal rostrum; four genital pores; the blades of the ophicephalic pedicellariae have broad basal and distal parts separated by a short constriction.

Description. The test is large (Table 2), thin and brittle. Its outlines, when viewed from the top, resemble the sagittal leaf of a plant with obtuse ends, when viewed laterally, it resembles a non-isosceles triangle. The aboral side is conical, the oral side is flat, in the centre there is a small rise terminating posteriorly in a small subanal rostrum. The specimens from station 4213 have the highest tests, with a top displaced slightly toward the anterior; the tests of the specimens from station 5634 are the lowest, the top is considerably shifted toward the anterior.

The ambulacra on the aboral side are made up of hexagonal plates; the anterior, non-paired ambulacrum is narrower and shorter than the others, and slightly depressed along its centre line. Near the ambitus and on the oral side the ambulacral plates usually have an irregular shape, drawn out along the longitudinal axis of the test, their margins become wavy. The first plates of the posterior-lateral ambulacra, adjoining the labial lamina (I.a.1 and V.b.1), are, as a rule, divided into two parts: an 242
anterior part, having a pore and the shape of a barely noticeable narrow band at the peristomial margin, and a posterior part, adjoining the second pair of ambulacral plates. The ambulacral plates that divide the labial lamina from the sternal one are the largest. The ambulacral pores are small, single openings; in the aboral part of the unpaired ambulacrum they are larger, and sometimes in pairs.

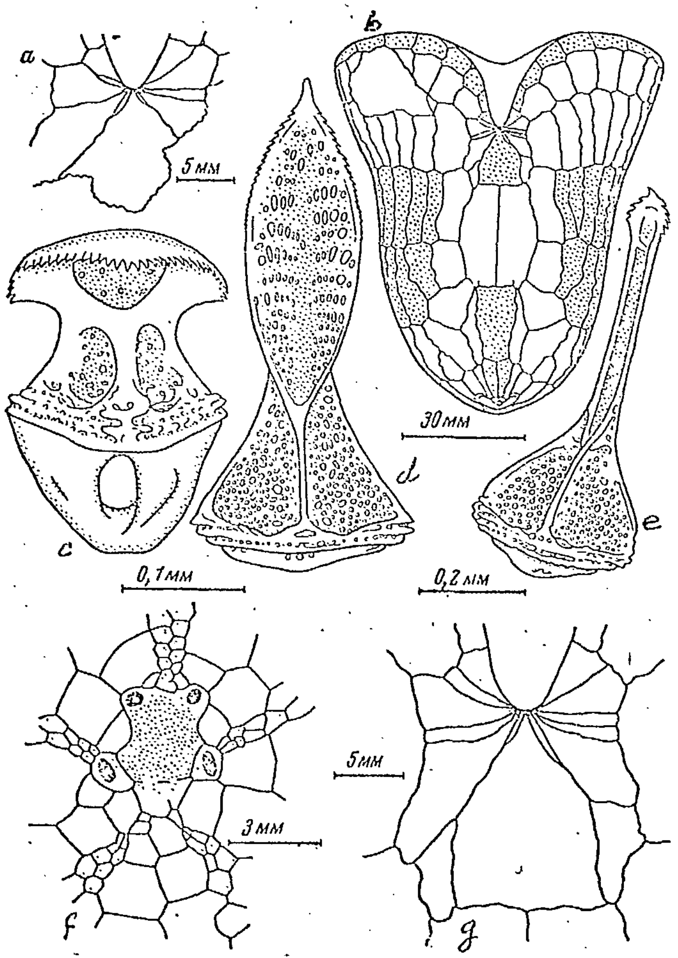

Fig. 1. 1. *Echinocrepis rostrata* sp. nov.

a, g -- structure of test near oral groove (station 4213 and 5634); b -- structure of oral test side (station 5634); c -- blade of ophicephalic pedicellaria; d, e -- blades of tridentate pedicellariae; f -- apical system (station 5634).

The interambulacra on the aboral side also consist of hexagonal plates; the unpaired, posterior interambulacrum is narrower and longer than the rest. Near the ambitus and on the oral side the plates are usually elongated longitudinally with wavy margins. The labial lamina is large, with a narrow anterior and a broad posterior end. The first and second plates of the posterior-lateral interambulacra are separated by the plates of paired ambulacra, in the some specimens the first plate (1.1 and 4.1) is completely reduced (Fig. 1, a).

The apical system is located somewhat to the rear of the conical apex of the test. It usually consists of three ocular plates (I, III, V), and one large plate perforated by four genital pores and numerous hydro- 243
pores. In some specimens the posterior genital openings may be located on separate plates; the posterior ocular plates are sometimes separated from the genital plates by one pair of interambulacral plates (Fig. 1, f), however the boundaries of the latter are usually indistinct owing to the extension thereon of the madreporite region.

The periproct is round, located inframarginally at the bottom of a periproctal depression, and enclosed between three pairs of interambulacral plates. The peristome is located above the labial lamina, at an angle of about 40° to the latter. It is elongated-oval with a broad central mouth opening.

Tubercles are scattered irregularly over the test. Near the ambitus, the apical system and particularly along the central rise on the oral side the primary tubercles are larger and more closely spaced.

A subanal fasciola is lacking.

The primary spicules are numerous, small, smooth or with sparse spines. On the aboral side they are straight, narrowing gradually toward the ends; the spicules on the oral side are thicker, curved slightly toward the ends, terminating in a flat, paddle-like blade. The spicules on the outer part of the oral groove have a pointed, curved end and bear spines; as we approach the peristome they become shorter and thicker; directly before the oral membrane they are short and closely packed. The miliary spicules have a terminal inflation, which is sometimes slightly flattened.

Sphaeridia, numbering four to six, have been observed only on the ambulacral plates adjoining the peristome.

The pedicellariae are tridentate, triphylite and ophicephalic (Fig. 1, c–e). The distal and basal parts of the blades of the tridentate pedicellariae have approximately the same width or, in larger pedicellariae, the distal part is elongated and becomes narrower than the basal part. The upper margin of the blades is dentate, the terminal tooth is considerably longer than the rest. Along the centre line of the outer side of the blades there is often a longitudinal keel. The largest tridentate pedicellariae are located on the oral side; the pedicellariae of the periproctal depression have wider blades. The triphylite pedicellariae are scattered over the entire test; the central constriction between the distal and basal part of the blades is indistinct. The ophicephalic pedicellariae are fairly numerous, their blades have broad basal and distal parts, separated by a short constriction; the distal part has a finely denticulate margin. One of the three blades has a more developed arch than the others.

The color of the dry test is greenish-violet.

Comparison. The main differences between E. rostrata and E. cuneata are the presence of a subanal rostrum and four genital pores. In cuneata there is no subanal rostrum, and there are three genital pores. In addition, the test of rostrata is higher and has a pointed apex, and its posterior half is relatively narrower than in cuneata.

Distribution. E. rostrata occurs only in the North Pacific: near the Kurile-Kamchatka trench, in the western Aleutian trench and along the coast of America from the Gulf of Alaska to California, at depths of 3,315–5,020 meters.

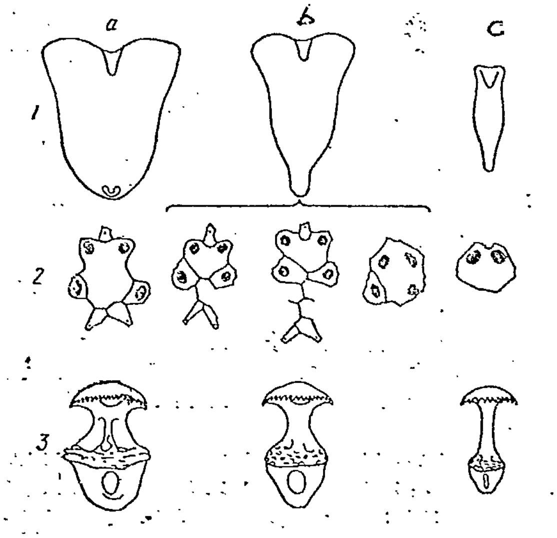

Fig. 2. Variation in the shape of the test (1), structure of the apical system (2) and shape of blades of ophicephalic pedicellariae (3) in Echinocrepis (a), Ceratophysa (b) and Echinosigra (c).

The schemes of the apical systems of Ceratophysa are based on study of materials on C. ceratopyga available to us.

Discussion

Sea urchins of the genus Echinocrepis together with members of three other genera -- Ceratophysa, Helgocystis and Echinosigra -- form a group that is morphologically distinct from the other Pourtalesiidae. The main character uniting these four genera and being of decisive importance for the taxonomy of the family is the separation of the labial and sternal plates by one pair of ambulacral plates. In three other genera of the family -- Spatagocystis, Cystocrepis and Pourtalesia -- two to three pairs of plates are wedged into the unpaired interambulacrum. The structure of the oral side of the eighth genus of the family -- Rodocystis -- is still unknown, however, study of numerous fragments of this genus available to us has shown that they differ greatly from all Pourtalesiidae in the structure of the apical system, the shape of the blades on the pedicellariae and the fasciola.

Although the differences between some characters of Echinocrepis, Ceratophysa and Echinosigra are considerable, we can, within this group, trace the emergence of some morphological characteristics from others. The trend of these developments allows us to establish the following sequence in the emergence of the genera: Echinocrepis → Ceratophysa → Echinosigra. This sequence is borne out by most morphological structures used as taxonomic characters: elongation of the test, development of a rostrum, fasciola and constriction between the anterior and central part of the test, elongation of the blades of the ophicephalic pedicellariae, the gradual separation of the posterior ocular plates from the genital ones and their subsequent reduction, the decrease in the number of hydropores (Fig. 2).

The shape and structure of the test of the fourth genus in this group -- Helgocystis -- argue for its emergence from Ceratophysa. However, the morphology of Helgocystis is characterized by such a primitive character as the presence of two pores in the adoral (aboral?) ambulacral plates. In all other genera of the family, including Ceratophysa, the foremost ambulacral plates have only one pore each. The presence of this character makes it difficult to form a definite opinion as to the origin of Helgocystis.

Of the two species of Echinocrepis, E. rostrata bears greater similarity to Ceratophysa. It is particularly evident in the outline of the test (when seen from the top), in the development of the rostrum and in the structure of the apical system. Such characters as the relatively great length of the test and the presence of three genital pores characterize the second species, E. cuneata, as specialized and diverging from the general developmental trend of the group.

Information as to the origin of the genera of the other group -- Spatagocystis, Cystocrepis and Pourtalesia -- is contradictory. We may state that of the three, Spatagocystis is the least and Pourtalesia the most specialized. The specialization and organization of these genera 245 is distinctly visible in the elongation of the test, the increase in the number of paired plates separating the labial plate from the sternal, in the greater reduction of the ocular plates, in the shape of the pedicellarian blades.

Thus, within the family Pourtalesiidae we can distinguish more primitive and more specialized genera. Among the former we include Echinocrepis, Ceratophysa and Spatagocystis, among the latter, Echinosigra and Pourtalesia; Helgocystis and Cystocrepis occupy an intermediate position. We are as yet not prepared to make any definite statements as to Rodocystis, owing to lack of information. The primitive and specialized genera also differ in their habitats: the former are found only in the temperate and high latitudes of the Pacific and Indian oceans, the latter occur much more widely, in many deep-sea areas of the World Ocean. Echinocrepis and Ceratophysa are known from "Challenger" finds south of 33° south and "Vityaz'" finds north of 34° north. Sea urchins of the genus Spatagocystis were collected by the "Challenger" in the Indian Ocean south of 46° south, Helgocystis in the Pacific and Indian oceans south of 34° south. Cystocrepis was found by the "Albatross" in the Gulf of Panama and by the "Vityaz'" in the Gulf of Alaska. Echinosigra and Pourtalesia have been found frequently (including the expeditions on the "Vityaz'" and the "Akademik Kurchatov") in the Arctic, North Atlantic, West India, South Africa, Antarctic, the Arabian Sea, the Malay Archipelago, Japan, the Kuriles and Aleutians, in the Sea of Okhotsk and the Bering Sea, the Gulf of Alaska, along the Pacific coast of America from California to Peru and in the central Pacific.

The main differences in the distribution of the individual genera of Pourtalesiidae are apparently due to the ecology of the genera in the geological past and the adaptive changes of the animals.

No reliable information is available as to fossil Pourtalesiidae. However, from paleontological finds we are well acquainted with a group of sea urchins of the family Holasteridae, several of whose characters point to the assumption that they are the ancestors of the Pourtalesiidae. The Holasteriidae make their first appearance in the Cretaceous, but even at the start of the Tertiary their numbers drop off sharply, and in the modern seas they are represented by only two genera, Stereopneustes and Sternopatagus. Thus the Pourtalesiidae arose not earlier than the Cretaceous. On the other hand, it seems most likely that the first representatives of the group appeared not later than the Upper Cretaceous or the start of the Tertiary, as the morphology of some Upper Cretaceous Holasteridae already bears a fair resemblance to that of the Pourtalesiidae. Poslavskaya and Solov'yev (1964) even propose to include in the Pourtalesiidae the genus Galeaster (Upper Cretaceous-Paleocene), which is usually assigned to the family Holasteridae. The high degree of specialization of individual modern Pourtalesiidae also argues for a considerable age of the group as a whole.

Similar to their holasterid ancestors, the first pourtalesiid sea urchins most likely had their basic habitat in the Thetis Sea. Bearing in mind that the Thetis Sea was circumtropical and that the modern representatives of the Holasteridae have been found only in the tropical belt (region of the Malay Archipelago), one may assume that at first the Pourtalesiidae also had a tropical or even circumtropical habitat. An analogous example is provided by the general confinement to the tropical belt of the group of soft sea urchins, which arose during the time of the Thetis Sea.

Subsequent transformations of the ocean led to a considerable change in its ancient character. It is natural to assume that this process was accompanied by drastic changes in the ecology of marine organisms. 246
These changes had the least effect on the area of the Indo-Malay Archipelago, which explains why modern representatives of a number of ancient Echinodermata are confined to it (Mortensen 1923; D'yakonov 1950). Apparently this region remained for a long time a centre of species formation of both shallow-water and deep-sea marine organisms. It is most probable that it is precisely in this region that the first representatives of the modern genera Echinocrepis, Ceratophysa and Spatagocystis had their origin.

The further dispersion of the Pourtalesiidae occurred in conditions similar to the modern ones. As all Pourtalesiidae are fairly rigidly confined to eutrophic regions, they were able to extend their habitats most successfully only in a longitudinal direction. West and east of the Malay Archipelago there are vast oligotrophic regions, while the deep-sea regions near Australia and East Asia are most favorable for the lifestyle of these sea urchins. Along the continental coasts and underwater ridges the sea urchins could, on the one hand, penetrate into antarctic waters and, on the other, migrate northward and eastward, reaching the Aleutian chain and the American coast. Consequently, the bipolar distribution of the primitive members of the family may reflect a longitudinal symmetry in relation to the centre of origin, the Malay Archipelago. As to why they are lacking in the tropical zone it is difficult to form an opinion at this moment.

The formation of specialized genera probably took place in the temperate or high latitudes of the ocean. Helgocystis is found only south of 34° south. The most primitive member of Pourtalesia, P. aurorae, lives in the Antarctic, which argues for an antarctic origin of the genus. The distribution pattern of Echinosigra (taking into account the results of the expeditions of the Oceanographic Institute) points most likely to either an antarctic or a North Pacific origin of the genus.

The dispersion of the Pourtalesiidae was accompanied by constant adaptive changes in their morphology in response to living conditions in abyssal depths and, above all, in soft bottoms. In the case of Echinosigra and Pourtalesia we see the final results of these transformations: the test has become greatly elongated; the size has decreased; in the anterior part the test begins, as it were, with a broad funnel (groove) capable of seizing with its edges large quantities of bottom material; inside the oral groove there are rows of thick, short spicules serving for pushing the bottom material into the wide oral opening; the well-developed subanal fasciola makes it possible to effectively remove from the burrow the oxygen-depleted water. The combination of such adaptations considerably increased the migration opportunities of Echinosigra and Pourtalesia. These are the only deep-sea sea urchins that succeeded in penetrating into the Arctic and the ultra-abyssal zone, to depths exceeding 7,000 meters. Secondarily they settled in the continental shelf zone and in the Atlantic.

Thus we can distinguish three basic stages in the history of the settlement patterns of the Pourtalesiidae: (1) Tropical (possibly circumtropical) settlement during the age of the Thetis Sea; (2) expansion of the habitat from the Indo-Malay Archipelago to the north and south; (3) the migration of young forms well adapted to life in the abyssal zone to all deep-sea parts of the ocean.

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POGONOPHORE FAUNA OF THE NORTH PACIFIC

By A. V. Ivanov, M. A. Gureyeva

This paper gives the results of the study of pogonophores collected by the "Vityaz'" in the Gulf of Alaska, the Aleutian trench and partly in the Japan and the Idzu-Bonin trenches. We should like to express our heartfelt gratitude to Z. A. Filatov and G. M. Belyayev for making these collections available to us.

The samples yielded nine species of pogonophores, three of which we were unable to determine as they were represented only by bits of empty tubes. Several empty tubes of Lamellisabella sp. found in the Gulf of Alaska and adjacent parts of the Pacific may possibly belong to the recently described L. coronata Southward. This species is known from 43 individuals obtained west of the British Columbia coast (Southward 1969a). One specimen of L. coronata was obtained in 1968 by the Oceanographic Institute expedition on the "Akademik Kurchatov" in the area of the Peru-Chile trench. Thus the habitat of L. coronata appears to extend along the west coast of both North and South America. Only one new species turned up, Polybrachia choanata, which indicates the relatively high level of knowledge of the pogonophores in the North Pacific. In addition to Soviet expeditions operating mainly on the "Vityaz'" the area has also been studied by members of Canadian fisheries research institutes J. C. Hunter in 1960 and D. B. Quayle in 1957-68. The Canadian pogonophore collections were studied by E. Southward (1969a, b).

Special Part

1. Siboglinum pusillum Ivanov

Ivanov 1960a: 158-60, Fig. 114; Ivanov 1963: 221-24, Fig. 114; Southward 1969a: 395-96, Fig. 1.

Material. Station 6134, 6135. Occasional animals. Station 6136, 33 animals and many empty tubes. Station 6140, 2 empty tubes. Station 6094, four tubes with animals. Station 6120, 48 tubes, 38 with animals.

Distribution. This species has been described from the northwestern Pacific, where it was first discovered between Onekotan Island (Kuriles) and the northern part of the Kurile-Kamchatka trench (Ivanov 1960a). The collections of the Canadian expeditions from the waters of the British Columbia coast have yielded about 700 specimens (Southward 1969a). Thus, taking into account our collections, we may say that S. pusillum is a species quite typical of the North Pacific, both in the west and in the east. It is quite likely that in future it will be found along the entire island chain of the Aleutians. S. pusillum has not as 249
yet been found in the Bering Sea. The depth at which S. pusillum lives ranges mainly from 2,000 to 4,000 meters, but in the eastern Aleutian trench it descends to 7,000 meters.

2. Siboglinum fedotovi Ivanov

Ivanov 1957: 449, 453-59, 495-97, Fig. 23-27 (in German); Ivanov, 1960a: 137-140, Fig. 6, 65, 87, 101, 102; Ivanov 1963: 193-97, Fig. 101, 102 (in English); Southward 1969a (S. vancouveriensis): 396-99, Fig. 2.

Material. Station 6095, 3 empty tubes. Station 6120, 19 tubes, nine with animals. Station 6121, 2 tubes, one with an animal.

Pogonophore finds on stations of Cruise 45 of "Vityaz'"

Station № станции	Coordinates		Depth, m Глубина, м	Equipment used	Species Вид
	N. Lat. Широта, сев.	Long. Долгота			
Gulf of Alaska Залив Аляска					
6094	57°44′	148°37′ з.W	2400	T trawl	*Siboglinum pusillum* *Siboglinum* sp. *Lamellisabella* sp.
6095	57°37′	148°36′ з.W	3240—3300	T	*Siboglinum fedotovi*
6096	57°12′	148°44′ з.W	4190	T	*Lamellisabella* sp.
6120	56°40′	136°26′ з.W	1960—1965	T	*Siboglinum pusillum* *Siboglinum fedotovi*
6121	56°43′	136°11′,5 Wз.	1600	Д bottom grab	*Polybrachia canadensis* *Polybrachia annulata* *Siboglinum fedotovi* *Polybrachia canadensis*
Aleutian trench and adjacent areas Алеутский желоб и прилегающие районы					
6132	53°43′	163°38′ з.W	1550	Д	*Siboglinum* sp.
6134	53°43′	163°33′ з.W	1950	Д	*Sibodlinum pusillum*
6135	53°30′	163°22′ з.W	3800	Д	*Siboglinum pusillum*
6135	53°32′	163°22′ з.W	2880—2930	T	*Lamellisabella* sp.
6136	53°25′	163°28′ з.W	4260	Д	*Siboglinum pusillum* *Diplobrachia japonica*
6140	53°25′	163°20′ з.W	6960	T	*Siboglinum pusillum*
6140	53°27′	163°15′ з.W	6980	Д	*Siboglinum pusillum*
6144	51°42′,5	168°05′ з.W	7200	T	*Diplobrachia japonica*
Japan trench Японский желоб					
6151	34°41′	143°54′ в.E	7370	T	*Diplobrachia japonica* *Polybrachia choanata*
6152	37°00′	143°23′ в.E	6600—6670	T	*Diplobrachia japonica*
Idzu-Bonin trench Идзу-Бонинский желоб					
6135A	34°32′,5	142°06′ в.E	8800—8830	T	*Diplobrachia japonica*

Remarks on taxonomy. We regard *S. vanouveriensis* Southward as a variety of *S. fedotovi*, which is typical of the northeastern inshore 250
zone of the Pacific. Our specimens from the Gulf of Alaska turned out to be identical with *S. vancouveriensis*, but at the same time they are nearly indistinguishable from the typical *S. fedotovi* from the Bering Sea. Among the distinguishing characters of *S. fedotovi* var. *vancouveriensis* we should cite, apart from those noted by Southward (smaller tube, different arrangement of the grooves on the forepart), the dimensions of the spermatophores. In typical *S. fedotovi* they measure about 200 microns, while in the Canadian variety their length is about 150 microns. *S. fedotovi*, it seems, resembles *S. albatrossianum* Cutler (1965) found at a depth of 1,354 m at Cape San Francisco near the coast of Ecuador in the collections of the American expedition on the "Albatross" in 1888. In that form the spermatophores are even smaller — 70 microns. As Southward correctly notes, *S. fedotovi* is also very similar to *S. veleronis* Hartmann (1961), found along the coast of southern California by the "Velero IV" at a depth of 976 m.

Distribution. Typical specimens of *S. fedotovi* come from the southwestern Bering Sea (Ivanov 1957), where the species is very common at depths of about 3,000-4,000 m. In the northeastern Pacific, apart from the Gulf of Alaska, the species, as already noted, is common along the coast of British Columbia (*S. vancouveriensis* Southward 1969).

3. Diplobrachia japonica Ivanov

Ivanov 1960a: 220-23, 226, 263, Fig. 87, 148-51; Ivanov, 1963: 371-76, fig. 148-1951 /sic/.

Material. Station 6136, 1 tube with animal. Station 6144, 6 tubes with animals and 18 pieces of empty tubes. Station 6152, 366 tubes, of which 124 had animals. Station 6135A, 4 empty tubes. At station 6152 a large part of the individuals is represented by not fully mature specimens, often very young, with a single tentacle. On the other hand, we found three individuals with three tentacles.

Distribution. D. japonica was first described from the Japan trench from mass collections made by A. I. Savilov ("Vityaz'" station 3571, depth about 7,500 m). New samples show that the species also lives in the Aleutian and the Idzu-Bonin trenches.

4. Polybrachia annulata Ivanov

Ivanov 1952: 379-82, Fig. 13-18; 1960a: 231-35, Fig. 156-58; 1960b: 17-18; Ivanov 1963: 394-98, Fig. 156-58.

Material. Station 6121, 18 fragments of tubes, of which 8 had parts of animals.

Distribution. P. annulata belongs to typical representatives of the abyssal zone of the Bering Sea, which has yielded large numbers of these pogonophores (Ivanov 1960a, b). Several specimens of P. annulata are known from the Sea of Okhotsk. The find of the species in the Gulf of Alaska indicates that it is widely distributed in the North Pacific.

5. *Polybrachia canadensis* (Ivanov)

Ivanov 1962 (*Heptabrachia canadensis*): 897-99, Fig. 45; Ivanov 1963: 362-65, Fig. 114H, J.
Southward 1969b (*Polybrachia canadensis*): 449-67, Fig. 1-13.

Material. Station 6120, 4 specimens. Station 6121, 5 tubes, 2 of them with animals.

Remarks on taxonomy. This species was described from one
specimen and originally assigned to *Heptabrachia* (Ivanov 1962). Shortly 251
thereafter E. Southward (1969b) made a detailed study of the postembryonic development and growth of this species from extensive collections obtained along the coast of British Columbia (over 1,400 individuals). She showed that the original description was based on a young, not fully developed specimen and that, on the basis of characters of fully mature individuals, the species must be assigned to *Polybrachia*. *P. canadensis* is most similar to *P. annulata* and in the view of Southward represents a species replacing the latter in the eastern Pacific. In view of this the find of *P. annulata* in the Gulf of Alaska is of particular interest.

Distribution. All known specimens of *P. canadensis* have been collected in one area of the northeastern Pacific, the Gulf of Alaska to the northwest and west of the Queen Charlotte Islands.

6. *Polybrachia choanata* sp. nov.

(Fig. 1-4)

A trawl raised by the "Vityaz'" in the Japan trench from a depth of about 6,600 m turned up many pieces of brown-black tubes of Polybrachiidae with a series of large funnels. From some of the tubes we extracted incomplete (lacking posterior ends) young and sexually mature animals, altogether 78 specimens. A comparison with known species of the Polybrachiidae showed that they belonged to a new species of Polybrachia which, because of the typical tube funnels, we are proposing to name Polybrachia choanata. The same species had been found previously in the Kurile-Kamchatka trench, but it was not described owing to insufficient material.

Material. Station 6152, 170 tubes, 78 of them with fragments of animals. Among these there are many sexually immature specimens, beginning with very young, small specimens, having a simple transparent tube and 1, 2 or 3 tentacles. Station 2217 (Kurile-Kamchatka trench, Cruise 14 of the "Vityaz'", 1953), depth 9,000-9,050 m, several fragments of tubes and pieces of animals (Polybrachia sp. B, Ivanov, 1960b, appendix III:19).

Description. The forepart of the body is cylindrical, its length is 4-5 times its width (Fig. 1 A, B). The bridle is situated (similarly as in H. gracilis) just slightly ahead of the centre. The head lobe is relatively large, triangular with a rounded top; its epidermis is amply supplied with high glandular cells (c). The protosoma has a shallow ventral medial groove and four (as in adult P. canadensis) transverse annular grooves (s), which are less distinct on the dorsal side. The tentacular crown consists of over 20 tentacles; we also have in our collection juveniles with 4-10 tentacles. Each tentacle bears two rows of fairly long, sparse pinnules.

The bridle keels are dark brown, narrow, somewhat broader at the ventral ends; they do not link up on the dorsal side of the body (Fig. 1 A, B, f). The structure of the bridle is generally similar to

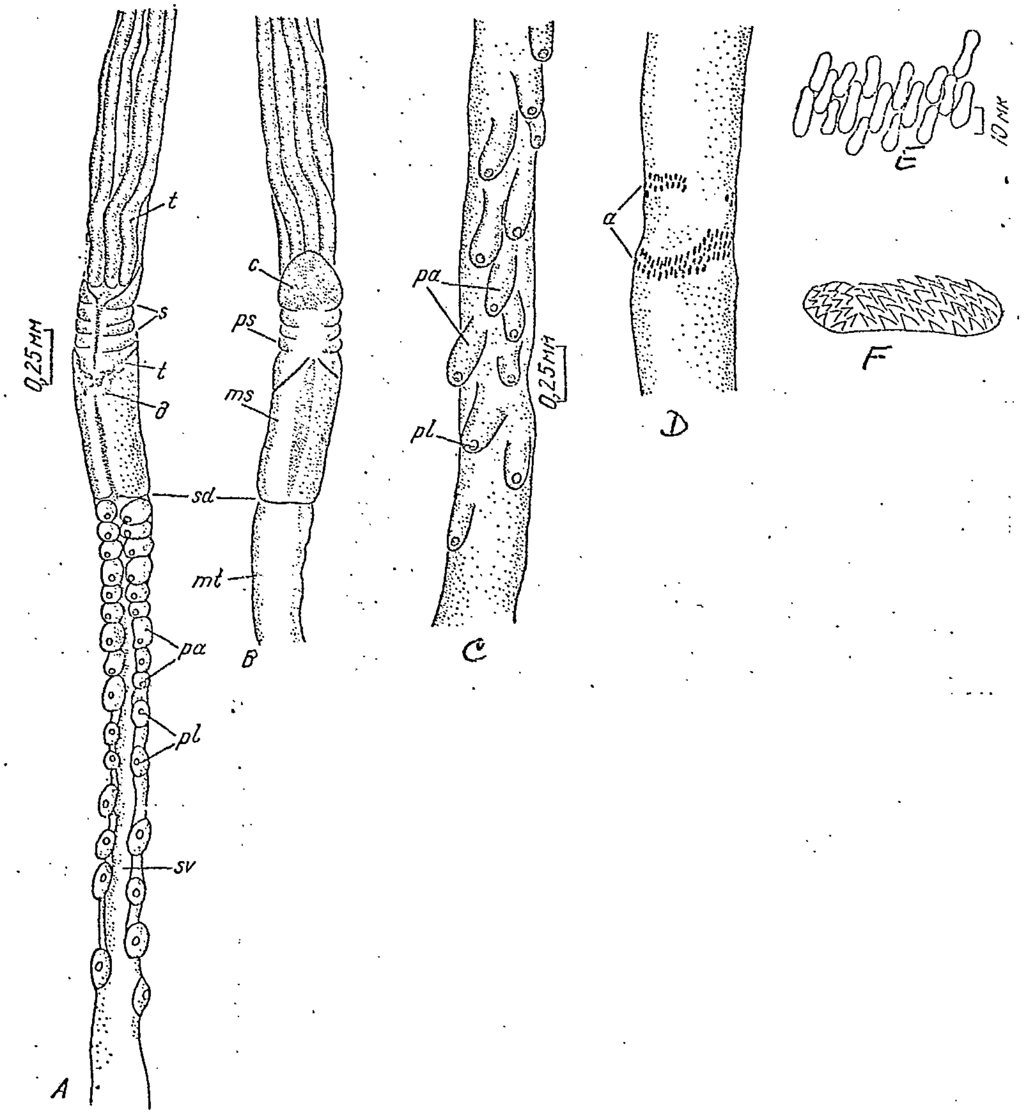

Fig. 1. Polybrachia choanata sp. nov.

A -- forepart, ventral view; B -- idem, dorsal view; C -- zone of closely packed papillae, ventral side; D -- girdle region; E -- portion of girdle; E -- denticulate platelet. a -- girdles; c -- head lobe; f -- bridle; g -- glandular band on epidermis; ms -- mesosoma; mt -- metasoma; pa -- adhesive papillae; pl -- cuticular laminae; ps -- protosoma; s -- secondary grooves of protosoma; sd -- boundary between meso- and metasoma; sv -- ventral groove of metasoma; t -- tentacles.

that of young P. canadensis (Southward 1969a). In immature individuals with few tentacles each keel is adjoined posteriorly by one row of brown oval cuticular corpuscles, in mature animals there are two irregular rows of corpuscles (Fig. 2 A, B). An indistinct band of glandular epidermis, which differs in color from the surrounding mantles, is observable in some individuals posterior of the bridle (Fig. 1 A g). The boundary between the meso- and metasoma has the shape of a simple annular groove (sd). The metameric section of the preannular section of the metasoma is short and bears from 13 to 20 pairs of adhesive papillae with cuticular platelets (Fig. 1 A). The latter have a typical shape: oval with a transversely striate, inflated, darkish anterior margin (Fig. 2 c). The diameter of the platelets of the metameric papillae is about 20-30 microns. The zone of closely packed papillae is distinct, it has about 15 large sucker-like papillae scattered irregularly over the ventral side (Fig. 1 C). 252

Each papilla has a large, round platelet with a chitinized sickle-shaped anterior margin. The diameter of the platelets is 30-50 microns.

There are two incomplete girdles of denticulate platelets (Fig. 1 D). The yellowish platelets are arranged in two to three rows (Fig. 1 E). The average length of the platelets is 15-18 microns. The anterior group of small denticles is 3-4 times shorter than the zone of posterior denticles, which, as a rule, are pointing forward (Fig. 1 F). On the postannular section of the metasoma there are transverse ventral rows of small adhesive papillae, 3-4 in each row. The chitinoid platelets on these papillae are oval and equipped with a transverse inflated ridge (Fig. 2 d); the diameter of the platelets is not less than 25 microns.

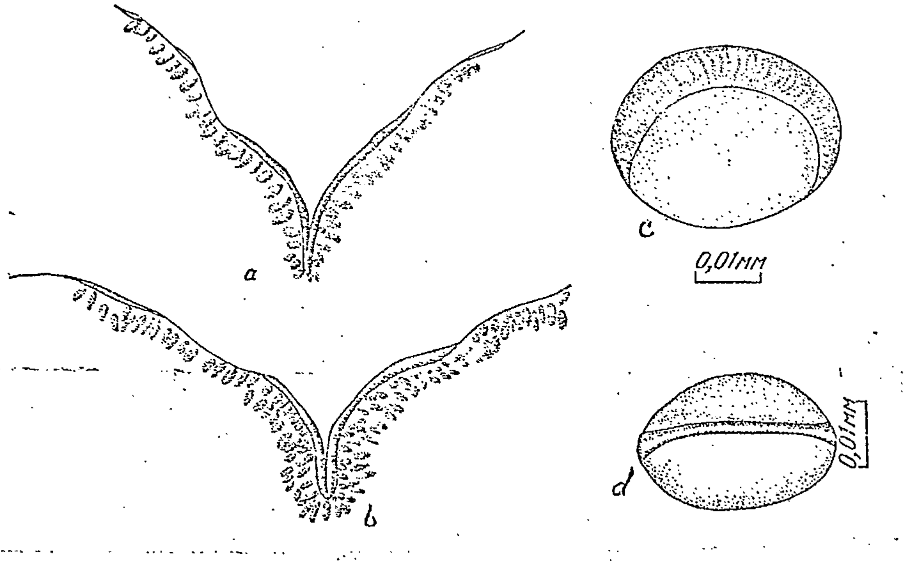

Fig. 2. Polybrachia choanata sp. nov. a -- bridle of young individual; b -- idem, adult; c -- adhesive platelet from the region of metameric papillae; d -- idem, from postannular section of metasoma.

The length of the forepart of the body is 1.8 mm, its width attains 0.4 mm. In the most sexually mature specimen (female) the tentacular crown has a length of 16.5 mm, the preannular section of the metasoma, a length of about 27 mm.

In one animal we found numerous spermatophores, which have a rather typical shape. The spermatophore looks like a delicate triangular leaflet, drawn out at one end into a long, narrow, tongue-like "tail" (Fig. 3). The sperms are located only in the wide part of the spermatophore, where they make up two distinct bundles. The "tail" of the spermatophore is always free of spermatozoids. The base of the spermatophore thread looks like a broad, triangular lamina which narrows abruptly. The length of the spermatophore (without the base of the thread) is about 400 microns; the "tail" accounts for not less than half that length. The width of the spermatophore is somewhat less than 100 microns.

The tube of P. choanata is very hard, opaque, and for a large part of its length black-brown in color; only its posterior parts are light brown or even grayish brown. Its wall is thick and very brittle, so that the tube is easily broken in the trawl. The anterior part of the tube consists of very large, soft brown funnels closely inserted into each other (Fig. 4 a). They have a fibrous structure, their fringed margins appear, so to speak, unravelled. In the next section the funnels become smaller and thinner, the fibrosity disappears. They become membranous, transparent and more or less fragile and are not so closely packed as in the anterior -- there are considerable gaps between adjacent funnels (Fig. 4 b). Soon after the funnels are transformed into short fringes located between adjacent segments of the tube, whose walls become transparent. Further on the fringes disappear, and the tube, over a considerable extent, looks uniform and smooth.

The posterior part of the tube is irregularly ringed (Fig. 4 c). The posterior section is without rings, grayish or whitish, shiny (Fig. 4 d).

The diameter of the tube attains 0.6 mm, the diameter of the funnels attains 1.9 mm. The largest tube fragment measures 136 mm in length.

Comparison with other species. After extensive analysis of the growth changes of the tentacular crown, the anterior section of the body, the bridle, the girdles and various other characters of the metasoma and the tube of Polybrachia canadensis undertaken by Southward (1969b) it

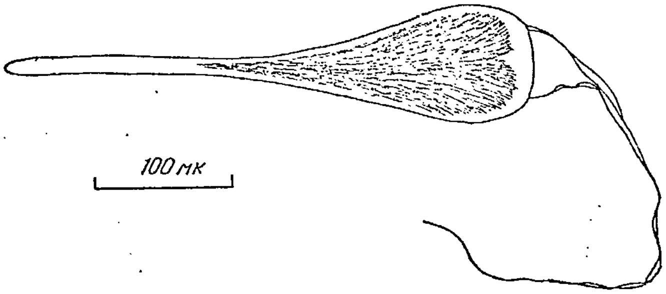

Fig. 3. *Polybrachia choanata* sp. nov.

Spermatophore.

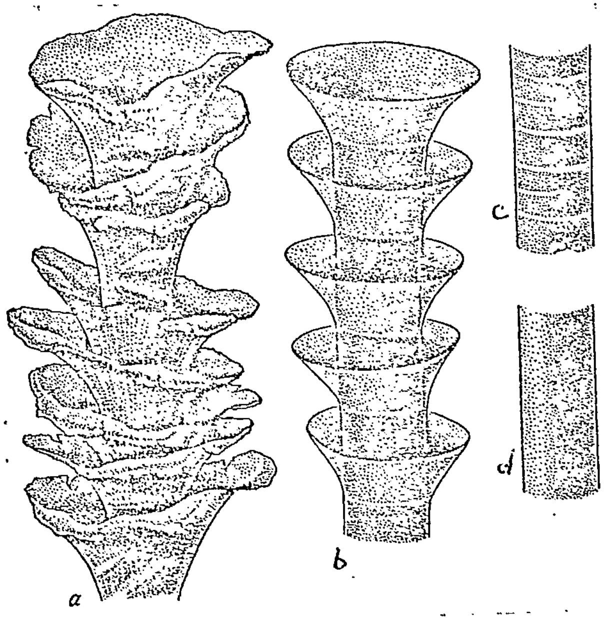

Fig. 4. Polybrachia choanata sp. nov.

Tube: a -- anterior end; b -- next part with funnels; c -- ringed part; d -- posterior section.

became clear that the two genera, Heptabrachia and Polybrachia 254 (Ivanov 1952) are very similar and it might even be advisable to abolish the former. The number of tentacles in the crown, which had formerly seemed a typical character of different forms, actually increases greatly with growth. Although, in general terms, this had become evident earlier (Ivanov 1960a), it is now established exactly in the case of P. canadensis. At the moment it is hard to say by what characters the two genera should be distinguished. It would appear that a very typical distinction of Polybrachia is the development of segmented funnels on the tube, which appear in sexually mature individuals. Be that as it may, P. choanata must be compared with members of both genera.

In the differentiation of the mesosoma, namely in the presence anteriorly of the bridle, in addition to the primary boundary between proto- and mesosoma, of three secondary annular grooves, our species resembles P. canadensis and P. annulata. Other species have two such grooves (H. ctenophora Ivanov, H. beringensis Ivanov), one groove (H. celebensis Southward, H. gracilis Ivanov), or no grooves at all (H. subtilis Ivanov, H. abyssicola Ivanov).

In the structure of the bridle, P. choanata resembles the 255 juveniles of P. canadensis and differs from other species. In the development of an (the?) anterior group of denticles on the platelets of the girdles all species of Heptabrachia and Polybrachia are similar, although in H. subtilis and H. abyssicola the platelets are remarkable for their relatively great width, and, in H. beringensis, for the rudimentary state of the zone of anterior denticles. In the character of the zone of closely packed papillae our species is closest to H. beringensis,

H. ctenophora and H. subtilis. The most typical features of the new species, however, are the shape of the spermatophores and the character of the tube.

Conclusion

A detailed study of the pogonophore fauna of the four trenches of the North Pacific that are linked by a common origin reveals certain common elements. Diplobrachia japonica lives in the Idzu-Bonin, Japan, and Aleutian trenches. Its future discovery in the Kurile-Kamchatka trench seems predictable. The Kurile-Kamchatka and Japan trenches house Polybrachia choanata.

We must also note, as a typical phenomenon, the penetration of abyssal and even sublittoral species from the ocean areas near the trenches into the trenches themselves. Thus, the depths of the Kurile-Kamchatka trench have been reached by Siboglinum caulleryi Ivanov, one of the typical species of the Sea of Okhotsk. In the Aleutian depression we find Siboglinum pusillum, an immigrant from the nearest parts of the ocean. Many more such cases will probably come to light in the future.

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DISCOVERY OF A RARE DEEP-SEA FISH BATHYPRION DANAE MARSHALL (SUBORDER ALEPOCEPHALOIDEI) ALONG THE COAST OF JAPAN

By N. V. Parin and Yu. N. Shcherbachev

The aberrant alepocephaloid fish Bathyprion danae recently described by Marshall (1966) as a new species belonging to a new genus and a special monotypic family* was heretofore known from only two individuals. The holotype of the species with a length of 382 mm was caught in 1929 in the Tasman Sea (33°26' south, 157°02' east) with a non-closing net from a depth of about 2,500 m over a total depth of 4,830 m. The second specimen, with a length of 388 mm was caught in 1965 near Madeira (32°28' north, 16°48' west) with the multi-depth Isaacs-Kidd trawl from 2,700 meters.

A third specimen of this species was caught during Cruise 45 of the "Vityaz'" (see figure). The fish was discovered on July 2, 1969, in a bottom trawl of the Sigsby type at a depth of 8,800 m in the Japan trench (station 6154, 34°24' north, 141°55' east); apparently, it entered the trawl while the latter was being raised. Along with B. danae the

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* The separate identity of the family Bathyprionidae has also been adopted by Gosline (1969).

catch also contained other deep-sea pelagic fishes -- the shark Isistius brasiliensis, the Gonostomidae Gonostoma gracile, Cyclothone atraria and the luminescent anchovy Lampanyctus sp.

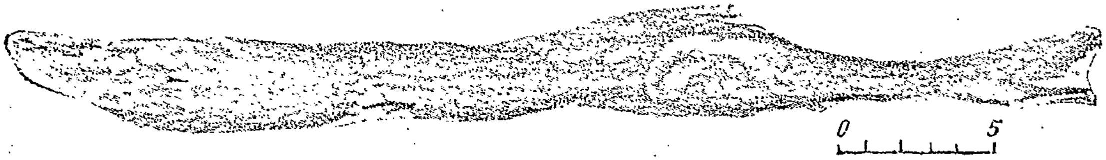
Our specimen is a female with a length of 317 mm, slightly damaged (the wall of the ventral cavity is torn as is the left side of the body between the dorsal and the anal fin); it agrees well with the type description.

The body is streamlined, covered with small cycloidal scales: in a longitudinal row along the side of the body there are about 95-100 scale pockets; in an oblique transverse row anterior of the ventral fin, there are 17; before the start of the anal fin, 19, and at the start of the caudal peduncle there are 10 scale pockets. The dorsal and anal fins have long bases that are opposite. D 25, A 24, P 10 (from left 8), V 8. The head is large, bare; the eyes are small; the snout or pre-orbital region of the head is long and pointed; the jaws are long, there are two supramaxillary bones. On the praemaxillare there are 5 (from the left, 8) small teeth, on the maxillare, 18 (16) large teeth, on the dentale about 22 small teeth, on the palatinum 5 teeth. There are ten branchiostegal rays on the gill membrane. On the first arch there are 2+1+13 gill rakers (from the left, 2+1+12). There is no air bladder. The stomach is small with seven digitate pyloric caecae. There are 52 vertebrae.

Some measurements (as percentages of the body length, SL): length of head, 28.6; length of snout , 11.4; length of upper jaw, 18.0; lower jaw, 18.6; eye diameter 2.4; width of interocular distance, 6.4; height of body before start of dorsal fin 9.2, width before the start of the start of the dorsal fin 9.2; height of caudal peduncle, 4.8, width 3.2, length 17.1; prepectoral distance 29.4, preventral distance 44.8, predorsal distance 57.4, pre-anal distance 60.8; length: of pectoral fin 4.6 (from left 3.9), ventral fin 4.6, base of dorsal fin 23.2, base of 257 anal fin 21.2.

Part of the ovary was preserved in the body cavity with oocytes of two size groups: small (diameter 0.3-0.5 mm) and large (up to 3.7 mm). In the view of T. A. Ostroumova, the eggs are of the pelagic type.

The specimen described here differs in some respects from the individuals of B. danae studied previously: fewer fin rays -- D 25 (against 26-27), A 24 (against 25-26), P 8-10 (against 10-11), V 8 (against 9); fewer branchiostegal rays -- 10 (against 12). Marshall (1966) cites for the holotype 25 transverse rows of scales anterior of the ventral fin, and 35 rows at the start of the anal fin, however his figure shows in either case no more than 20 rows, which is also in agreement with the quantities in our specimen. We do not hazard to attach to these differences any systematic significance, at least not until more is known as to intraspecific variation in B. danae.



Bathyprion danae (*l*=317 *мм*) Specimen caught at Station 6154.

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АКАДЕМИЯ НАУК СССР

1973 ТРУДЫ ИНСТИТУТА ОКЕАНОЛОГИИ Том 91

COMPLEX INVESTIGATIONS OF THE CONTINENTAL SLOPE OF THE GULF OF ALASKA

SUMMARY

This publication deals with the results of investigations caried out on board of the r/v «Vityaz» during the 45-th biological cruise (April — June, 1969).

The main purpose of this expedition consisted in study of the composition, qualitative and quantitative distribution and the trophic zonation of the fauna living in the bathyal zone of the Alaska Bay and in the Aleutian trench. The biological contributions make up the greater part of the publication.

The paper by L. A. Zenkevitch deals with the problem of the investigation of the life in the oceanic bathyal zone in general. The richness of the fauna in this zone and the prospects of fishery here are noted and discussed.

In the article by R. Z. Kovalevskaya and Ju. G. Guiguinyak are reported the data on the primary production and chlorophyll «A» content in the area investigated. The lowermost values of both were observed in the northern part of the Gulf of Alaska early in May (12—50 *mg* $C/m^3/day$ and 0,3—0,5 mg/m^3, respectively). The highest values in the offshore waters along the eastern Aleutian islands were observed during the period of the seasonal thermocline development (70—165 $mgC/m^3/day$ and 0,8—2,0 mg/m^3).

In the paper by A. V. Tsyban are treated the composition and quantity of bacterioplankton and bacterioneuston. The first is extremely poor in the Alaska bay and somewhat more abundant over the Aleutian trench. A peculiar assemblage of the bacterioneuston is connected with the water surface film, where the numbers of the microbia cells are high and increase towards the open sea. The pigmented microorganisms predominate in the bacterioneuston, the concentration of which is positively correlated with that in bacterioplankton. A rich microflora was found in the sea foam.

Biochemical oxygen consumption (BOC) in the surface layers of bottom deposits was measured by I. A. Melnikov. The BOC rate on the slope is on an average twice as high as in the abyssal depths. The BOC rate is correlated with the biomass of the bottom animals, thus indicating that the distribution of these animals is dependent of the content of the easily-assimilable organic matter in the bottom sediments.

The benthic biomass (L. I. Moskalev a. oth.) on the slope of Gulf of Alaska decreases with the increasing of depths from n $10^1 g/m^2$ near the shelf edge to n 10^{-1} near the slope foot. The biomass of the bottom animals in the eastern part of the Aleutian trench is by one order of magnitude higher than at the similar dephts in other areas of the Gulf of Alaska. The local decreases of the biomass in the areas with the oxygen deficiency are noted.

Five biocenoses of bottom fauna are described in the bathyal and abyssal

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zones of the guff of Alaska by Z. A. Filatova. They changed each other with the increasing depths from 450 to 3950 m.

The composition and distribution of trophic assemblages of benthic animals in the bathyal and upper abyssal zone of the Gulf of Alaska are described by A. P. Kuznetsov a. oth. The leading role on the shelf edge play sessile suspension feeders. Deeper on the slope the content of organic detritus in the sediments are higer and the detritus and deposit feeding animals become prevalent.

Some papers describe the composition and distribution of some groups of benthic and pelagic animals in the nortnern and north-eastern Pacific: Foraminifera (T. A. Khusid), Pennatularia (F. A. Pasternak); Polychaeta (R. Ya. Levenshtein), Cirripedia (g. Scalpellum)— (G. B. Zevina); Tanaidacea (R. K. Kudinova-Pasternak); Hyperiidia — (g. Vibilia; T. N. Semenova); Pycnogonida (E. P. Turpaeva); Brachiopoda (O. N. Zezina); 9 new species and one new genus of Tanaidacea, a new species and a new genus of Pantopoda are dercribed. V. J. Lus describes a new genus and species of Gastropoda inhabiting the depths of 5500 to 6740 m. A. N. Mironov describes a new species of deep-water sea urchins (fam. Pourtalesiidae) and discusses the evolutionary trend in this family. K. N. Nesis gives a review of distribution of pelagic and benthic Cephalopods in the North Pacific and typifies their ranges. He determines the boundaries of zoogeographic regions and subregions in the North Pacific on the base of the cephalopod distribution.

N. V. Parin and Yu. N. Scherbachev report a new finding of a rare deep-sea fish in the Japan trench.

The biological papers are preceeded by some other, where the meteorological conditions during the expedition are described (Yu. A. Shishkov); the descripton of water masses and stratification in the Gulf of Alaska are given by V. S. Arsenyev a. oth., the hydrological (V. N. Novozhilov) and hydrochemical (A. M. Chernyakova) chatacter of the water in the gulf of Alaska and in the Aleutian trench are analized.

A good correlation was found between the distribution nutrient salts and that of phytoplankton. An oxygen minimum layer was found on the depths from 600 to 800 *m*. A well mixedstrata of the deep waters in the Alaska trench was noted.

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