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UDC 639.27/29

This compendium of reports presented to the 4th All-Union Conference on commercial Invertebrates contains the results of research into various aspects of the biology, distribution, abundance and breeding problems of commercial and commercially promising crustaceans (crab, shrimp, crayfish, antarctic krill), cephalopods, bivalve mollusks, gastropods, echinoderms. A number of papers deals with the use of new methods of research, as well as the effect of environmental factors on marketable hydrobionts.

(3)*

GENERAL PROBLEMS. METHODS OF RESEARCH.

UDC 574.52(262.5)

Natural regulation of mass spawning of invertebrates in the coastal zone of the sea

by B.G. Aleksandrov (Odessa branch of INBYuM)

The comprehensive July 1985 study of the results of a prolonged wind-related drop in water level in Odessa Gulf enabled us to establish the stimulating effect of water temperature changes on the mass spawning of coastal invertebrates. We recorded an increase in surface water temperature from 9.0 to 18.5°C over a period of 4 hours (gradient: 0.04° per min). Consequently,

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*The numbers in the right-hand margin are the pages of the Russian text - translator the abundance of 1st-2nd-instar Balanus larvae, which up to that time had been kept in the brood pouch of mature individuals, increased 60-fold and reached 1800 specimens/m^3 eleven hours after the stimulating effect of temperature change. The fertilization of the majority of invertebrates, particularly the commercially important Mytilus and Mya, takes place exogenously. The formation and development of their larvae takes a long time, from 10 to 30 days in warm weather, and up to 3 months in cold weather (Torson, 1950). Indirect proof of the effect of brief wide-range water temperature changes on mass spawning of these organisms is the fact that larvae are encountered throughout the year and their numbers fluctuate frequently during the warm periods.

Consequently, along with the factors known to stimulate mass spawning of invertebrates in the coastal zone of the sea, i.e. half-month and monthly lunar rhythms (Korringa, 1947) and the appearance of high concentrations of ultra- and nanoplankton, which is the main food of larvae (Rzhepishevsky, 1960), some significance should also be attached to tidal phenomena.

(4)

UDC 574.52(262.5)

Present hydrochemical conditions in the northwestern part of the Black Sea

by G.P. Garkavaya, Yu.I. Bogatova (Odessa branch of INBYuM)

The study of the hydrochemical conditions in the northwestern part of the Black Sea at the present time is particularly important to the determination of biological productivity. The development of eutrophication processes, which began in the 1970's and covered a large part of the Black Sea, altered the hydrochemical characteristics of sea waters significantly. Research into the seasonal dynamics, salinities, pH, EH, and the content of oxygen, silicon and mineral and organic nitrogen and phosphorus compounds has shown that they depend greatly on the volume of river runoff and the time at which high water begins. A special role is played by the change in the qualitative characteristic of the freshwater runoff.

During the period of 1977-1982 (high-water years), we have noted the formation of oxygen-deficient fields in the bottom layer of the sea from the mouth of the Dnieper-Bug Liman to the Danube. They are formed predominantly at depths of 10-20 m in summer, and at depths of 20-36 m in autumn, which is related to the period of accumulation and mineralization of organic matter in the bottom layer of the sea. As anaerobic processes take place and reduce the pH and EH values in the bottom layer, we note intensive discharge of ammonium compounds, phosphates and silicon from the muddy waters in the bottom layer of the sea. For example, the content of phosphates in the bottom layer with an oxygen content of less than 1 ml/l increases from 0 to 10 μg-at/l. During the summer, when the nutrient salts in the photic layer of the sea are utilized to the maximum, the discharge of nitrogen and phosphorus from the muddy waters can effect a new spurt of phytoplankton development.

Whereas the discharge of biogenic matter from the bottom sediments prior to the 1970's was usually caused by intensive

turbulence due to storm activity or the activity of benthic organisms, the discharge of nitrogen and phosphorus salts and silicon from the muddy waters at the bottom under conditions of (5)
oxygen deficiency is of an almost constant nature during the summer-autumn period.

The hydrochemical conditions of the low-water year of 1984 differed drastically from those of previous years. We have noted a decrease in the sea area affected by the anthropogenic runoff of rivers, which has resulted in a decrease of nitrogen and phosphorus in the seawater. Maximum development of photosynthetic processes was noted only in the narrow coastal part of the freshened zone. This has affected the formation of organic matter and its accumulation in the bottom layer of the sea. A decrease in oxygen content (less than 2 ml/l) in the bottom layer of the northwestern sector of the sea was noted only in some parts of the Danube-Dnieper interfluve. The decrease in the freshwater runoff into the northwestern part of the Black Sea due to the rechannelling of some of the Danube water via the Danube-Dnieper Canal, as well as the dam across the estuary of the Dnieper-Bug Liman, will reduce the content of mineral and organic nitrogen and phosphorus compounds in the water, which should improve the hydrochemical conditions of this region. The present intensive development of photosynthetic processes is effected by a high level of biogenic substances, particularly phosphates, 0.75 µg-at/l in the northwestern part of the sea and 1.3 µg-at/l (average content for the photic layer of the sea) in the Dnieper-Bug area.

A decrease in the inflow of phosphates with the freshwater run-off will reduce their concentration in the sea 2—3-fold, which will match the conditions of the 1950's, conditions that were conducive to the development of biological processes.

UDC 574.586

<u>Some approaches to the study of biological succession</u>

by L.B. Dalekaya, O.A. Shakhmatova (INBYuM, Acad. of Sci. Ukr. SSR, Sevastopol)

The purpose of our study was to supplement biological methods with physiological and biochemical ones which would enable us to come closer to the solution of questions related to the inter-actions between the organisms of a coenosis. (6)

For a number of years, we have observed recurrent changes in the structure of a community, changes related to periodic temperature flucutations and the duration of the functioning of the dominant species of interest to aquiculture (hydroids, mus-sels, ascidians).

The number of species in a community depends greatly on the temperature conditions of the sea, whereas the succession of the dominant species is most likely determined by the biochemical conditions of the habitat. Consequently, we have attempted to examine the relationships between the organisms of a community at the level of a number of external metabolites.

Besides utilizing the rate of oxygen consumption by the community, the change in pH, the dynamics of excretion of dis-solved organic matter and the ratio of the organic and mineral components in the coenosis, we also determined the activity of some of the exoenzymes of phosphorus metabolism. The change in the activity of nonspecific alkaline and acid phosphatase and adenosine triphosphatase, which play key roles in metabolism, serves as a reflection of the physiological state of the organisms of a community. An important indicator of the state of a community is the rate of oxygen consumption, which in turn determines the rate of excretion of organic and nonorganic metabolites. The energy metabolism is determined by the dominant species. The presence of associated species did not have any significant effect on the metabolism of the community.

The change in the rate of oxygen consumption is closely associated with the physiological state of the population. At the early stages of development, the hydrobionts consume a substantial amount of oxygen and excrete practically no dissolved organic matter, whereas the excretion of organic matter increases significantly at the reproductive stage. This is particularly evident when mussels are dominant in the community. A sharp increase in the concentration of dissolved organic matter occurs when the community passes to the next stage as the hydrobionts die off and the colonies fall apart.

In a number of cases, the community displays stability of the parameters of dissolved organic matter, perhaps because of simultaneous excretion and utilization, which is one of the factors of the dynamic stability of a community. (7)

During our study of the dynamics of exoenzymes, we observed a significant increase in the activity of the enzymes excreted into the water at the stage of rapid growth of the dominant species, which was not observed at the other stages of development of an oligomictic community.

Thus, our detailed study of the dynamics of excretion of metabolites into the water and their utilization by the population has shown that oxygen consumption, the content and dissolved organic matter and enzyme activity vary significantly with the physiological state of the organisms at the different stages of ontogenesis.

With the use of a multiple approach to studying a community, we can characterize a coenosis to the fullest extent, taking the practical side of it into account. Furthermore, the indicators used can serve as criteria for establishing the relationships between organisms in a community.

UDC 639.27/.29:639.3/.6(268.45)

Main trends and results of ecological research of Barents Sea invertebrates in connection with their commercial utilization and mariculture

by S.G. Denisenko, Y.N. Gudimova, V.E. Kostylev and Ye.N. Luppova (MMBI)*

In addition to the marketable Todarodes sagittatus and deepwater shrimp, the commercially promising invertebrates of the Barents Sea include a number of species of large bivalves, echinoderms and coastal crustaceans. The decision regarding the commercial utilization of these animals should be based on the results of a thorough study of their biology, which would enable us to

*Murmansk Marine Biology Institute - transl.

conjecture the productive potentials of the recommended populations, their role in the functioning of the ecosystems and the measures that must be taken to protect and renew the reserves.

For a number of years, the Murmansk Marine Biology Institute has been studying their biology, their role in the ecosystems, and measures for protecting and renewing the reserves of these (8)
invertebrates. The subjects of our study were *Chlamys islandicus*, *Modiolus modiolus*, *Cucumaria frondosa* and *Gammarus oceanicus*.

The Iceland scallop is common in the areas with active benthopelagic hydrodynamics, on coarse- and medium-grained sandy sediments with an admixture of coarse-detrital material. A preliminary estimate of its reserves in the Barents Sea has shown that it is possible to organize specialized seasonal harvesting of this species with small "Seiner"-type vessels with an annual yield rated at 2-3% of the biomass of exploitable populations. The establishment of a profitable scallop-breeding enterprise in the Arctic at this point in time would not be a realistic undertaking because of the low growth rate of this species. It would be more efficient to organize moderate harvesting of it combined with inexpensive measures for replenishing its natural stocks by gathering the settling young individuals on collectors and dispersing them in suitable areas.

Modiolus modiolus is a common species that is encountered in the sublittoral of the Murman Coast, predominantly on crushed shell rock and stones, frequently with the Iceland scallop. This mollusk tastes like the mussel, and contains biologically active substances. Investigations are being carried out to study the distribution and habitat of _M. modiolus_ in the Barents Sea. Most of the attention is being devoted to studying the growth rates and life span from different aspects in an effort to substantiate the possibility of breeding the mollusk for commercial purposes.

Cucumaria frondosa is encountered throughout the Barents Sea, and is part of numerous bottom-dwelling communities. However, unlike its Far Eastern relative, which is used as a food product and a source of biologically active substances, this species has not yet attracted the attention of the fishing industry. Concentrations of these animals are confined to the zones affected by the warm Atlantic waters with active benthopelagic circulation. Holothurians prefer hard sediments with patches of mud and an abundance of detritus.

Amphipods of the species _Gammarus oceanicus_ may be of interest to mariculture as a source of animal protein for valuable fish species. Since 1978, we have been studying the age and sex structure of its populations, as well as its life cycle, fecundity and reproduction in the littoral zone of Eastern Murman. We now have data on the annual production and stock of these crustaceans, (9)
as well as data regarding the best time and rate of harvesting the species for practical purposes.

The possibility of keeping and raising _Mytilus_, _Modiolus_, _Cucumaria_ and _Gammarus_ in aquariums and tanks is currently being studied. There are plans to establish an experimental _Mytilus_-_Laminaria_ plantation in Dal'ne-Zelenetskaya Guba in the nearest future.

UDC 591.524.11.08

Underwater methods of counting bottom-dwelling animals

by V.Ye. Dzhus, Ye.A. Frolova (MMBI)

The Murmansk Marine Biology Institute estimates the stock of benthic animals, including commercial and commercially promising species, by the diving and hand camera method, underwater automatic stereophotography, and by manned observation chambers. The use of lightweight diving equipment enables us to count the benthic animals at depths up to 40 m. Underwater hand cameras provide us with photographic documents of the results. The 60x60 mm "Salyut" camera is used for underwater photography. Depths of up to 350 m are accessible to the automatic underwater stereophotostation "Zelenetskaya-2" (80 mm format). The photograph is taken the minute the guide rope touches bottom. The stereophotostation has been used to survey the Murman coast of the Barents Sea, the White Sea Basin and the Spitsbergen area. The photographs have helped us to establish the density of the animal population, the uniformity (aggregation) of distribution, the behavioral patterns and activity of the animals. With the use of size-weight ratios, we can estimate the biomass of the benthic epifauna. In an observation chamber (ГКС-6 bathysphere), a researcher can submerge to a depth of up to 300 m under normal atmospheric pressure. The searchlights installed on the chamber illuminate the bottom. The underwater conditions are evaluated visually and reported by telephone to the mother ship.

The underwater methods allow us to collect data on the abun- (10)
dance and distribution of the animals without harming them.

UDC 639.3/.6

Prospects of breeding marine organisms in a polyculture

by V.V. Yevdokimov (TINRO*)

We have studied the ontogenesis in Yezo scallops (*Patinopecten jessoensis*), sea-urchins (*Strongylocentrotus nudus*) and algae (*Gracilaria verrucosa*) in a monoculture and a polyculture under laboratory conditions in order to trace any changes that may occur in their reproductive system during separate and combined cultivation, and to determine the optimal reproductive conditions. The experiments were carried out at different times of the year with the temperature taken into account. Prior to and following each experiment, we conducted a morphometric and histological study of the reproductive organs of the species being dealt with. The results were processed statistically. We have found that temperature has a stimulating effect on the reproductive process both in a monoculture, and in a polyculture. At the same time, the coefficient of maturity of the reproductive organs of the animals and the increase in the biomass of *Gracilaria verrucosa* proved to be the highest in the polyculture. The germ cells obtained were morphologically the same as the genital products that form in a natural environment, which has been confirmed by experiments with embryos. It should be said that the highest percentage of fertilization and survival of the organisms was noted in the brood stock of the polyculture. The complex interaction arising between organisms during their reproduction in a polyculture can be explained in the following way.

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*Pacific Scientific Research Institute of Fisheries and Oceanography - transl.

First of all, we should note the interrelation of the food chain in the community in question. During their active life, the animals excrete nitrogen, phosphorus and a large amount of ammonium which serve as additional food for Gracilaria verrucosa. This is why the latter grows more rapidly and accumulates more biomass in a polyculture, than in a monoculture. In turn, the sea-urchins (11) make the primary production accessible to the animals that feed on detritus, and since detritus constitutes 30-70% of the diet of the Yezo scallops, the bivalves of the given community are provided with additional food. The bivalves themselves, by filtering the suspended matter through their body, clean the water. Consequently, the more efficient assimilation of food in a polyculture affects the physiological state of the organisms as a whole, and this is expressed in an increase of their total biomass. Nutrients also accumulate in the gonads. Considering the fact that red algae contain acetylcholine, we can say that Gracilaria verrucosa influences the reproductive process of the animals in the given community, since the cholinergetic system participates in the regulation of spawning in marine invertebrates.

Thus, our data indicate that it is more profitable to keep commercially valuable marine animals in a polyculture when breeding them.

UDC 597.153:594.5+595.384.12(261.5)

The role of cephalopods and shrimps in the feeding of fish in the central East Atlantic

by L.N. Domanevsky and F.A. Patokina (AtlantNIRO*)

We have examined the feeding habits of more than 300 species of fish from 4 groups collected during trawl surveys in the central East Atlantic. The collection and processing of the material were carried out by the gravimetric method.

Group 1, from the shelf zone, is broken down into the following three subgroups according to vertical distribution: a) the shelf pelagic subgroup (43 species) with 10% feeding on shrimps and 20% on squids. In the subtropical zone (Casablanca, Western Sahara), shrimps constitute up to 10% by weight of the food consumed by the dominant scad, mackerel and scabbardfish. These include bathypelagic (*Sergestes*) and bottom-dwelling burrowing shrimps (*Parapenaeus longirostris*, *Solenocera membranacea*, etc.), as well as the young of shrimps. Squids of the genus *Alloteuthia* constitute 20% of the food bolus. In the tropical zone, the (12) prolific jacks (*Caranx* spp.) and cutlassfishes also feed on bathypelagic (*Heterocarpus ensifer*) and burrowing species of shrimps (*Metapenaeopsis* sp., *Parapenaeopsis* sp.), squids (*Alloteuthia* sp.) and cuttlefish (*Sepia* sp.). Thus, the pelagic shelf fishes of both zones feed both in open water (on bathypelagic shrimps and squids), and at the bottom (on burrowing shrimps and cuttlefish); 2) the shelf benthopelagic subgroup, the most numerous one (150 species), with 80 species feeding on shrimps, and 15 species on squids. In the northern zone, the dominant

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*Atlantic Scientific Research Institute of Sea Fisheries and Oceanography - transl.

porgies (_Dentex macrophthalmus_, _Pagellus acarne_) and hakes (_Merluccius merluccius_, _M. senegalensis_) feed on burrowing shrimps (_Alpheus glaber_, _Processa_ sp., _S. membranacea_), less commonly on bathypelagic shrimps (_Plesionika_ sp.), the young of shrimps, squids (_Alloteuthis_ sp.) and cuttlefish. In the southern zone, the prolific porgies (_Pagellus coupei_, _P. ehrenbergi_) and triggerfishes (_Balistes_ sp.) feed predominantly on the burrowing species of shrimps (_Metapenaeopsis_ sp., _Solenocera africana_), the young of shrimps, _Alloteuthia_ and _Sepia_. Thus, the benthopelagic species feed mainly on burrowing shrimps and cephalopods;

c) the shelf bottom-dwelling subgroup (43 species), with 10 species feeding on shrimps and 5 species on squids. The prolific skates (Rajidae in the northern zone, and Dasyatidae and others in the southern zone), as well as the flounders and eels in both zones feed on bottom-dwelling burrowing species of shrimps (on _Alpheus glaber_ and _S. membranacea_ in the north, and on _Metapenaeopsis_ and _Sicyonia_ in the south), as well as on _Loligo_ and _Alloteuthis_ squids and cuttlefish.

Group 2, from the coastal-estuarine zone (11 species). In the tropical zone, the prolific species are beardfishes*, captainfishes, green grunt and ilisha which feed on bottom-dwelling burrowing shrimps (_Alpheus_ sp., _Nematopalaemon hastatus_, etc.). Only the green grunt feeds occasionally on squids.

Group 3, consisting of fishes of the continental slope, is broken down into the following two subgroups: a) pelagic slope fishes (11 species) which feed mainly on Myctophidae and Gonostomiatidae in the subtropical zone. They feed on shrimps and

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*conjectural, implied by Russian name "borodachi" - transl.

squids occasionally. In the tropical zone, the tunas and cigar-fishes feed on the bathypelagic species of shrimps (*Systellaspis* sp., *Sergestes* sp.); b) benthopelagic slope fishes (45 species), with 10 species feeding on shrimps and 4 species on squids. The (13)
dominant species, grenadiers and *Hoplostethis* in the northern part, and grenadiers, hakes, *Synagrops* and greeneyes in the southern part, feed on bathypelagic (*Systellaspis* sp., *Sergestes* sp., *Heterocarpus* sp.) and epibenthonic (*Pasiphaea* sp., *Plesionika* sp.) species of shrimps, as well as squids of the genera *Alloteuthis* and *Loligo*, octopus and cuttlefish.

Therefore, shrimps and cephalopods play a significant role in the feeding of various ecological groups of fish off the coast of West Africa, the benthopelagic and pelagic fishes of the slope feeding on bathypelagic shrimps, the benthopelagic shelf fishes on benthopelagic shrimps, and the benthopelagic and bottom shelf fish, as well as the bathyal benthopelagic fishes in the southern part of the region, on epibenthonic shrimps. The burrowing shrimps serve as food for the benthopelagic, bottom and, less commonly, pelagic fishes of the shelf. All of the ecological groups of fish feed on the young of shrimps.

UDC 639.27/29(262.54)

Commercial and feed invertebrates of the Sea of Azov and their potential volumes of utilization

by V.P. Zakutsky (AzNIIRKh*)

The marketable and feed invertebrates of the Sea of Azov consist of five species.

The biocoenosis of Pontogammarus occupies nearly the entire pseudolittoral of the Sea of Azov, except for the areas contaminated with industrial waste, eel-grass and jellyfish ejecta, clay outcrops, etc. The reserves of these crustaceans vary from year to year, and are directly related to the oxygen content of the water and depend on water salinity and temperature, the type of bottom and the availability of food. They vary from 10,000 to 33,000 tons. The harvesting limit is 33-50% of the total reserves. Fishery cooperatives do not usually harvest this crustacean, though the latter is excellent live feed for sturgeons.

Artemia is found throughout the salt lakes of the northern Azov area, Sivash, in the Crimean lakes Popovskoye, Moynakskoye, Dzharylgach, Sasyk, etc. The reserves of live biomass and diapausing eggs of Artemia amount to 20-154 tons. The reserves of (14)
crustaceans and eggs are greatly affected by the salinity and temperature of the water, oxygen and feeding conditions, and also wind conditions. This is an excellent feed in aquiculture.

The area of the Mytilus biocoenosis is equal to 5500-7000 km^2. Mytilus had never been encountered in the Sea of Azov before. After the salinification of the sea to 13-14% , Mytilus beds formed on the Zhelezinsky Bank, as well as in the Berdyansk, Obitochny and Utlyuksky limans. The rock form of Mytilus is noted in the Kerch Strait—Kazantip area. The mussel reserves have been confirmed by estimates, and vary from 500,000 to 1,000,000 tons. From 20,000 to 30,000 tons could be harvested for economic needs. However, no special selective equipment has been designed for the Sea of Azov.

A biocoenosis of Mya formed almost along the entire perimeter of the Sea of Azov. Mya is found at practically all depths and on all substrates. Particularly high concentrations are noted along the northern shores (Berdyansk and Obitochny bars), including the western part of Taganrog Bay up to the city of Zhdanov. The clam reserves amount to about 25,000 tons. Mya is regarded as a good product for mariculture.

Medusa. As a result of the salinification of the Sea of Azov in 1973, a mass of jellyfish (Rhizostoma and Aurelia aurita) appeared in the sea. The highest biomass of jellyfish in this body of water is observed every August. Depending on the year, the abundance of jellyfish amounts to 500,000,000 to 7,000,000,000 individuals with a total biomass of 2,000,000 to 13,500,000 tons (1974-1976). The maximum number of jellyfish is observed in the shallow saline and contaminated areas. Attempts are being made to utilize jellyfish in the construction business for the production of ceramic tiles, as fillers during welding, and as supplements to livestock and poultry feed.

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*Azov Scientific Research Institute of Fisheries - transl.

UDC 574.34 (15)

On the correlation between life span and mortality in an animal population

by V.N. Zolotarev (Odessa branch of INBYuM)

One of the methods of determining the life span in some animal populations is to estimate the age of the individuals which in a given age group and subsequent age groups constitute a certain proportion of the total numbers of the population or a part of it. When the mortality rate remains constant as the animals age, the age (t_p) of the individuals, the abundance of which has a given frequency of occurrence (**P**) at this and an older age, is determined by the equation $t_p = t_x - \ln P/\alpha$, where t_x denotes the age of the younger age group in the given sample, and α the mortality rate (Zolotarev, 1982).

Assuming that t_p is equal to the age of the oldest individuals (**n** denotes their number in a group of animals with an abundance **N**), the equation $P=n/N$ will characterize their frequency of occurrence. In this case, the mortality rate is determined by means of the maximum age t_m and the abundance of the studied sample of animals, i.e. by the equation $\alpha = \frac{\ln (n/N)}{t_x - t_m}$. This relationship can be used to determine the mortality of the animals in the case of a limited number of age determinations, or when it is impossible to determine this parameter by the usual methods.

The homology of the mortality rates calculated by the derived equation (α) and by the commonly used correlations of abundance of various age groups (**Z**) has been verified on samples of <u>Mytilus galloprovincialis</u> from different areas of the north-western part of the Black Sea. With the abundance of these samples ranging from 140 to 1600 individuals, we observe a fairly high convergence of these indices with the correlation coefficient 0.953. A higher $\mathbf{Z}$ than α is characteristic of samples with a small number of underyearlings, due either to an actual shortage of them as a result of a low recruitment, or to sampling irregu- (16) larities. For colonies with a normal age structure, the estimated values of α are usually slightly higher than the values of $\mathbf{Z}$ (up to 20%). The cause of this systematic deviation is associated with the accepted assumption that the probable age t_p and the maximum age t_m are identical.

UDC 639.42(262.5)

<u>Approaches to zoning the coastal zone of the sea in an effort to accommodate mussel plantations</u>

by I.V. Lebedeva (INBYuM)

The economic structure of the production of mussel products consists of both sea and land elements. The industrial and technological ties between these elements are maintained by the system of sea and land transport.

The development of mariculture on the Black Sea coast involves the accommodation of these establishments on land and water areas belonging to highly developed agricultural establishments, fisheries and recreational facilities. The necessity of "incorporating" a new element into the existing structure of nature utilization on the coast requires that all of the physicogeographical and economic-geographical factors be taken into account. An important stage in the selection of sites for maricultural establishments is the geographic zoning of the water areas suitable for the cultivation of marine organisms.

Two approaches to zoning are possible. Zoning for the purpose of selecting sites for maricultural establishments requires that we establish which areas on the coast have a combination of the hydrological, hydrochemical, hydrobiological and economic-geographical factors conducive to cultivation. However, areas characterized by the ideal combination of these factors may not be available at all, or they may be extremely limited. It would be more realistic to speak of "more" or "less" favourable areas for the already developed biotechnologies of mussel cultivation. (17)

Mytilus biocoenoses are found along the entire coast of the Black Sea, which means that the entire area of the sea is potentially suitable for mussel plantations. In this case, the biotechnology of cultivation and its individual elements and methods should be subjected to zoning. For example, storm-resistant equipment will have to be used in areas more prone to storm damage. The collectors with mussels can be moved to areas with an unexploited feed potential. The use of areas and depths with different temperatures will enable us to regulate the reproduction of mussels and the quality of the product.

The data of hydrobiological monitoring and the efficiency statistics of experimental plantations can serve as the criteria for the zoning and evaluation of the different zones of the sea.

UDC 594.1(265.54)

Main stages of the embryonic and early larval development of commercial bivalves in the Sea of Japan

by V.V. Malakhov and L.A. Medvedeva (MGU, TOI DVNTs)*

1. The least researched period in the life cycle of bivalves is the period from the onset of cleavage to the stage of early veliger. Even with respect to such commercially important and long-cultivated forms as mussels, oysters and scallops, the data available in the literature are meagre and inconsistent. Our paper sums up the original data on the embryonic and early larval development of 5 prolific commercial species of bivalves found in the Sea of Japan, *Mytilus edulis*, *Crassostrea gigas*, *Patinopecten yessoensis*, *Mactra chinensis* and *Spisula sakhalinensis*.

2. Cleavage is spiral and heteroquadrant in all of the species studied. Cleavage in *M. edulis*, *C. gigas* and *P. yessoensis* takes place with the formation of polar lobes in the first (18)
three cleavage divisions. *M. chinensis* and *S. sakhalinensis* do not have polar lobes. Analysis of the data taken from the literature has brought us to the conclusion that cleavage with the formation of a polar lobe is a general tendency in all Filibranchia, whereas no polar lobes are formed in Eulamellibranchia.

3. Cleavage in all of the species studied results in a sterroblastula, inside of which there is an X-blastomere that represents one of the descendents of the first somatoblast.

*Moscow State University and the Pacific Ocean Institute of the Far Eastern Scientific Centre - transl.

The sterroblastula of the majority of the species studied (with the exception of P. yessoensis) bears three rows of cilia, swims actively in the open water, and represents the first larval stage of marine bivalves.

4. Due to a series of uniform divisions of the X-blastomere, an invaginated shell gland opening in a wide transverse aperture (conchostome) on the dorsal surface is formed. The invagination of the entodermal material results in the formation of the archenteron which is linked with the external environment by means of a blastopore. A larva with two invaginations (shell gland and archenteron) bears three rows of locomotory cilia, an apical tuft of sensory cilia, and posterior sensory cilia. A larva with this type of structure was observed in all five species, and it has been suggested that it be called by the special name of conchostoma.

5. After the eversion of the shell gland, a shell begins to form, initiated as a bilobed plate on the dorsal surface. As it develops, the shell encompasses the larva from the sides and finally splits into 2 valves along the median line of the dorsum. At the same time, reorganization of the larva takes place, i.e. a velum forms from the 3 rows of cilia, the rudiment of the cerebral ganglion appears under the base of the apical tuft, and the intestine occupies a different position inside the larva, attaching itself by its distal end to the ectoderm of the ventral side where the anal aperture burst open. The intestine in the early veliger larva is differentiated into an infundibular oesophagus, a stomach with which the hepatic lobes and the cecum of

the crystalline style gland is connected, and a thin hind-gut. The muscle system of the early veliger larva includes an unpaired anterior adductor, three pairs of larval retractors and a pair of velar retractor muscles.

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6. The basic stages of embryonic and early larval development proceed in a similar manner in all the species examined in this paper, and are probably characteristic of the marine Autobranchia as a whole. A knowledge of these stages is required in order to control the early stages of ontogenesis of commercial bivalves under artificial breeding conditions, and to study the effect of environmental factors on their development.

UDC 639.27/29(265.5)

Commercial stock of invertebrates in the Far Eastern seas

by V.V. Miroshnikov and V.Ye. Rodin (TINRO)

During the period from 1975 to 1985, the staff members of the TINRO Laboratory of Commercial Invertebrates, together with the staff members of VNIRO and ZIN* (on "Dal'ryba" vessels of TURNIF**, SEKBP*** and VRPO**), carried out more than 80 specialized research-scouting trips to study the distribution and determine the stock of commercial invertebrates in the Far Eastern seas. These investigations covered the most productive zones of the sublittoral and eulittoral where the biology and ecology of 24 species of various invertebrates were studied.

As a result of these investigations, we learned that the Sea of Okhotsk was the main source of commercial invertebrates in the Far Eastern region. Approximately 55% of the total commercial

*Zoological Institute of the USSR Academy of Sciences; **acronyms unknown; ***Special Experimental Design Bureau of Commercial Fishery of AtlantNIRO - transl.

stock of invertebrates is concentrated in this region; the commercial stock of invertebrates in the Sea of Japan and in the northwestern part of the Bering Sea amounts to only 20 and 18% respectively.

The distribution of the stock of individual commercial species of invertebrates in the Far Eastern seas is given in the following table.

Table 1. Correlation of the commercial stock (% of the total value) of the principal commercial species of invertebrates in the Far Eastern seas.

Commercial invertebrates	Commercial areas of the Far Eastern seas					
	NW part of Bering Sea	Eastern Kamchatka	Northern Kurilian	Southern Kurilian	Sea of Okhotsk	Sea of Japan
A. Crab, including:	15.1	1.3	1.8	1.0	67.0	13.8
Kamchatka crab	0	0	0.3	0.3	96.5	2.9
snow crab	34.1	2.6	5.1	0	29.6	28.6
other species	31.8	3.5	0	5.9	35.3	23.5
B. Shrimp, incl.:	43.2	0	0	1.2	27.8	27.8
bent-tailed shrimp	63.2	0	0	0	36.8	0
deepwater shrimp (humpback, pink, _Pandalopsis_)	14.9	0	0	3.0	14.9	67.2
C. Mollusks, incl.:	16.7	0	6.7	3.7	61.2	11.7
gastropods	20.7	0	0	4.1	73.1	2.1
pink scallops	0	0	45.5	2.3	6.8	45.4
D. Echinoderms, incl.:	0	0	0	25.0	16.7	58.3
sea-urchins	0	0	0	20.0	0	80.0
Cucumaria	0	0	0	28.6	28.6	42.8

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UDC 639.2.001.5:629.127.4.077.2.621.397

Television method of estimating the abundance of commercial invertebrates from a "Sever-2" submersible

by V.B. Murav'yov (VNIRO)

The conventional method of quantitative determination of commercial invertebrates (hydroacoustical, trawl surveys, dredging) do not show the actual nature of distribution or the total numbers of the animals, whereas the TV method enables us to count all of the animals.

On three trips of the "Ikhtiandr" and "Odissey" support vessels (1981-1984), we counted the number of commercial invertebrates by means of the TV method. We used the results of visual observations from a submersible apparatus to decipher the TV image and establish its reliability.

During the total count of invertebrates, we kept to a steady course and velocity of the submersible with respect to the bottom, and recorded the direction and velocity of the current and the height of the submersible above the bottom. The time step of recording was equal to one minute or five minutes of travel of the submersible, depending on the density of distribution of the commercial invertebrates. The travel parameters were selected with the safety of the submersible apparatus taken into consideration.

By applying the theory of mass coverage and the recommendations of engineering psychology, we determined the potentials of the visual method of estimation.

The actual area (S_{vis}) of the information field (area of the observable bottom) amounted to 25, 34 and 41 m^2 with the distance of horizontal visibility equal to 6, 7 and 8 m respectively; these values were determined with the zone of human peripheral vision taken into account. The time spent on processing the information on one organism during an individual count (without observing behaviour) varied from 1.5 to 4 seconds.

With an operator (underwater observer) on board a submersible apparatus travelling at a speed of 1 knot, the researcher can record the maximum allowable concentration of 20 specimens per 100 m^2. The invertebrates missed during a total count consti- (22)
tute the error ; its value depends on the experience and psychophysical condition of the observer.

Television filming of a transect has a number of advantages over the visual method; these include documentation of the initial data and frequent repetition. The disadvantages are a low resolution and the difficulty of identifying objects depending on their size, the distance of visibility and the degree of contrast in relation to the background (the bottom).

Hydroperspective TV filming was carried out from the submersible at an angle of 25^o to the horizon. The minimum length of the invertebrates relative to the height of the submersible apparatus above the bottom (from 1.4 to 2.5 m) varied from 18 mm to 34 mm in the centre of projection. The readings were taken from a video screen after the submersion of the submersible apparatus, and for better identification of the animals, the upper part of the screen showing the farthest animals was not taken into account.

The experimental material of three trips, processed by methods of mathematical statistics, indicates that our quantitative evaluation data (visual and TV) on large commercial invertebrates (spiny lobster) are in good accord, and shows that the TV method gives results that are 4-5 times too low where the distribution of small-sized shrimp is concerned. This is determined by hydroperspective filming, the behaviour and distribution of the shrimp above the bottom and by the low degree of contrast in relation to the background.

Manned submersibles should be used for developing the method of instrumental evaluation in order to reliably decipher the images (TV and photo) and derive the correction coefficients, whereas unmanned towed TV and photosystems should be extensively used for quantitative estimation of commercial invertebrates. At the same time, the sampling area (number of samples) increases, while the cost of research in comparison with the use of submersibles is incomparably lower. Extensive TV filming and photography can help to determine the reserves of commercial invertebrates more accurately.

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UDC 639.32

On the development of selection criteria during the siting of maricultural establishments

by T.F. Narusevich (INBYuM)

The purpose of our study was to evaluate the biological characteristics of the waters in the western half of the Black Sea. The abundance of microzooplankton was determined by microscoping a bathometric sample of sediment. In all, we processed 49 settled bathometric samples from 7 stations in the central part of the sea and in the main Black Sea current (in the vicinity of the Crimea, Cape Kaliakra and the Bosphorus). The samples were taken from the 0-100 m levels on 15-20 July 1984, from the Acad. Kovalevsky research vessel. There were no drastic changes in weather.

The microzooplankton consisted mainly of nauplii, larval stages and mature individuals varying from 57 to 500 μm in size. *Noctiluca miliaris* measuring 400-800 μm were frequently encountered. Tintinnids and pelecypod larvae were rare. The microzooplanton are the main consumers of the phytoplankton. As we know, phytoplankton develops at the fastest rate in the main current, where active turbulent mixing of the waters and an underflow of nutrients is noted. The main current comes closest to the shores of the Crimea, i.e. the 1000-metre isobath occurs 11 miles from the shore. An abrupt decrease in depth causes turbulent mixing in this area. The thickest cold intermediate layer (CIL) was detected off the coast of the Crimea; this layer, bounded by the 8° isotherm and the natural temperature-depth distribution curve, constituted 393 conventional units. The average content of the crustacean microzooplankton for the 30-100 m layer amounted to 12.8 specimens per litre. At the other stations in the main Black Sea current, we noted that the microzooplankton tended to increase with a decrease in CIL thickness; its average content in the 30-100 m layer at stations 36, 34 and 38 was 13.6, 14.4 and 16.6 specimens/l with a CIL thickness of 248, 220 and 184 conventional units respectively. Since the level of microzooplankton development off the coast of the Crimea is lower than in other coastal areas and even in the open part of the sea, we can assume that the CIL waters, under the present conditions, have a negative effect on the plankton that serves as food for filter feeders. The waters of the cold intermediate layer (CIL) form during the winter in the northwestern and western parts of the sea, and then spread at depths of 40-75 m over the entire area of the sea. The negative effect of CIL waters may be due to the accumulation of toxic compounds that run into the sea from large rivers (Danube, Dnieper, etc.). Consequently, the thickness of CIL can serve as a criterion of the biotic properties of the studied coastal or open region of the sea.

Another important factor is the stable deep suspension layer (SDSL), detected and studied by researchers of Moscow State University (Neuimin, 1970). It occurs in the 100-180 m interval. Off the coast of the Crimea, the SDSL reaches its maximum thickness during the summer—autumn period; it does not occur at all in the shallow and coastal parts of the sea. Formed from the remains of organisms, the SDSL can send toxic and radioactive substances into the upper layers of the sea. Therefore, the choice of areas least affected by the CIL and SDSL is an important factor to be considered when organizing maricultural establishments.

UDC 551.465:591.524.11

Questions related to the distribution of benthic animals according to the hydrodynamics of the bottom waters

by K.P. Repin and S.Yu. Yashchenko (MMBI)

The hydrodynamics of the bottom waters is an important ecological factor that affects the distribution of living organisms at the bottom. A weak turnover of water does not provide the optimal living conditions for the animals, whereas an overly strong turnover detaches the animals from the substrate, and carries them off to other places and, in many cases, to their death.

The use of standard current gages for recording bottom currents poses a problem, since their size is comparable with that (25)
of the animals, and the instruments are not designed for installation on the bottom. Taking these limitations into account, we have developed an attachable guide-rope device consisting of a ballasting receptacle for a solution of fluorescent dye with a system of inlet and discharge valves. The dye is sprayed into the bottom zone within the visibility of an underwater camera 0.45 seconds before triggering the shutter. This is enough time for the cloud of dye to move towards the guide rope in proportion to the strength of the bottom current. Similar measurements

carried out in the coastal region of the Barents Sea have enabled us to establish the relationship between the abundance of prolific bottom-dwelling animals and the strength of the bottom currents.

A new ecological parameter, the strength of adhesion of sea animals to the substrate (bioadhesion), had to be introduced to analyze these measurements. To measure this parameter, we developed a method whereby a spring-actuated dynamometer with a special grab mechanism is used by a diver. For sea-urchins, starfishes and Modiolus, the strength of adhesion to the substrate varied from several tens of grams to several kilograms, depending on the strength of the bottom current, depth, the substrate and other factors.

The use of these methods of measuring the strength of bottom currents and bioadhesion appears promising for the study of commercial invertebrates such as mussels, oysters, etc.

UDC 574.587:628.394(26)(262.5)

Variability in the structure of the benthos of the Black Sea under the conditions of anthropogenic intervention

by E.Z. Samyshev, I.G. Rubinshtein, P.N. Zolotarev and N.M. Litvinenko (AzCherNIRO*)

Analysis of long-term observations has revealed significant negative changes in the structure of the benthos in the northwestern part of the Black Sea. The essence of these changes lies in the populational degradation of the dominant species from the three main biocoenoses of the region, i.e. Mytilus, Phaseolina**

*Azov and Black Sea Scientific Research Institute of Sea Fisheries and Oceanography; **conjectural spelling of genus (?) - transl.

and *Phyllophora*, as well as a number of dominant secondary forms, (26) and in the appearance on these freed territories of certain temporary communities with primarily secondary forms dominant in them.

The degradation of the benthos as a whole in the northern and western parts of the region is due mainly to mortality caused by a lack of oxygen brought on by changes in the hydrostructure (caused, in turn, by stoppage of the freshwater runoff) and eutrophication. The deterioration of *Mytilus* populations is also caused by the adverse effect of dredging and bottom trawling which transform the substrate and destroy the mussel colonies. The main cause of the degradation of *Phaseolina* is bottom fishing on the territory of its biocoenosis, which destroys these mollusks directly. The decrease in the area of Zernov's *Phyllophora* field and the reserves of algae in it is due to the deterioration of light conditions on the bottom, which is associated with eutrophication and the influx into the area of a mass of pelitic particles that are broken up during trawling operations on the territory of the *Phaseolina* biocoenosis.

These changes in the components of the benthic biocoenoses of the given region point to the necessity of resorting to emergency preventive measures. To develop such measures, we must review the structure of the benthic communities in the sea as a whole, and monitor the entire territory of its shelf zone.

UDC 639.32:628.394(26)

Effect of tidal electric power plants on the state of the biological resources of closed sea inlets and the prospects of developing mariculture in them

by V.N. Semyonov, Ye.I. Zhukov, S.G. Denisenko and V.N. Makarov (MMBI)

Investigations in Kislaya Guba of the Barents Sea, a basin closed off by the dam of an experimental tidal electric power plant (TEPP), have shown that the latter has a detrimental effect on the biological resources of the inlet when the water exchange with the sea is less than 10-20% of the natural turnover. As a result of freshening and a decrease in tidal amplitude, the (27) littoral macrophytes and the several tens of animal species biocoenotically related to them have completely disappeared, and the vertical biological zonality of the littoral and upper sublittoral has changed. The littoral producers (macrophytes) have been replaced by other, less productive and less valuable ones, mainly Cyanophyceae and Diatomeae. The irregularity of the water level in the basin, the marked summer stratification of the waters with the accumulation of hydrogen sulphide in the deep parts, and the increase in the ice and snow cover in winter have added to the detrimental effect on the vegetation and animal population.

The species composition of the benthos in Kislaya Guba has decreased by 46% on the whole, and 3—7-fold in the littoral zone. The trophic structure of the benthic communities has undergone significant changes. Due to a decrease in water movement, the content of suspended matter has dropped, and the feeding conditions of the benthic filter feeders have deteriorated, and with an increase in silting, these organisms have been replaced by detrivorous ones. Unfavourable conditions have arisen for a number of commercially valuable algae (*Laminaria*, Fucales) and bivalves (*Mytilus*, *Modiolus*, *Chlamys islandicus*). Some of these have disappeared almost completely. The population of the Iceland scallop, which inhabited the central part of the inlet, has diminished substantially, and the shells of the remaining ones are covered with a thin layer of silt. The growth rate of this species has dropped by 35%.

At the same time, a small area of *Laminaria* overgrowths has appeared not far from the dam of the electric power plant, in the zone affected by the waters of the water conduits. This prompts us to recommend that the possible decrease in the reserves of commercial algae in the basins of planned major TEPP be compensated by artificial cultivation of them on plantations located in the optimal hydrodynamic zones close to the TEPP dams. The possibility and efficiency of applying this method of cultivation will depend on the width of the dammed zone (i.e. the length of the part that consists of the hydrodynamically active units of the TEPP) and on the flow rate of the water. Algae plantations can be combined with mussel farms, or with simultaneous cultivation of *Mytilus* and *Modiolus* on floating collectors, but only in the absence of contaminated runoff and with a water turnover of not less than 90-95% of the natural level, since significant ecological disturbances can already occur with an 11% decrease in tidal amplitude (Mitchell, Probert, 1984). In areas with a regular semi- (28)
diurnal tide, the given values of water turnover can be maintained

in a single-basin TEPP system by combining forward and reverse turbine and pump operation in the a1b2c3d4 regulation cycle (Zhibra, 1974), but only when the total diameter of the working water openings of TEPP ensures normal (without regulated flow) high-tide rates of flow through the TEPP section. TEPP basins can also be used for the maturation of the young of certain invertebrate species that settle on the floats (e.g. the Iceland scallop, etc.), in order to later resettle the exploitable populations in the TEPP basins and in the open parts of the sea for better reproduction. Experiments in a natural environment must still be conducted to determine which species of maricultural importance should be given preference under these conditions. The recommendations that can be developed on the basis of our investigations are important because powerful and superpowerful tidal electric power plants are being designed and slated for construction within the century, and the dams of these TEPPs will be closing off vast areas of the White Sea and the Sea of Okhotsk.

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UDC 574.9:592:693.3.04

<u>How the structure of the fauna affects the introduction of commercially valuable marine invertebrates</u>

by V.N. Semyonov (MMBI)

The success of introduction and acclimatization depends not only on the ecological conformity of the introduced species and the recipient ecosystem conducive to the parasitological situation, but also on the faunal-structural conformity of the biogeographic characteristics (origin) of the species and the place of its introduction. The following chorologic laws of the biotic (florofaunal) level of organization of life should be taken into consideration during introduction.

1. The live cover (biota as a whole) consists of spatially discrete syntopic elements that unite species (regardless of their biocoenologic relationships) with a similar geographical and verical distribution.

2. The combinatorial principle of populating a widescale geobiotopic (synchronous) system with syntopic elements of the biota is the basic principle (Semyonov, 1979), and it lies in the fact that the congruent areas (co-areas) of the species constituting this or that syntopic element may overlap one, two, three or more elementary geobiotopes (synchores) of a geographical environment. At the same time, the co-areas of the different syntopic elements overlap a different number of elementary synchores of the environment, and in the most diverse combinations. The boundaries of the synchores, the units of the environment that correspond to the co-areas of syntopic elements, are determined in the marine environment by the boundaries of the water masses and their vertical structural zones, the natural boundaries of marginal seas and refugium bays with their own water masses, large orographic obstacles such as continental isthmuses, shelf glaciers, etc., and in some cases, in the zones of biotic equilibrium, by the previous (geohistorical) boundaries. A large part of these synchoric boundaries is determined by the hydrological frontal zones in the open ocean.

3. The boundary effect. This phenomenon is important to the introduction theory (Semyonov, 1977); its essence lies in the fact that boundary groups of species with "localized areas" which are not encountered anywhere else are concentrated in the frontal hydrologic zones of many of the regions of the shelf and continental slope. (O. Kamenskaya, 1977, also came across such species at the boundaries of the bathyal and the deep-sea amphipod faunas). The explanation of the boundary effect is ambiguous (Semyonov, 1977). The first hypothesis is a relict one. The second, migrational, hypothesis is important to introduction. It is based on the fact that hydrologically isolated micropopulations of benthic species with severed areas of distribution are concentrated in the same frontal zones, and the existence of these species is sustained by the drift of planktonic larvae. New species eventually develop from the micropopulations as their isolation increases. From the migrational hypothesis which has been substantiated in many ways, it follows that the most successful introduction of species (both spontaneous, and controlled) proceeds from large evolutionally advanced centres of speciation (Briggs, 1974) and faunigenesis towards the less advanced and less species-saturated peripheral regions. Apart from peripheral (30)
refugia with their under-saturated ecosystems, the areas most conducive to introduction are perhaps the frontal hydrologic zones where Hutchinson's multidimensional "space" of ecological niches is filled not as densely as in the regions with more stable environmental conditions. Next in this series come the transgressive hydrologic zones (Semyonov, Berman, 1978) of

vertical superposition of water masses of different origin and the regions of development of seasonal modifications of water masses in the temperate and subpolar zones.

UDC 639.2.081.117.004.17:639.281.2

Study of the fishing efficiency of a shrimp trawl by means of underwater photography

by L.I. Serebrov and G.P. Tarasova (PINRO)*

A specialized bottom shrimp trawl is used in the Northern Basin both for landing *Pandalus borealis*, and for studying its stock. In connection with this, data on its fishing efficiency are required for the solution of numerous scientific and practical problems.

The quantitative expression of the fishing efficiency of a trawl (FE) is the ratio of the number of shrimps caught with a trawl to the number present in the area fished, i.e. the volume of water filtered through the netted part of the trawl. The size composition of the shrimps and its abundance in this zone were determined photogrammetrically with the vertical distribution of shrimps in the near-bottom layer taken into account. The photographs were taken with a "Triton" automatic camera installed on a trawl. The results of 24 trawlings were analyzed. They are given in the table below.

The fishing efficiency of a trawl used to catch shrimps at different times of the day

FE, %	Length of shrimp in mm across the carapace							Mean FE, %
	7–9	10–12	13–15	16–18	19–21	22–24	25–27	
During the day		5.9	6.9	53.4	14.3	2.3	1.2	20.7
At night	1.1	6.9	8.0	6.5	8.9	3.2		7.6
Overall	0.9	6.8	24.0	25.1	12.7	4.5	0.8	17.8

*Polar Scientific Research Institute of Sea Fisheries and Oceanography – transl.

(31)

The results indicate that the fishing efficiency of a trawl varies significantly with the length of the shrimps, particularly during the day. These differences balance out at night, while the average fishing efficiency is 2.7 times lower than during the day.

On the whole, the nature of the shrimp-trawl interaction is apparently quite complex, and does not boil down to simple mechanical filtering of it through the meshes of the net.

UDC 639.27?29:/639.2.001.5:629.127.4.007.2

The use of manned submersibles for studying commercial invertebrates

by V.V. Fyodorov (VNIRO)

Manned submersibles have been used extensively over the past years to study the biological resources of the ocean. In the ten years that "Tinro-2", "Sever-2" and other Soviet submersibles have been used for scientific purposes, we have acquired a great deal of experience in studying commercial invertebrates. As a result of these investigations, the problems that can be successfully solved with the help of submersible apparatuses have been determined.

1. Quantitative determination of commercial invertebrates. The use of submersibles enables us to acquire the most accurate and reliable information about the numbers of Kamchatka crab, snow crab, humpback shrimp, gastropods (Neptunea and Buccinidae), pink scallop, cuttlefish, deepwater spiny lobster, etc. No conventional method is as accurate as the underwater method.

2. Spatial distribution of commercial invertebrates. Visual observations along lengthy routes make it possible to determine the peculiarities of distribution of commercial invertebrates, find the areas of high local concentrations, and establish the time-related changes in the internal structure of populations (seasonal changes in habitat, density of concentration, tendencies of distribution of the Kamchatka crab on the shelf of Western Kamchatka, etc.).

3. Ecology of commercial invertebrates. Submersible appara- (32)
tuses assist us in studying the effect of environmental factors on the distribution and behaviour of hydrobionts. For many species, we have noted a close relationship with the relief of the bottom (shelter) and the types of bottom sediments (substrate), and have determined the critical values of a number of hydrologic and hydrochemical parameters (temperature at the peak of spawning of the Kamchatka crab, the minimum threshold concentration of oxygen for deepwater spiny lobsters).

4. Behaviour of commercial invertebrates. The use of submersibles opens great possibilities for studying the behaviour of not only fish, but also marketable invertebrates. Invertebrates are, perhaps, in the most advantageous position as compared with fish, since submersibles affect their behaviour to a lesser extent. Submersibles enable us to study the characteristics of the solitary and group behaviour of hydrobionts, which cannot be studied by other methods, and to establish their typical defence reactions and their changes depending on the biological state (stance of aggression of the Kamchatka crab

and its attack on the submersible during the wintering period, retreating from the submersible during the breeding period). Submersibles provide valuable information on intraspecific and interspecific relationships (food competition of the Geryon crab and deepwater spiny lobster, etc.).

5. Effect of artificial stimuli. A submersible apparatus is a complex stimulus for commercial invertebrates. During submersion, it can study the reactions of hydrobionts to physical and chemical stimuli, and test various baits.

6. Influence of the anthropogenic factor on the populations of commercial invertebrates and bottom ecosystems. An example is the study of the various aftereffects of commercial fishing with bottom gear in the northwestern part of the Black Sea.

7. Commercial fishing. Submersibles are an effective means of controlling the operation of the gear used to catch commercial invertebrates (traps, drag nets, trawls). The results of first-hand observations enable us to improve the design of the gear and the methods of its utilization.

UDC 595.3 (33)

Determination of the temperatures of active reproduction of commercial crustaceans on the basis of the upper lethal temperatures

by N.N. Khmelyova, Yu.F. Mukhin (Institute of Zoology of the Byelorussian Academy of Sciences)

The temperature of reproduction is an important indicator of the activity of hydrobionts. The temperature range of the reproductive period is much narrower than that of the subsistence of a species. The life temperature range within an area may expand significantly in comparison with the local populations. However, the temperature range of the reproductive period remains fairly stable due to the conservativeness of the reproductive process. The temperature range of reproduction for crustaceans is, on the whole, $-2 — +50^{\circ}C$. The maximum number of crustacean species breeds in the $24—36^{\circ}C$ interval. The extreme temperatures of reproduction are characteristic only of individual species in a natural environment.

The temperature range of the reproductive period of all crustaceans is far from the extreme values at which they are capable of enduring adverse conditions. Thus, the process most important to the survival of a species, reproduction, is ensured ("safeguarded").

It has been established (see table) that the temperature range of reproduction is 3-4 times lower in cryophilic animals, twice lower in eurythermic animals and 1.5 times lower in thermophilic animals as compared with the upper lethal temperatures (TL_{100}).

Therefore, it is possible to determine the temperature of active reproduction of crustaceans on the basis of the data on upper lethal temperatures. On the other hand, knowing the temperature of intensive reproduction, we can derive the upper threshold at which the animals die.

Our results can be used to determine whether crustaceans have a chance for survival when moved to new habitats.

Temperature of the reproductive period in some species of crustaceans

Species	TL_{100}	Temperature of reproduction	
		estimated	natural
Cryophilic			
Mysis relicta	20.0	5.0	2-6
Astacus leptodactylus	35.0	9.0	6-10
Eurythermic			
Daphnia magna	39.0	19.5	8-30
Asellus aquaticus	33.5	26.8	10-22
Thermophilic			
Macrobrachium nipponense	40.5	25.3	20-32
M. rosenbergii	42.0	28.0	22-34

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COMMERCIAL AND COMMERCIALLY-PROMISING MARINE CRUSTACEANS

UDC 693.4/.7.001.57:681.3

Model study of the effect of growth characteristics on the population dynamics of commercial invertebrates

by A.I. Abakumov and N.V. Kol'yev (TINRO)

Many species of commercial invertebrates have growth characteristics that differ sharply from those of other animals. This consists of a spasmodic change in the size of the animals (so-called moulting). Biology specialists have repeatedly noted the importance of taking this growth characteristic into account when studying population dynamics [1, 2]. By taking this characteristic and the growth irregularities and possibilities of missed moults into account, we arrived at the following equation of the population density dynamics (N) of groups measuring ℓ:

$$\frac{\partial N}{\partial t} + \int_0^1 \frac{\partial(\varphi f N)}{\partial \ell} dp = -D \cdot N \qquad (1)$$

This equation describes the moulting process during a continuous change in time **t**. The time-discrete analogue of this equation is

$$N_1(\ell_1) = \int_0^{p^*} q(p,\ell_0)\cdot s_0(\ell_0)\cdot f(p,\ell_0)\cdot N_0(\ell_0)\cdot \Big/ \frac{\partial \ell_0(p,\ell_1)}{\partial \ell_1} \Big/ dp \; +$$
$$+ \int_0^1 (1-q(p,\ell_1))\cdot s_1(\ell_1)\cdot f(p,\ell_1)\cdot N_0(\ell_1)\, dp$$

where $\varphi(p,\ell,t)=\frac{d\ell}{dt}$, $f(p,\ell,t)$ is the density of distribution probability **N** based on parameter **p**. Parameter **D** characterizes the process of natural mortality, **q** – the probability of individuals moulting. S_0 and S_1 – the survival of individuals in the process of moulting and when moulting is missed respectively, and ℓ_0 and ℓ_1 – the size of the animals prior to moulting and after moulting respectively. The subscript in **N** bears the same meaning. Parameter **p** characterizes the preparedness of individuals for moulting, and depends on their development during the interlarval (36)
period.

On the basis of these equations, we have developed a number of models of the population dynamics of a commercial invertebrate and estimated the population of the Kamchatka crab in comparison with conventional models of the age dynamics of a population, and also drew comparisons with biological data [3]. We also used models to study the dependence of the catch on intrapopulational nonuniformity.

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UDC 595.383.1(269.7)

Some distributional and biological characteristics of antarctic krill in the Sea of Cooperation

by Yu.P. Aseyev, A.V. Klyausov and V.I. Lanin (AzCherNIRO)

At the present time, there is no common and clear concept of the mechanism by which concentrations of krill are formed in the shelf zone of the Sea of Cooperation, or the role of the spawning stock of these concentrations in the reproduction of the population.

On the basis of a summary of the data for 1977-1985 on the distribution, biology and ecology of krill in the central part of the Indian Ocean sector of Antarctica (south of 60°S to the ice edge and between 60 and 80°E), we have established that the most promising krill region is the shelf zone of the central part of the Sea of Cooperation, where a quasi-stationary mesoscale cyclonic eddy is noted annually.

The recruitment of krill in the given area in the form of 2-3 younger size-age groups takes place in cycles, approximately every three years (in 1977, 1980, 1983). Every third year after recruitment, we note the ageing and natural mortality of the given group of krill after spawning at the age of 4 years.

The 3-year cyclicity of small-sized krill in the shelf zone of the sea is due to a periodic increase in the inflow of middle waters of a higher than usual temperature and salinity to the given area from the north, and to their upwelling into the subsurface layers, as indicated by the material of oceanographic surveys during the study period. In our opinion, the mechanism of this process is inseparably related to the 3-year fluctuations in the intensity of the Antarctic Circumpolar Current (Sarukhanyan, 1980) which, in turn, can be determined by the year-to-year variations in the intensity of the large-scale western-eastern atmospheric transport of air in the zone of the Antarctic Circumpolar Current.

Retrospective analysis of the series on atmospheric circulation in the region of 50-60°S between 40 and 80°E during the period of 1966-1980 points to the high stability of the 3-year fluctuation of this characteristic (one irregularity with a 2-year maximum period was observed during the 15 years).

The biological material shows that the spawning of krill and the appearance of larvae in the shelf zone occurs practically every year. This fact has in the past enabled us to regard the coastal zone of the sea as the basic area of krill (Samyshev, 1983). However, the 3-year cyclicity of the en masse appearance of young krill due to the cyclicity in the intensity of advection of middle waters from the north permits us to speak of the predominant role of the spawning krill of the open sea in replenishing the krill population.

UDC 639.281.2(268.45) (38)

Method of determining the reserves of the pink shrimp* in the Barents Sea

by B.I. Berenboym and V.Z. Salmov (PINRO)

Since 1984, the shrimp reserves in the Barents Sea and Bear Is.—Spitsbergen area have been determined with the help of trawl surveys and the "strata method". This method enables us to obtain comparable material for a number of years, assess the reliability and accuracy of the survey results, and to reduce the time and material spent on the surveys by decreasing the number of trawls and by utilizing Norwegian data to some extent. Furthermore, curtailment of the survey period enables us to assess the shrimp reserves during the optimal period of the polar day, when the greater part of the populations is concentrated in the fishing zone of the survey trawl.

An increase in accuracy and a decrease in survey expenditures are achieved by dividing the zone of primary distribution of shrimp into sectors (strata) in which the density of the shrimp concentrations are believed to be more or less uniform and different from that of other areas, i.e. the average value of the catches during a survey trawl differs significantly from the average catches in the adjacent strata. Stratification of the survey area was carried out with the use of data on the ecology and distributional tendencies of the pink shrimp in the Barents Sea and Spitsbergen area, commercial fishing statistics,

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*Pandalus borealis eos - transl.

and the Norwegian chart of strata from a similar trawl survey. Thus, 19 strata were established in the Barents Sea, and 25 strata in the Spitsbergen area.

When planning a survey of the shrimp stock, given the value of accuracy of the tentative results, we determined the required number of survey trawls in each stratum. The strata were then broken down into equal blocks in which one survey trawl was carried out in each. The site of the trawl in a block was determined by the method of random numbers. After selecting the starting points of the trawls, we determined the optimal survey route. The mean-square error of determination of the shrimp biomass in the Barents Sea by the given method was 9%.

(39)

In 1985, simultaneously with biomass determination, we also determined the numbers of shrimp, both the total number and according to size-age groups. The calculations were carried out on the EC and "Iskra-226" computers.

UDC 595.384.12

The motor reactions of *Pandalus latirostris* Ratbun in light fields of different intensity

by A.B. Burba (IZiP AN LitSSR)*

The purpose of these investigations was to study the reactions of the grass shrimp *Pandalus latirostris* in light fields of different intensity. The ecological characteristics of this shrimp indicate that sight plays a significant role in its life.

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*Institute of Zoology and Parasitology of the Academy of Sciences of the Lithuanian SSR - transl.

The experiments were conducted in June-September on the shore of Ussuri Bay in the Sea of Japan. During the day, the shrimpswere allowed to choose between the open and darkened part of the basin. At night, we created light zones of thousandths, hundredths and tenths of a lux, several lux, as well as tens and hundreds of lux. In a separate series of experiments, a spot of light 1 m in diameter with a light intensity in the neighbourhood of 5-10 lux was projected onto the underwater part of the wall of the basin. We then recorded the behavioral characteristics of the shrimpsand their number in the zones of different light intensity.

Our results have shown that the motor activity and behavior of the shrimpsare determined by the intensity of light and, apparently, by the direction of the visual markers.

During the day, before the zones of different light intensity had been set up, the shrimps in the basin moved mainly along the walls, touching them with their antennae, antennulae and walking legs. They stopped primarily in the corners where they even formed temporary aggregations sometimes. At night, the shrimps were more uniformly distributed on the bottom, though the main mass swam and walked along the walls. The speed of their continuous movement at night was half of what it was during the day.

During the day, the grass shrimp preferred the darkened part of the basin (light intensity about 1 lux) to the open part where the light intensity amounted to about 70,000 lux on a sunny day. (40)

During the dark hours, when zones of different light intensity had been created, behavioral changes and intermittent movement related to this were noted in the zones where the light intensity was in the neighbourhood of several to several tens of lux (2-35 lux in our experiments). The shrimps would stop, turn their heads to the wall and push into it with the rostrum. These changes were particularly manifest in the spot of light projected on the vertical wall. The number of animals in it doubled in 3 minutes. Projection of light onto the bottom of the basin did not evoke this type of reaction.

UDC 595.384.12

On the ecological niches of two bathypelagic companion species of shrimp

R.N. Burkovsky (AtlantNIRO)

In this paper, we compare the bathymetric distribution and feeding characteristics of the shrimp species *Systellaspis debilis* and *Acanthephyra purpurea* (Oplophoridae) from the region of the Northern Subtropical Convergence of the Atlantic Ocean. Our material consisted of 86 hauls of a pelagic trawl from depths of 18-1260 m at 20:00-24:00 hours, and 28 hauls from depths of 500-700 m over a 24-hour period; 1717 stomachs of *S. debilis* and 1194 of *A. purpurea* were dissected.

A. purpurea, a N Atlantic species, is encountered from 53° N to 17° N, at depths of 150-4850 m. It grows to a length of 80 mm, maturing at a length of 56-60 mm. *S. debilis* is a cosmopolitan species which is encountered in the Atlantic Ocean from southern Greenland and the Faeroe Islands to the Gulf of Mexico in the west, and to South Africa in the eastern part of the Atlantic, at depths of 50-4594 m. It does not exceed a length of 60-62 mm, and matures at a length of 45-48 mm.

In the area studied, both species of shrimp are the markers of a taxocene; they were encountered with a frequency close to 100%, constituting more than 60% of the biomass of caridean shrimp.

The main items in the diet of both species in the study (41)
area are fish and euphausiids, with fish predominating in *A. purpurea* and euphausiids in *S. debilis*. The fish consumed by these species consist of the young and the small-sized species of Myctophidae, Gonostomidae and, less commonly, Sternoptychidae with a body length of not more than 30 mm, while euphausiids feed mainly on *Meganyctiphanes norvegica*. The secondary items in the diet of these species (Coelenterata, Chaetognatha, Amphipoda) are also similar. The greatest difference in diet is a slight predominance of shrimp in the diet of *A. purpurea*. We noted a far greater difference in the age-related variability of feeding. *S. debilis* is characterized by a transition from feeding on fish and copepods (the dominant food of the young of both species) to feeding mainly on euphausiids, whereas the food bolus of mature *A. purpurea* consisted of approximately equal parts of fish, shrimps and euphausiids. Despite the significant similarity of the bathymetric distribution of both species and the fact that they live in the same structural zone of water, their maximum values of density do not coincide. At night (between 20:00 and 24:00 hours), the highest abundance of *S. debilis* is noted in the 100-300 m interval, and the highest abundance of *A. purpurea* in the 300-700 m interval. The separation intensifies as a result of oppositely directed diurnal vertical migrations, due to which both

species dominate in the catches at the given depth at different times of the day, but the peaks of active feeding in them coincide in time, which is not quite common for predators that consume the same kind of food. The hunting method of both species is similar, and can be arbitrarily called combined predation, which means that a number of predatory methods such as gathering, attacking and grazing are used in combination. True, with all the common features, the two species differ somewhat in their specific methods of attacking the same target. However, the main mechanism that serves to minimize the competition between these two species is the difference in the accessibility of the food items, i.e. prey of the same size are accessible to predators of different size that are known to occur at different depths.

Consequently, the non-overlapping of the ecological niches of the two pelagic shrimps inhabiting the same structural zone of water, belonging to the same life form, feeding on the same organisms and having a similar diurnal rhythm of feeding is ensured (42)
by the food size selectivity of the predators and by the difference in the diurnal pattern of their vertical migrations, the second probably being the result of the first.

UDC 595.384.12:639.512

Biological prerequisites and results of the cultivation of the grass shrimp *Pandalus* Kessleri

by A.Ya. Yefimkin (TINRO)

The grass shrimp is a characteristic form of the *Zostera* biocoenosis where it forms concentrations and populates the 0.5 to 10-12 m layer of the sublittoral zone. The abundance of this species depends not only on the size and density of the Zostera overgrowths, but also on the favourable hydrological conditions of the bays and inlets. This shrimp does not live in waters with a salinity of less than 13‰, and reproduces at a salinity of not less than 24‰; the optimal salinity is 30-34‰. Its life span is 3-4 years in a natural environment; it becomes a mature male in its second year, and a female in the third year.

As our investigations in Peter the Great Gulf (near Popov Is.) have shown, the component ratio of the food consumed depends on the age and sex of the shrimps. Plants (predominantly Zostera) constitute not more than 1/3 of the food bolus in the females, approximately 1/2 of the food bolus in the males, and up to 70% of the food bolus in the young. The remainder of the food is of animal origin. Small mollusks and crustaceans are the most commonly encountered organisms. Cannibalism is quite pronounced in shrimps. The daily amount of food consumed by underyearlings is equal to 5.7% of the body weight of the animal, and that of yearlings, males and females 6.9%, 3.2% and 1.4% respectively. The average fecundity of a shrimp is equal to 268 eggs. Less than 10% of the hatched individuals survive up to a year in a natural environment.

In an effort to replenish the natural populations, we have developed a method of deriving shrimp larvae and raising them to hardy stages under artificial conditions. Ovigerous females (43)
were caught in May—beginning of June, and placed in incubator aquariums with a closed system of seawater circulation. The density of plantation was 10 females per 50-litre aquarium. In

each aquarium, the upper part with the female shrimpswas partitioned off with a 10 mm mesh nylon net from the bottom part which was designated for the hatched larvae. Several days later, the larvae began to hatch; this continued for 4-5 days, predominantly at night. The larvae measured 9-9.5 mm in length, and weighed 4.2-5.0 mg. Up to 95% of the total number of eggs deposited by a female hatched under aquarium conditions. Optimal conditions, i.e. temperature 12-19^{o}C, oxygen 99-100% saturation and salinity 34-35‰, were maintained throughout the period of incubation and aquarium life. After the hatching of the larvae, the females were removed, while the larvae were kept in the same aquariums at the initial stages of development (up to the 4th stage). *Zostera* and *Ulva* were placed in the aquariums to provide food of plant origin for the larvae. The food of animal origin consisted of minced fish, crustaceans and mollusks. After the larvae had passed into the juvenile stage, they were transferred to nursery aquariums where they were raised for about 4 months. The conditions and ration of the young were the same as for the larvae (6% of the body weight of the shrimp). When live plants were not available, the minced fish fed to the young was supplemented with up to 40% *Zostera* meal. After 4 months, the young shrimps measured 30-35 mm and weighed 350-450 mg; they had reached a vigorous stage and could be released into the sea to replenish the natural populations of the grass shrimp.

UDC 595.384.2

Biology and behavioral characteristics of the deepwater red crab *Geryon quinquedens*

by M.L. Zaferman and A.M. Sennikov (PINRO)

Joint expeditions of PINRO during the period from 1977 to 1983 in the open regions of the North Atlantic discovered banks and seamounts where *Geryon quinquedens* is a common (44) species. The zone of the subarctic front is apparently the northern boundary of the species.

The gear for landing the crab consisted of various modifications of bottom crab traps. In July-October 1983, observations on the distribution and behavior of the species were carried out from the "Sever-2" submersible apparatus on the banks of the Mid-Atlantic Ridge and the Corner Seamounts.

The upper boundary of distribution coincided with the boundary of occurrence of natural shelters. The young of the species were encountered at a bottom temperature of $4.4-4.5^{\circ}C$, and mature individuals at $5-12^{\circ}C$. The largest number of crabs was caught at a temperature of $6-9^{\circ}C$ and salinity of 35.2-35.8‰. The proportion of males increased from 70 to 95% with depth.

The traps caught individuals with a minimum carapace width of 6.0-7.0 cm, but usually specimens ranging from 10.0 to 17.0-19.0 cm. The absence of smaller crabs in the catches was apparently due to the high selectivity of the gear. Crabs display sexual dimorphism according to size, i.e. the females are smaller (average 12.4 cm, 0.60 kg) than the males (14.5 cm, 0.87 kg). The minimum size of females with eggs on the abdomen was 9.5-10 cm.

The fecundity of the females in different geographic zones varied from 50,000 to 550,000 eggs (average from 200,000 to 350,000 eggs).

The deepwater crabs are typical benthophages as to the type of feeding. Sponges, bryozoans, hydroids and macrophytes (less commonly fragments of decapods) predominated in their stomachs.

Based on the results of the underwater observations, these crabs were most commonly encountered at outcrops of calcareous rocks encrusted with ferromanganese, where numerous caverns, niches and cavities form, as well as in overgrowths of epifauna (sponges, hydroids and corals). The density of the animals was determined by the visual geodetic method. The average value of density did not exceed ten specimens per 1000 m^2. Since a large number of crabs stays in natural shelters, the derived densities are probably lower than the actual ones.

In the zone of the baited traps, we noted that the crabs approached the bait against the current at a speed of 10-30 cm/s. The traps were at first approached by the larger individuals to which the smaller crabs had yielded. Consequently, the traps are quite selective, catching the largest, predominantly male, (45) crabs. Directly at the trap, a crab would try to approach the bait by the shortest possible way. The design characteristics of certain types of traps in which the trap entrance is not the shortest possible way to the bait greatly reduce the trapping efficiency. With an upper entrance, the crabs get into the trap only in the case where, having caught hold of the upper part of the framework with the legs of one side of the carapace, they can find some support below for the legs of the other side.

These behavioral characteristics of the species are probably present in other species of crabs, and can be utilized for the purpose of trapping the animals, determining their reserves and designing traps for them.

UDC 595.384.12(265.5)

Distribution of congregations and population structure of the bent-tailed shrimp (*Pandalus goniurus*) in the Far Eastern seas

by K.A. Zgurovsky (TINRO) and I.A. Alikin
(Far Eastern State University)

The bent-tailed shrimp, *Pandalus goniurus*, is the most prolific species of shrimp in the northwestern part of the Pacific Ocean (Ivanov, 1979).

Its biology and distribution were studied during the period from 1967 to 1984 in joint TINRO-VNIRO and TINRO-SEKBP* expeditions. As a result, we have found where the main concentrations of this species are located. They are found in Anadyr Gulf and in the Olyutorskoye-Navarin area in the Bering Sea, and in the Kvacha Bay area (western Kamchatka) and Aniva Gulf (southern Sakhalin) in the Sea of Okhotsk. The most detailed investigations have been carried out in the western part of the Bering Sea where the densest concentrations were discovered (Ivanov, 1981; Zgurovsky, Ivanov, 1982). From the results of trawl and hydrological surveys, we have determined the main tendencies of the migration of these concentrations, the year-to-year variability of their biomass and the size-sex structure of the population. Investigations with a manned TINRO-2 submersible apparatus were

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*See footnote on p. 23 - transl.

carried out to determine the absolute density of the concentrations, calibrate the principal gear used for this purpose (otter trawl), and to study the behavior of the shrimp.

(46)

Shrimp concentrations form during the period of hydrological winter, and usually last up to the beginning of August, after which they gradually disperse. The presence of frontal zones, circulations and negative forms of relief are conducive to the formation of higher than usual concentrations of shrimps.

This species is characterized by diurnal vertical migrations (Barsukov, Ivanov, 1979). It has been hypothesized that these shrimps are carried by the currents during these migrations, which, along with the transport of larvae, is a mechanism by which concentrations are brought together.

In order to determine the similarities and differences between shrimps of different populations, we compared their biometrics (8 meristic characters), their absolute and relative fecundity and their size-sex structure by the methods of multivariate statistics. Correlation and regression analysis of the characters was carried out. The most informative characters were the length of the body and carapace for differentiating the shrimps from different seas, and the length of the telson for samples from the same sea. The length of the rostrum is the least useful for differentiating the samples.

Regression analysis has shown that the length of the body and overall length of the Sea of Okhotsk shrimps are greater than in the Bering Sea shrimps with the same length of the carapace.

The samples are divided into the following two groups on the basis of multivariate statistical criteria: 1 - individuals from the Bering Sea; 2 - individuals from the Sea of Okhotsk, the maximum differences being observed between the most distant areas (Aniva Gulf and Anadyr Gulf).

Maximum fecundity is characteristic of Bering Sea shrimps with similar body dimensions, and decreases towards the southern boundary of the western part of the range.

The presence of differences between the Okhotsk and Bering populations is due to the lack of any link between them via larval transport with the currents and the different habitats in these areas.

(47)

UDC 595.384.12(265.518)

Study of the growth of the bent-tailed shrimp (*Pandalus goniurus*) of the Bering Sea

by B.G. Ivanov and D.A. Stolyarenko (VNIRO)

Age determination and the study of growth in shrimps are the two interrelated key problems that we are faced with when monitoring the populations of this commercial invertebrate. Because of the absence of monitoring structures in shrimps, growth is studied by measuring the length (most commonly the length of the carapace) in a vast number of specimens, and the concepts of growth and age are applied to the whole population, i.e. they are regarded as populational concepts. Since only random observations are possible when studying the size composition of a population, the given problems must be regarded as statistical ones.

This particular paper is devoted to the assessment of the average annual increment of year-classes as the first stage in the study of growth in shrimps. It is based on the results of long-term observations of the commercial Pandalus goniurus population in Anadyr Gulf, derived by TINRO and VNIRO expeditions during the period from 1972 to 1983. The data was collected during trawl surveys. In each resultful trawl (from 12 to 60 during different years), we took a random sample of 100-500 shrimps, and on the basis of this plotted a histogram with a grouping interval of 1 mm.

The method of succession of the relationship of year-class strength (Ivanov, Stolyarenko, in press) for determining increment is based on the functional relationship of the size composition of the population of two consecutive years, i.e. $y_i = a_i z_i / \sum_{s=1}^{p} z_s$, $i = 1, 2, \ldots, p$, (1)
where y_i denotes the proportion of the i-th size class on the histogram of the first of the two years ($\sum_{i=1}^{p} y_i = 1$), Z_i - the proportion of the same class a year later, and a_i - the transitional coefficient. The boundaries of the size classes (grouping intervals) are interrelated by the law of growth (hypothetically linear at the first stage): $\lambda_i = \ell_i + \tau$, $i = 1, \ldots, p+1$ (2)
where ℓ_1 denotes the boundary of the i-th size class on the histogram of the first year, λ_i - the boundary of the same size class a year later, and τ - the annual increment. To replace $z_1, \ldots, z_p$ with size classes having the same boundaries of grouping intervals as $y_1, \ldots, y_p$, we resort to smoothing (with the nucleus - density of normal distribution) of the histogram of the second year with

$x_1, \ldots, x_m$, and regrouping. Thus, the following regression function is carried out:

$$y_i = f_i(x_1, \ldots, x_m, a_i, \tau), \; i=1, \ldots, p.$$

The parameters $a_1 \ldots, a_p$ and τ are determined from observations by the iteration method of weighted least squares with reweighing (Stolyarenko, 1985).

By determining the strength of the size class as $S_i^{(1)} = Y_i / g_i$, $S_i^{(2)} = z_i / g_{i+\tau}$, where g_i denotes the proportion of the i-th size class on the average long-term histogram, and $g_{i+\tau}$ - the arbitrary proportion of the size class on the same histogram with the λ_i boundaries defined by (2), we derive the following from (1):

$$S_i^{(1)} / S_j^{(1)} = S_i^{(2)} / S_j^{(2)} . \qquad (3)$$

Equation (3) signifies the continuity of the strength of size classes (and, consequently, year-classes) from year to year.

The method of succession is effective with a fairly long sequence of observations and large series of observations in a single survey, as well as with considerable variations in the strength of the year-classes. It makes much greater use of the information arising from the given observations as compared with the heuristic method of deviations (Skuladottir, 1981) which, because of a low "sensitivity", does not enable us to process observation data gathered with a one-year interval.

UDC 551.463.26:595.3 (49)

Swimming speed of macroplanktonic crustaceans from the sonic scattering layers of the Indian Ocean

by S.M. Ignat'yev (INBYuM)

Organisms of the sonic scattering layer (SSL) are of interest to us as potential commerical organisms. Diurnal vertical migrations are characteristic of the SSL. Evidence of the biological nature of SSL is the fact that the main parameters of their migrations (time, velocity) coincide with the analogous migrational parameters of the scattering organisms. Consequently, a study of the SSL may provide us with significant information on the vertical distribution of the hydrobionts. We have made use here of the data on the locomotory characteristics of macroplanktonic crustaceans (euphausiids, pelagic shrimp), an important component of the SSL fauna, obtained during the 18th trip of the N. Reshetnyak research-scouting vessel (June-November, 1981) to the tropical zone of the Indian Ocean. The material was collected by brief fishing of the epipelagic SSL with an Isaacs-Kidd trawl. After a 1/2-hour adaptation period, the crustaceans were photographed in hydrotroughs with a scale grid marked on them, using a KCP-1M movie camera and KH-2 and A-2 35-mm film (8-32 exposures per second). By analyzing the cinegrams, we were able to determine the swimming speed of certain euphausiids and shrimps from the SSL fauna (only the velocities of swimming by means of the pleopods are given below).

	v, cm/s
Euphausiids:	
Thysanopoda tricuspidata, *Th. monacantha*	0.5-9.0 to 15.0
Euphausia diomedae, *E. triacantha*	0.5-27.0
Shrimps:	
Lucifer sp.	0.5-1.9
Sergestes sp.	0.5-9.0
Funchalia sp.	6.0-32.0
Parapandalus richardi	2.0-15.0
Oplophorus sp.	3.0-27.0
Acanthephyra sp.	2.0-35.0
Systellaspis sp.	9.2-27.0

(50)

According to the data recorded continuously with an echo sounder (during the 8th trip of the Prof. Vodyanitsky research vessel), the velocity of vertical migrations of SSL in the tropical zone of the Indian Ocean varies from 2 to 12 m/min (average 4-6 m/min), i.e. from 3 to 20 cm/s (average 6-10 cm/s). Therefore, the velocities of SSL migrations and the swimming speed of crustaceans from the SSL fauna are characterized by magnitudes of the same order.

UDC 591.524.12(269.4)

Characteristics of the life cycles of some planktonic organisms of the Atlantic sector of the Antarctic Region in connection with the year-to-year variability in environmental conditions

by N.N. Zhigalova, V.I. Latogursky, S.N. Semyonova
and P.P. Fedulov (AtlantNIRO)

The increase in marine expeditionary investigations in the Atlantic sector of Antarctica (ASA) during the 1970-1980's has resulted in significantly more information on the life cycles of hydrobionts in different parts of this region, which has enabled us to trace the year-to-year variability in the life cycles of the phytoplankton, some species of the mesozooplankton (MZ) and euphausiids in a number of regions of ASA.

The seasonal variability of the hydrometeorological and ice conditions, the length of the vegetative period of the phytoplankton and the peculiarities of the life cycles of the indicated hydrobionts in these regions have allowed us to subdivide the regions into 3 groups. Group 1 includes South Georgia Is., Bouvet Is. and the South Shetlands Islands where the vegetation of phytoplankton lasted the longest. Here we observed two peaks in the development of the phyto- and zooplankton, and two peaks in the maturation and spawning of euphausiids.

Group 2 includes Bransfield Strait, the South Orkney Islands and the area between 60-65° S and 20° W — 30° E with a shorter vegetative period. Here, during the cold years, we observe one peak of algal "blooming", two adjacent peaks of mesozooplankton development and one peak in the maturation and spawning of euphausiids. During the warm years, we observe two peaks of algal "blooming", two peaks of mesoplankton development and two peaks in the maturation and spawning of euphausiids. (51)

Group 3 includes the areas around the Lazarev and Riiser-Larsen seas. Here we always observe one peak of phytoplankton "blooming", one peak of mesozooplankton development and one peak in the maturation and spawning of euphausiids.

The data obtained at the end of the 1970's and beginning of the 1980's permit us to conclude that the periods of onset of the seasonal plankton peaks in all the regions of the ASA occur earlier (by about a month) than indicated in Hart's and Foxton's well-known charts. These changes are due to the overall rise in temperature observed during the present climatic period as compared with the 1920-1930's when the Discovery Committee conducted the investigations.

Taking into account the seasonal characteristics of the life cycles of the phytoplankton, zooplankton and euphausiids in the second group of regions, we can say that here, during a warm climatic period, we will observe two peaks of phytoplankton "blooming", two well-delineated peaks of mesozooplankton development and two peaks of maturation and spawning of euphausiids. In the end, this will bring about an increase in the number of regions in the ASA with two peaks of euphausiid reproduction, and the appearance of two generations at 1—2-month intervals, which will increase the heterogeneity of the size-age structure of the species in the Atlantic sector of Antarctica (ASA), as well as their abundance as a whole.

UDC 639.28:639.2.081.117.004.17 (52)

Study of the fishing efficiency of a midwater trawl by means of instruments during removal of euphausiid concentrations

by S.M. Kasatkina and A.S. Myskov (AtlantNIRO)

In order to improve the fishing gear used for any biological organism, we must know its fishing efficiency. We know of a number of methods of instrumental determination of the fishing efficiency of trawls, and of attempts to correlate the information recorded by echo-integrators with the size of the catches (E.A. Karpenko, 1984; V.A. Yermol'chev, 1979; Yu.V. Shishlo, 1975).

We have attempted in our investigations to make more extensive use of the potentials of modern hydroacoustic equipment to study the fishing efficiency of a midwater trawl during removal of euphausiids. To do this, we carried out echo-integration of their concentrations under the fishing vessel and in the trawl mouth with the use of a shipborne hydroacoustic system consisting of a "Sargan-E" echo-sounder and an OM-MK-П echo-integrator ("Simrad" Norway), and a system based on the "Kalmar" echo-sounder, the ИГЭК-Y trawl-depth recorder and the АЦЭИ-1 echo-integrator. The fishing efficiency of the different netted parts of the trawl was studied on the basis of the number of euphausiids that got out through the net, using the small-mesh netting method.

The investigations were carried out by the "Argus" research-scouting vessel in 1985 during the trawling of euphausiid concentrations in the South Atlantic.

A mid-water rope trawl with a 72 m headline was used to catch euphausiid concentrations of different types in the 10-150 m interval at different times of the day and night. At the same time, the vertical opening of the trawl varied from 25 to 45 m, and the trawling speed from 2.5 to 4.0 knots, which altered the angle of attack of the trawl net from 4 to 10°.

The testing was preceded by the calibration of the hydroacoustic instruments by a method applying sample spheres and experimental measurement of the target strength of the euphausiids.

We studied the total fishing efficiency and its elements. Our experimental data are quite comparable with the theoretical (53) calculations carried out by methods of the statistical theory of fishing systems, developed at AtlantNIRO (Kadil'nikov, 1985). The number of euphausiids escaping through the netting increases with the angle of attack of the trawl net and the speed of trawling.

It is not by chance that we selected euphausiids as the organism on which to study the possibilities of instrumental determination of trawl net efficiency. The comparatively poor swimming ability of euphausiids enables us, on the basis of the calculations of a number of efficiency elements, to equate it to one. Theoretically, this narrows the scope of the elementary events, while in practice it enables us to carry out observations with fewer influencing factors.

UDC 639.28:639.2.081.7(261.5)

Study of the distributional characteristics of euphausiid concentrations in the South Atlantic by means of the hydroacoustical method

by S.M. Kasatkina and A.P. Khmelnitsky (AtlantNIRO)

As we know, the accessibility of biological resources and the effectiveness with which the fishing system is utilized depend on the parameters of distribution of this or that species (Kadil'nikov, 1983). At the same time, the literature on euphausiids contains only individual data on some of the parameters of their concentrations (Kalinovski, 1981, 1984; Michail, 1984, etc.).

With the help of the hydroacoustical method, we studied the distribution of the parameters of euphausiid concentrations with the mathematical model of the fishing system for slow-moving organisms taken into account. At the same time, we studied euphausiid concentrations of different types. We primarily dealt with such parameters of spatial distribution of aggregations as horizontal and vertical distance, the depth of occurrence, biomass density and the relative density of population.

The investigations were conducted in the South Atlantic during 1980-1985. The hydroacoustical results were analyzed on a computer.

Round-the-clock hydroacoustical surveys enabled us to examine the diurnal dynamics of these parameters.

The biomass density (g/m^3 or t/mi^2) was measured by a method based on calibration from live euphausiids in a holding net.

We have established certain tendencies in the distribution of the parameters of different types of euphausiid concentrations.

Statistical data were used in the theoretical calculation of the total fishing efficiency and its elements for a trawl intended for pelagic concentrations of euphausiids.

The results were compared with the efficiency data obtained by other methods (instrumental), based on the number of organisms escaping through the trawl net determined by the small-mesh netting method, and on hydroacoustical data.

UDC 595.384:597-153(262.5)

Role of decapod crustaceans in the diet of fishes of the northwestern part of the Black Sea

by M.M. Kirilyuk, Yu.N. Makarov and S.K. Borodin
(Odessa branch of INBYuM, Odessa branch of AzCherNIRO)

Over 2000 fish stomachs were analyzed during the period from 1966 to 1984. It has been established that decapods are consumed by relatively large fishes such as sturgeons, righteye flounders, skates, gobies, cods and perches.

The fishes in which the food bolus consists mainly of decapods include the thornback ray (*Raja clavata*), the stingray (*Dasyatis pastinaca*), the turbot *Scophthalmus maeoticus maeoticus*, the flounder *Platichthys flesus flesus* and the toad goby *Gobius batrachocephalus*.

The following were encountered in the stomachs of these fishes: (55)
Palaemon adspersus, *P. elegans*, *Porcellana longimana*, *Macropipus arcuatus*, *Pilumnus hirtellus*, *Xantho poressa*, *Phithropanopeus harrisi tridentata*, *Diogenes pugilator*, *Upogebia pusilla* and *Callianassa pestai*.

In the central regions of the northwestern part of the Black Sea, the stomachs of the thornback ray were in many cases more than one-half filled with *C. crangon*; this species of shrimp also plays an important role in the diet of *Scophthalmus maeoticus maeoticus* and *Platichthys flesus flesus*. Together with *M. arcuatus*, *C. crangon* constitutes an average 56% of the food bolus in the stomachs of *Platichthys flesus flesus*.

In the area of the sea adjacent to the Danube-Dniester interfluve, *Raja clavata* feeds predominantly on the shrimp *P. adspersus* which together with *M. arcuatus* makes up 61% of the total stomach contents on the average. The diet of *Scophthalmus maeoticus maeoticus* in this area is more varied, and consists of *Crangon crangon* (19.8%), *M. arcuatus* (7%), *P. adspersus* (5.6%), *D. pugilator* (4.8%), *P. hirtellus* (2.2%), *U. pusilla* (2.2%) and *X. poressa* (0.8%).

Off the Tendra Peninsula (sea and bay), *P. adspersus* was found in a large quantity in the stomachs of *Platichthys flesus flesus* (together with *M. arcuatus* 74%), *Scophthalmus maeoticus maeoticus* (29%) and *Raja clavata* (up to 72%).

In Karkinit Gulf, the diet of *Scophthalmus maeoticus maeoticus* consists primarily of *C. crangon* (41%), followed by *P. arcuatus* (32%), *P. adspersus* (6.6%), *D. pugilator* (3.3%) and *X. poressa* (2.6%). The diet of *Dasyatis pastinaca* consists 71% of *P. adspersus*, and the dominant food of *Raja clavata* is *C. crangon*. On the average, the stomachs of *Gobius batrachocephalus* contained 7.2% *P. longimana*, 6% *C. crangon*, 4.8% *P. adsperus* and 4.2% *M. arcuatus*.

As a result of the substantial freshening of the Khadzhibeysky Liman, its fauna has acquired a mixed character. It now consists of marine and freshwater organisms. No special attention has been devoted to the role of the marine elements in the diet of freshwater fishes. Among the decapods encountered in the Khadzhibeysky Liman, *P. elegans* and *Rh. h. tridentata* are the most abundant. Both species appear to be the favourite food of the freshwater perch *Perca fluviatilus*. In the majority of cases, the perch (56) stomachs were 100% full of these two species with the predominance of one or the other in different parts of the liman. A 26 cm fish can in one meal consume up to 132 *P. elegans* and 81 *Rh. h. tridentata*. During the moulting period, the shrimps are occasionally consumed by Carassius auratus gibelio which is currently the principal commercial fish of the Khadzhibeysky Liman.

Thus, freshwater fishes in the Khadzhibeysky Liman can turn to feeding on non-typical food. In the open parts of the sea, the most extensive variety of decapods is consumed by Scophthalmus maeoticus maeoticus.

UDC 595.384.12(267)

Species composition and trophic interrelations in the taxocene of pelagic shrimps in the subequatorial waters of the central part of the Indian Ocean

by O.V. Kol'tsov and Ye.A. Pakhomov (AzCherNIRO)

Eighteen species of pelagic shrimps belonging to 6 genera and 4 families have been encountered in the subequatorial waters of the central part of the Indian Ocean at a depth of 0-350 m. Sampling was carried out during the 4th trip of the "Professor Vodyanitsky" research-scouting vessel in June-September 1978, by means of a large Juday plankton net, predominantly in the evening. A total of 363 specimens was collected.

We studied the size composition, the condition of the reproductive system (11 species) and the feeding habits (10 species) of the most prolific species in our collections. From the fragments found in the shrimp stomachs, we re-established the approximate initial sizes of the prey.

The fauna consisted of 11 cosmopolitan species (Gennadas bouvieri, G. parvus, G. acutatus, Funchalia balboae, F. villosa, Stilopandalus richardi, Oplophorus gracilirostris, O. spinicauda, O. spinosus, O. typus, Acanthephyra quadrispinosa), two species

(57)

known from the Atlantic Ocean (Gennadas brevirostris, Funchalia taaningi) and two species noted only in the Indian Ocean (Thalassocaris obscura, Gennadas incertus). T. obscura can be regarded as the leading species of the taxocene as to the frequency of occurrence and abundance.

All of the shrimps encountered are bathypelagic interzonal species that live at depths of up to 4000 m and more. At depths of up to 350 m in the given area, they are mostly represented by sexually immature specimens and ones maturing for the first time (10 species). Perhaps the epipelagic zone is the foraging part of their range.

The food spectra of all the species studied are similar to each other, due to the use of the same food resources consisting of euphausiids, ostracods, copepods, chaetognaths and young fish. However, the interspecific competition is minimal due to the fact that each species consumes only a certain size of organisms. For example, T. obscura (13-14 mm long) preys on 1.5-2 mm organisms, O. spinosus (21-22 mm long) on 10 mm organisms, and A. sanguinea (59 mm long) on organisms up to 25 mm long at the most. Furthermore, A. sanguinea also feeds extensively on the small prolific species of shrimps, T. obscura and S. richardi.

Consequently, all of the shrimp species studied are predators with respect to the mode of food capture. The first of the species listed, T. obscura, is more of a "grazing" species, while the other two are attacking predators. Furthermore, A. sanguinea can be a regulator of the numbers of other prolific species of shrimps (primarily T. obscura and S. richardi), and all the shrimps together regulate the numbers of the epipelagic community of the subequatorial waters of the central part of the Indian Ocean.

UDC 595.384.12(267)

(58)

Some biological characteristics of the shrimp *Thalassocaris obscura* from the Indian Ocean

by O.V. Kol'tsov and Ye.A. Pakhomov (AzCherNIRO)

The shrimp *Thalassocaris obscura* is an endemic of the Indian Ocean, and beyond it is encountered only in the Red Sea. The vertical range of its habitat is quite extensive, from the surface to a depth of 1000 m and more (Williamson, 1971).

To study some of the biological questions not discussed in the literature, we examined the shrimps collected during the 4th trip of the "Professor Vodyanitsky" research-scouting vessel in July-August 1978 from depths of 0-150 m in an area located at 4-7^{o}N and 77-89 E. The material was collected with a large Juday plankton net in the evening. A total of 154 specimens was analyzed. This species was the most prolific one in the given area (frequency of occurrence in the catches 36.4%). Female specimens predominated somewhat (56.2%) in the catches. The body length of the shrimps (from the orbit to the end of the telson) varied from 9.9 to 16.3 mm. The modal sizes of the males and females are 14.2 and 13.8 mm respectively. The shrimps weigh 15-63 mg. The females with a body length of more than 12-13 mm were somewhat heavier than the males due to the development of gonads in them. The females reach sexual maturity for the first time at this size. The sampling period coincides with the spawning period of the shrimp; 28.4% of the females had gonads at the 5th stage of maturity and 55.4% bore eggs on the pleopods. The development of eggs on the pleopods takes place simultaneously with the maturation of a new batch of oocytes. This type of parallel development enables the shrimps to produce a large number of generations within a single spawning period.

The highest absolute individual fecundity (the number of oocytes in a gonad at the 5th stage of maturity), up to 200 oocytes, was noted in the largest females; the average fecundity was 142 oocytes. The largest number of eggs on the pleopods, 142, was also noted in females of the older size-age groups; the average number of eggs on the pleopods was 27. The egg losses during the incubation period amount to 60-80%; therefore, the average working fecundity (the number of eggs on the pleopods at the 5th stage of development) amounts to only 6-10 eggs. As the egg develops, its major axis increases by 21.5% (from 0.65 to 0.79 mm), while its minor
axis remains unchanged (0.46 mm). The eggs of the older size-age (59)
groups are larger than those of the smaller individuals at all the stages of the development.

Analysis of the stomach contents did not reveal any significant differences between the food consumed by the males and females. The bulk of it was made up of small crustaceans, i.e. copepods (43.5% frequency of occurrence and 31.3% of the food bolus) and ostracods (24.5 and 30% respectively). Larger organisms were consumed to a smaller extent; these included euphausiids (21.8% and 12.2% respectively), polychaetes (19.7 and 5.4%) and fish (16.3 and 3.5%). Judging by the size of individual food fragments, the initial size of the prey was up to 1.5-2 mm (possibly larger), i.e. 10-15% of the body length of the shrimp. The number of food components in a stomach averaged 2.45. Such a low coefficient of food diversity is characteristic of attacking predators (Burukovsky, Froyerman, 1974). However, the discovery in some stomachs of up to 5 ostracods comprising 100% of the food bolus permits us to assume that _T. obscura_ can function as a "grazing" predator capable of selecting only certain organisms to feed on.

UDC 595.384.2

Maturation and fecundity characteristics of some commercial species of crabs in the Sakhalin-Kurile region

by Yu.R. Kochnev and K.G. Galimzyanov (SakhTINRO)

The material on the fecundity and maturation of crabs was collected over the period from 1974 to 1983.

Analysis of the correlation between ovigerous females and those without eggs has shown that the females of the Kamchatka crab reach the first stage of sexual maturity and begin to breed upon reaching a carapace width of 10 cm, and full-scale maturation begins when the carapace is 11-14 cm wide (table 1).

(60)

The minimum size of sexually mature female crabs and the size at full-scale maturation are specific for each individual species (table 1). Because the rate of growth of the crabs differs according to the area, sexual maturation in females is observed at different sizes. The ovigerous females of the Kamchatka crab had a carapace width of not less than 10.0 cm off eastern Sakhalin and in Aniva Gulf, 11.4 cm in the Tatar Strait and 12.0 cm off the Southern Kuriles; the minimum carapace width of snow crab females from the same areas were 3.8, 5.0 and 6.0 cm respectively.

Table 1

Species	Width of carapace, cm						
	Females without eggs			Females with eggs			
	No. of specimens	Variation	Average	No. of specimens	Variation	Average	Full-scale maturation
Kamchatka crab	720	4.1-19.5	11.5	2041	10.0-20.0	14.3	11-14
Deep blue crab	237	3.1-13.9	10.5	237	8.7-15.0	11.3	9-12
	118	7.0-11.1	9.5	122	8.3-14.6	11.0	9-11
Snow crab	2951	0.4-11.0	3.8	2795	3.8-11.0	6.0	4-7
Kenagi	794	2.0-10.0	7.0	284	5.0-10.0	7.0	6-8

In crabs of the genus *Paralithodes* and the snow crab, the proportion of ovigerous (sexually mature) females increases with body size, and upon reaching a certain size, practically all of them have eggs under the abdomen. In the kegani, the maximum number of females in the size groups does not exceed 32.1%. Apparently, some of the sexually mature females of this species do not participate in spawning. The ratio of ovigerous females and females without eggs in the size groups can be expressed by an equation of logistic relationship in crabs of the genus *Paralithodes* and the snow crab, and by an equation of parabolic relationship in the kegani.

The absolute individual fecundity of crabs varies from 37,326 eggs in the snow crab to 180,609 eggs in the Kamchatka crab (see table 2).

(61)

The absolute individual fecundity increases in all the species of crabs with an increase in body size. The relationship between the absolute individual fecundity and body size is a linear one. The absolute individual fecundity diminished in the Kamchatka and snow crabs as we moved farther northward.

Table 2

Species	No. of specimens	Width of carapace, cm		Fecundity (number of eggs)	
		Range of variation	Average	Range of variation	Average
Kamchatka crab	129	10.0-19.4	14.16	35,840-451,276	180,609
Kegani	58	5.0-8.8	7.12	13,577-255,367	112,056
Snow crab	159	4.5-7.8	5.88	14,250-74,447	37,326

UDC 595.384.15(267.2)

Visual observations on the distribution and behaviour of spiny lobsters on one of the seamounts of the West Indian Ridge

by A.B. Levin, M.V. Kolesnikov and D.K. Gutsal
(Sevastopol Experimental Design Office for Undersea Research)

With the help of a submersible apparatus (SA), we conducted observations of the biota on the summit of a seamount located on the northern slope of the West Indian Ridge. This seamount is a part of its largest elevations. It is bounded by the 200 m isobath, and has the form of a submeridionally elongated plateau with two rises separated by a trough.

Of the crustaceans here, *Jasus* sp. were of interest to us; they were encountered from the summit of the seamount to a depth of 360 m. Uniformly distributed solitary individuals were encountered both on the summit, and on the slopes of the seamount (approximately (62)
1 specimen per 2000 m^2). The spiny lobsters were not confined to any particular type of substrate or form of microrelief.

We observed the behaviour of the spiny lobsters near the trap attached to the submersible. Not a single spiny lobster was observed at the time the submersible touched bottom. The first specimen appeared at the trap 10 minutes later and immediately began to look for a way in. In an hour, 9 spiny lobsters had approached the trap, all moving against the current. They found the way into the trap quite quickly, but not all of the animals could get into it because of its poor construction.

Despite the poor structural qualities of the traps, we were still able to get 100 spiny lobsters. The largest hauls were taken at night; however, observations from the submersible have shown that spiny lobsters actively respond to the bait during the day as well, and will do everything in their power to reach it.

The average size and weight of the spiny lobsters amounted to 37.68 ± 0.67 cm and 1.668 ± 0.730 kg respectively.

A rough estimate of their biomass was also derived.

Despite the large sizes of the spiny lobsters, the given population is characterized by a slow rate of growth. Considering their small density, we can also say that the given population is not a commercially important one.

UDC 595.384.12(268.45)

Pink shrimp populations of the fjords of western Norway: functional characteristics and role in the structure of the range of the species

by A.Yu. Lysyi (MMBI AN SSSR)

According to the data of Norwegian researchers (Grieg, 1927; Rasmussen, 1947, 1953; Bøhle, 1974, etc.), large populations of the northern shrimp *Pandalus borealis* are found in many of the deepwater fjords of western Norway. However, their role in the replacement of the commercial shrimp concentrations of the south- (63)
western part of the Barents Sea is not quite clear yet.

In order to establish the possible interrelationship of the fjord populations of the western coast of Norway and their relationship with the more northern shrimp groupings, we carried out 3 macroplanktonic surveys based on a network of stations with constant coordinates from 62° to 68° N lat and from 3° to 11°E long in the vicinity of the Norwegian shoals in April 1980-1982 (Lysy, 1983, 1984, 1985). The gear consisted of a 10-foot model of an Isaac-Kidd trawl and an ИКС-80 net.

The results of these surveys, which showed that there were hardly any larvae of the pink shrimp in the waters of the Norwegian coastal current, point to a high degree of isolation and, consequently, the independent nature of the populations in the fjords of western Norway. Obviously, the larvae that hatch out in the first half of March in these fjords, most of which have a "threshold" at the entrance (an abrupt 100 m or higher elevation of the bottom), are practically never carried out into the open sea; they remain in the fjords up to the time they settle. Only a small part of them may be carried out of the fjords by the tides towards the end of the pelagic period of development. However, in this case too, the larvae are not carried very far from the place of hatching in the period remaining up to time they begin to settle. This type of occurrence was observed in detail in Motovka Gulf of the Kola Peninsula (Lysy, 1981) where, even with no "threshold", the larvae are carried from the depths of the gulf only several miles closer to its mouth during the pelagic period of development (at the age of about 4 months).

Consequently, the fjord groups of shrimps from the western coast of Norway should be regarded, according to V.N. Beklemishev's classification (1960), as relatively isolated independent populations which are almost unrelated to the Barents Sea superpopulation of the species, do not perform any "maternal functions", and do not play any significant role in maintaining the numbers of the coastal groupings of shrimps located farther to the northeast. This points to the independent nature of the populations in the southwestern part of the Barents Sea shelf, which do not get any larvae from the south and, therefore, maintain their numbers exclusively by (64) means of their own reproductive forces, at the same time performing "maternal" functions as well.

UDC 595.383.1

Study of the age structure of a *Euphausia superba* population

by R.R. Makarov, V.A. Spiridonov (VNIRO)

The problem of establishing the number of year-classes in a *E. superba* population has not been solved yet. The difficulties of identifying the modal peaks on variation curves with the year-classes of crustaceans in a population are well-known. The current concepts regarding the age to which *E. superba* survive are quite different, though we observe a clear tendency towards a gradual increase of this age. According to Ettershank's conclusions (Australia), the age of *E. superba* already "approximates" 10 years (the titre of lipofuscin was used to indicate the course of the "biological clock" in the crustaceans).

The most promising method of determining the composition of a *E. superba* population is the geographic one which is based on the determination and comparison of the abundance and variability of the size groups recorded in large water areas. The initial stipulation for such comparisons is Ye.V. Solyankin and V.V. Maslennikov's concept regarding the modifications of antarctic waters. The pelagic biocoenoses in these waters are characterized by their own specific features; consequently, we can speak of individual subpopulations of plankters.

The variability of the size composition of these crustaceans has been noted in the material of the "Akademik Knipovich" research-scouting vessel from the Bellingshausen, Scotia, Lazarev and Cosmonauts seas. If we compare only the most frequently encountered, regular modal groups (without the larvae), there will be 2 (3) year-classes in the *E. superba* population at the low latitudes, and 3 (4) year-classes in the subcontinental high-latitude waters. (65)
Such differences are associated spatially with waters of different modifications.

In the zones where waters of different origin converge, we note an increase in the number of modal size peaks as a result of the mixing of different subpopulations that vary in size composition. The growth of the crustaceans varies in individual areas occupied by the same subpopulation, which also leads to an increase in the number of size groups. Consequently, analysis of single catches from places located quite a distance from each other is insufficient for surveys of this type. It is necessary to carry out frequent trawling that would make it possible to draw comparisons in which groups poorly represented in some cases would stand out clearly in others. In this way, we can characterize the groups in detail, and determine their relative abundance. In connection with this, the formal approach based on the group-generation principle cannot be regarded as acceptable, though the statistical preparation of the material on the size composition of the crustaceans is necessary for establishing the significance and contribution of the size groups represented in the sample.

When analyzing the samples, we must definitely take into account the size composition of both sexes, as well as the degree of their maturity. Repeated observations during the season have shown a time-related displacement of the modal peaks. It is quite possible to trace these displacements, e.g. for a number of areas of the Antarctic Region. The "movement" of the size peaks takes place at different rates according to the seasons, both as a whole, and relative to each other. In the course of wintering (see Ikeda and Dixon), this movement, i.e. the growth of the crustaceans, may not only stop, but go into reverse. The negative growth of the crustaceans noted under experimental conditions must still be confirmed in field experiments. According to our data (including our material on non-antarctic euphausiids), the negative growth is insignificant.

UDC 595.384.12(262.5) (66)

Migrations of Crangon in the western half of the Black Sea

by Yu.N. Markarov (Odessa branch of INBYuM)

In the Black Sea, we know of three species of shrimps of the family Grangenidae, which belong to the genera *Crangon* and *Pontophilus*. Species of the genus *Pontophilus* (*P. trispinosus* and *P. fasciatus*) are encountered very rarely and, therefore, have been poorly researched. The most common genus is *Crangon* which is represented by one species, *C. crangon*, encountered throughout the Black Sea shelf up to a depth of 100 m. This species is caught in large quantities in the countries of Western Europe. In the north-western part of the Black Sea, this species constitutes the bonus catch accompanying palaemonids. Observations have shown that the reserves of crangonids in the Black Sea approximate those of palaemonids.

We have studied the migrations of *C. crangon* throughout the year on the basis of trawl samples from the western shelf and northwestern part of the sea.

In September, this species forms the highest concentrations at depths of 30-40 m in the northwestern part of the sea. During this period of the year, *Crangon* is not found at depths of 5-10 m. On the western shelf along the coast of Bulgaria and Turkey, these shrimps accumulate at depths of 60-100 m where they probably remain throughout the winter. Observations have shown that the *Crangon* population migrates closer to shore in May, and forms concentrations along the shore in July, where its area of distribution is confined to the 15-metre isobath. During the summer months, the highest concentrations of shrimps are observed in the estuarine areas adjacent to the Danube, Dniester and Dnieper rivers. As a rule, mainly young shrimps gather in these areas.

An interesting fact is that a small number of the Crangon females (up to 5%) that migrate to large depths in autumn have eggs on the pleopods. Females with eggs on the pleopods at the prehatching stage are encountered even in November. Nekton samples taken at the same stations where trawling was carried out sometimes (67)
confirmed the presence of larvae at the surface of the water both in the northwestern part of the sea, and in its southwestern part right up to the Turkish coast. Consequently, the migrations of Crangon are not related to the reproductive process as in other genera of shrimps, e.g. palaemonids. Crangon reproduces both in summer close to shore, and in late autumn far from shore. In all probability, these migrations are related primarily to temperature distribution. The migration of the shrimps seaward in winter is due to the drop in temperature during this period in the coastal zone of the sea.

The distances of migration vary with the area of the sea. They depend on the width of the shelf zone. For example, the shrimps can cover a distance of 50-60 miles in the northwestern part of the sea where the 100-metre isobath is far from shore, whereas they migrate over a distance of not more than 12-16 miles on the comparatively narrow southeastern shelf.

UDC 574.55(267.2)

Some characteristics of the biological productivity of waters in the area of the West Indian Ridge

by S.V. Martynenko and V.A. Sumerin (SEKBP*)

Investigations were carried out in the area of the West Indian Ridge during the 7th and 9th trips of the "Ikhtiandr" research-scouting vessel in September 1981 and February 1983. The most detailed investigations were carried out in its central part above a seamount with a characteristic depth of 150 m and coordinates of $35^{\circ}54'9$ S lat and $53^{\circ}14'6$ E long. Our investigations included a series of oceanological observations, zooplankton sampling by standard methods and catching benthonic invertebrates.

On the slopes of the bank at depths of 190-370 m, we noted a bottom current on a 300° course with a velocity of 0.2-0.3 knots. Directly above the plateau and the adjacent depths of the southern and southwestern slopes up to 150-350 m, we noted the downwelling (68)
of surface waters, while on the northern and northeastern slopes, we noted the upwelling of subsurface waters. This is due to the presence of a quasistationary anticyclonic vortex (registered during the period of our investigations) in the vicinity of the bank.

The upwelling and turbulent mixing of the biogen-enriched (content of phosphate phosphorus 0.94 μg-at P/1), low-salinity (less than 34.9‰) and cold (temperature below $10.5^{\circ}C$) subsurface and intermediate waters in the northern and northeastern parts of the bank, as well as the maximum content of dissolved oxygen

* See footnote on p. 23 - transl.

(over 5.6 ml/l; 89.6% saturation) in the photic layer here are conducive to the maintenance of optimal conditions for the development of the phytoplankton and zooplankton. The zooplankton biomass directly above the northern and northeastern slopes of the bank in the 0-100 m layer varies with the seasons from 30 to 45 mg/m^3. The horizontal drift transport of the plankton from the northeastern to southwestern part of the area and the anticyclonic topographic circulation are conducive to its accumulation above the plateau of the bank. Because of this, the zooplankton biomass in the vicinity of the seamount is approximately 1.5-2 times greater than in the waters surrounding it, amounting to 55 mg/m^3 in the 0-100 m layer. The biomass amounts to 20-30 mg/m^3 west and east of the bank, and 35 mg/m^3 above the southern and southwestern slopes.

Thus, the prevalent anticyclonic circulation above the bank helps to get the oxygenated and nutrient-enriched surface waters to its summit, which creates the conditions necessary for the active life of the demersal fauna. We can also assume that the stability of this circulation is important to the reproduction of bottom fishes and invertebrates, as it prevents their eggs and larvae from being carried off beyond the boundaries of the elevation.

UDC 639.519 (69)

Experiments on the artificial breeding of the Kamchatka crab (*Paralithodes camtshatica*)

by L.V. Mikulich and A.Ya. Yefimkin (TINRO)

Research into the cultivation of the Kamchatka crab was begun in June 1980 at the Marine Experimental Station of TINRO on Popov Island in Peter the Great Gulf (Sea of Japan).

The first stage of the investigations included the selection of aquarium conditions for the spawners (ovigerous females). This was accomplished by determining the water temperature, salinity, oxygen content, as well as the composition of the feed and the daily rations.

The ovigerous females were kept in flow-through fibre glass plastic 1.6 m^3 aquarium incubators. The temperature of the water in the aquariums varied with the season from 1.4^{o}C in winter to 22.0^{o}C in summer. The salinity varied from 32‰ to 34‰, and the content of oxygen was 70-100% saturation.

The meat of various fishes, mollusks, crustaceans, starfishes and sea-urchins was used as feed. The latter was given daily. The crabs in the aquariums fed well at a temperature of 5-15^{o}C; they foraged throughout the year, except during moulting, at which time the interval between feedings varied from 3 to 23 days in different individuals; prior to and after moulting, the crabs willingly consumed large quantities of starfishes and sea-urchins, food with a high content of lime.

The daily average rations of the experimental females varied from 0.17 to 1.13% (average 0.50%) of their body weight.

With an increase in water temperature to 19.5-20.0°, the females stopped feeding and died soon after that.

To get larvae during the natural period, female Kamchatka crab were caught at the beginning of April, and before long 100% of the larvae hatched out in the aquariums.

Under experimental conditions, the transition of zoeae I to exogenous feeding is noted on the second day after hatching. The feed consisted of egg powder, unicellular algae *Monochrysis lutheri* and live *Artemia* nauplii. Visual observations showed (70)
that the crab larvae consumed the egg powder and unicellular algae, but they preferred the *Artemia* nauplii which they seized with their extensible jaws. We have found that crab larvae do not hunt *Artemia* nauplii, but seize them when they are close to the mouth. In connection with this, the concentration of nauplii during the feeding of crab larvae should be high enough to enable the larvae to seize them and satisfy their food requirements.
It takes a crab larva 3-5 minutes to seize and swallow nauplii, and 20-30 minutes to completely digest the food consumed. Crab larvae consume nauplii at the highest rate when the water temperature is 8-10°C. We noted a significant drop in the feeding rate with an increase in water temperature; the larvae stopped feeding at 17°C.

Under experimental conditions with optimal parameters of the environment, the transition from zoea I to zoea II takes place within 6 days. This transition is prolonged to 18-20 days at a water temperature of 2-6°C.

Experiments have shown that 500 larvae per 10 litres of water is the optimal density of planting.

An oxygen content of 33% saturation (2.3 ml O_2/1) proved lethal for crab larvae in aquariums.

UDC 595.384.2

Some data on the biology of two commercially valuable Guinea crabs

by V.V. Murina and M.B. Diallo (INBYuM)

From November 1982 to October 1983, we studied the biology of two commercially valuable crabs, *Callinectes gladiator* and *Menippe nodifrons*, at the Hydrobiology Laboratory of the Guinean Scientific Centre Rogbane (Conakry, Fr. Guinea).

(71)

Callinectes gladiator, one of the most prolific crabs of Guinea, is extensively consumed by the local population. We have studied 60 specimens of this species, caught mainly with a bottom trap net in Rogbane Bay (Conakry). During the dry season, males with an average carapace width of 101 mm predominated. During the wet season, females with an average carapace width of 112 mm predominated. Fecundity was also determined. It amounted to 240,800 eggs in the largest female (130 mm). The eggs measured 0.25-0.30 mm in diameter, and one egg weighed 0.019-0.020 mg.

This species was often encountered in the catches of commercial vessels at a depth of 10-15 m. The crab migrates to the upper sublittoral to breed. For instance, a large number of young crabs measuring 24 mm on the average were caught with a midwater trawl at a depth of 5-6 m near Boffa in April 1983.

Mature individuals were often encountered in the muddy-sandy littoral of mangroves at a temperature of 28-30°C and salinity of 34-38‰. This species is an endemic of West Africa according to its geographic distribution; it is known from Mauritius to Angola. According to our data, it is found at depths from 0 to 15 m.

Unlike *Callinectes gladiator*, *M. nodifrons* is confined to the littoral zone in its distribution. The local population collects many of these large crabs during low tide in the rocky littoral where the crabs seek shelter under rocks and in crevasses. Two hundred specimens collected mainly in the environs of Conakry in the littoral of Kamayenne, Rogbane and Bulbine* were analyzed. The ratio of the sexes is approximately equal. The males reach sexual maturity at a carapace width of 20 mm, having a fully formed copulatory organ. The maximum size of the males is 73 mm, and the maximum weight is 85 g. The females have ripe eggs at a length of 22 mm. The largest female encountered had a length of 76 mm and weight of 93 g. Ovigerous females were encountered in the littoral both in the dry, and in the wet season. Perhaps these crabs migrate to the lower littoral to breed. The absolute fecundity in a female with a carapace measuring 68 x 50 mm amounted to 117,000 eggs. One egg measured 0.35-0.38 mm, and weighed 0.014 mg.

M. nodifrons is extensively encountered in the littoral of Guinea, particularly in the environs of Conakry and on the Los Islands. The usual biotope of this crab consists of the muddy-stony (73)
littoral of the middle and lower horizons where it is encountered together with other crabs (*Pisidia longimana*, *Pachygrapsus gracilis*

*conjectural spelling - transl.

and Panopeus africanus). It prefers water with a normal oceanic salinity of 35-36.5‰, and avoids freshened areas (mangrove overgrowths). It is a tropical Atlantic species as to its geographic distribution; it is known along the American coast of the Atlantic Ocean from Florida to Brazil, and along the African coast from Senegal to Angola.

UDC 639.28:639.2.081.117.004.17:(639.2.001.5:629.127.4.007.2)

Determination of the trawl efficiency for the Kamchatka crab with the help of a "TINRO-2" submersible apparatus

by V.I. Myasoyedov (TINRO)

During the spring of 1983, we conducted our usual investigations on the distribution, biology, abundance, reserves and behaviour of commercial invertebrates, particularly the Kamchatka crab, on the shelf of western Kamchatka.

The investigations were carried out by means of a trawl survey combined with visual observations from a "TINRO-2" submersible.

One of our tasks was to determine the trawl efficiency for the Kamchatka crab, the accumulations of which vary in density and structure.

With the submersible on the bottom, we determined the density of the crab accumulations visually, by the geodetic method (Recommended Methods for Instumental Estimation of Commercial Targets, Murmansk, 1979). After the submersible had surfaced, trawling and direct gauging of the trawl (by the same recommended methods) were carried out along its route.

The efficiency of the trawl was calculated on the basis of 8 submersions and the trawlings that followed. Its value varied

(73)

from 0.27 to 0.96, with an average of 0.71. We have in the past (since 1978) used a value approximating this (0.75) to estimate the numbers of the Kamchatka crab on the shelf of western Kamchatka.

UDC 595.383.1

Analysis of the current biomass estimates for antarctic krill

by A.G. Naumov and V.V. Shevtsov (VNIRO)

The estimates of antarctic krill biomass and production differ approximately 300-fold. These estimates reflect the different methods used for the calculation of them. The minimum values (up to $200\text{-}500 \cdot 10^6$ t) are derived by the authors who carry out calculations "from the bottom to the top", from primary production (P_p) to the herbivorous species of plankton. In this case, the ratio between *Euphausia superba* and the herbivorous species of plankton is accepted a priori as 50:50%.

However, the data on the annual value of P_p for antarctic waters are usually much too low. These values vary from $0.6 \cdot 10^9$ tC (Holm-Hansen et al., 1977) to $3.2 \cdot 10^9$ tC (El-Sayed, 1967). Assuming that the content of carbon in the wet mass of algae constitutes 10%, the present estimates of P_p for the oceans of the world, based on a review of the methodological errors of the radiocarbon method and more accurate estimates, range from $880 \cdot 10^9$ t raw weight (Tseitlin, 1983) to $1500 \cdot 10^9$ t (Vinogradov and Shushkina, 1984). The unrevised values of P_p for antarctic waters are estimated at 0.4-4.5% of the total P_p of the world's oceans. However, the productivity of antarctic waters is higher than average, and their area constitutes 10% of the total area of oceans. Consequently, the values of P_p for antarctic waters and the estimates of biomass and production of herbivorous zooplankton based on them have proved to be much too low.

Revision of the data (Naumov, 1985) has shown that the P_p of
antarctic waters should be about $125 \cdot 10^9$ t in raw weight or (74)
$8.75 \cdot 10^9$ tC (allowing for a 7% maximum content of carbon).

Voronina (1983, 1984, 1985) believes that a "third" method of determining biomass, without the use of "bottom to top" or "top to bottom" calculation (latter based on the consumption of krill by the consumers) is possible, and she proceeds from the value of herbivorous zooplankton production. At the same time, she utilizes the lowest of all the published data on the average biomass of _E. superba_ in the zones of concentration of these crustaceans ("zone of dominance") and reduces the area of this zone and the area of distribution of the species ($3.5 \cdot 10^6$ km^2 compared with 5.5–$6.5 \cdot 10^6$ km^2 and $18 \cdot 10^6$ km^2 compared with 32–$36 \cdot 10^6$ km^2 respectively). Voronina then "verifies" the "maximalistic" values of food availability for these crustaceans, accepting the krill biomass as $6.0 \cdot 10^9$ t and regarding the P_p values as noncritical. By introducing corrections in Voronina's calculations (1983) and accepting the krill biomass as equal to $2.5 \cdot 10^9$ t and the content of crustaceans in the zone of dominance as equal to 50% of the total biomass of the species, we find that not 3500 gC$\cdot$m^{-2} is required annually to ensure this biomass and corresponding production of crustaceans (as indicated by Voronina), but about 250 gC$\cdot$m^{-2}, which is quite close to the average value of P_p for antarctic waters (about 242 gC$\cdot$m^{-2} annually).

The most realistic way of estimating the total biomass and production of antarctic krill is by "top to bottom" calculation based on the reconstruction of the trophic structure (food chains) of the community of antarctic waters and the determination of the lowest possible energy requirements of the consumers. This method, like the model calculations based on an energy transfer grid (Doi, Kavakami, 1979), inevitably results in "maximalistic" values of antarctic krill biomass ($1-3 \cdot 10^9$ t). At the same time, we should note that underestimation of the major consumers of antarctic krill, i.e. fishes and squids, lead to some underestimation of the final result in this case (Doi, Kavakami - about $1 \cdot 10^9$ t; Lyubimova, 1985 - $0.3-0.7 \cdot 10^9$ t).

We should note that the above-mentioned methods of estimating krill biomass are applicable only for the whole superpopulation of antarctic waters. The regional values were derived with the help of hydroacoustic trawl surveys. At the same time, however, the trawls do not entrap the young krill (less than 30 mm long) very well, and larvae are not caught at all. The surveys carried out on an area of about $0.5 \cdot 10^6$ km^2 (8-10% of the total area of krill accumulations) have shown that from 45 to $60 \cdot 10^6$ t of crustaceans (over 30 mm long) gather at the same time in the areas surveyed. If we take into account that the biomass of the smaller crustaceans makes up approximately one-half of this value, we will find that direct stock-taking surveys provide us with results that are in good accord with the total biomass estimates of $1-2 \cdot 10^9$ t.

UDC 595.384.12(262.81)

Reproduction of *Palaemon elegans* in Sulak Bay of the Caspian Sea

by A.I. Nesterovich and A.V. Alekhnovich
(Institute of Zoology of the Academy of Sciences of the Byelorussian SSR)

The common eurybiontic species *Palaemon elegans* acclimatizes quite well to new and at times unusual habitats. In 1982, we studied the reproductive tendencies of these shrimps in the Caspian Sea where this species was introduced in 1930-1934 (Karpevich, 1975).

In Sulak Bay, shrimps with eggs on the pleopods can be encountered in the second half of May. At the end of September, our samples contained only shrimps with eggs at the final stages of embryonic development. The length of the ovigerous females (L) from the tip of the rostrum to the end of the telson varied from 39.0 to 56.8 mm, and the absolute fecundity (E), i.e. the number of eggs deposited on the pleopods, varied from 575 to 2875. During the reproductive season, the ratio of absolute fecundity to body size is of a similar nature, and is expressed by the equation

$$E = 0.00025\ L^{4.071} \quad (r=0.72;\ N=84)$$

The species is characterized by extensive variability of the absolute fecundity depending on the habitat of the populations, and by a general increase in E from south to north.

In Sulak Bay, the generative cycle (the interval between two consecutive egg deposits) during the breeding period in summer was only 24 hours longer on the average than the period of egg development. We also noted individuals in which both the hatching (76) of the larvae, as well as moulting and the deposition of new eggs took place in a single night. This process was prolonged to 2-3 days in a few individuals, especially in September when the temperature of the water dropped. The females did not grow larger after moulting and oviposition, i.e. all the energy provided by the food consumed during the reproductive period is used for sustaining the vital activity of the shrimps and their generative processes; no somatic growth is observed at this time.

We believe that the females breed only once, at an age of one year or slightly more, and die during the second year.

Under the conditions of Sulak Bay, the shrimps produce 7-8 egg deposits during that one reproductive period of their life. To derive this figure, we took into account the seasonal variations in temperature and the related length of embryonic development.

We did not detect any regular changes in the dry weight of an egg according to the time of egg formation or the size of the female. On the average, the mass of one egg amounted to 0.0404 mg, and its caloricity 6.2 $cal \cdot mg^{-1}$ dry weight.

As in other species of shrimps, the hatching of the larvae in _P. elegans_ takes place during the dark hours of the day, and progresses rather quickly. Aquarium-maintained females with eggs at the final stages of development usually spawned their larvae within a single night; during the following night, they moulted and deposited a new batch of eggs. These processes took place so rapidly that the females cast off the exuviae with some unhatched embryos still attached to them. The number of these embryos varied from 9 to 192 (average 57). This occurred in 30% of the 40 females studied. While the female is carrying the eggs, some of them die due to this or that disease, overgrowing with epibionts, or simply the breaking off of individual clusters.

The average mortality of the eggs and the size of the females are interrelated; for example, egg losses amounted to 15% in 40 mm shrimps, and 60% in 50 mm shrimps.

Consequently, rapid development, a short life span, the lack of somatic growth during the reproductive period and, as a result, the increase in [energy] expenditures on reproduction, a high (77) fecundity and a large number of egg deposits ensure a high rate of acclimatization of this species to new habitats.

UDC 595.384.12:597.562(268.45)

Antiphasic changes in the reserves of cod (*Gadus morhua morhua*) and pink shrimp (*Pandalus borealis*) in the Barents Sea

by I.Ya. Ponomarenko, B.I. Berenboym and N.A. Yaragina
(VNIRO, PINRO)

The pink shrimp (*Pandalus borealis*) industry underwent rapid development in the 1980's in the Barents Sea and adjacent waters, and with this arose the problem of predicting its reserves and regulating commercial catches of the species. However, the tendencies of its population dynamics were never studied, and surveys of the stock were not conducted prior to the 1980's.

A major consumer of this species in the Barents Sea is the cod, the feeding of which has been observed throughout the year over the past several decades by reseachers of the Polar Institute using the method of field analysis. An average 25,000 stomachs has been analyzed each year. It has been found that the organisms which abound in the given area, season and year always predominate in the stomachs of cod. Consequently, the changes in the average annual frequency of occurrence of this shrimp in the diet of cod to some extent reflects the variations in the reserves of this species of shrimps.

This particular study is the continuation of the investigations (Ponomarenko and Yaragina, 1984) demonstrating a significant increase in the importance of this species in the diet of cod at the end of the 1970's—beginning of the 1980's, as well as the tendency towards an inverse relationship between the annual variations in the cod stock and the frequency of occurrence of this species of shrimp in its diet over a 32-year period (r = -0.76).

The calculation of the Pandalus borealis stock in 1980-1985 by Soviet and Norwegian specialists has enabled us to directly compare the year-to-year variations in this stock, first of all the changes in the average annual frequency of occurrence of this (78) species in the stomachs of cod, and secondly the dynamics of the commercial stock of cod (the biomass of cods from the age of three years and up based on the estimates of the ICES* Working Group, Anon, 1986). A fairly close positive relationship (r=0.84) is observed in the first case, and a negative one (r=-0.94) in the second case. Consequently, the biomass of P. borealis concentrations and the frequency of its occurrence in cod stomachs vary naturally with the biomass of the commercial stock of cod. For example, a sharp decrease in the cod stock at the beginning of the 1980's due to the appearance of six poor year-classes in a row

*International Council for the Exploration of the Sea - transl.

(1976-1981) caused a significant decrease in the pressure of the predator on the shrimp, and resulted in a substantial growth of its numbers. As a result, the frequency of occurrence of *P. borealis* in the stomachs of cod increased 4—5-fold in comparison with the level at the beginning of the 1950's.

The established relationships can be used when predicting the stock and haul of *P. borealis* in the Barents Sea and adjacent waters. However, in doing so, we must not ignore the possible effect of intensive commercial exploitation of the species on its stock. The close interdependence of the haul of *P. borealis* and the size of its stock (r=0.78) indicates that this species was exploited fairly intensively in the Barents Sea in the first half of the 1980's, the haul in 1984 constituting 116,700 tons according to ICES statistics (v. 69).

The noted tendency in the growth of the Lofoten-Barents stock of cod in connection with the appearance of the comparatively abundant 1982-1983 and 1985 year-classes will definitely bring about a decrease in the stock and haul of *P. borealis* in the second half of the 1980's.

UDC 595.384.8(265.53)

Distribution of the Kamchatka crab under different hydrologic conditions off western Kamchatka

by V.Ye. Rodin and V.V. Miroshnikov (TINRO)

The western Kamchatka shelf is the principal region of the domestic specialized Kamchatka crab industry. Over a number of years (1957-1985), the Pacific Ocean Scientific Research Institute

(79)

of Fisheries and Oceanography (TINRO) has been conducting standard hydrobiological and hydrological surveys in this area to estimate the abundance and dynamics of the stock of this species.

We have studied the material of 740 comprehensive stations for 1964-1969 (typical years with different hydrologic conditions) in order to correlate the data on the distribution and biology of the crabs and the hydrologic conditions of the area.

According to T.T. Vinokurova (1964), the following three types of hydrologic years can occur in the Sea of Okhotsk depending on the position of the cold water masses with low sub-zero temperatures at the bottom (at depths of 75-200 m): "warm" ones (1968 and 1969), "intermediate" ones and "cold" years (1966 and 1967).

It has been noted that the spatial position of individual migrational groupings (concentrations) of the Kamchatka crab depending on the depths and the hydrologic conditions of the waters differs for the different types of hydrologic years. For instance, under "normal" hydrologic conditions (in 1964-1965), the Kamchatka crab is comparatively scattered vertically, forming a somewhat higher than usual concentration at the junction of the "warm" and "permanently cold" water masses. During "cold" years, the crabs gather in two main concentrations, i.e. in the coastal zone (at depths of 15-20 m) and in the areas where the water masses come together, the density of the concentrations in the coastal zone being the highest. During warm years, depending on the extent of the warm-up, we observe similar concentrations of the Kamchatka crab either at depths of 40-55 m (as in 1968), or in the coastal zone (as in 1969).

On the whole, the observed dependence of distribution of Kamchatka crab on the type of "hydrologic year" can be characterized in the following manner: an increase in the density of concentrations is observed during "cold" years, and a decrease in the density of concentrations during "warm" and "normal" years.

This relationship is of great practical significance when predicting the commercial stock of this species off western Kamchatka over a long period.

UDC 595.384.12(261.7) (80)

On the biology of *Parapenaeus longirostris* at the southern boundary of its geographical range

by L.P. Romensky (AtlantNIRO)

P. longirostris is encountered in the waters of the Atlantic Ocean from Portugal to Namib Desert (18°28 S lat), and is a typical inhabitant of the muddy bottoms of the outer margin of the shelf and its rim.

In the SE Atlantic near the mouth of the Cunene R., we find one of the most southern colonies of this species which, unlike other colonies, is confined not to muddy bottoms, but to a narrow strip of glauconite sands which form in areas of the most frequent upwelling of abyssal waters. As in the more northern areas, this species of shrimp in the given area inhabits the waters of the boundary layer between the surface and intermediate structural zones at depths of 150-280 m, but does not form mass concentrations.

We have analyzed about 2000 specimens from 50 hauls taken in the given area in 1969-1983. One hundred and forty-three of the stomachs examined contained food, and 78 of them were full.

The hydrologic conditions of the coastal waters of the area inhabited by *P. longirostris* are determined by the dynamics and interaction of the waters of the cold Benguela Current whichpasses along the coast from south to north and the warm intermediate Angola Current flowing in the opposite direction , as well as the southeastern equatorial current that predominates in this area. As a result of the interaction of the currents, favourable conditions are created for the development of the eggs, young and adults of fish and invertebrates, as well as their food resources. The location of the zone of mixing varies with the force of the southern winds, intensifying or weakening the Benguela Current. On the other hand, the zone where optimal conditions are temporarily created for the young and adult individuals is most stable on the shelf near the mouth of the Cuene River (Kudersky, Komarov, 1962; Kudersky, Strogalev, 1973).

The size of *P. longirostris* varied from 30 to 125 mm. During the autumn-winter period, both the females and males had two modal groupings represented by the young and adult individuals, 40-60 mm and 90-110 mm. In the spring and summer catches, we noted only one mode, 70-90 mm, but the reliability of this is still difficult (81) to assess in view of the limited number of observations during this period.

The females dominate throughout the observation period (54.3-65.6%). Individuals with gonads at the 1st-3rd stages of maturity (growing period) dominate in January and June (weakening of south winds, intensification of the Angola Current, and, as a result of downwelling on the shelf, the formation of maximum biomasses of zooplankton). Spawning comes at the end of the summer and winter periods, and coincides with the intensification of the vertical water movements near the coast. The spawning peaks in September, at which time the catches contain up to 11% spawning females, i.e. the peak comes later than in the central and northern parts of the range (Crosnier et al., 1970; Burukovsky, 1981).

The young are usually found at depths of 230-250 m. The majority of the males begins to mature at a length of 70-80 mm, and the females at a length of 80-87 mm. Maturation takes place at the end of the first year of life; it continues for the same length of time in both sexes, for approximately 2 years at the southern boundary of the range. In spring, this species feeds quite inactively during the day; a relatively small number of full stomachs was noted only after midday. Foraminifers and amphipods were the most frequent items in their diet (48.3% and 44.1% respectively). Third on the list were fishes (39.9%) and polychaetes (39.2%), and these were followed by euphausiids and anisopods. Amphipods, euphausiids and polychaetes constituted 37.4%, 29.9% and 13.3% of the food bolus in volume. In other parts of the SE Atlantic, fish, shrimp and amphipods play a leading trophic role during this period (21.1%, 14.5% and 14.5% respectively).

UDC 595.384.12:(574.5:615.9)

Dependence of the level of chlorinated hydrocarbon accumulation on the weight of *Pandalus borealis* Kröyer

by V.M. Savinov and T.N. Savinova (MMBI)

Over the past ten years, the pink shrimp industry has been undergoing intensive development in the Barents Sea. Furthermore, (82) these shrimps are extensively used to control the level of chlorinated hydrocarbons in the northern seas (Portmann, 1979; Murray, 1979, 1981, 1982).

We have studied the content of residual chlorinated hydrocarbons in *P. borealis* caught in the western part of the Barents Sea.

The results of gas-chromatographic analysis revealed the presence of residual quantities of DDT and its metabolites (DDE, DDD), γ-hexachlorocyclohexane (Lindane) and polychlorinated biphenyls (PCB) in all the samples. The ratios of the average concentrations of these toxicants are 1:0.25:1, 17:1.88. The overall level of contamination of *P. borealis* does not exceed the national and international maximum allowable standards for these toxicants in sea products, i.e. 0.5-5.0 mg/kg of total DDT (Maugh, 1975) and 1 mg/kg PCB (Rentsch, 1982).

Analysis of the relationship between the concentration of residual quantities of toxicants and the weight of the shrimps (in the 1.0-10.0 g range) has revealed a negative correlation. The relationship values approximated equations of the $C=aW^b$ type, where C denotes the concentration of the toxicant, and W the weight of the shrimp. Coefficient **a** in the equations characterized the highest recorded levels of chorinated hydrocarbon contamination of the shrimps. **b** was equal to -1.101 for DDT, -1.681 for DDE, -1.212 for DDD, -0.840 for γ-hexachlorocyclohexane, and -0.870 for PCB. Analysis of these figures brings us to the following conclusions: the mechanisms of accumulation (elimination) of the given toxicants by the shrimps vary, due to the difference in their physicochemical properties; with an increase in the weight (age) of the shrimps, the processes of DDT metabolism become more active.

The results of our study show that the size of the shrimps (83) must be taken into account when they are being used for monitoring the detoxication of xenobiotics by crustaceans, or as a marketable product. The latter is particularly important, since 1 kg of small shrimps contains a much larger quantity of contaminants as compared with an equal haul of large shrimps.

UDC 595.384.12(265.518)

Dependence of body mass, total length and commercial length on the length of the carapace in prolific crangonids of the Bering Sea

V.M. Strelnikova (VNIRO)

Sclerocrangon boreas and *Sclerocrangon salebrosa* live in all of the Far Eastern seas in places with a low bottom temperature, but not deeper than 150-200 m, and they form small concentrations. A bonus catch of 450 kg is sometimes landed in half an hour of trawling. These species should be regarded as commercially promising ones for the nearest future.

The material for our study was collected during a joint VNIRO and TINRO expedition on the "Adler" trawler in the Bering Sea in June-July 1974.

The crustaceans were weighed, their sex determined, and the physiological condition of the females during this period established. The length of the carapace (l_c, mm) was measured from the eye socket to the middle of the dorsal surface of the carapace, the commercial length (L_{com}, mm) from the eye socket on the carapace to the end of the telson, and the total length (L_{tot}, mm) from the tip of the rostrum to the end of the telson. The females had no eggs on the pleopods during the observation period.

The measurements and weights of the shrimps were used to derive the dependences of fresh weight, total length and commercial length on the length of the carapace. The relationship between the body mass of the shrimps and the length of the carapace is an exponential one, while the relationship between body (84) size and the length of the carapace is a linear one. The parameters of the given relationships are given in the table below.

Dependence of body mass (W, r), total length (L_{tot}, mm and commercial length (L_{comm}, mm) on the length of the carapace (l_c, mm) in _Selerocrangon boreas_ and _S. salebrosa_

Relationship	No. of determinations	Coefficients		
		a	B	r
		S. salebrosa		
$L_{tot}-l_c$	247	-5.26	4.33	0.998
		S. boreas		
$L_{tot}-l_c$	394	-3.00	0.29	0.994
$L_{comm}-l_c$	394	-1.15	0.36	0.992
$W-l_c$	350	0.0018	2.93	0.992

UDC 595.383.1

Ecological study of the "green" krill phenomenon

by V.A. Sushin (AtlantNIRO), N.I. Sakhnov (KGU*), A.S. Fedotov (AtlantNIRO) and Yu.I. Zhurov (Kaliningrad branch of IOAN**)

As we know, the colour of Euphausia superba in the southern hemisphere changes from pink to green during the spring-summer period. This phenomenon, which is associated with an increase in the feeding intensity of the crustaceans and is referred to as the "green" krill phenomenon, is accompanied by a highly significant deterioration of the technological properties of raw krill. The study of this phenomenon from the ecological point of view is very important to the development of the commercial tactics for antarctic krill.

(85)

Our investigation is one of the first attempts made to study the problem of "green" krill from the ecological point of view.

Our material consisted of the data of two AtlantNIRO expeditions to the western part of the Atlantic sector of Antarctica during the appropriate seasons of 1983/84 and 1984/85.

The whole colour diversity of the crustaceans is differentiated into 4 main types based on the intensity of the green colour and the transparency of the liver (see table). Six variations of body colour are distinguished in each type. The colour types and variations have been tabulated as follows:

No.	Colour type	Colour of liver	Transparency of liver
I	Red (pink)	Colourless of slightly greenish	Transparent
II	Light green	Light green	Transparent
III	Green	Green	Slightly transparent
IV	Dark green	Dark green of various hues	Not transparent

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The intensity of feeding of _E. superba_ was determined by the degree of fullness of the gastrointestinal tract (GIT), which was calculated by the formula $\mathbf{D} = \frac{F+K_1+K_2+K_3+K_4}{20} \cdot 100$, where **D** denotes the degree of GIT fullness, %; **F** - the fullness of the stomach based on a 5-point scale (from 0 to 4); K_1, K_2, K_3, K_4 - the fullness of different parts of the intestine in the region of the cephalothorax, and the first, second and third pairs of the abdominal segments respectively, based on a 5-point scale.

Analysis of the material has shown that the clearly defined green colour in _E. superba_ (types III and IV) is observed when there is no diurnal rhythm of feeding and the degree of GIT fullness increases steadily to 64 and 75% respectively. A comparison of the distribution of colour types in the crustaceans and phytoplankton of the surface layer indicates that the "green" krill is confined to the zones with a higher than usual concentration of feed. An increase in feeding intensity and a change to a green colour were observed with a chlorophyll content in the surface layer equal to 0.62 $mg \cdot m^{-3}$.

(86)

UDC 591.524.11(265.53)

The feeding and food relationships of commercial invertebrates of Terpeniye Gulf (Sakhalin)

by V.D. Tabunkov and E.R. Chernysheva (SakhTINRO)

The biomass of the large forms of the invertebrate epifauna in the ecosystem of Terpeniye Gulf amounts to 200,000 tons. Ophiurans, starfishes, gastropods and crabs are distributed to the greatest extent throughout the gulf with the maximum concentration of biomass in its centre. Shrimps, holothurians and sea-urchins are concentrated closer to shore and at smaller depths.

During the spring, summer and autumn of 1978, 1982 and 1984, we studied the feeding of 8 species of shrimps (Sclerocrangon boreas, S. salebrosa, Mesocrangon communis, Argis lar, A. boreas, Lebbeus groenlandicus, Crangon dalli, Pandalus goniurus), 5 species of crabs (Paralithodes camtschatica, Chionoecetes opilio, Telmessus cheiragonus, Erimacrus isenbeckii, Hyas coarctatus), 5 species of hermit crabs (Pagurus ochotensis, P. undosus, P. pectinatus, P. brachiomastus, P. pubescens), ophiurans of the species Gorgonocephalus caryi, and holothurians of the species Cucumaria japonica.

The food spectra of the given species were quite diverse, except for those of the ophiurans and holothurians which feed on detritus. For example, the food of shrimps usually consisted of polychaetes (from 21.7 to 42.6% of the mass of the food bolus), mollusks (6.6-19.1%), and of various small crustaceans (2.7-37.1%). P. camtschatica and E. isenbeckii fed predominantly on crustaceans (about 60%) and mollusks (30-40%). T. cheiragonus and Ch. opilio showed a preference for worms (54.2 and 74.1% respectively). H. coarctatus foraged mainly on sipunculids (50.3%). At the same time, other benthonic organisms were also encountered in the stomachs of all the species of crabs. All the species of the genus Pagurus fed on crustaceans and polychaetes, mostly on gammarids, hyperiids, isopods and decapods (54.5-98.9%).

On the whole, the intensity of feeding of the given species was relatively low and time-dependent. For example, Ch. opilio and P. camtschatica fed more intensively (and fewer empty stomachs

(87)

were encountered) in spring (85.0‰ and 61.0‰ respectively), while S. boreas, S. salebrosa and G. caryi foraged more intensively in summer (147.9‰, 39.7‰ and 295.4‰ respectively). The index of fullness in autumn decreased on the whole in all the species studied, and did not exceed 28.4‰ (in P. pubescens).

The volume of competition between the invertebrates is also insignificant. The greatest similarity in food composition was observed, for example, between S. boreas and L. groenlandicus (49.7), A. lar (47.8), Ch. opilio (45.5) and P. pubescens (54.5), and between T. cheiragonus and Ch. opilio (47.3) in April, as well as between P. goniurus and S. salebrosa (70.4) in autumn. The food similarity between the rest of the species did not exceed 35.0.

The weak competition between the given species is due to the abundance of the benthos (Tabunkov, 1979), the nonconcurrence of the foraging grounds and ecological niches, and to the difference in food specialization.

References

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UDC 595.384.12(574.5:615.9)

Chronic effect of zinc on the grass shrimp (*Pandalus latirostris*) at the early stages of ontogenesis

by V.A. Ternovenko (TINRO)

One of the main factors that lower the efficiency of aquicultural establishments is the effect of pollutants on the hydrobionts being cultivated. The situation becomes more complex when aquiculture is conducted in inland waters, surface waters, or in shelf and estuarine areas which, at the same time, are the zones of pollution. We know of cases of mass destruction in aquicultural areas, metabolic disturbances as a result of low concentrations of toxicants, as well as disturbances in the biocommunication and behavioral and adaptive reactions of the organisms. (88)

We have studied the long-term effect of zinc on the commercially important grass shrimp at the early stages of development.

Larvae developing in a toxicant lagged in growth. The difference was already obvious at the age of two weeks, but these differences became particularly significant by the end of the third week of larval development, when the distance from the posterior margin of the eye to the tip of the telson equalled 14.6$\pm$1.2 mm in the control animals, and 12.6$\pm$1.8 mm and 11.9$\pm$2.1 mm for larvae from the 20 and 60 µg/l pollutant respectively. The differences in the weight of the animals are less significant. The body mass of month-old shrimps was 28.4$\pm$3.2 mg, 27$\pm$2.3 mg and 25$\pm$2.8 mg for the controls and for the 20 and 60 µg/l zinc levels respectively. This tendency was also observed at the later stages of development.

Toxicological tests indicate that the young of shrimps are capable of adapting to the pollutant. For example, the median lethal concentration of zinc amounted to 7.52 mg/l for the month-old control animals, 7.77 mg/l for the larvae developing in 20 µg/l of the pollutant, and 13.1 mg/l for shrimps from 60 µg/l of zinc. The adaptation to sublethal concentrations of zinc manifested itself in a higher resistance to copper as well [LD_{50} (48 h) 0.43 and 2.46 mg/l for the control and acclimatized animals).

The ability to avoid unfavourable environmental conditions was studied experimentally by means of a gradiometer. The avoidance reaction was observed at an age of 1.5 months in the controls, whereas a chemical sensitivity developed later in those acclimatized to zinc, a reaction to the latter being observed at the age of 2 months.

UDC 595.383.1

Ontogenetic migrations of euphausiids

Euphausiids are large planktonic crustaceans that form rather dense concentrations in certain areas of the world's oceans. The (89) fact that these crustaceans are a promising marketable commodity has made it necessary to study their life cycles in detail.

The life cycle of euphausiids is superposed on a chain of vertical migrations, including ontogenetic ones, i.e. related to the changes in depth in the process of their development.

The following three groups can be established on the basis of the ontogenetic migrations:

1. Species with full-cycle ontogenetic migrations (submersion of developing embryos with subsequent surfacing of the larvae. As the larvae develop, the depth of their habitat increases). The antarctic *Euphausia superba* is a typical representative of this group.

2. Species with incomplete-cycle ontogenetic migrations. This group is subdivided into a) species which carry the embryos in an ovisac and free themselves of the larvae in the upper layers of the water column, and in the process of development increase the depth of their habitat, and b) species which deposit their eggs

or free themselves of the larvae at considerable depths; the larvae then surface, but later on descend to the habitats of the adults.

For example, *Stylocheiron maximum* can be assigned to the first subgroup, and *Bentheuphausia amblyops* and *Thysanopoda microphthalma* to the second subgroup.

3. Species with no ontogenetic migrations (*Thysanopoda cornuta* and *T. egregia*).

Euphausiids inhabit mostly productive areas where a comparatively small number of species of randomly filter-feeding plankters develop in large numbers due to the abundance of phytoplankton there. Because of this, the submersion of the embryos beyond the layers in which the filter-feeders forage represents an adaptation aimed at reducing the mortality at the early stages of ontogenesis. The surfacing of the larvae is related to the onset of exogenous feeding, and is necessitated by the need for extra energy for metamorphosis. Consequently, the biological significance of ontogenetic migrations lies primarily in reducing the mortality of the embryos and larvae, and in increasing the ecological valence of the species as a whole.

(90)

UDC 595.384(268.45)

Distribution of decapod larvae in the coastal zone of Eastern Murman

by S.F. Timofeyev and S.V. Timofeyeva (MMBI)

The larvae of decapods constitute a significant part of the meroplankton and, because of the commercial exploitation of many of the species of these crustaceans, are being studied extensively.

The biology, distribution and population dynamics of Pandalus borealis have been studied relatively well in the Barents Sea (Lysyi, 1984). At the same time, the larvae of other Decapoda are practically always present in the plankton. We have attempted to show the ratio of the larvae of different decapod species in the plankton off the coast of Eastern Murman, as well as their distribution.

Our material consisted of plankton collected with a ИКС-80 egg net in May-June 1982 and September 1984 at profiles of the Kola meridian (33°30'E), Dal'nezelenetsky profile (36°06'-37°12' E) and Svyatoy Nos profile (39°48'-41°21' E). Samples were taken from the bottom—100 m, 100-50 m, 50-25 m and 25-0 m.

The May samples contained the larvae of Pandalus sp., Sabinea sp., Pagurus sp. and Hyas sp.; the larvae of Lithodes sp. were added to this list in June; only Pandalus sp., Munida sp. and Galathea sp. were encountered in September. An abundance of Pandalus sp. was noted in the Murman coastal current, the maximum numbers (2.4 specimens/m^3 being observed at the Dal'nezelenetsky profile. On the whole, these larvae dominated among the other Decapoda at the western profiles, i.e. the Kola meridian (94% of the total numbers in May, and 80% in June) and the Dal'nezelenetsky profile (84% in May and 71% in June). The same distribution was noted in the larvae of Sabinea sp., but they were encountered singly. In September, the larvae of Pandalus sp. were encountered in small numbers, and only on the Kola meridian; Munida sp. were found at individual stations at the Dal'nezelenetsky profile. In addition, one specimen of Galathea sp.

parasitized by the isopod Phryxus abdominalis was caught in the central branch of the North Cape Current.

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For the greater part of the day, the larvae of Pandalus sp. were concentrated in the 50-150 m layer, surfacing for a short time only during the evening (21.00-23.00), mainly to the 10-25 m layer.

At the eastern Svyatoy Nos profile, the dominant role among Decapoda at practically all the stations is played by the zoeae of Hyas sp. (47% in May and 62% in June). Their abundance in the samples is inversely related to the depth at the stations, and can amount to 50 and more specimens/m^3 in the shallow areas. The vertical distribution of the zoeae depends on the tidal currents. The maximum concentrations of larvae were noted in the surface layers during low tide , and in the near-bottom layers during high tide. The larvae of Pagurus sp. and Lithodes sp. were encountered singly only at this profile.

Thus, the larvae of Pandalus sp. and Hyas sp. are the dominant decapods in the plankton off the coast of Eastern Murman. The numbers of Pandalus sp. are the highest in the current carrying transformed Atlantic waters along the coast of the Kola Peninsula, while the zoeae of Hyas sp. keep to the shallow waters of the eastern regions.

UDC 551.463.8:551.464.7(262.7)

Distributional characteristics of suspended organic matter in the Sea of Cooperation during the summer of 1984

by I.N. Tribrat (AzCherNIRO)

In February 1984, the content of suspended organic matter (SOM) was determined in the Sea of Cooperation; among other things, SOM can serve as a source of food for antarctic euphausiids.

The SOM content in the surface layer varies from 32 to 905 μgC/l, an average of 197 μgC/l. The maximum concentrations were observed in the areas of anticyclonic vorticity, and minimum ones in the zone of antarctic divergence. Apart from being affected by biological productivity, the vertical distribution of SOM is greatly influenced by the hydrological structure of the waters, on the basis of which the northern, central and southern regions are distinguished.

(92)

The central region takes in the zone of antarctic divergence. Here, low concentrations of SOM are noted throughout the water column, except at the surface where the content of SOM increases somewhat.

In the northern part of the Sea of Cooperation, higher than usual concentrations of SOM were noted in the surface layer; furthermore, the accumulation of SOM was recorded in the layer of the summer pycnocline and at the boundary of the antarctic winter and circumpolar abyssal waters. These maxima did not usually go deeper than 200 m.

The distribution of SOM was of the most complex nature in the southern part of the area. Here, as in the north, we noted the following three maxima of SOM: 1 - at the surface, 2 - in the layer of the summer pycnocline at the 50-100 m horizon, and 3 - in the layer of the main pycnocline, at a depth of 500 m, where the concentration of SOM reached 100 μgC/l.

A distribution of this type is due to the fact that SOM accumulates at the surface and in the layer of the summer pycnocline during the summer. Its transport to the lower horizons begins with the approach of winter, when the waters become colder and the layer of the summer pycnocline dissipates. When the surface of the sea is covered with ice, the productive processes are virtually at a standstill, and so no fresh SOM is produced. The SOM that had accumulated at the surface during vegetation (and this includes both detritus, and living cells) will sink to the layer of the main pycnocline, i.e. to approximately 500 m, and on the shelf to the very bottom.

Stored in the water column as in a refrigerator, the organic matter, due to the low temperature and low microbiological activity, can serve as a source of food throughout the winter for larger living organisms, including euphausiids.

UDC 595.384.2 (93)

Characteristics of the reproductive process in the snow crab *Chionoecetes opilio*

by V.Ya. Fedoseyev (TINRO)

Ch. opilio belongs to the animals with a clearly defined seasonal reproductive cycle. The larvae, which develop on the pleopods of the female, hatch out in spring. However, the mating of the animals and the laying of a new batch of eggs can be lengthy processes. This is due to the peculiarity of the histological structure and functioning of their reproductive system.

The male reproductive system consists of paired organs, each of which in turn consists of a testis, sperm duct, spermatophore sac, rosette and vas deferens. The testis has the form of a thin contorted tubule which is segmented on the inside. The segments are separated from each other by a small layer of connective tissue. Each segment of the testis consists of two chambers in which two generations of germ cells develop asynchronously in relation to each other.

A wave of spermatogenic epithelium extends the length of the testis in the snow crab. It is characterized by ordered distribution of asynchronously developing generations of germ cells along the sperm duct. As a result of this, the testis is never equally mature throughout. All the forms of germ cells (spermatogonia, spermatocytes, spermatids and spermatozoa) are encountered in it at any time of the year. Owing to the wave of spermatogenic epithelium, the formation of spermatozoa is not confined to any particular season; it occurs continuously. Spermatogenesis is not a lengthy process in the snow crab. The period of development from spermatogonia to spermatozoa lasts 84 days. From the testis, the spermatozoa enter to sperm duct where they become spermatophores. The spermatophores then accumulate in the spermatophore sac where they are stored up to the time of copulation. Because of this, the males of the snow crab are ready for copulation at practically any time of the year. Based on the number of genital products present at the time of spawning, the snow crabs are classified into two size groups. Prior to spawning, the spermatophore sac contains approximately 200,000 spermatophores in small males (width of carapace up to 10 cm), and about 400,000 in the older age group (width of carapace over 10 cm). (94)

The spawning period in snow crabs may last for several months. The small crabs are the most active at the onset of spawning, while the older animals are more active towards the end of it.

After copulation, the spermatozoids are found in the internal spermathecae of the females, where they can be stored for more than a year and used for the fertilization of mature eggs during this period (Hartnoll, 1981).

UDC 595.383.1(269.4)

Euphausiid larvae in some areas of the eastern part of the Atlantic sector of Antarctica in the late summer and autumn of the southern hemisphere in 1983

by A.S. Fedotov (AtlantNIRO)

The larvae of euphausiids are a significant component of the pelagic coenoses of the Southern Ocean, and they play a particularly important role during the vegetative period when they constitute a large portion of the biomass of the zoocoenosis. This has evoked great interest among researchers in the distribution and qualitative composition of the larvae of antarctic euphausiids.

On the basis of the plankton samples collected during the 4th trip of the "Vol'nyi Veter" trawler-freezer (in the 0-100 m layer with 36/50 Juday and 80/113 Bogorov-Russ nets, mesh No. 38) in the coastal and oceanic parts of the Lazarev and Riiser-Larsen seas (from January 12th to April 22nd 1983; no observations were carried out in March), we analyzed the seasonal age composition and distribution of the euphausiid larvae.

The larvae of four species of euphausiids were encountered in the study area - *Euphausia frigida*, *E. superba*, *E. crystallorophias* and *Thysanoessa macrura*. The larvae of *E. frigida* were not encountered south of 51°20' S lat. The larvae of *E. crystallorophias* were encountered exclusively in the neritic region (along the mainland between 67° S lat and the coast). The larvae (95)
of *E. superba* were encountered mainly beyond the continental slope, the highest concentrations being found in the seamount zones in the vicinity of the Maud Seamount and further out to sea from Leningradsky Bay. The latter may be an indication of the spawning efficiency of *E. superba* in these areas.

The larvae of *Th. macrura* were distributed more extensively. Large accumulations of them were noted both in the oceanic, and in the coastal parts of the range.

In February, the larvae of *E. crystallorophias* were represented by calyptopes I-III (93%); larvae older than furcilia II were not observed. In February, the larvae of *E. superba* consisted exclusively of calyptopes I-II (100%). In April, a large part of the larvae was already at the stages of furcilia I-III.

The larvae of *Th. macrura* were far ahead of the rest of the species of euphausiids in their development during the seasons they were encountered together. Among the larval forms of *Th. macrura*, furcilias I-III dominated in February, and late furcilias (stages IV-VII) dominated in April. By the end of April, there were hardly any young or middle stages (calyptopis—furcilia III) in the *Th. macrura* population.

As we can see, the euphausiid larvae of the study area are characterized by nonconcurrence of the developmental stages, which is most likely due to the differences in the time at which these species of antarctic euphausiids begin to reproduce. For example, it is a well-known fact that *E. superba* is the last of the species to begin spawning in low-latitude regions such as the Scotia Sea, and *Th. macrura* is the earliest spawner (Makarov, 1979). However, our material has shown that a similar reproduction time sequence is preserved in the euphausiids of the high Antarctic region as well. *Th. macrura* begins to spawn first, then *E. crystallorophias*, and finally *E. superba*.

(96)

UDC 591.524.12:595.34(268.45)

Role of the age stages of *Calanus* in the formation of the total zooplankton biomass in the coastal waters of Murman

by O.K. Fomin (MMBI)

One of the ways in which we can increase seafood production is by commercial exploitation of pelagic phytophagous crustaceans, including the North Atlantic *Calanus* (Vinogradov, 1979). Though the profitable utilization of this crustacean as a direct source of proteins for human consumption still poses a problem (Erhard, Sezhen, 1984), this does not exclude the possibility of utilizing it efficiently as a food supplement for fish, in the vitamin, pharmaceutical and perfume industries, as well as for technical needs.

Intensification of fishing for plankton-eating fishes in the coastal zone of Eastern Murman may bring about the under-utilization of a part of the secondary product and, consequently, its removal from the sea.*

The space and time distribution of the age stages of the prolific Barents Sea *Calanus finmarchicus* was determined on the basis of the coastal population off Eastern Murman. Because of complex hydrologic conditions, the population of this area is dependent on the transport to this area of some individuals from the west. This proportion at some stages of the life cycle of the spring-summer generation can amount to 35% of the total number of age-equivalent stages.

The biochemical composition of these crustaceans, i.e. their nutritional value, varies with age.

The quantitative content of live zooplankton in the photic layer of the coast during the year is 30-1500 mg/m^3. The *Calanus* product that forms during the spring-summer peak period (May-July) constitutes 80% of the total annual production of *Calanus*, or 60% of the total annual production of zooplankton. The biomass of *Calanus* under 1 km^2 of a 100-metre column of subsurface waters is equal to 12.5 tons.

The curve describing the dynamics of *Calanus* abundance and biomass during the spring-summer peak period has two peaks in all of the layers of water studied. The first peak (beginning of June) (97)
is well-defined, and is due to the presence of copepodites of the 3rd, 4th and 2nd stages in the 10-0, 25-10,50-25 and 75-50 m layers (40, 30 and 20% respectively), and to the presence of copepodites

*Meaning of Russian sentence highly obscure - transl.

of the 4th, 5th and 2nd stages and mature females in the 100-75 m layer (31, 13, 10 and 10% of the total *Calanus* biomass respectively). The appearance of a second peak (end of July) in the 10-0, 25-10 and 50-25 m layers is due to the appearance of a large number of copepodites of the 5th stage (90-95%). The second peak is weakly defined in the 75-50 m layer. The formation of a peak in July in the 100-75 m layer is due to the presence of copepodites of the 5th and 4th stages (69 and 26% respectively). The biomass of the naupliar stages amounts to about 10% of the total *Calanus* biomass, and its role in the formation of the productive layers is evident only at the time the spring-summer peak begins to form in the 10-0 and 25-10 m layers. The second autumn peak in the zooplankton and *Calanus* biomass is 10-15 times weaker than the first, and so it does not play a significant role in the accumulation of the plankton food reserves in the coastal zone. The results of our study make it possible to catch *Calanus* selectively for experimental and commercial purposes.

UDC 595.384(267.6)

Buoyancy and hydrostatic adaptations of phyllosoma larvae of *Scyllarides* sp. (Scyllaridae, Decapoda) from the Sumatra-Java region of the Indian Ocean

by S.A. Khvorov (INBYuM)

We studied the average density and buoyancy of phyllosoma larvae of *Scyllarides* sp. from the epipelagic zone of the Sumatra-Java region of the Indian Ocean.

We have established that the buoyancy of the larvae varies within the planktonic range of Δ values (from -0.03 to -0.06), being clearly negative on the whole. The variation in the buoyancy of phyllosoma larvae is apparently of an ontogenetic nature, since the lowest buoyancy is observed in 80 mm larvae, and the highest buoyancy in 29 mm larvae. A decrease in buoyancy in the course of biological development reflects the transition of the larvae from a planktonic to a benthonic mode of life.

The negative buoyancy of phyllosoma larvae is an indication (98)
that they expend a certain amount of energy on swimming movements. The value of these energy expenditures decreases as the larvae develop a system of hydrostatic and hydrodynamic adaptations aimed at reducing the rate of gravitational sinking.

Our study of the hydrostatic adaptations of phyllosoma larvae has shown that the absolute and relative thickness of their weakly calcified exoskeletons is by an order of magnitude smaller than that of benthonic crustaceans of the same size. Furthermore, phyllosoma larvae are capable of increasing the buoyancy of their body by accumulating water in the cavity of the cephalic shield, as indicated by its transparency and dorsoventral thickening. This visually noted change in the volume of the liquid in the cavity of the shield has caused ecologically significant buoyancy variations within a range of hundredths of a unit. The mechanism of water transport is still unknown.

The hydrodynamic adaptations involve the development of an efficient parachute system consisting of a discoid cephalic shield and fanlike pereiopods. With an increase in the size of the larvae, this system becomes more efficient due to an increase in the vertical area of their body.

UDC 595.383.1:571.526.325(269.4)

Primary production and estimated biomass of euphausiids in the West Atlantic sector of the Southern Ocean

by Yu.A. Shulyakovsky (AtlantNIRO)

A change in primary production (PP) was observed in the western part of the Atlantic sector of Antarctica from November 1984 to February 1985.

Off the South Shetland Islands northwest of Mordvinov Is., the average PP values amounted to 343.4 mgC/m^2/day in the second half of November, 612.0 during the first ten days of December, 543.9 during the third ten days of December, and 496.9 mgC/m^2/day in January. Off the South Orkney Islands, primary production was (99)
1359.0 mgC/m^2/day in the middle of November, 852.2 in the middle of December, and 477.2 mgC/m^2/day at the beginning of February. The substantial December decrease in transparency (disc turned white) along with an increase in primary production could have been the result of a local increase in productivity due to dynamic causes. The phytoplankton of both areas was probably over the peak of its development at the time our investigations began.

The values of the maturity index of the community, calculated on the basis of production data and the value of destruction of heterotrophs (Vinogradov, Shushkina, 1985), have shown that the development of the plankton community off the South Orkney Islands is slower than in the area of the South Shetland Islands. During the observation period (November-February), we noted a steady increase in the maturity index in both areas.

The photosynthetic efficiency off the South Orkney Islands from November to February decreases from 1.42 to 0.76% of the photosynthetically active radiation (PhAR), averaging approximately 1.0% on the background of a decrease in the quantity of phytoplankton and fairly high values of diminishing radiation. The efficiency level is somewhat lower off Mordvinov Is. (South Shetland Island), constituting 0.49, 0.69, 0.67, 0.66 and 0.65 % in November, the first and third 10 days of December, January and the beginning of February respectively (average for the entire period 0.63% of PhAR).

The results of PP determination were then used to determine the biomass of the main consumer of the newly formed organic matter in these areas (macrozooplankton, e.g. euphausiids).

Calculations have shown that the yield of primary production from November to January in the vicinity of Mordvinov Is. could have met the energy requirements of 205,000-620,000 tons of euphausiids. In the vicinity of the South Orkney Islands, the values of euphausiid biomass based on the production indices amounted to 40,900-136,300 tons in the middle of December.

The wide range of changes in the estimated biomass values is due to the different proportions of euphausiids in the total zooplankton (from 30 to 100%).

(100)

UDC 639.512

Cultivation of shrimp in the Shabolat Liman

by V.V. Yaremenko and T.L. Pankratova (Odessa branch of AzCherNIRO)

Prior to 1985, the commercial exploitation of *Palaemon adspersus*, used as a food supplement for farm animals, was not extensive in the northwestern part of the Black Sea. As the stock diminished, only individual fishermen went after this shrimp. The decrease in the stock of this species raised the question of its artificial cultivation.

P. adspersus is characterized by a rapid rate of growth; it reaches marketable size in a single vegetative period. In 1984, cultivation of this species was carried out in the following stages at the "Budaki" fish station of the Experimental Mullets Plant in the Shabolat Liman: the capture of adult shrimps, the placement of the latter in troughs, the production and raising of the larvae, the transference of the latter to a nursery basin and the raising of them to adults. The cultivation period lasted from June to September, with the water temperature at 17-22°C, salinity at 13-15‰, and oxygen concentration at 8.2-10.6 mg/l.

Paired Yeya-type troughs were used as the breeding containers. Three rectangular troughs were set up parallel to each other at a 10° slant. A closed water circulation system was used; the water was fed by two air lift pumps from the middle trough into the side ones at the beginning of the slope, and by siphons into the middle trough at the end of the troughs. The troughs were aired with air passed through 3 litres of a mixture of ion-exchange resins

and a 10% solution of $KMnO_4$. Acidity was reduced by means of macrophytes. At the beginning of June, the middle trough was filled with about 1.6 m^3 of purified Shabolat water to which 2.4 kg of minced fish (1.5 kg/m^3) was added for the development of microalgae and infusorians. By the fifth day, the environment in the trough had stabilized, the water had become clearer, the oxygen level had returned to 8.8-10.5 mg/l, with pH 8.6 and the density of the microalgae at 12,000 cells/l. By that time, the side troughs had been filled with filtered liman water (gauze No. 55) and five artificial shelters (nylon spools used for thread in the textile industry) placed in each trough. Eight gravid (101)
females and 12 males were placed in each of these containers. Larvae appeared on the 3rd-4th day; the hatching continued for 6 days. During the first 10-20 days, they fed on microalgae and infusorians; having attained a length of 3.5-8.4 mm, the larvae were transferred to a 75 m^3 nursery basin. The water from the liman was filtered through a conical net (gauze No. 20); the young were prevented from leaving the basin by a net (gauze No. 45) at the spillway. A total of 48,000 young was transplanted. In addition to the microalgae in the basin, the larvae and young began to consume planktonic organisms (rotifers, copepod nauplii); larvae at the mysis stage were also given *Artemia* nauplii periodically, and, as they grew, minced mussel and anchovy (1:1) was added to their diet. In September, the females had a length of 5.5-8.8 cm (average 7.1 cm) and an average mass of 3.42 g, and constituted only 38.5% of the total numbers. There were more males, but their size ranged from 2.5 to 4.5 cm (average 3.5 cm),

and they weighed 0.15-0.9 (0.52 g). A total of 2640 shrimps was raised.

Our experiment has shown that it is possible to cultivate shrimps under the conditions of the northwestern part of the Black Sea area.

UDC 595.383.1(269.7)

New data on antarctic krill

by N.I. Mironenko (AzCherNIRO)

An estimate of the eggs and larvae of antarctic krill was carried out during mesoscale surveys in areas of stable commercial aggregations in the Sea of Cooperation in 1980 and 1984. In both cases, the commercial aggregations of these crustaceans were found in the boundary zone of the shelf and continental slope. The eggs and larvae were taken from the standard layers 0-25, 25-50, 50-100, 100-200 and 200-500 m with a JOM* net (gauze No. 49).

The results were similar for both cases.

In the areas studied, the eggs and larvae were found at (101)
different stages of development, from metanauplii to furcillia larvae of the 1st-3rd stages. At the same time, the usual vertical distribution of the larvae was observed, i.e. the early stages (metanauplii) were confined to the bottom layers of water, and the later stages to the upper layers. However, contrary to our expectations, the concentration of krill eggs and larvae in the areas of commercial aggregations of krill was insignificant and characteristic of open waters. Analysis of the combined oceanological data of a number of expeditions indicates that the

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*acronym unknown; perhaps the author is referring to a Juday plankton net - transl.

low concentrations of larvae and, therefore, the low spawning efficiency of krill in the areas of its commercial aggregations is due to the fact that the eggs are carried to the deep-sea part of the range by the currents.

UDC 595.383.1:639.28:639.2.)53.1(269)

Main results of ecosystem research in the areas of distribution of antarctic krill

by E.Z. Samyshev (AzCherNIRO)

Based on the example of a model region comprising a part of the *Euphausia superba* "ring" of distribution between 55° and 90° E long., we conducted our regular set of observations aimed at eventually substantiating the rate of commercial elimination of this crustacean from 1977 to 1984. We studied the functional structure of the geographic range, the tendencies of distribution and the quantitative characteristics of the krill population, its bioenergetics, the composition, abundance and production of the phytoplankton and bacterioplankton, the composition and abundance of the micro- and mesozooplankton, the content and distribution of suspended organic matter, as well as oceanographic conditions.

Efficient spawning of krill is possible only in the coastal zone of the shelf and in the shallow waters above seamounts. The large part of the species range located above abyssal areas is virtually the zone of gradual expatriation of the animals, the intensity (and efficiency) of which increases northward. The specific nature of the hydrostructure within the area and the

life cycle of _Euphausia superba_ determine the most important characteristics of its population. It would appear that, due (103)
to the extreme ruggedness of the Antarctica coastline which lends relative stability to the system of circulations (topogenic effect), an environment conducive to prolonged isolation of a part of the population is formed in the seas close to the continent; on the other hand, the presence of large-scale currents and the variability of the local coastal circulations determine in the long run the genetic unity of the entire population. The formation of large krill aggregations is determined by the gregarious mode of life of this species and its active feeding behaviour, probably with the proper combination of favourable factors (stationary circulations and high concentrations of phytoplankton).

The quantitative characteristics of the krill population (its size, concentration) undergo long-term fluctuations which, being related to the intensity of expatriation of the mature animals, are determined by the variability in the intensity of the regional large-scale cyclonic circulations which in turn are determined by the changes in the direction and intensity of the atmospheric transfers.

Calculated on the basis of experimentally determined bioenergetic characteristics (with the seasonal changes in feeding intensity taken into account), the annual P/B coefficient for the adult part of the krill population is approximately 1.0.

According to the results of model and balance estimates, the calculated values of primary production are considerably lower than the actual ones under natural conditions. The latter in the given region reach 1.5-3.0 gCm^{-2} and more for the photic layer in the middle of summer.

The development of the phytoplankton is characterized by the localness of successional phenomena, the constant dominance of forms characteristic of the second phase of successions superposed on the background of continuous return to its initial stage, determined by the nonuniformity and variability of the hydrologic structure, as well as by the year-to-year variability in abundance due to the varying degree of mixing of waters above the seasonal pycnocline.

The space and time changes in the structure of the mesoplankton manifest themselves mainly in the structural changes of the coarse and fine filterers dominant in it.

In summer, the total consumption of energy by heterotrophic organisms amounts to 20-25% of the energy produced; of this, (104)
60-80% is due to bacteria and infusorians; 75-80% of the primary production forms detritus daily.

The data obtained on the functional role of the main components of plankton communities have enabled us to verify the data of a direct estimation of krill.

The theoretically possible size of a krill catch in the region is determined by the size of the population during a specific year, and varies up to 6—7-fold in accordance with its fluctuation. The actual haul requires correction with the availability of the target taken into account, and, theoretically, is several times lower.

UDC 639.28

Methods of calculating the quantity of *Euphausia superba*

by E.Z. Samyshev and N.G. Petrova (AzCherNIRO)

The extensive geographic range of the species and the irregular aggregated nature of krill distribution due to the non-uniformity of environmental conditions, as well as the gregarious mode of life and active behaviour of the animals make it difficult to count them directly. Because of this, the quantitative determination of the *Euphausia superba* population on the basis of observations on limited areas has resulted in conflicting results in the majority of expeditions, regardless of the technology used.

An alternative to this is to take a direct count of *Euphausia superba* in "rings" enclosed in unified quasistationary large-scale circulation systems and consisting of various structural components characteristic of the range as a whole, i.e. components that can serve as a unique model. The main advantages of this approach lie primarily in the information content of the data derived (all the functional characteristics of the population are placed under observation), and also in the possibility of carrying out surveys (both one-time surveys and regular ones) by a small number of vessels (even one).

Long-term investigations (1977-1985) in the region of the Sea of Cooperation have shown that this is the competent way (105)
of solving the problem. A method based on echo recordings and the data of trawl catches has been developed for counting the animals. The relative size of the echo sounding area is one of

the major conditions that determine the statistical reliability of the information. We have established that its optimal value for the given region is 0.2%. As this value decreases, we observe an increase in the superposition of the Poisson process on the parametric values of aggregations (their size, mass) which are usually characterized by logarithmically normal distribution. The permissible minimum of this factor should not be lower by more than an order. The volume of the essential information based on trawl catches is determined by the nature of the distribution of aggregations and the types of concentrations. The processing of the data after that was carried out on a computer in accordance with a developed algorithm. The data derived were transferred to a map. The final calculations were carried out after the appropriate interpolation and selection of similar parts in the mass of information.

The results proved to be similar to those of the FIBEX krill survey for the corresponding periods; they also enabled us to detect significant year-to-year fluctuations in the quantitative characteristics of the krill population, fluctuations related to large-scale changes in the atmosphere and hydrosphere.

(106)

FRESHWATER COMMERCIAL CRUSTACEANS (CRAYFISH, SHRIMP)

UDC 595.384.12

Potentials of the generative growth of shrimps

by A.V. Alekhnovich, V.M. Baichorov (Institute of Zoology of the Academy of Sciences of the Byelorussian SSR)

By studying the reproductive potentials of shrimps, we can determine the tendencies of their reproduction and find the practical solutions to the problems of preserving, exploiting and cultivating them. We have studied the reproductive characteristics of tropical, subtropical, boreal and arctic species of shrimps. The species studied differ significantly in their size. Because of this, it is impossible to compare their reproductive values directly.

The following indices were used for comparative analysis of the energy expended on reproduction in shrimps of different species: reproductive effort (E^1) and the rate of generative growth (P_{ov}). By E^1 we mean the ratio of the energy equivalent of oviposition to an analogous coefficient of a female without generative products. The value of P_{ov} is determined as the ratio of the energy equivalent of the mass of the egg deposit to the time it takes the egg deposit to form. Since not all of the eggs survive and the dry mass and caloricity decrease in the process of their development, we used only eggs at the initial stages of cleavage to determine the different values of reproduction.

The reproductive effort in subtropical, boreal and arctic species of shrimps varied from 0.25 to 0.60, increasing as we moved farther north. The lowest reproductive effort (0.14) was noted in the tropical species Macrobrachium rosenbergii. On the basis of our results, we can say that a reproductive effort equal to 60% of the energy equivalent of a female approximates the highest one possible for shrimps. When determining reproductive (107) potentials, we must analyze the time-related dynamics of the reproductive parameters, in addition to the relative values.

If we equate the length of the generative cycle to the length of embryogenesis (D_q) and the reproductive effort to 0.60, the highest possible rate of generative growth (P_{max}) will be derived by the formula $P_{max} \leqslant \frac{0.6 \cdot C_♀}{D_q}$, where $C_♀$ denotes the energy equivalent of a female without generative products. By this formula, we can roughly determine the limits of the generative growth of shrimps, and in this way assess their potentials (see table below).

Species	P_{ov}, $cal \cdot indiv^{-1} day^{-1}$	P_{max}, $cal \cdot indiv^{-1} day^{-1}$	P_{ov}/P_{max}, %
Macrobrachium rosenbergii	149	641	23
Macrobrachium nipponense	16	35	46
Pandalus kessleri	13	23	58
Palaemon elegans	41	51	80

Thus, the experimentally derived rates of generative growth approximate the maximum ones as we move from the tropical species to the boreal ones. This indicates that the reproductive potentials of shrimps are realized to a greater extent in a temperate climatic zone, due to the fact that the reproductive season is shorter.

UDC 595.384.12

Lethal temperatures of the eastern river shrimp from the cooler reservoir of the Beryozovsky State Regional Electric Power Plant

by Yu.G. Giginyak (Institute of Zoology of the Academy of Sciences of the Byelorussian SSR)

Determination of the temperature range of survival for hydrobionts, particularly commercial invertebrates, gives us some idea of their potentials for survival, acclimatization and dispersal in water bodies with different temperature conditions. Among the freshwater shrimps found in our country, the subtropical species (108) *Macrobrachium nipponense* (eastern river shrimp), introduced to the USSR from the Far East, occupies a special place at the present time. The naturalization of this species has been most successful in the cooler reservoir of the Beryozovsky SREPP (Byelorussian SSR) where these shrimps can endure the highest possible temperatures for this body of water (35-36°C), and have already become part of the diet of the perch, trout, catfish and a number of other fishes.

The lethal temperatures for shrimps were determined by increasing (or reducing) the temperature of the water containing the shrimps at a rate of 1-5° per hour.

In the shrimps studied from the cooler reservoir system of the Beryozovsky SREPP, we noted a correlation between the upper lethal temperature of survival and the temperature of the habitat which, on the whole, depends on the season. The correlations between these temperatures were as follows: 30°:8°, 32°:10°,

$35^{\circ}:14^{\circ}$, $39-40^{\circ}:20-21^{\circ}$, $39-40^{\circ}:24^{\circ}$, $39-40^{\circ}:30^{\circ}$ and $39-40^{\circ}:35^{\circ}$. However, this correlation is observed only up to the time when a temperature of $20-22^{\circ}$ is reached and the shrimps begin to breed. After that, the upper lethal temperature fluctuates slightly around $39-40^{\circ}$, which is the upper lethal temperature for the larvae, juvenile stages and adults of shrimps. All of this evidently indicates that by the time the reservoir heats up to $20-22^{\circ}$, the point at which the shrimps begin to breed, their thermal adaptive capacities peak, and all the vital processes after that are aimed mainly at reproduction. Before the water in the reservoir reaches $20-22^{\circ}$, the difference between the upper lethal temperature and the temperature of the habitat is practically always about 20°. It decreases after that.

The lower lethal temperature for larvae was found to be $4-5^{\circ}C$ (100% survival up to 8°, 80-20% at 7°, 10% at 6°, and 0% at $4-5^{\circ}$). We found that it was possible for larvae to hatch from ovigerous females found in $3-5^{\circ}$ water for 5-12 hours. The lower lethal temperature for juvenile and sexually mature shrimps lies in the range of $1-3^{\circ}$, at which point both the reproductive, and the trophic functions are blocked. Among other things, we noted that the shrimps stop feeding at $8-10^{\circ}C$, and they cease to breed at temperatures under $20^{\circ}C$. Even with their abdomen frozen into the ice, the shrimps still stay alive, moving their gressorial limbs. (109)
On the whole, the lethal temperatures are $3-5^{\circ}$ lower than the temperatures at which hydrobionts can survive for a long time.

Thus, the temperature range between the lower and the upper lethal temperatures in shrimps from the cooler reservoir of the

Beryozovsky SREPP varies from 2-7° to 39-40°. Such a wide temperature range points to the high ecological flexibility of this valuable commercial species, and permits us to recommend the introduction of it in reservoirs with a higher than usual temperature, particularly the cooler reservoirs of thermal electric power plants and atomic electric power plants.

UDC 595.384.16

The introduction of crayfish and the prediction of their adaptability to a new habitat

by Yu.V. Doroshenko and A.Yu. Rukshenas (IZIP AN LitSSR)*

A study of the behavioral adaptation of the young of crayfish (the material to be introduced) can help us predict the success of their introduction into new bodies of water. Chemoreception plays a special role in the life of aquatic organisms. The normal functioning of the systems of chemoreceptors enables the animal to survive in unstable and, occasionally, highly contaminated environments. It would be extremely interesting to learn about the chemical sensitivity of crayfish in the course of their biological development.

The behavioral escape reaction was chosen as the criterion of assessment of the reaction of crayfish to a nonhomeostatic environment. We attempted to determine the presence and nature of this reaction in the young of crayfish at the early stages of their development (3rd larval stage). The somewhat modified gradiometer (Cherkashina, 1983) used for this enabled us to determine the threshold of chemical sensitivity in the young of crayfish.

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An aqueous solution of $ZnSO_4 \cdot 7H_2O$ was used as the test toxicant.

The following three types of behavioral responses to various concentrations of the toxicant were noted: 1) the absence of a reaction with a concentration of 0.01-0.02%, 2) the escape reaction (jerk of the tail) with concentrations from 0.025 to 0.028%, and 3) the reaction of dying or stiffening (no movements of effector organs) with concentrations from 0.03 to 2.0% and higher.

The use and improvement of the given method of bioassay will help us to decide which body of water to choose for the introduction of crayfish, and will in this way ensure the success of the venture.

UDC 639.512

Monoculture and polyculture of the subtropical freshwater shrimp *Macrobrachium nipponense* (de Haan) in the waste water of a thermal electric power plant

by V.F. Kulesh (Institute of Biology of the Academy of Sciences of the Byelorussian SSR)

The subtropical freshwater shrimp *Macrobrachium nipponense* is a new useful element of the fauna found in the cooler reservoirs of thermal electric power plants (Khmeleva, Giginyak, Kulesh, 1982). In 1982, these shrimps were successfully introduced in the cooler reservoir of the Beryozovsky State Regional Electric Power Plant in the Byelorussian SSR. As further investigations have shown, the introduction was successful. The shrimps dispersed throughout the ecosystem of the cooler reservoir, and became part of the diet of the perch, trout and catfish there.

This species is also a promising one for aquiculture. However, in order to assess the profitability of cultivation, we must study the growth potentials of this species under different maintenance conditions. With monoculture of the shrimps in ponds or tanks, the water mass remains basically free of them, since shrimps are bottom-dwelling animals. This can lead to uncontrolled development of planktonic unicellular algae, filamentous benthos algae, etc., which causes anoxia, ecological instability, etc. One of the ways of solving this problem is to cultivate the shrimps together with fish species suitable for this purpose (Cohen, Ra'anan, 1983).

In this connection, we undertook to study the weight indices (111)
of growth in Macrobrachium nipponense in closed metal tanks (50x50x70 cm) placed in a reservoir with carp, and in tanks of the same size placed in a pond. Water from a warm run-off canal of the Beryozovsky SREPP was continuously fed into the reservoirs and experimental ponds. The density of stocking was 60 shrimps/m^3.

Date	Length of cultivation, days	Fresh mass of shrimps, mg	
		monoculture	polyculture
Nov. 26	0	234.9	226.0
Jan. 30	65	262.8	305.2
April 25	150	282.0	430.0

As we can see from the table, 5-month polyculture of young shrimps and carp produced good results. At the same time, the ultimate mass of the individuals raised in carp reservoirs was 35% greater than that of the monoculture animals, despite the low temperature in winter (9-12°C). There was no supplementary feeding in either of the variants. The shrimps fed only on the natural supply of food developing in the tanks. The main food of the shrimps in the fish reservoirs consisted of the remains of the mixed feeds given to the carps, which accumulated on the bottom and were not consumed by the carp directly. In this respect, the shrimps also play the role of sanitationists, which is particularly important when cultivating fish, especially in summer when a deficiency of oxygen arises due to greater contamination of the water with food waste.

Consequently, _Macrobrachium nipponense_ can be recommended for cultivation in closed tanks together with carp and other species of fish.

UDC 595.384.16 (112)

Study of the biochemical polymorphism of the long-clawed crayfish, _Astacus leptodactylus_

by V.V. Makarenko, V.F. Bezrukov (UkrNIRKh*, Kiev State University)

Our research was devoted to the search for the polymorphic enzymes of the long-clawed crayfish, which could be used for studying the genetic structure of the populations of this species. We studied the tissue specificity and variability of the following enzymes: acidic phosphatase, alkaline phosphatase, esterase, alcohol dehydrogenase (ADH), amylase, proteases, peroxidase, catalase, ribonucleases, desoxyribonucleases, α-glycerophosphate dehydrogenase (α-GPDH), diaphorase, glyceraldehyde-3-phosphate dehydrogenase (G-3-PDH), glucose-6-phosphate dehydrogenase (G-6-PDH), 6-phosphogluconate dehydrogenase (6-PGDH), xanthine

*Ukrainian Scientific Research Institute of Fisheries - transl.

dehydrogenase (XDH), lactate dehydrogenase (LDH), malate dehydrogenase (MDH), phosphoglucomutase (PGM), tetrazole oxidase (TO), the malic enzyme and the abundant proteins of the haemolymph. The haemolymph, muscles, hepatopancreas, testes and ovaries were taken for analysis. The method of disc-electrophoresis in 10% and 7% polyacrylamide gel and in 12% starch gel in various buffer systems was used.

After selecting the optimal separation and staining conditions, we detected a variability in the electrophoretic mobility of esterase (in the hepatopancreas and muscles), alkaline DNA-ase (in the muscles), peroxidase (hepatopancreas and muscles), TO (hepatopancreas), amylase (muscles), G-3-PDH, G-6-PDH, 6-PGDH, α-GPDH and the abundant proteins of the haemolymph.

Of these, G-3-PDH, G-6-PDH, 6-PGDH and α-GPDH had identical enzymograms; the use of different buffer systems did not alter the similarity. This permits us to assume that in this case, one and the same enzyme with a fairly extensive substrate specificity appeared in the gels.

The variability of alkaline phosphatase, XDH, the malic enzyme and alkaline RNA-ase was vague, and the causes of their variability are still not clear. Well-defined spectra with a fairly clear genetic interpretation of variability were obtained for esterase, TO, alkaline DNA-ase, peroxidase and the abundant proteins (113)
of the haemolymph. The rest of the proteins and enzymes were monomorphic.

The derived biochemical markers were used to study the genetic structure of three populations of crayfish.

UDC 595.384.16

Influence of feeding on the level of metabolism in the young of *Pacifastacus leniusculus*

by G.Yu. Matskyavichene (Institute of Zoology and Parasitology of the Academy of Sciences of the Lithuanian SSR)

The successful acclimatization and artificial breeding of a new promising species of freshwater crustaceans, the American *Pacifastacus leniusculus*, depend primarily on the solution of the problem concerning supplementary feeding of the young during cultivation. The nature and intensity of feeding, the food requirements and the level of metabolism change in the young of river crayfish at the early stages of ontogenesis (Tsukerzis, 1970; Matskyavichene, 1979). The activity of digestive enzymes in the crustaceans is a good indicator of the level of metabolism, and is directly dependent on the intensity of feeding. The influence of feeding on the activity of digestive enzymes in the young of *Pacifastacus leniusculus* has not been studied. The purpose of our investigation was to study how the composition of food of plant and animal origin influences the proteolytic activity in the digestive system of the young. In order to establish the optimal composition of their ration, the crustaceans were given supplements of fish, *Chara*, detritus and mixed feed separately.

In the opinion of numerous researchers, detritus is often the main component of the diet of aquatic crustaceans; however, its nutritional value is not clear. The study of detritus consumption by crayfish is of theoretical and practical interest to us, since *Pacifastacus leniusculus* is a promising species for introduction into the fauna of the inland waters of Lithuania.

Experiments were carried out in an artificial environment and under semi-natural conditions. In our experiment of raising underyearlings of Pacifastacus leniusculus in aquariums with running lake water, we established that the maximum level of proteolytic activity in the digestive gland and digestive tract of the young is attained when the animals are given fish. A comparatively high proteolytic activity was noted in the digestive system of the crustaceans which were given only supplements of fresh detritus from the littoral zone of the lake. The lowest level of proteolysis in the digestive system was noted with a Chara supplement, which is in line with the data on the increments of body mass. The highest content of protein in the young of Pacifastacus leniusculus was noted when the animals were given detritus and fish supplements. (114)

Based on our results, we recommend that detritus be added to the food of plant and animal origin in the diet of young Pacifastacus leniusculus when raising the young of this species under semi-natural and artificial conditions.

UDC 595.384.16:576.8(28)

Some data on the anaerobic microflora of the digestive tract in Pacifastacus leniusculus

by L.M. Mitskenene (IZIP AN LitSSR)

The acclimatization of the American Pacifastacus leniusculus in the waters of the Lithuanian SSR has raised a number of questions which must be solved in order to provide the conditions best suited for increasing the numbers of this species. In order to solve the questions related to the feeding of the animals, we must know the physiology of digestion and the microbiological processes that occur in the digestive tract.

The goal of our investigations was to learn whether anaerobic microorganisms are present in the digestive tract of *Pacifastacus leniusculus*, and to determine the number of anaerobic microorganisms of certain physiological groups.

Our investigations were conducted in 1984 in the laboratory dealing with the physiology of sporulating bacteria at the Institute of Microbiology of the USSR Academy of Sciences. The study material consisted of adult *Pacifastacus leniusculus* (males) from Lake Nevardas (Lithuanian SSR), as well as crayfish which had been (115)
kept in an aquarium and given artificial feed (fish + *Chara*). The isolation of anaerobic microorganisms was carried out in strictly anaerobic conditions (Hungate, 1969, Holdeman and Moore, 1975).

We have established that a characteristic anaerobic microflora is constantly present in the contents of the digestive tract of the crayfish. Bacteria of the following physiological groups were isolated: proteolytic, amylolytic and lactic acid. No anaerobic cellulolytic microflora was detected. Proteolytic bacteria are the most abundant in the contents of the digestive tract of the crayfish, both with natural and artificial feeding. One gram of the contents of the digestive tract (fresh weight) contain $3.8 \cdot 10^8$ proteolytic bacteria, $2.0 \cdot 10^8$ amylolytic bacteria and $1.5 \cdot 10^8$ lactic acid bacteria which are capable of growing in strictly anaerobic conditions. The anaerobic bacteria in the contents of the digestive tract of *Pacifastacus leniusculus* constitute 60% of the total number of bacteria isolated. When the microorganisms of the contents of the digestive tract are grown in strictly anaerobic conditions, we find that the morphological groups of microorganisms are more diverse than in an aerobic environment.

UDC 595.384.16:639.517

Fecundity of the long-clawed crayfish and recommendations on the biotechnology of its cultivation

by V.N. Nefedov and G.V. Kolesnikova (Volgograd branch of GosNIORKh*)

In connection with the development of methods of crayfish cultivation, we have done some research on the fecundity of the females of the long-clawed crayfish found in the water bodies of the Volga-Akhtuba floodplain, and conducted experiments to obtain viable larvae during incubation of the eggs in different types of apparatuses.

Our analysis of long-term data has enabled us to establish a relationship between the maturation of the crayfish and the length of their body. After examining all the facts, we found (116) that the absolute fecundity, i.e. the number of egg cells in the ovary of sexually mature females (y), depends on the length of its body (x, mm), i.e. $y = 668 - 12.01x + 0.089\ x^2$.

The relationship between "working" fecundity (y) (the number of eggs deposited by the female on the abdominal pleopods) and the body size of the females (x, mm) is described by the equation $y = 518 - 10.55x + 0.07x^2$ (for the lakes of the floodplain) and $y = 606 - 11{,}89x + 0.079x^2$ (for rivers).

*State Scientific Research Institute of Lake and River Fisheries - transl.

The working fecundity is lower than the absolute fecundity based on estimated data by an average 47% in the lakes of the floodplain, and by 37% in the shallow channel Staraya Akhtuba. Therefore, one must consider the type of water body when undertaking the cultivation of crayfish, and the spawners should be raised in rivers prior to the formation of the brood stock in the nurseries of crayfish farms.

Removal of the eggs from the female pleopods does not disrupt the processes of metabolism in the developing embryos, nor does it affect the main biochemical characteristics of the hatched larvae. This enabled us to produce the young of the long-clawed crayfish mainly with the help of Tsukerzis' apparatuses (modified somewhat) in which the incubation of the eggs is under constant control. The results of our long-term observations have brought us to the following conclusions:

1. The onset of hatching, the duration of the first stage of postembryonic development and the duration of the first moult depend on the temperature of the water flowing into the apparatuses. The total amount of heat required for the larvae to hatch out of the eggs is 135-140 deg/days, while the transition to the second stage requires 170-180 deg/days. An increase in water temperature reduces the period of the incubation cycle, but the viability of the young may diminish significantly when the eggs are incubated at extremely high temperatures (24-25°C and higher).

2. The efficiency of hatching in the apparatuses and the weight of the 1st and 2nd larval stages depend on the morphometric characteristics of the eggs and the intensity of the metabolic

processes occurring in them. In turn, the average weight of the individual eggs depends on the size of the females and the value of their working fecundity. As a rule, the size and weight of the individual eggs decrease when the fecundity of the females is very high. Spawners within the 111-140 mm range should be used for the cultivation of crayfish.

3. Our study of the growth tendencies of the young in ponds with a natural food supply has shown that underyearlings attain a length of 70-80 mm and weight of 8.0-9.0 g by the end of the vegetative period. The maximum size of the crayfish is 121 mm at age 1+. Estimates have shown that the cultivation of crayfish at an establishment organized on the basis of well-heated eutrophic lakes can produce a marketable product in the second year of cultivation of the long-clawed crayfish on the Volga-Akhtuba floodplain. At the same time, the yearlings can attain a length of 125-130 mm, and then the yield of crayfish will amount to at least 200 kg/ha. (117)

UDC 595.384.12

Comparative analysis of lactate dehydrogenase in freshwater shrimps of the genus *Macrobrachium*

by A.Ye. Plenin (Institute of Zoology of the Academy of Sciences of the Byelorussian SSR)

The purpose of our investigation was to study the isoenzyme content and some of the properties of lactate dehydrogenase in two thermophilic freshwater shrimps of the genus *Macrobrachium*, the eastern river shrimp *M. nipponense* and the tropical giant shrimp *M. rosenbergii*. These species are of nutritional value, and so they are cultivated in many countries. The eastern river shrimp has been successfully introduced in the cooler reservoir of the Beryozovsky State Regional Electric Power Plant (Byelorussian SSR).

Fractionation of proteins of the abdominal muscle and egg cells at different stages of development with the use of electrophoresis in polyacrylamide gel has revealed the presence of only one enzyme zone with lactate dehydrogenase activity. The presence of one molecular form of lactate dehydrogenase is typical of many crustaceans, whereas the lactate dehydrogenase in vertebrates is characterized by a more complex spectrum. This can be attributed to the appearance of numerous loci producing isoenzymes in the course of the evolutionary process.

An important part of studying the functional significance of (118)
individual molecular forms, in addition to studying the isoenzyme spectrum, is the characterization of individual enzymes in terms of a number of biochemical parameters with the habitats of the organisms taken into account. With this purpose in mind, we studied the kinetics of the lactate dehydrogenase reaction with a pyruvate concentration of 0.03-0.9 mM, an invariable concentration of NADN and pH 7.4, as well as the sensitivity of lactate dehydrogenase to a high temperature and the ratio of malate dehydrogenase activity to lactate dehydrogenase activity. The latter is used to characterize the resistance of hydrobionts to hypoxia.

The kinetics of the lactate dehydrogenase reaction showed a hyperbolic dependence on the values of K_M for both species of shrimps in the $0.5\text{-}0.8 \cdot 10^{-4}$ M range, which is similar for other species of crustaceans. An important characteristic of shrimp lactate dehydrogenase was its high resistance to the inhibiting effect of high concentrations of pyruvate. For example, it retained its activity right up to $6 \cdot 10^{-3}$, which is higher than in _Artemia_ and the Kamchatka crab. A comparison of the thermal stability of lactate dehydrogenase, based on the temperature of 50% inactivation in 15 minutes, has shown that this parameter is higher in _M. rosenbergii_ (59.0°C) than in _M. nipponense_ (56.8°C), which correlates with the temperature conditions of the species' habitat. The higher coefficient of malate/lactate deydrogenase activity in _M. nipponense_ (1.5) as compared with that of _M. rosenbergii_ (0.65) characterizes it as more resistant to hypoxia.

Thus, the use of biochemical indices gives us not only additional information about the species, but also enables us to establish the adaptive changes that broaden its potentials.

UDC 595.384.12:639.512 (119)

Embryonic and larval development of the giant tropical shrimp _Macrobrachium rosenbergii_ during its cultivation

by V.Ye. Roshchin (Institute of Zoology of the Academy of Sciences of the Byelorussian SSR

Macrobrachium rosenbergii is widely cultivated in the countries of SE Asia. In the majority of countries, however, the cultivation of shrimps is of an extensive nature, due to the poor development of the biotechnology of their cultivation at the larval stage. In a natural environment, this stage of biological development takes place in the brackish waters of estuaries (salinity 8-12‰). Upon completion of larval development, the animals grow and breed in fresh water.

The Institute of Zoology of the Byelorussian Academy of Sciences has begun work on the development of the technology of shrimp cultivation. Plastic fish-breeding troughs were used for the cultivation of juveniles and adults.

Under laboratory conditions, the animals reach sexual maturity by the end of the first year of life at a temperature of 29-30°C. The females begin to breed upon attaining a length of about 120 mm, depositing batches of eggs periodically with a frequency not determined by the season. The mass and energy equivalent of one egg at the beginning of development are equal to 0.0748$\pm$0.003 mg/specimen and 0.206 cal/specimen respectively. During embryonic development (17-18 days at 29°C), the fresh mass of the egg increases to 0.105$\pm$0.004 mg/specimen, and the energy equivalent decreases to 0.103 cal/specimen. The efficiency of utilization of the yolk energy during embryogenesis reaches 50%.

After hatching, the larvae were transferred to special aquariums with a closed water circulation and a system of coarse and fine filters. Natural seawater (10-20%) was used for cultivation. The overall volume of the aquarium was 20 litres, and the water temperature was 29$\pm$0.5°C. Larval development under these conditions lasted 35-38 days. During this period, the larva passes through 11 morphologically different stages. At the end of this (120)
period, the morphology of the juveniles is practically the same as that of the adult animals. By this time, the young have attained a mass of 7.5-8.0 mg.

The main difficulty of cultivating larvae lies in the selection of feeds for the first days of development (1st-3rd stages). The yield of juveniles can be increased substantially by choosing the right feeds and feeding regime.

UDC 595.384.16:639.517

Growth and development of the young in aboriginal and acclimatized species of crayfish

by Ye.A. Tamkyavichene (Institute of Zoology and Parasitology of the Academy of Sciences of the Lithuanian SSR)

The successful acclimatization of Pacifastacus leniusculus in an isolated lake poses new problems concerning expanded reproduction of this species in the lakes of the Lithuanian SSR. The extensive material accumulated during the breeding of the aboriginal broad-clawed crayfish (Astacus astacus) and long-clawed crayfish (A. leptodactylus) shows that positive results can be obtained only when good-quality material at the age of underyearling is introduced.

Our experiments in raising underyearlings of Pacifastacus leniusculus in special apparatuses set up in a lake have shown that the young grow and develop quite well. During the first summer, the crayfish grew very rapidly. Over a period of 4 months, they moulted 9 times, and attained an average length of 30 mm and body mass of 587 mg. The underyearlings of Pacifastacus leniusculus attained a body mass 2.5 times greater than that of the underyearlings of Astacus astacus and 1.5 times greater than that of Astacus leptodactylus. The larvae of A. astacus moulted 5 times during the first year of life, and attained an average length of

16.57 mm and mass of 138 mg. Only 13% of the larvae moulted 6 times, and attained an average length of 19.74 mm and body mass of 227.42 mg. The young of Astacus leptodactylus moulted 6 times, and attained an average length of 21.49 mm and body mass of 349 mg.

The yield of underyearlings amounted to 40-52% during the cultivation of all three species of crayfish. This was due to the relatively high degree of cannibalism at the initial stages of development of the young. Natural mortality was not observed. (121)

The results of our investigations indicate that it is possible to raise the young of Pacifastacus leniusculus, and that the latter grow and develop rapidly during the first year of life. The raised underyearlings of Pacifastacus leniusculus can be used to stock isolated lakes in the Lithuanian SSR.

UDC 639.281.7(262.81:282.247.41)

Present condition and potentials of the crayfish industry in the Volga-Caspian Basin

by L.S. Khuras'kin and N.A. Pochtoyeva (KaspNIRKh)

The crayfish in the Volga-Caspian Basin are represented by the long-clawed and the thick-clawed crayfish. The long-clawed crayfish (Astacus leptodactylus) is the most common; its geographic range covers the Volga-Akhtuba floodplain and the delta and prodelta of the Volga, and in the sea it is encountered from the water line to a depth of 70-80 m. In the sea zone, commercial concentrations of Astacus leptodactylus form only along the eastern coast of the Caspian Sea from Yeraliyev to Krasnovodsk Bay inclusively. The thick-clawed crayfish (Latin name not given)* has a discontinuous range, i.e. the eastern shores of the central and

*Perhaps the author is referring to the broad-clawed crayfish, Astacus astacus - transl.

southern Caspian Sea (Rumyantsev, 1974). The thick-clawed crayfish constitutes an insignificant portion of the commercial catches, usually less than 15% in the sea landings.

The catches of freshwater crayfish in the Volga-Caspian Basin have varied from 280 to 30 tons over the past ten years. The State remained virtually uninvolved in the crayfish industry in 1984-1985; it was managed by a system of procurement offices, and yielded 20-30 tons of crayfish. The sudden drop in crayfish production was caused by different factors. First of all, there was a decrease in the exploitation of crayfish in the sea. With the loss of Krasnovodsk Bay to an ornithological sanctuary, areas yielding up to 120 tons of crayfish during certain years were lost to the crayfish industry. Other stable crayfish areas (Aim, Karshi) were very rapidly depleted by overexploitation. At the present time, the new productive fishing areas discovered (122)
by KaspNIRKh deep-sea divers (Ushivtsev, 1983) in the more northerly waters on the Kara-Bogaz-Gola and Duldulat traverse are not being utilized well enough by the industry.

The decrease in crayfish reserves in the main commercial waters of the floodplain and upper delta of the Volga River is due to a number of anthropogenic factors. The unstable hydrologic and hydrochemical conditions caused by fluctuations in the water level have resulted in the shallowing, drying up or fouling of a whole series of crayfish habitats. Other negative factors include water pollution, the harvesting of spongillidae, the almost illegal spontaneous harvesting of the species by amateurs, and the chronic overexploitation of crayfish in well-known rivers.

On the other hand, stable yields of crayfish characterize the lower part of the Volga delta and prodelta (Belinsky, Gandurinsky and Nikitsky banks, etc.), particularly the eastern branches (Mokrinsky, Kanychinsky and Igolkinsky banks). The latter are noted for a higher than usual crayfish productivity, where the catch per effort amounts to 3-5 kg/day. As for the organizational side of the crayfish industrv, the incidental catches of crayfish during fyke-net fishing or mobile crayfish trapping units set up by procurement offices will make it possible to increase the yield of crayfish.

UDC 639.281.7:639.517

Means of restoring the reserves of crayfish in the waters of the northwestern part of the USSR

by Ya.M. Tsukerzis (IZIP, Academy of Sciences of the Lithuanian SSR)

At the beginning of the 20th century, the rivers and lakes in the northwestern part of the USSR abounded with the most valuable species of crayfish, the broad-clawed crayfish (*Astacus astacus*). For example, the rivers and lakes of the Baltic Sea area annually yielded up to 10,000,000 broad-clawed crayfish (400 tons). Called the noble crayfish because of its good taste and nutritional qualities, this aboriginal species of the north- (123)
western part of the country was in great demand on the world market and exported to different countries.

However, the exploitation of *Astacus astacus* began to diminish in the middle of the 20th century, and ceased almost entirely in the 1960's due to water pollution and crayfish diseases which greatly reduced the stock of crayfish, as well as to the nonprofitability of the industry as a result of high labour intensity and low market prices. Despite the fact that the stock of Astacus astacus in some regions (e.g. the Lithuanian SSR) has increased somewhat, it provides only enough for the amateur fishermen who, travelling back and forth in motor vehicles, have made the rivers and lakes with crayfish far more accessible, but at the same time more difficult to protect against poachers. Crayfishing in natural bodies of water using conventional traps is still unprofitable. Only an intensive method and the organization of crayfish farms will make it profitable. An example of this is the state of Louisiana in the USA, where 40,000 hectares was set aside for crayfish ponds in 1982, and the state of Mississippi where the income from the crayfish industry amounted to 175,000,000.00 dollars in 1983.

Experiments on the artificial breeding of the young of Astacus astacus and their introduction into natural water bodies were carried out in the 1960's in an effort to develop the crayfish industry in the Lithuanian SSR. A device for the incubation of crayfish eggs was designed and a method of artificial breeding of crayfish was developed (both registered as inventions); as a result, we managed to get A. astacus underyearlings not in late autumn as in a natural environment, but in the middle of summer, which greatly increased their survival rate during introduction. More than 400,000 young A. astacus have been introduced into the lakes of Lithuania. However, the time required for the development of A. astacus to marketable size

(4-5 years) has prevented the successful introduction of the method of artificial breeding of *A. astacus*.

Because of this, the fast-growing, highly fecund and disease-resisant American *Pacifastacus leniusculus* was brought into the Lithuanian SSR from Sweden at the beginning of the 1970's for acclimatization. This species reaches marketable size in the second to third year of life, and its taste and nutritional qualities are not inferior to that of *Astacus astacus*. At the same time, *Pacifastacus leniusculus*, though immune to crayfish pestilence*, is a carrier of its causative agent. This (124)
has given rise to the erroneous opinion that *Pacifastacus leniusculus* is harmful to the local species, and has impeded the expansion of its further acclimatization. However, as the investigations carried out in Finland and the Lithuanian SSR at the beginning of the 1980's have shown, *Pacifastacus leniusculus* does not have any adverse effect on the local species when sharing the same lakes with them. The acclimatization of *Pacifastacus leniusculus* in the lakes of Lithuania has produced positive results. For example, a population numbering over 60,000 in 1982 was obtained from the 32 males and 60 females introduced in Lake Nevardas in 1972, and the artificial breeding of the young has also produced good results.

The above data indicate that crayfish ponds or crayfish nurseries with a crayfish breeding unit should be organized for the renewal of the crayfish stock in the rivers and lakes of the northwestern part of the USSR. *Pacifastacus leniusculus* is the most promising species of crayfish for this purpose. The prices

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*a disease of the European crayfish (*Astacus*), caused by *Bacillus pestis astaci* - transl.

on marketable crayfish should be increased substantially.

(125)

CEPHALOPODA

UDC 594.582.2/.8

The level of energy metabolism in the epipelagic squid *Sthenoteuthis pteropus* at different swimming speeds

by G.I. Abolmasova, Yu.S. Belokopytin (INBYuM AN UkrSSR)

Past studies of the total energy metabolism of the prolific epipelagic squids of the genus *Sthenoteuthis* were carried out with free-swimming squids in a ring respirometer. We found that the level of metabolism in them was very high. Since the squids are fast swimmers, we thought it would be interesting to study the total and active metabolism at different swimming speeds. In 1984-1985, we studied the metabolism in *St. pteropus* from the Atlantic Ocean. The experiments were performed on board a vessel in a 30-litre hydrodynamic respirometer. The rate of the water flow was regulated by changing the revolutions of the screw propeller from a direct-current motor within the range of 0.1-1.0 m/s. The active metabolism was calculated on the basis of the difference between the total metabolism at a given speed and the basal metabolism estimated by extrapolation of the experimental data to zero speed.

Using the equation $Q_w = qb^v$, we calculated the energy expended for the given size range at a relative swimming speed of 1 body length$\cdot s^{-1}$ (15-20 cm/s). Based on these calculations, the energy expended by squids at a swimming speed of 1, 1.5 and 2 b.l/s increases 1.4-2.2, 1.7-3.3 and 2.0-4.9—fold respectively as compared with basal metabolism. The intensity of metabolism in *St. pteropus* is very similar to the level of metabolism in other species of squids at the same temperature and degree of activity. The similarity in the levels of metabolism points to the functional unity of these active pelagic carnivores. In this respect, they are more similar than pelagic fishes. (126)

The quantity of the ration maintained in different species of squids at the same temperature and swimming speed was also similar.

Based on the data regarding the total metabolism of *Sth. pteropus* swimming freely in a 153-litre respirometer and the metabolism at different swimming speeds in a hydrodynamic respirometer, we can assume that a speed of 1.0-1.5 b.l/s is the optimal one for squids.

UDC 639.273:(639.2.0.81.7:621.397)

Underwater observations of the Commander Is. squid

by D.O. Alekseyev, V.A. Bizikov and D.N. Khromov (VNIRO)

Because of the active exploitation of the Commander Is. squid (*Berryteuthis magister*) in the Soviet Union, more and more importance is being attached to the study of its behaviour and distribution in the natural environment.

This study is based on the observations carried out from a "Sever-2" submersible apparatus (SA) during the 33rd and 34th trips of the "Odissei" support vessel in 1984-1985. The observations were carried out in the water column and at the bottom at depths of 0-1200 m from the ocean side of the Southern and Central Kuriles in July-August and December-January, from the

Okhotsk side of the Northern Kuriles in August, and in the Sea of Japan in December.

During the summer months, the highest concentrations of squids were observed off the islands of Paramushir and Shiashkotan. Squids with 10-30 cm mantles were encountered at depths of 100-900 m, and the maximum concentrations were noted in the 200-600 m layer. In winter, squid concentrations were found on the Kita-Yamato Bank and off Simushir Is. The squids were encountered at a depth of 140-670 m, with the maximum density noted in the 400-540 m layer. Only the relative density of the concentration of squid can be determined by observations from a submersible. During the daylight hours, the squids are dispersed throughout the water, and at night they form concentrations at the bottom.

We observed five types of behavioural reactions to a steady source of light (lamp of the submersible): 1) approaching the light, hitting the submersible and then hovering in shock for 3-20 seconds, and finally leaving the illuminated zone with a discharge of ink; 2) approaching the light as in the first case, suddenly diverting 1.5-2 m from the submersible, and then leaving the observation zone; 3) approaching the light source from the side or back, touching it (1-3 seconds), and leaving the zone as in the first two cases; 4) intersecting the illuminated zone at an angle to the ray of light without stopping or changing direction; 5) lying on the bottom when in the illuminated zone.

We noted the following three types of reactions to a light pulse of a flashtube: 1) convulsive movements 0.5-1 s after the

flash while hovering in shock in front of the submersible;
2) a sudden increase in speed with a change in direction and discharge of ink when passing through the illuminated zone;
3) no reaction when lying on the bottom.

The reactions of the squids to the submersible itself were not recorded. The squids sometimes captured fish (Myctophidae) in the observation zone, but discarded it soon after immobilizing it with their beak. They often brought up their food after hitting the submersible.

Apart from observing individual squid, we also studied groups of them. The groups usually consisted of 5-7 (less commonly 2-3 to 15-30) individuals of the same size moving in the same direction. The distance between them was 0.3-3 m, and the density of the group increased in proportion to its numbers. A group is characterized by the 1st, 2nd and 4th types of reaction to a lamp, and by the 1st and 2nd types of reaction to a flashtube.

UDC 594.582.2/.8:551.465(265.1)

Space and time variability of distribution of *Dosidicus gigas* in the Peru area of the Pacific Ocean

by Yu.A. Aleksandronets and A.V. Parfenyuk (AtlantNIRO)

The neritic ocean squid *Dosidicus gigas* is widely distributed in the Eastern Pacific, and is an endemic species of epipelagic squids of the Peru area (5-20^{o} S lat) where it forages in the transformed water masses of the Peru Current (PC). The (128)
intensity and nature of the distribution of these waters predetermine the distribution of *Dosidicus gigas* during the foraging

period. The available potential energy (APE) is the most representative characteristic of the water dynamics (Tsyganov, Bendik, 1984). Analysis of the data obtained in 1981-1984 has shown that the areas of higher than usual abundance of foraging squids are confined to the zones of maximum APE. As we know, the areas with a higher than usual biomass of plankton are also confined to the zones of maximum APE.

In the distribution of these animals, we distinguish a number of situations that depend on the abiotic (hydrometeorological) conditions and the stages of the life cycle. They are:

1. The divergence of the Peru Current which is responsible for the upwelling of highly productive waters. This zone is quasi-stationary, though its location and intensity of vertical movements vary with the year and season.

2. The formation of highly bioproductive zones south of the equatorial front is related to the water dynamics of the eastern branch of the Peru Current and the intensity of the southeastern trade wind. With a stable trade wind, the eastern branch of the Peru Current north of 16° S lat generates a number of meanders and carries the highly productive subantarctic waters out of the zone. As the trade wind weakens, the structure of the waters begins to change, becoming rotational; this is responsible for the patchiness of squid distribution. With a steady weakening of the trade wind (arrival of El Niño), the Peru Current weakens and the intensive advection of the equatorial waters adversely affects the bioproductivity of the entire Peru area.

3. With the intensification of the Peru Current in the region of the equatorial front, its alongshore branch, turning along the southern periphery of the front, carries the highly productive waters of the upwelling into the Eastern Equatorial region where concentrations of large pre-spawning *Dosidicus gigas* have been noted.

4. The local upwelling regions in the dynamically active zones of the oceanic part of the Peru area are of no interest to us because of their low bioproductivity due to the vertical entrainment of tropical waters that lack biogenic elements.

Of the listed mechanisms of formation of dynamically active (129) zones and areas abounding in squids, the first two are the most extensive and stable. The rest are of a more local nature, and are characterized by a less predictable space and time variability.

UDC 594.582.2/.8(265.1)

The growth rate and periodization of the biological development of *Dosidicus gigas* from the southeastern part of the Pacific Ocean

by A.I. Arkhipkin and S.A. Murzov (AtlantNIRO)

The epipelagic neritic ocean squid *Dosidicus gigas* is one of the endemic species of the tropical waters of the East Pacific. Its general growth tendencies have been studied only from the results of a cohort study of the size structure of *Dosidicus gigas* from the Gulf of California (Ehrhardt et al., 1982, 1983). To determine the age and growth rate of *Dosidicus gigas*, we used the statoliths of 113 individuals with a mantle length (ML) of

0.9-49 cm from the equatorial zone of the eastern part of the Pacific Ocean and the area of the Peru Basin. The statoliths were fixed in 70° alcohol and processed by a method modified by us. The age of the squids was determined by counting the diurnal concentric growth rings on thin sections of the statoliths. The individual rate of growth was determined in practically all of the squids studied, despite the difficulty of reading the marginal zone of the section, particularly in male specimens. The dependence of statolith length on the number of rings (age) is approximated by the exponential function which can be used as a quick test for age determination, i.e.

$t = 5.19 \times 2.08^{Lst}$ or $t = 5.0 \times 3.23^{Lbst}$, where t denotes the age of the squid in weeks, Lst - the length of the statolith in mm, and Lbst - the length of the body of the statolith in mm. The age of the specimens studied varied from 1 to 9 months. The first males begin to mature at the age of 17 weeks at a mantle length of 18 cm, and the females at an age of 27 weeks at a mantle length of 23-24 cm. In the peripheral zone of the statoliths in almost all of the mature specimens, we have noted more distinct markings, probably the result of (130) several growth rings coming together. Perhaps they indirectly reflect the sudden deceleration of growth in the squids during oviposition in the females or mating in the males. While analyzing the daily increments and the formation of growth zones in the statoliths, we periodized the ontogeny of the large form of *Dosidicus gigas* females that reach the maximum sizes for the given population (Nigmatullin et al., 1983), for which extensive material is available.

1. The embryonic stage. The nuclear zone of the statoliths without growth rings corresponds to this stage. The absence of growth rings is possibly due to the lack of a diurnal rhythm in the growth of the embryos.

2. The larval stage (ML from 0.1 to 0.9-1 cm) corresponds to the development of the second perinuclear zone of the statolith, which is clearly demarcated from the nucleus by the first distinct growth ring that reflects the onset of rhythmic larval growth. This stage lasts 25-30 days.

3. The fry and juvenile stage (ML from 0.9-1 to 10-12 cm) lasts 35-55 days. The "dark" zone, an area of maximum growth of the statoliths, corresponds to this stage. The growth rates in these animals are very high; the average mass of an individual increases from 0.5 to 30 g in five weeks, a relative weight increase of 17-20% daily. The formula for weight increment is $W = 0.01e^{0.8t}$, where W denotes body mass in g, and t - the age in weeks.

4. The transitional stage (ML from 10-12 to 14-16 cm) lasts 10-15 days, and corresponds to the initial part of the peripheral zone of the statolith, which is characterized by a sudden decrease in ring step (growth rate of the statolith) and, apparently, the growth rate of the squid during its transition to the life of an active nektonic animal.

5. The immature adult stage (ML over 14-16 cm) corresponds to the peripheral zone up to the first "spawning" ring, which is characterized by a gradual decrease in the growth rate. We have studied the following three arbitrary stages: a) ML from

14-16 to 20-24 cm. The average body mass of an individual increases from 30 to 300 g in 10 weeks, and the relative rate of weight increment is 3.6-3.8%. $W=3.0e^{0.23t}$; b) ML from 20-24 to 31-33 cm. Body mass increases from 300 to 950 g in 7 weeks, and the daily weight increment is 2.5-2.8%. $W = 12.5e^{0.16t}$; c) ML from 31-33 to 46-49 cm, body mass increases from 950 to 3500 g in 6 weeks, and the daily weight increment is 2.2-2.5%. $W = 18.9e^{0.145t}$.

6. The sexually mature stage probably corresponds to the zone extending from the first "stress" mark to the margin of the section. The somatic growth of the squids is minimal, since the greater part of the energy is expended on generative meta- (131)
bolism. Assuming that the growth rates characteristic of the 5th stage are retained thereafter, we can say that the squids attain a mantle length of 75 cm and a body mass of 24-26 kg by the first year. If, on the other hand, the instantaneous growth rate decreases consistently, the yearlings will have a mantle length of 70 cm and a mass of 16-18 kg. These data are substantiated by the results obtained by Ehrhardt and coauthors (Ehrhardt et al., 1982, 1983).

UDC 594.582.2./8(261.76)

Vertical and horizontal distribution of the larvae of *Sthenoteuthis pteropus* (Ommastrephidae) in the Gulf of Guinea in winter

by A.I. Arkhipkin and A.S. Shchetinnikov (AtlantNIRO)

Up to the present time, practically no research has been done on the spatial distribution of the larvae and fry of the endemic nektonic species of the tropical region of the Atlantic, Sthenoteuthis pteropus. Our study is based on the data of a plankton survey (60 stations, 147 trawlings) in the area of 1^{o}N lat—$3^{o}30'$ S lat and $7-4^{o}$ W long in July-August 1985. The trawling at the stations was carried out at night with a "Bongo" plankton recovery sonde (diameter of mouth 60 cm), rate of trawling 1.6-1.8 knots with 15 minutes spent on each haul, mesh size of netting 0.5 mm. The trawling was carried out mainly at three levels: in the upper mixed layer of water at depths of 3-10-15 m, in the layer of the thermocline at 20-30 m, and under the thermocline at 40-55 m. The vertical distribution was studied at two diurnal stations where the trawling was carried out both at night and during the day at depths of 3-5, 12-15, 30-40 and 80-85 m. The larvae of Sthenoteuthis pteropus were differentiated from the similar larvae of Ornithoteuthis antillarum by their general habit, and by the development of an intestinal and an anal photophore in individuals of different size.

In the study area, we observed the interaction of two water masses, the southern equatorial current (SEC) with a temperature of $24-25^{o}$ and salinity of 35.0-35.5‰ spreading in the surface (132)
layer at depths of 0-30-50 m and the Lomonosov Counter Current (LCC) with a temperature of $22-23^{o}$ and salinity of more than 35.8‰ located under SEC. In the places where SEC was weakened, LCC came almost to the very surface.

Most of the larvae kept to the upper mixed layer of water 0-10-15 m deep with a temperature of $24-25^{o}$C both at night and during the daylight hours. Individual specimens (up to 5%) were encountered above the upper boundary of the thermocline layer at depths of 17-20 m, and it is quite possible that some of them may have been caught during retrieval of the plankton recovery sonde from the upper layers of water. No larvae were encountered below the 20-25 m depth.

As to the horizontal distribution of the larvae, practically all of the (95%) were caught in the waters of the southern equatorial current, and mainly at the stations where the flow velocities were the highest (up to 1.6-1.8 knots). The mantle of the captured larvae measured 0.23-0.95 cm in length. Their numbers were extremely low (1-4 specimens per haul, or an average 1 specimen per 130-200 m^3), which correlates with the extremely low frequency of occurrence of mature females during this period in the Gulf of Guinea (about 1%). No larvae were encountered in the areas covered by the waters of the Lomonosov Counter Current. Fry 1-1.3 cm long were caught in small numbers in the areas adjacent to the southern equatorial current.

Thus, during the winter of the southern hemisphere, the larvae of *Sthenoteuthis pteropus* are carried in the surface layer of the SEC core from their hypothetical spawning grounds (eastern part of the Gulf of Guinea) into the open ocean to the west. As they grow (up to 1-1.3 cm), the fry migrate from SEC to the adjacent waters. The migration of larvae from the equatorial region (Zuyev et al., 1985) eastward into the Gulf of Guinea with the waters of LCC was not noted.

(133)

UDC 594.582.2/.8

Method of studying the feeding habits of epipelagic nektonic squids

by S.I. Bazanov (AtlantNIRO)

To study the qualitative composition of the food and the number and size of the prey of epipelagic nektonic squids, we usually analyze the stomach contents in animals caught at drift stations under conditions differing from the natural ones, created by introducing an artificial light field. Because of this, doubts may arise as to the reliability of the results. Therefore, we have attempted to determine the effect of light on the hunting behaviour of two prolific species of squids (*Dosidicus gigas* and *Sthenoteuthis oualaniensis*) by means of underwater observations.

Our underwater observations (630 hours) were conducted at drifting light stations in the southeastern part of the Pacific Ocean (in the vicinity of the Peru Basin) from a protective device resembling a "shark cage" in the 0-25 m layer of water. The number and size of the prey in the stomachs of the captured squids were determined.

In the light zone at night, the squids form concentrations of varying density, hunting with variable activity. Squids with a mantle length (ML) of more than 15-18 cm prey mainly on lantern-fishes and lightfishes, less commonly squids and flyingfishes. The hunting behaviour of these two species is basically the same, but *Dosidicus gigas* gets better results.

A concentration of squids from different size groups forms and remains in the light zone. A smaller concentration of lanternfishes is also noted. The density of squids here is much higher than under normal conditions. A high intensity of illumination greatly increases the availability of lanternfishes, which contributes to the success of the hunt. With lanternfishes in high abundance, a large squid can seize 2 fish (and sometimes 3) at the same time, but often does not consume them entirely. Having had its fill, a squid will often bite a captured fish into two or three parts and discard it. In 80% of the cases, these (134) pieces are consumed by hungry squids, and so parts of the same lanternfish may find their way into the stomachs of 2-3 squids.

A high density of concentration of the squids results in a higher degree of general activation of the animals, as well as spurts of hunting activity often followed by provoked attacks on their own kind. This usually occurs when the lanternfish manage to escape the squid pursuing them. Hungry and excited by the hunt, the squid attacks the squid closest to it. Seizing it, the hunter bites through its head and makes off into the depths with its prey. Very often, the squids attacked other squids caught with a jigger as they were being pulled on board, chewing away part of the mantle or fin. In all of these cases, the size of the prey could have comprised 70-120% of the absolute length of the attacking squids, whereas the usual size of the prey is 5-20%.

Thus, the presence of an artificial light field is conducive to the formation of squid concentrations, and increases the availability of prey (lanternfishes). This, in turn, increases the degree of general activation, and distinctly alters the natural hunting behaviour of the squids, including the frequency of cannibalism. This should be taken into account when analyzing the stomachs of individuals caught in a light zone. It would be more correct to analyze the stomachs of squids caught within the first 20-30 minutes after switching on the lights, with the elimination of the data on recently swallowed pieces of food. These factors should be taken into consideration when analyzing data on the stomach contents of squids that have spent a considerable length of time in an illuminated zone.

UDC 639.273:(639.2.001.5:626.02)

Vertical distribution of squids in an illuminated zone and methods of counting the animals

by S.I. Bazanov and A.V. Parfenyuk (AtlantNIRO)

The numbers and biomass of epipelagic nektonic squids are recorded at nocturnal drifting stations, from a vessel, in a (135) spot of light in the 0-2 m layer (Zuyev, Nigmatullin, 1974). With the use of the deep-sea diving method, we studied the vertical distribution of two endemic species of the southeastern part of the Pacific Ocean (Peru Basin), *Dosidicus gigas* and *Sthenoteuthis oualaniensis*, in the 0-25 m layer, determined the preliminary values of the correction coefficients of vertical distribution (CVD - ratios of the number of individuals observed from under the water and from the vessel), traced the formation of the "light" concentration, and developed the specifications for the method of counting the squids. The underwater observations were carried out from a protective device similar to a "shark cage". The total time spent on above-water observations was 1000 hours, and the time spent on underwater observations was 630 hours. The coefficient of vertical distribution (CVD) was determined by synchronous recording of the squids by a deep-sea diver and by an observer on board the vessel.

The species studied are nektoepipelagic, rising to the 0-30 m layer at night. In an illuminated zone, they form concentrations of varying density, consisting of individuals of different size groups of one or both species.

A concentration of squids forms in the light zone 1.5-2 hours after the lamps are switched on. The density of the concentration depends on the abundance of squids at the given point. The size of the animals decreases and their numbers increase with depth, Dosidicus gigas usually keeping above Sthenoteuthis oualaniensis of the same size in mixed concentrations. The largest squids of those observed at the station (usually 5-20% of them) occupy the upper 0-2 m layers and constitute the base of the squids recorded from the vessel. The smaller individuals that comprise the greater part of the concentration keep to the deeper layers, rising to the 0-2 m layer only occasionally in ones or in small groups, which distorts the true picture of abundance and size structure when the animals are counted from the vessel.

The CVD values vary extensively, depending on the hydrometeorological conditions, the abundance of squids at a given point, and on their size and species composition. Considering that Dosidicus gigas usually keep above Sthenoteuthis oualaniensis

of the same size in mixed concentrations, the coefficient of vertical distribution (CVD) for the second species varies within a wider range than for *Dosidicus gigas*. For the latter, the CVD averages 1.5-2 with a biomass of 10-100 kg/km^2, and 3-4 with a biomass of 100-500 kg/km^2. With a density of more than 500 kg/km^2, the minimum CVD equal 5-7, and the maximum values up to 100-300. (136)
In areas where large squids dominate, counting from a vessel provides sufficiently accurate results; the error increases with the number of small individuals.

Consequently, the vertical distribution of the squids in concentrations is characterized by a nonuniformity in quantitative, size and species composition. For more accurate determination of the stock of squids by conventional methods, we must introduce corrections for the coefficient of vertical distribution. Furthermore, to eliminate the error resulting from the squids being attracted to the light zone from a large area, the animals should be counted only during the first hour after switching on the lamps and while the squids are in the upper layers for a fixed time (from 20.30-21.00 to 03.00-04.00 hours).

UDC 594.56(261.7)

On the biology of the common octopus off the coast of Mauritania

by A.Ye. Barkovsky (AtlantNIRO)

We have studied the size-weight composition and condition of the reproductive system in the common octopus (*Octopus vulgaris*) from 383 samples (8300 specimens) collected in June-September 1985 south of Cap Blanc (20°08'-20°28' N lat) at depths of 8-20 m from sandy-shelly bottoms overgrown with eel-grass and algae.

The period of our observations coincided with the summer spawning migration of octopuses from the foraging grounds to the spawning places in the shallow areas. At certain points between, we observed the formation fo dense temporary foraging and pre-spawning concentrations, particularly in August and at the beginning of September. They dispersed later on. Pre-spawning females predominated in the samples (up to 50% of the total number); most of the male were mature. The modal length of the mantle increased from 11 to 17 cm from June to September. The males and females did not differ in size, but the maximum size of the males (up to 22 cm and 4.6 kg) exceeded that of the females (up to 20 cm and 3.3 kg). The sex ratio was characterized by a slight dominance of the females (45% males and 55% females (137)
on the average).

Octopuses feed most intensively during the morning (7.00-9.00) and evening (17.00-18.00). On the whole, the feeding activity of the octopus is higher during the daylight hours.

Our investigations have confirmed Hatanaka's assumption (Hatanaka, 1979) that two spawning periods exist for the octopus off the coast of Mauritania, a winter and a summer one. This points to the presence of two sympatric groupings of the octopus, the development cycles of which are dissociated in time.

UDC 594.582.2/.8(265)

Distribution of the Bartram squid in the vicinity of the Pacific drift

by A.V. Golenkevich (TINRO)

The Bartram squid, a prolific epipelagic species in the northern part of the Pacific Ocean, is distributed from Japan and the Southern Kuriles to the western coast of North America. Its geographic range is delimited by the subarctic front from the north, while its southern boundary extends along 23-25^{o} N lat.

Our material was collected in the vicinity of the Pacific drift in March-July 1980 on the "Novoul'yankovsk" research-scouting vessel, and in October-January 1982-1983 on the "Novo-kotovsk" RSV. The squids were caught at depths of 0-140 m at a water temperature of 10.7-22.7^{o}C.

In the Northern California area in spring (35-36^{o} N lat., 126-130^{o} W long), the Bartram squid was represented by two size-age groups: 1) small squids - males at the 1st-2nd stages of maturity, average size 23.0 cm, and females at the 1st stage of maturity, average size 24.0 cm; 2) large squids - males at the 4th stage, 29.8 cm, and females at the 1st-3rd stages, 41.9 cm. By July, the large immature females had migrated after the retreating subarctic front to forage in the north (at 42-43^{o} N). Sexually mature males were no longer encountered; having matured considerably earlier than the females, they apparently died off (138)
after copulation. At the same time, the small squids were distributed farther south of the large females, their average size gradually increasing in the northward direction from 17.6 cm at

$34^{o}24'$ N lat to 23.1 cm at $41^{o}16'$ N lat. The groups of large squids apparently migrate with much greater speed and farther north than the small ones.

In October-November, the Bartman squid was encountered between 24 and 47^{o} N lat from the western coast of North America up to 131^{o} W long. Mature and maturing males (3rd-4th stage, 28.8 cm) dominated in the southern part of the region, and small immature females (1st stage, 26.9 cm) in the northern part. In January, the large foraging and maturing females also moved southward. Between 141^{o} and 170^{o} W long, 2nd—3rd-stage females were encountered from $40^{o}37'$ to $34^{o}09'$ N lat; they were represented by two size groups measuring 36.3 and 49.3 cm on the average. At the same time, the males were encountered slightly farther south, from $38^{o}46'$ to $33^{o}25'$ N lat, and were at the 2nd-4th stages of development; 2nd—3rd-stage males dominated north of 35^{o} N lat, and 4th-stage males south of 35^{o} N lat. The size of the males in January did not exceed that in October (average length of mantle 28.5 cm). It is possible that the males stop growing after reaching maturity.

Thus, immature Bartram squids migrate northward in spring to forage. In autumn-winter, the matured and maturing squids migrate southward to spawn. The males greatly outpace the females in development, and begin their migration to the spawning areas before them.

UDC 639.273

Reserves of oceanic squids in the tropical and temperate waters of the world's oceans and the problems of their commercial utilization

by G.V. Zuyev (InBYuM AN UkrSSR) and Ch.M. Nigmatullin (AtlantNIRO)

One of the main trends in the development of the USSR fishing industry is the development of the commercial reserves of the open waters of the world's oceans. This problem can be solved successfully if new products, particularly ocean squids, are added to the list. (139) Based on the results of visual and trawl surveys extrapolated on the area of the specific ranges, the total biomass of Ommastrephidae exceeds 20,000,000 tons.

On the whole, the ocean squids have not been researched well enough. The tropical waters of the eastern Atlantic, southwestern Atlantic, southeastern part of the Pacific and North Pacific have been studied relatively better than other areas. In these regions, we have established potentially commercial areas close to dynamically active zones (hydrological fronts, vergencies, cyclonic circulations, etc.) characterized by local upwellings. The stock (biomass) of squids and the volumes of potential removals were estimated for each area.

The ocean squids are classified into two groups, i.e neritic ocean species (Argentine squid in the southwestern Atlantic and *Dosidicus gigas* in the southeastern Pacific) and strictly ocean species (the subtropical Bartram squid and the tropical Atlantic *Sthenoteuthis pteropus* and Indo-Pacific *S. oualaniensis*). The species of the second group comprise approximately 80-90% of the total stock of ocean squids in the tropical and temperate waters. Because of their abundance and high productivity due to rapid growth and a short life cycle (1-2 years), the volume of commercial utilization of ocean squids can go as high as their biomass without disrupting the reproductive capacity of the species (up to about 20,000,000 tons a year).

The disparity between such impressive reserves of ocean squids and the actual catch is due primarily to the lack of economically efficient methods, equipment and technology for catching them. Consequently, the next necessary step in the research of ocean squids should be to acknowledge the development of new methods and equipment for their commercial exploitation, particularly the method of attracting them with light, sound and chemical stimuli. We need a basically new approach to the commercial exploitation of animals that do not form dense concentrations, but do abound in the open waters of the world's oceans.

(140)

UDC 594.582.2/.8

Potential volume of daily rations in pelagic ocean squids

by N.Ya. Lopskaya (VNIRO)

Squids grow rapidly, especially at the early stages. The daily weight increments can amount to 14-18% during the first month, 5-8% in 1.5-month-old squids, and 1.5-2.5% in 3—5-month-olds. The coefficient of food utilization for growth (K_1) in cephalopods amounts to 30-60%, most commonly 40%. The energy expended on metabolism constitutes 10-15% of the body mass daily.

High coefficients of food utilization for growth with a highly active mode of life are possible only when food consumption is high. We have estimated the daily ration for the young of *Sthenoteuthis oualaniensis* with a body mass of 15-200 g and a mantle length of 8-17 cm. Based on the level of metabolism T=15% and K_2=40% (Mangold, 1983), the volume of the daily ration constitutes

$$\Pi = \frac{T \cdot K_2}{100-K_2} = 10\%; \quad P = 1.25\ (\Pi + T) = 31\%.$$

A daily ration equal to 31% of the body mass should be regarded as the minimal one, since it is estimated on the basis of the minimal metabolic energy losses which in a natural environment will be higher than under experimental conditions. 31% lies between the very high (40-110%) daily rations derived under experimental conditions in a laboratory (La Roe, 1971) and the low ones obtained in field conditions (Zuyev et al., 1985). If the daily ration is equal to 6%, the size of the squid 8 cm, its mass 15 g and its daily rate of growth 2.5% (Zuyev et al., 1985), then $K_1 = \frac{2.5 \cdot 100}{6} =$ 41%. This figure is quite realistic.

Proceeding from the balance equation, the energy expended on metabolism should be equal to 2.3% ($T = 0.8\ P - \Pi$). This value corresponds to the energy losses of an octopus with the same mass ($T = 2.5\%$; Maginnis, Wells, 1969), and is 1.5 times lower than in the carp (Ivlev, 1962) and 5-6 times lower than in flyingfishes and lanternfishes (Lipskaya, 1974; Gorelova, 1975; Stolbov, 1984). As to the mode of feeding, squids are carnivores that pursue their prey, and so their level of metabolism is apparently higher than (141) that of the octopuses. We cannot imagine how with this level of metabolism the squid can pursue prey (lanternfishes, flyingfishes) in which the level of metabolism is several times higher than its own.

The following daily rations are more realistic. The daily ration in 1—2-month-old squids can amount to 50% of their body mass; in young squids (15-200 g), it can amount to 30%. In the older age groups, the growth rate is smaller, so the volume of the daily rations should diminish. If we take into consideration the genital products which were not included in the calculations, as well as the increase in swimming speed with age which results in an increase of active metabolism, the decrease in the daily rations will not be so great.

In presenting these estimates, I am not attempting to prove that they are more accurate than those of other authors. I wish only to point out the conflicting nature of the daily rations derived in field conditions and in experiment on the one hand, and the disparity between this data (field and experimental) and the estimated data on the other, and in doing so, to spark an interest in determining the causes of this inconsistency, since the daily ration is utilized in all trophodynamic calculations.

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UDC 594.582.2/.8:551.465(265.1) (142)

Oceanological conditions and mesoscale distribution of *Sthenoteuthis pteropus* in the eastern tropical part of the Atlantic Ocean

by Yu.A. Loktionov (AtlantNIRO)

In June-August 1985, investigations were conducted on the "Prognoz" MFTF* 1246 to determine the mesoscale variability characteristics that affect the distribution of *Sthenoteuthis pteropus* in the equatorial part of the eastern tropical Atlantic. A mesoscale ecological survey was carried out at 0°30' N lat—03°30' S lat and 5°30'—7°00 W long. On the basis of its results, we selected an ecological study area that repeated itself 4 times, i.e. a square with a 60-mile side in which oceanological stations were set up at 15-mile intervals. The variability of the southern equatorial current and the Lomonosov Counter Current and its effect on the density of squid distribution was studied in a complete profile along 7° W long, repeated four times with different time intervals. This resulted in material from 172 oceanological and 75 light stations. During this period, the temperature of this area's active layer of water was 2-5° lower than the long-term average. The depth of the upper boundary of the thermocline also

*medium fishing trawler-freezer - transl.

differed from the usual depth.

The higher than usual density of squid distribution was confined to the regions of sharp gradients of oceanological characteristics, particularly in the places where the Lomonosov Current comes to the surface. We noted that the variability of the local cross-circulation influenced the mesoscale distribution of the squid. It is possible to use elements of the topography of the thermocline as an indicator of a higher than usual density of squid distribution.

(143)

UDC 594.582.2/.8

Elementary composition of the mantle and liver of squids

by N.L. Lukinykh and I.S. Kuznetsov (AtlantNIRO)

The method of atomic-absorption spectrophotometry was used to determine the content of K, Na, Ca, Mg, Cu, Fe, Zn, Mn and other metals in the mantle and liver of three species of squids: *Dosidicus gigas*, *Illex argentinus* and *Todarodes sagittatus*.

We did not observe any statistically significant species differences in the content of these metals in the mantle of these squids. The macroelement composition of the squid mantle (K, Na, Ca, Mg) is similar to that of the muscle tissue of bony fishes and sharks. The role of these metals in the biochemical processes of the body is obviously identical.

We found no differences in the content of Mn, Ni and other metals in the mantle of squids and the muscle tissue of fish. The content of Cu and Zn is higher in the mantle of squids than in the muscles of fish. Copper is a constituent of hemocyanin, a respiratory pigment of mollusks; therefore, it is natural for squids to have a higher content of Cu. Squids grow rapidly. Under normal conditions, a higher than usual content of Zn is observed wherever vigorous cell division takes place (fungi, yeast, young growing organisms) (Nozdryukhina, 1977). The higher content of Zn in the muscle tissue of squids is apparently due to intensive cell division.

No relationship between the Fe, Cu, Zn content of the squid mantle and the size of the squid has been noted.

The content of transitional metals in the liver of squids is higher than in the mantle muscles by an order of magnitude and more. The noncorrespondence of the content of Zn and accompanying metals in the mantle and liver may be related either to the unusually high rate of Zn metabolism in the environment—organism system, or to the specific role of the metals accompanying zinc in the squid.

The given species of squids inhabit areas that are not affected by the coastal run-off, which permits us to regard the derived levels of metal content as natural ones.

(144)

UDC 594.582.2/.8

The fauna and vertical distribution of squids in the upper layers of the epipelagic zone of the southeastern Atlantic

by S.A. Murzov (AtlantNIRO)

The fauna of epipelagic squids of the tropical eastern Atlantic has not been researched well enough, while the vertical distribution of the squids has not been studied at all. A trawling study area consisting of 15 stations located on a one-degree grid was marked out in the vicinity of 6°-10° S lat and 4°-6° E long in April 1985. One daytime and 3 night trawls were carried out at each station with a non-closing 13.6 m PT/TM fry trawl with a small-mesh (6 mm) inset. The operation lasted 30 minutes with a travel speed of 3.6 knots. During the day, the trawling was carried out in the SRV* horizon in the 27-50 m range; at night, it was carried out in three horizons: above the thermocline layer, in the thermocline (from 25 to 50 m), and directly above it (up to a depth of 84 m). The frontal zone, which presumably separated the equatorial-tropical waters (28.0-30.2°; 35.32-36.49‰) and the tropical water masses (26.9-28.0°; 36.34-36.82‰), intersected the area from the southeast to the northwest at approximately 8° S lat.

Twenty-one species of squids from eleven families were found in the catches, 20 species (10 families) in the night landings and 10 species (6 families) in the daytime ones. The size of the squids varied from 0.4 to 13.5 cm (some Cranchiidae measured up to 17-18 cm). The following species were found: *Abraliopsis atlantica* (encountered at night, 0.5-3.6 cm), *Enoploteuthis leptura* (at night, 0.36-7.3 cm), *Ancistrocheirus alessandrinii* (at night, 1.3-6.0 cm; during the day, 1.5 cm), *Pterygioteuthis gemmata* (at night, 0.8-3.1 cm), *Octopoteuthis sicula* (at night, 3.2 cm), *Onychoteuthis banksi* (at night, 0.7-8.3 cm; during the day, 0.8-1.5 cm), Onychoteuthidae gen. sp. (juv.) (at night, 0.6-3.3 cm), *Ctenopteryx sicula* (at night, 1.1-1.3 cm), *Histioteuthis reversa* (at night, 0.6-2.3 cm), *H. meleagroteuthis* (at night, 0.6-2.3 cm), *Ornithoteuthis antillarum* (at night, 0.7-8.1 cm; during the day,

*speed-regulator valve - transl.

1.1-1.4 cm), *Sthenoteuthis pteropus* (at night, 0.9-13.5 cm; during the day, 1.4-1.9 cm), *Thysanoteuthis rhombus* (at night, 3.4 cm), *Tetronychoteuthis dussumieri* (at night, 1.4-5.5 cm), *Chiroteuthis veranyi* (at night, 1.7-4.5 cm; during the day, 2.5 (145) cm), *Grimalditeuthis bonplandi* (during the day, 6.5 cm), *Cranchia scabra* (at night, 0.4-8.5 cm; during the day, 0.6-4.5 cm), *Liocranchia reinhardti* (at night, 0.5-17.8 cm; during the day, 0.6-3.7 cm), *Leachia atlantica* (at night, 1.0-10.0 cm; during the day, 4.2-8.0 cm), *Megalocranchia oceanica* (at night, 7.5 cm) and *Helicocranchia pfefferi* (at night, 0.7-6.2 cm; during the day, 1.9-3.0 cm).

The following three groups are differentiated on the basis of the vertical distribution characteristics: 1) Species concentrated mainly in the upper homogeneous layer and in the thermocline. This includes the young of ecologically different species, i.e. nektonic *S. pteropus*, *O. antillarum*, *O. banksi*, and planktonic *L. reinhardti*, *C. scabra* and *H. pfefferi*. 2) Species concentrated in the thermocline with minimum numbers in the subsurface layers. A characteristic representative of this group is the micronektonic *A. atlantica* (mature individuals dominate in the catches). *A. atlantica* from the thermocline constituted up to 90% of the numbers of this species in the catches from three horizons, and up to 80% of the total number of squids from the thermocline. This group includes *E. leptura* and *P. gemmata*. 3) Species that do not ascend above the thermocline. These include the young of the mesopelagic and bathypelagic species *H. reversa*, *H. meleagroteuthis*, *A. alessandrinii*, *T. dussumieri*,

C. veranyi (and "Doratopsis"), O. sicula and M. oceanica. A tendency of increase in the average size of an individual with depth has been noted for the overwhelming majority of the species (especially Cranchiidae). For example, the average size of L. reinhardti was 1-3 cm in the catches from above the thermocline, 3-4 cm in the catches from the thermocline, and 4-5 cm (up to 13-18 cm) in the catches from below the thermocline.

Based on the catches from the northern and southern parts of the study area, the qualitative composition of the endemic species of squids did not change, but the abundance of certain species was much higher in the northern part. For example, the average catch at a northern station as compared with a station in the southern part of the study area was 161 as opposed to 59 in A. atlantica, 42 compared to 1 in O. antillarum, 45 compared to 3 in O. banksi, and 25 compared to 8 in C. scabra (based on three nighttime catches).

UDC 594.582.2/.8(265.53) (146)

Berryteuthis magister and Gonatopsis borealis in the Sea of Okhotsk

by K.N. Nesis (Institute of Oceanology of the USSR Academy of Sciences)

The study material was collected in September-October 1984 on the "Novoul'yanovsk" research vessel from 61 hauls of a 118/620 pelagic trawl at 300-1500 m and 52 hauls of a DT-43 bottom trawl at 55-2000 m. Twelve species of pelagic cephalopods and 11 species of benthic ones were found in the catches. As to the number of individuals, the gonatid* squids (8 species) constituted

*conjectural - transl.

over 90% of the total catch and over 98% of the catch from the pelagic zone. The dominant species were Gonatopsis octopedatus (1611 specimens examined), Gonatus madokai (1317), Berryteuthis magister (1219) and Gonatopsis borealis (984). We have established that the gonatids with a 7-rowed radula (B. magister and G. borealis) do not undergo the gelatinous regeneration of tissues typical of gonatids with a 5-rowed radula during sexual maturation, and even fully mature individuals are edible.

Berryteuthis magister was encountered throughout the study area, in the pelagic zone at a depth of 300-1500 m, as well as over great depths, and near the bottom at 145-1500 m. Its abundance per hour of trawling in the pelagic zone was half of what it was at the bottom. The greatest abundance was observed at 300-500 m in the pelagic zone, and at 400-900 m at the bottom. The mantle length (ML) averaged 115 mm in the pelagic zone (110 mm at 300-500 m, 124 mm at 500-1000 mm), and 175 mm at the bottom (ML varies nonuniformly with depth, but it is greater at all the depths than in the pelagic zone). The minimum ML is 15-19 mm in the pelagic zone, and 46 mm at the bottom; the maximum for males is 224 and 306 mm, and for females 266 and 379 mm respectively. The size series are 2-peaked, with the peaks at 40-60 and 160-180 mm in the pelagic zone, and 140-160 and 240-260 mm near the bottom. Spawing in the Sea of Okhotsk is apparently seasonal (according to Japanese data, in June-August), and the life cycle covers two years. The proportion of males and females is similar. The males begin to mature at a ML of 14-18 cm, and mature at 20-22 cm; one-half of them are mature at 22 cm, and all of them at 27-28 cm.

The females begin to mature at 14-20 cm, and reach maturity at 24-26 cm; one-half of them are mature at 30 cm, and all of them at 32 cm. In the pelagic zone, maturing and mature squids were caught one by one; the onset of mass maturation (ML 20-24 cm) coincides with the migration of most of the squids to the bottom (147) (ML 20 cm). The animals forage mainly in the pelagic zone. Their principal food consists of crustaceans, mainly euphausiids (61% of the indications), less commonly fish (17.5%). Almost all of the squids from the bottom had empty stomachs. We can assume that, inhabiting the epipelagic zone, the larvae of this species spread far and wide throughout the sea; however, as they grow older, they migrate to the mesopelagic, less commonly bathypelagic, zone where they forage actively. At a ML of 6-8 cm, the squids begin to gradually migrate towards the slope and down into the near-bottom layers. The main downward migration takes place at the beginning of sexual maturation during the second year of life. Having matured, the squids (particularly the females) gradually stop feeding and live on the fat stored up in the digestive gland. Mating takes place shortly before spawning (females at stages V_1-V_2). The nidamental glands are very large, up to 45% of ML; their growth accelerates upon maturation (ML 24-25 cm), and becomes linear after that. The diameter of ripe eggs is 3.5 mm. The eggs are probably deposited on the bottom.

G. borealis is encountered mainly in the pelagic zone (frequency of occurrence 95%); only single individuals are encountered near the bottom at 400-1375 m (26%). The abundance of this species in the pelagic zone at 300-500 m is twice as high as at 500-1000 m;

it is low at depths greater than 1000 m. The mantle measures 24-330 mm; young squids with a mantle length of 40-80 mm dominate, and very few adults are encountered. The average size is the same at all the depths. Spawning probably takes place throughout the year. The male-female ratio is 1:1.35. The males begin to mature at a mantle length of approximately 12 cm, and one-half of them is mature at 14-16 cm; the females begin to mature at a length of 14 cm, and reach maturity at about 16 cm. We encountered three large immature squids (ML 195-330 mm) from the late-maturing ocean group. The nidamental glands were smaller than in B. magister, up to 1/3 of ML. The spermatophores are transferred onto the oral membrane of the female (as in Gonatus), instead of into the mantle cavity. Feeding is fairly intensive. The average index of fullness was 1.6, the percentage of empty stomachs 17%, and the percentage of full stomachs (index of fullness 3-5) 24%. The food preferred by this species consists of crustaceans, mainly euphausiids (37% of the indications), and fish (33%), occasionally squids. Mature squids do not stop feeding.

Neither of these species are caught commercially. The total catch of cephalopods did not exceed 7-9 kg/h in the pelagic zone and 45 kg/h near the bottom; the average catch for all the trawls amounted to 2.8 and 9.8 kg/h respectively.

(148)

UDC 594.582.2/.8

Structure of the geographic range and intraspecific groups of *Illex argentinus*

by Ch.M. Nigmatullin (AtlantNIRO)

1. In 1969-1976 and 1981-1985, the seasonal changes in the functional differentiation of the geographic range and population structure of *I. argentinus* were studied at different stages after the fry stage in the vicinity of 40-54° S lat.

2. This species inhabits the waters of the shelf and slope of the tropical and subantarctic structures of the southwestern Atlantic from 20° (mainly 25-30°) to 55° S lat. The reproductive part of the range is located north of 47-49° S lat, and the foraging grounds are located south of it. Unlike that of the rest of the genus with reproductive ranges confined to the subtropical zones far from the influence of cold currents (Labrador, Benguela), the reproductive part of the range in *I. argentinus* extends right up to the southern periphery of the temperate zone, and is directly contiguous to the waters of the Falkland Current over a distance of 400-500 miles in the east. The main trend of ecological expansion of this genus is the assimilation of the shelf and temperate waters from its initial biotope on the edge of the shelf in the subtropical zone (Nigmatullin, 1979). These tendencies have manifested themselves more fully in *I. argentinus* as compared with allied species, which was largely due to the expansion of the lower temperature threshold at which embryogenesis can take place to 4-6°C.

3. Adult females measure 15-40 cm, and adult males 14-32 cm. With monocyclic development, their life span does not exceed 12-14 months. The sexually mature period (stages V_1-VI) lasts about 3-6 months in males, and about 2-3 months in females. The mating in males and egg deposition in females last about 2-3 months, and take place several times. Spawning is year-round, with peaks in winter and smaller ones in autumn and summer. The following four groups have been preliminarily established on the basis of a number of ecological characteristics:

Summer group (SG). The entire life cycle takes place in shelf waters. Spawning takes place in December and up to the beginning of February over depths of 100-200-250 m at a water (149) temperature in the 0-100 m layer from 6-7 to 12-15°C, with adult males measuring 14-22 cm and adult females 15-25 cm. In January 1964, spawning and spawned out females and males were observed over depths of 120-200 m right up to the surface; the wall of their mantle was 3-4 times thinner, the mass of the liver had decreased, and the body proportions had changed. As a result, their habitus approximated that of *I. oxygonius*.

Autumn group (AG). Spawning takes place at the end of March and up to the beginning of May above depths of 200-400 m in slope waters (mixing of shelf waters and subantarctic surface waters) with a temperature of 4-10°C in the 0-400 m layer, with the adult males measuring 18-26 cm and the females 22-30 cm; foraging takes place in shelf waters during the spring-summer period.

Winter group (WG). Spawning takes place from the end of May-June and up to the beginning of August in slope waters above depths of 400-800 m (prevalence of subantarctic surface and antarctic intermediate waters) at a temperature of 3.5-6°C in the 0-600 m layer, with the males measuring 24-32 cm and the females 28-40 cm; the growing period of the larvae and young is spent above the continental slope, and the foraging period in the shelf waters.

Spring group (SpG). This group was established conjecturally on the basis of N. Brunetti's material (Brunetti, 1981). It inhabits shelf waters, and spawns in September-November above depths of 60-150 m at a temperature of 5-8°C in the 0-150 m layer, with the adult males measuring 21-28 cm and the females 28-35 cm.

4. The status and interrelations of these groups are not clear. There are two alternative hypotheses: 1) the generalist is represented by a single populational system with high plasticity and a prolonged spawning period with the dominance of centripetal tendencies due to extensive recombination of the species population; the seasonal change in spawning depths is maintained by selection for maximum survival of the larvae and young; 2) the indicated groups (at least SG, WG and AG, or WG+AG) are the result of the intraspecific differentiation that occurs as a result of allotopic and allochronic processes during the assimilation of new expanses and resources yearly at all the trophic (ontogenetic) levels; these are separate groups, different populational systems, and, in the extreme case, incipient biological species.

Considering the climatic (seasonal) and hydrological characteristics of the studied part of the range of I. argentinus, the vastness of the Patagonian shelf (volume and nonuniformity of the biotope), the ecological specificity of the groups and the preliminary data of genetic and biochemical analysis, the second hypothesis is preferable. In order to arrive at a final conclusion, we must have some key data on age structure with the dates of birth and genetic-biochemical analysis indicated.

UDC 594.582.2/.8

Population dynamics and size structure of *Sthenoteuthis pteropus* in the surface layer of the equatorial region of the Atlantic Ocean in connection with the variability of the food resources of the species

by V.N. Nikol'sky and O.P. Ovcharov (INBYuM)

The variability in the abundance and size composition of *Sthenoteuthis pteropus* was studied in the surface layer of the equatorial region of the Atlantic along the equator from 0 to 20°W long during the 18th trip of the "Professor Vodyanitsky" research vessel (February 1985). The squids and subsurface ichthyofauna were counted and caught at nocturnal drifting light stations. The number of squids observed per hour was accepted as the index of abundance. The study area was broken down into three sectors, i.e. eastern (0-6° W long), central (6-16° W long) and western 16-20° W long).

The abundance of squids diminishes naturally from east to west, but their average size increases. For example, the index of abundance amounted to 90 specimens/h with an average mantle length (ML) of 16 cm in the eastern sector of the study area, 70 specimens/h with an 18 cm ML in the central sector, and 50 specimens/h with a 20 cm ML in the western sector. In the eastern part of the profile, the index of abundance amounted to about 40 specimens/h with an average ML of 18 cm in the evening hours; it increased to 100 specimens/h and the average ML decreased to 16 cm in the middle of the night; during the hours before dawn, the abundance of squids reached its maximum, up to 125 specimens/h, due to the appearance of smaller squids at the surface, and the average ML dropped to 15 cm. In the central part of the profile, the abundance of squids doubled during the night, and their average size decreased from 20 to 17 cm. In the western part of the profile, the abundance of squids almost doubled as well, but their average size hardly changed at all during the night.

(151)

As we know (Nigmatullin, Toporova, 1982), subsurface Myctophidae are the basic food of *Sthenoteuthis pteropus*. Two species dominated among the subsurface Myctophidae in the study area, *Myctophum affine* and *M. nitidulum*. The first species is small, in our samples 1.7-4.3 cm long (average 3.1 cm). *M. nitidulum* is much larger, 2.7-7.7 cm long (average 6.6 cm). The absolute dominance of small *M. affine* was noted in the eastern sector.

At our easternmost station, this species dominated throughout the night; at the other eastern stations, *M. nitidulum* dominated at the surface in the evening, and *M. affine* dominated after midnight. In the central sector, the abundance of *M. affine* decreased considerably, and the change in dominant species during the night was less pronounced. In the western sector, *M. nitidulum* dominates throughout the night, while *M. affine* is hardly ever encountered at this time.

The decrease in the abundance of squids with their average size from east to west, as well as the variability of their size structure in the surface layer during the night is consistent with the gradual change in the dominant species of subsurface Myctophidae.

(151)

UDC 594.582.2/.8

Quantitative feeding characteristics of *Sthenoteuthis pteropus* in the Eastern Atlantic

by V.N. Nikol'sky and M.V. Chesalin (INBYuM)

The quantitative aspects of the feeding of *Sthenoteuthis pteropus*, which plays a major role in the trophic system of pelagic communities of the Atlantic Ocean, have not been studied to this day. We have analyzed the field and experimental data obtained during the 18th trip of the "Professor Vodyanitsky" research vessel (December-March 1984-1985). The results of 290 experiments on the maintenance of squids in flow-through aquariums without food have shown that food is digested in 8-10 hours at a temperature of 26-28°C. The initial, or instantaneous, speed of digestion, based on the decrease in the average indices of stomach fullness, is equal to 0.42% of the raw body mass per hour. The (152)
rhythm of feeding throughout the night was determined by the dynamics of the fullness indices grouped according to time. The squids with a mantle length (ML) of 8-15 cm showed two periods of higher than usual fullness, in the evening at 19.00-21.00 hours (1.7% of the mass of the squid) and during the hours before dawn at 03.00-05.00 hours (1.4%), and one period of minimum fullness, in the middle of the night at 23.00-01.00 hours (0.9%). Analysis of the

variability in the indices of fullness in the medium-sized group (ML 15-30 cm) did not reveal any statistically significant differences in the average values of the indices during the night, i.e. the squids fed at a constant rate, maintaining a fullness level of 1.1%. The indices of fullness of squids larger than 30 cm gradually increased by dawn.

Using the data on the rhythm of feeding and the rate of digestion, we determined the daily rations for the average group of squids in a natural environment. The ration is equal to 10.4% of the total body mass with a ML of 8-15 cm, 5.9% with a ML of 15-30 cm, and 5.2% of the total body mass with a mantle length of more than 30 cm. The food requirements of the different size groups of squids were determined on the basis of data on the rate of energy metabolism (Belokopytin, 1982; Abolmasova, 1984) and the rate of growth (Zuyev et al., 1985). The required daily ration is equal to 10-15% of body mass with a ML of 8-15 cm, 6-10% with a ML of 15-30 cm, and 4.5-6% with a mantle length of 30-50 cm.

The efficiency of food energy utilization for growth (K_1) is not high, which can be attributed to the high level of energy expended on metabolism. The K_1 coefficient decreased in the course of biological development from 23% (ML 7 cm) to 5.5% (ML 50 cm). K_1 is equal to 10-15% for medium-sized squids (15-30 cm), and the K_1 average for the population is 10.8%.

(153)

UDC 551.465:594.582.2/.8

Oceanological characteristics of the formation of *Berryteuthis magister* concentrations off Simushir Is.

by A.A. Malyshev and P.P. Railko (TINRO)

The investigations of a joint expedition on the "Mlechnyi put'" and "Sovremennik" research vessels in spring of 1985, carried out on the Pacific shelf and slope of Simushir Is. (of the Kurile chain of islands) with the help of the "Gidrozond" sounding system, revealed a sporadically emerging elliptical cyclonic-type eddy with 3—6-mile horizontal axes in the Dushnaya Bay—Cape Vasin area. The major axis of the ellipse is oriented shoreward on the surface, but it makes an almost 300^{o} turn at a depth of 500 m. A layer of cooled and less saline waters of an intrusive origin is found on the northeastern and eastern periphery of the ellipse at a depth of 150-300 m.

This intrusion is the result of the influx of colder and highly biogenic Okhotsk waters (which interact with the general flow of the Kurile Current) at the different stages of the ebb and flow cycle and in connection with the orographic occlusion of the island. The vertical structure of hydrostatic stability points to the negative buoyancy of the intrusion cores, which contributes to eddy formation.

The Pacific shelf and slope of Simushir Is. is the place where the largest known foraging concentrations of *Berryteuthis magister* form. Analysis of trawling data has shown that the main concentrations of this species form at a depth of 180-350 m, and that the relative density of its distribution in the Dushnaya

Bay—Cape Vasin area is 2-3 times higher than in the neighbouring sectors of the shelf and slope. In the zone covered by the described circulation, the average index of fullness of the squids is 1.5-2 times higher than in other parts of the area. The stomachs were found to contain mainly planktonic crustaceans (copepods and euphausiids), small Gonatidae, lanternfishes and the young of cods. Therefore, this species forms concentrations directly under the intrusion layer, where it forages intensively. Planktonic crustaceans, which attract young fish and squids, probably accumulate on the periphery of the circulation in the zone of the intrusion lens, where they create the conditions for the feeding of consumers of the 3rd-4th trophic levels.

We can now say that, as a result of the interaction of Okhotsk and Pacific waters, a highly productive frontal-eddy zone with a concentration of *Berryteuthis magister* is formed in the vicinity of the Pacific shelf and slope of Simushir Is. It is theoretically possible to determine the places of concentration of squids and fish by analyzing the microstructural characteristics of the waters.

UDC 594.582.2/.8(265:267)

On the speciation and distribution of the genus *Nototodarus* in the Indo-Pacific region

by O.A. Petrov (TINRO)

The material for this paper consisted of the results of morphological investigations of my own samples of *Nototodarus* during 1974-1978 from the western and southwestern sectors of the Pacific Ocean, and of individual *Nototodarus* specimens from the western part of the Indian Ocean, the south of Japan and from southern Australia, kindly placed at our disposal by M.A. Pinchukov, T. Okutani and M. Danning respectively.

In all probability, the Australia—New Zealand region is the centre of speciation of the genus. Here we find the original cold-water form, the New Zealand *N. sloani*, as well as several other forms which are probably independent species. These forms have separate geographic ranges, distinct morphological differences, and two of them (the Australian and New Zealand *Nototodarus*) are highly abundant. The major dispersal of *Nototodarus* could have occurred during the low-water periods of the world's oceans in the Pleistocene, and extended along the shoals, the slopes of exposed shelves and ocean rises. During the transgression periods, (155) all or the majority of the new habitats of *Nototodarus* became isolated from the once more or less continuous range of the genus. It is to this that we can attribute the existence of narrow ranges of these squids in some parts of the central, southern and eastern Pacific, and in the northern and western parts of the Indian Ocean. The primary form of *Nototodarus* apparently inhabited the moderately cold and moderately warm waters; having found itself in the less favourable climatic and ecological conditions of the subtropical and tropical regions of the Pacific and Indian oceans, it developed a number of morphological forms, The whole diversity of the known *Nototodarus* species, which is clearly established from the structure of the hectocotylus, can be brought down to three morphological groups, each of which is confined to specific areas of the Indo-Pacific region (Petrov, 1983). The boundaries of the ranges of these groups clearly coincide with those of the geographic fishing complexes established for these regions by Parin (1979).

UDC 639.273:639.2.081.117.004.17

Method of determining the trawling efficiency for squids

by P.P. Railko (TINRO)

The main difficulty of determining the density of squid distribution from the data of trawl catches lies in determining the fishing efficiency of the trawls.

As a result of the analysis of 1017 catches by different types of trawls in concentrations of *Berryteuthis magister*, the following was established:

1. The best results in landing *Berryteuthis magister* were obtained with 33.4, 43, 53 and 69 m trawls with an "overhang" above part of the wings. The maximum catches of symmetrical trawls (without an "overhang") are 30% smaller than with asymmetrical ones.

2. With an increase in trawling speed, the catches increase in accordance with the function $W = \frac{1}{1+10^{a+bx}}$ (1), where x denotes (156)
the trawling speed in knots; the coefficients a=2.1 and b=-0.9 were derived empirically for *Berryteuthis magister*.

3. The catches increase when the groundrope is made heavier and the vertical opening of the trawl is reduced, i.e. when the groundrope is pressed to the bottom. The optimal value of the vertical opening of the trawl (derived experimentally) is 0.9 of the rated value.

4. With a trawling speed of 2.8-3.6 knots, the squid becomes highly entangled in the wings of the trawl, which is not usually

noted for the majority of fish.

The listed characteristics indicate that squids interact differently than fish with the gear used to catch them; they do not move along the wing towards the codend, but instead retreat from the approaching netting, attempting to pass through the mesh, under the groundrope, or over the headline.

The higher than usual fishing efficiency of asymmetrical trawls permits us to assume that the probability of a squid escaping from a symmetrical trawl over the headline (p_{hl}) is equal to 0.3 ($p_{hl}=0$ for asymmetrical trawls).

The fact that the size of the catches depends on the degree to which the groundrope is pressed to the bottom indicates that it is possible for a squid to escape under the groundrope. The probability of escape (p_{gr}) approximates zero with maximum pressure of the groundrope against the bottom; when trawling in the pelagic zone, p_{hl} and p_{gr} can be equated to 0.3. The variations in p_{gr} from 0 to 0.3 can be described by the function

$$p_{gr} = \frac{0.3}{1+10^{a+bx}}, \qquad (2)$$

where x denotes the distance from the horizontal axis of the ellipse of the trawl entrance to the bottom (determined from trawl observation instruments); the coefficients a=3.9 and b=-0.79 were derived empirically for a 43/50.2 m bottom trawl.

The probability of a squid passing through the mesh of a trawl is inversely proportional to the ratio of the mantle girth of the squid in the widest part (c) to the perimeter of a mesh in the trawl wing (4a).

The derived functions enable us to determine the probability (157)
of catching a squid (P_x) located ℓ distance away from the trawling axis, i.e.

$$P_x = W(1-p_B-p_H)\cdot\left[1-\left(\frac{\ell}{H}\right)^{S\frac{c}{4a}}\right] \qquad (3)$$

where H denotes the distance from the trawling axis to the end of the wing (1/2 of the horizontal opening of the trawl), and S the coefficient of proportionality, which is dependent on the form of the trawl wing (S=3.7+4.0 for the majority of trawls).

If we integrate equation (3) with respect to h, we get the equation

$$K = W(1-p_B-p_H)\int_0 \left[1-\left(\frac{\ell}{h}\right)^{\frac{c}{a}}\right]dh\,, \qquad (4)$$

by which we can determine the fishing efficiency for squid by different trawls (K) and under different working conditions. Our calculations for a 43/50.2 m bottom trawl with a vertical opening equal to 0.9 of the rated value gave us K=0.59 for a trawling speed of 2.5 knots, K=0.84 for a speed of 3.2 knots, and K=0.95 for a speed of 4.0 knots.

UDC 594.582.2/.8(261.5)

Respiration in the young of ocean squids of the tropical Atlantic

by A.Ya. Stolbov (INBYuM AN UkrSSR)

It is extremely important to study the metabolic processes and physiological characteristics of ocean squids that play a major role in epipelagic ocean communities in order to assess the functioning of individual components of the ecosystem.

We have determined the metabolic rates and the critical and threshold values of oxygen saturation in the young of three species of Atlantic ocean squids, i.e. Sthenoteuthis pteropus (average mass

32.7±2.7 g, mantle length 9.4±0.4 cm), Onychoteuthis banksi (mass 12.5±3.6 g, ML 5.7±0.7 cm) and Thysanoteuthis rhombus (mass 55.0 g, ML 11.0 cm). The squids were caught with scoop nets at nocturnal light stations from the "Professor Vodyanitsky" research vessel in December 1984—March 1985 in the central-eastern Atlantic, and with all the necessary precautions transferred to a thermostatically controlled closed-type 17.2-litre respirometer in which oxygen consumption and the critical and threshold values of oxygen saturation were determined at a water temperature of 24.5–27.5°C. The oxygen content was determined by means of silver chloride sensors with simultaneous automatic recording of the results. The experiments lasted 2.7–6.2 hours. Oxygen consumption was expressed in ml O_2 $g^{-1} \cdot h^{-1}$.

The respiration intensity of the young is equal to 1.445 ml O_2 $g^{-1} \cdot h^{-1}$ for S. pteropus, 1.125 ml O_2 $g^{-1} \cdot h^{-1}$ for O. banksi, and 0.991 ml O_2 $g^{-1} \cdot h^{-1}$ for T. rhombus. The differences in the level of metabolism are determined by the ecological characteristics of the squids. They are also seen in their swimming characteristics, rhythm of respiration and behaviour under different oxygen conditions. The critical level of oxygen concentration for young squid is 28% of the initial concentration for S. pteropus, 45% for O. banksi, and 67% for T. rhombus; the threshold values are 17, 40 and 50% respectively.

UDC 594.582.2/.8(265.518)

The feeding rhythm of *Berryteuthis magister* in the western part of the Bering Sea

by Yu.A. Fedorets (TINRO)

The material on the feeding of *B. magister* was collected during the TINRO-TURNIF* expeditions in the Olyutorskoye-Navarin area of the Bering Sea in 1976-1981. Stomach fullness was determined on a 5-point scale. The stomachs of 5-36 cm squids were analyzed in 1606 females and 1559 males caught with bottom trawls at depths of 100-800 m. A significant increased in feeding activity was observed in March, June—July and in November; the index of fullness was 1.0-2.3. Feeding activity diminished in January—February, May and October, with the index of fullness equal to (159) 0.1-0.7. Individuals with an index of fullness equal to 4 were encountered throughout the year (20-25% of the squids). During low feeding activity, there was a significant increase in the number of squids with empty stomachs.

According to visual observations, the basic food of the squids consisted of crustaceans, particularly in April, May and part of June. Their diet included fish throughout the year, the proportion of cephalopods increasing in January, February, August and November.

The pre-spawning and spawning females continued to feed, but their activity (average index of fullness) was lower than in foraging individuals, especially in November—December and August, the time of spawning in the Olyutorskoye-Navarin area.

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*Second acronym unknown - transl.

The most active feeding of the squid takes place in the zones where the waters of the warm intermediate layer mix with the superjacent layers and the upper boundary of the warm intermediate layer (2.0-3.5°C) lies at a depth of 200-300 m. The squid feeds quite actively round the clock, slowing down somewhat during the day. It feeds predominantly on crustaceans and cephalopods at night, and on cephalopods and fish during the day. The diurnal decreases and increases in activity are probably due to the differences in the availability of the major food items at a depth of 100-800 m, as well as to the physiological condition of the squid itself, the feeding activity of which decreases significantly during the spawning periods.

UDC 639.273

Present state of the cephalopod industry

by Yu.A. Filippova (VNIRO)

Over the past years, cephalopods have begun to play an ever-increasing role in the world's fishing industry and on the world seafood market. Over the past ten years, the total catch of cephalopods has increased 1.5-fold, reaching 1,630,000 tons in 1983 (FAO, 1984).

(160)

Squids comprise a large proportion of the catch (70-75%); approximately 1,200,000 tons of them are caught annually. The greater part of the catch (over 60%) comes from the Pacific Ocean, and slightly more than 30% from the Atlantic; the contribution of the Indian Ocean is still insignificant.

The centre of the world's cephalopod industry was and still is the northwestern part of the Pacific Ocean (NWPO) which yields one-half of the world's landings (791,000 tons in 1983, according to FAO data). The areas of specialized cephalopod fishing today are the coastal waters of the northwestern Atlantic (NWA), the central-eastern Atlantic (CEA), the central-western part of the Pacific Ocean (CWPO), the southwestern part of the Pacific Ocean (SWPO) and the southwestern Atlantic (SWA).

Approximately 50 countries are involved in the cephalopod trade; 14 of these countries are responsible for 92% of the world's catch of cephalopods. Japan was and still is the leading producer and consumer of cephalopods. Its catch over the past years varied within a range of 600,000-700,000 tons. Japan fishes for cephalopods in its own waters, in the open ocean, and in the economic zones of other countries, altogether 7 fishing zones of the ocean, namely the central-eastern Atlantic, southeastern Atlantic, northwestern Atlantic, southwestern Atlantic, northwestern Pacific, southwestern Pacific and the northwestern part of the Indian Ocean. The demand for cephalopods in Japan is traditionally high. Japan has to import more than 100,000 tons of cephalopods annually to meet this demand (Sato and Hatanaka, 1983).

The other world leaders in the cephalopod industry are Korea, Thailand, Spain and Poland; their catch in 1983 amounted to 168,000, 128,000, 104,000 and 110,000 tons respectively (FAO, 1984).

Our own specialized squid industry, begun in 1982 and conducted off the northern Kuriles, on the Patagonian shelf and in New Zealand waters, is still insignificant.

Several species of cephalopods, primarily squids, comprise the bulk of the total cephalopod catch. The list of commercial species is headed by the Japanese squid (*Todarodes pacificus*), the Argentine squid (*Illex argentinus*) and the Bartram squid, the annual hauls of which average 300,000, 250,000 and 15,000 tons.

One of the features of the developing cephalopod industry is its international character. A large-scale cephalopod trade is conducted by numerous countries in the northwestern Atlantic, southwestern Atlantic, central-eastern Atlantic and southwestern Pacific. Ten countries, including newcomers Poland, Cuba, the German Democratic Republic and Bulgaria, operate in the southwestern Atlantic.

(161)

At the present time, the cephalopod trade is being conducted in shelf waters (with the exception of the Japanese operations in the open parts of the northwestern Pacific), and, in principle, less than 10% of the ocean area yields 90% of the total catch.

The introduction of fishing zones has prohibited the vessels of developed fishing states from entering the most abundant shelf regions of the ocean. A further increase in the cephalopod catch entails moving operations into the open waters of the ocean which are far more abundant in squids, primarily ommastrephids which have been estimated at hundreds of millions of tons. The successful development of these resources of the open ocean is inseparably related to the development of efficient fishing gear and technology, as well as methods of creating artificial concentrations.

The present total catch of cephalopods amounts to only 2% of the world's seafood production; however, the substantial reserves of cephalopods give us reason to believe that the catch of these valuable animals will increase significantly in the future.

UDC 594.582.2/.8

Ecology and population dynamics of the Atlantic shortfin squid, *Illex illecebrosus*

by Yu.M. Froyerman (AtlantNIRO)

During the period from 1962 to 1984, the distribution of the Atlantic shortfin squid in the northwestern Atlantic has been analyzed on the basis of 4175 trawl hauls and 1457 catches of a plankton recovery sonde; 174,160 specimens have been measured, and 47,988 squids subjected to biological analysis; the frequency of occurrence (%) has been determined in 3461 specimens, and the composition of the food bolus in 2049 squids; more than 48,000 individuals have been analyzed to determine the diurnal and seasonal dynamics of feeding intensity. The basic geographic range (reproductive-foraging zone) in the vicinity of the continental slope and shelf of the USA, the reproductive part of the range (continental slope of the USA south of 40^{o}N lat and the Gulf Stream), and the foraging grounds (continental slope and shelf of the USA and Canada north of 40^{o}N lat) have also been established. The life cycle of the species falls into 5 main ecological stages.* (162)
The planktonic stage lasts 20-30 days, and takes place in the pelagic zone above the continental slope and shelf of the basic part of the range, on the northern periphery of the Gulf Stream, and in its eddies; the nektonic pelagic stage lasts 3-4 months, and occurs beyond the shelf in the foraging area, on the shelf and above the slope in the basic part of the range; the nektonic

*The author calls these stages **lochi** (Gr.); see footnote on p. 211 - Translator benthic-pelagic stage lasts 4-10 months, and takes place in shelf waters; the migration to the spawning and maturing grounds in the slope waters lasts 1-3 months; mating and spawning in the pelagic zone above the slope of the basic part of the range takes less than one month. The entire life cycle averages one year. The redistribution from the basic part of the range to the foraging grounds is due to the passive drift of the eggs, larvae and fry in the Gulf Stream. This is followed by active migration from the northern periphery of the Gulf Stream to forage in the frontal zone of the shelf and slope waters and interior of the shelf.

The congregations of squids on the shelf during the foraging period are confined to the frontal zones with a high productivity of macrozooplankton (Georges, Browns, Emerald, Sable and Grand banks). The spatial separateness of the foraging and spawning areas with the same rate of the spawning migration and similar periods of its onset (October-November) determines the discreteness of the spawning peaks in time. The differences between the spawning peak and the euphausiid biomass peak (euphausiids are the main food of the squids during the foraging period) determines the growth rate, fecundity and mortality of the recruitment. An increase in water temperature and a decrease in the food supply accelerate maturation and lower fecundity. Therefore, the fecundity of the foraging squids in the basic part of the range is always lower than in the squids migrating from more northerly foraging grounds. The recruitment produced in autumn and at the beginning of winter feeds and grows more intensively (ration 5-6%) than the squids produced later (ration 2-3%), since they have a constant supply of food (at first euphausiids, then their own young and fish). The squids from a late spawning have a low fecundity, and are extensively eliminated by squids of their own species, as well as by fish, marine mammals and birds.

Migrating from the Gulf Stream into shelf waters and (at the end of the life cycle) from the northern regions to the southern ones, the squids establish links between the communities of the open ocean, the continental slope and the shelf.

The dynamics of the Gulf Stream is the main abiotic factor that regulates abundance. The temporal discreteness of the enomoties* that make up a lochus (Abakumov's terminology, 1970) within (163)
the third lochus is a result of the discreteness of the spawning peaks which, in turn, depend on the size of the foraging area. The redistribution of the squids of each generation within the boundaries of the range by the current ensures a high degree of species panmixis, so that the species is apparently represented by a single population. The summer-spawning group of squids is hardly an independent population, but this assumption requires verification.

The mechanism of the population dynamics of the Atlantic shortfin squid and other neritic-oceanic benthopelagic squids with similar areas of distribution is based on the mechanism of a self-oscillating type of space and time variability that develops as an adaptation to seasonal and long-term environmental changes. The principal one is the change in the position of the axis of the current with respect to the spawning area.

*Enomoty (Gr.) - a band of sworn soldiers, a division in the Spartan army; Lochus (Gr.) - a division of the army in Sparta and some other Greek states - Tr.

An increase in the numbers of the Atlantic shortfin squid in the foraging area of the range above the average level begins three years after the divergence of the Gulf Stream towards the spawning area; a decrease in numbers begins 3 years after the divergence of the Gulf Stream in the opposite direction. Three years is the lag period of the biological processes brought on by the change in current. The periods of high or low abundance are of the same duration as the divergence of the Gulf Stream from its average position over a number of years (5-7 years).

UDC 594.582(267.37)

Sepiidae of the Arabian Sea

by L.P. Khomenko (AzCherNIRO)

Cuttlefish of the fam. Sepiidae are one of the most valuable products of the fishing industry. They are caught in large quantities in certain parts of the Indian Ocean. Cuttlefish are particularly abundant in the shelf waters of the northwestern part of the Indian Ocean.

Twenty-seven species of *Sepia* and *Sepiella* are known in the Indian Ocean. The shelves of Western Indostan and the Gulf of Aden are known for the highest species diversity of these mollusks. (164
The entire life cycle of sepiids passes on the shelf, predominantly near the bottom. The depths of their habitat vary in the different species: 20-180 m in *Sepia pharaonis* and *S. stellifera*, 20-140 m in *Sepia aculeata*, 60-220 m in *Sepia prashadi*, 18-60 m in *Sepia omani* and *Sepiella inermis*, and 40-160 m in *Sepia arabica*. The highest species diversity is observed at a depth of 60-140 m.

S. pharaonis and *S. stellifera* constitute the greatest part of the catches off the coast of Western Indostan.

Based on Druzhinin and Filippova's material (1974) and our own samples from the Gulf of Aden, six species of sepiids are encountered along the southeastern coast of the Arabian Peninsula at depths of up to 220 m. *S. pharaonis* comprises the main part of the catches on the shelf and continental slope of the Gulf of Aden, and *S. prashadi* takes second place. *S. pharaonis* is the largest and most prolific species of cuttlefish in the Arabian Sea; it measures 4-42 cm, and weighs 50-4850 g. 12-22 cm individuals weighing 150-600 g constitute the bulk of the catches. The males are somewhat larger than the females.

The breeding periods of the cuttlefish off Western Indostan have not been established for certain. We only know that they deposit their eggs in batches (Zuyev, 1971).

According to our observations, mass spawning in *S. pharaonis* takes place at small depths in February-March and August-October. A large part of the sexually mature individuals take part in the autumn spawning, and they form the basis of the annual recruitment and increment in biomass of the population. The batches of eggs are laid on rocky substrates.

All cuttlefish are active predators. Analysis of the stomach contents of *S. pharaonis* has shown that the food bolus of both the males and females is composed basically of benthic and benthopelagic crustaceans and fishes, with an insignificant portion of cephalopods. In turn, *S. pharaonis* have been found in the stomachs of *Galeocerdo cuvier*, *Saurida tumbil* and *Epinephelus taurina*.

The potential catch of sepiids off the coast of the Arabian Peninsula is estimated at 200,000 tons (Filippova, 1979). The catch in the Gulf of Aden from 1969 to 1978 varied from 3000-4000 tons to 9000 tons, reaching 15,000 tons only in 1976 and 1977 (Aoyama, Nguyen, 1979). Japanese vessels harvested 2400-6800 tons a year in the Arabian Sea from 1967 to 1975 (Okutani, 1977).

(165)

The catch of cuttlefish in the northwestern part of the Indian Ocean can be increased significantly.

UDC 639.27

Present status of the cuttlefish industry and the prospects for its development

by D.N. Khromov (VNIRO)

Cuttlefish are an old and popular item of the fishing industry. They are caught in shallow waters mainly from small vessels with the help of various fixed gillnets and cast gear (traps, seines, hook-and-line gear), and recently with trawls. The catch of cuttlefish is steadily growing, and over the past years has persistently exceeded 10-15% of the total catch of cephalopods.

The Sepiidae of greatest commercial importance are the prolific, widely distributed and fairly large congregating species *Sepia officinalis*, *S. pharaonis* and *S. esculenta*, and the locally distributed but abundant *Sepiella japonica*, *Sepia brevimana*, *S. recurvirostra*, *S. madokai*, *S. lycidas* and *S. kobiensis*.

Over the past ten years, the cuttlefish industry has grown almost 1.5-fold, reaching 250,000 tons in 1983. In the mid 1970's, cuttlefish were caught mainly in the tropical regions of the

Western Pacific and Eastern Atlantic, which yielded almost 60% of the world's catch. At the beginning of the 1980's, a part of the industry moved into the subtropics; in 1983, about one-half of all the cuttlefish was caught in the northwestern part of the Pacific Ocean.

Significant changes also occurred in the distribution of the catch according to country. Japan's catch declined sharply (from over 30,000 tons a year in the 1970's to 10,000 tons a year in 1983). The catch of South Korea increased, and it became the top producer of cuttlefish (35,000-45,000 tons); the output of other Asian countries also increased, and together they accounted for more than 75% of the world's catch in 1983 (these countries operate mostly in the central western and northwestern parts of the Pacific Ocean). European countries (mainly Italy, Spain, France, Greece and Portugal) account for approximately 20% of the world's catch of cuttlefish (from the central eastern Atlantic and Mediterranean Sea). The catch of the Soviet fleet is not very high (up to 1.5% (166)
of the world's catch), and almost all of the cuttlefish are caught in Yemen waters and off the coast of Western Indostan.

Development of the world's cuttlefish industry will probably result in further shifting of the maximum-harvesting areas towards the subtropics, due to the high abundance of certain subtropical species (e.g. the Australian <u>Sepia apama</u> and <u>S. novaehollandiae</u>). A partial move of the industry from the northern hemisphere to the southern hemisphere is also likely to occur because of the extremely active utilization of the cuttlefish resources in the northeastern Atlantic, northwestern Pacific and central western part of the Pacific, and the obvious poor catch in the southern parts of the Atlantic, Indian and Pacific oceans. The waters of Southeast Africa and Australia are of particular commercial interest to us, for they contain an abundance of prolific and fairly large species (*Sepia confusa*, *S. incerta*, *S. simoniana*, *S. rex*, *S. novaehollandiae*, *S. cultrata*) which are promising ones for the fishing industry, in that they can replace in part the conventional commercial species (*S. officinalis*, *S. pharaonis*).

Despite its steady development, the cuttlefish industry is still not fully regulated. As a rule, the fishermen never know exactly which species they are dealing with. The successful assimilation of new species and the elimination of overexploitation of the old ones requires detailed research into the systematics and biology of the cuttlefish, primarily the systematization of fish data and the classification of the cuttlefish according to the main commercial genera and groups of species. This is also important because some of the species of cuttlefish will soon become an object of mariculture.

UDC 594.582.2/.8

Genetic-biochemical methods of studying the intraspecific structure of *Illex argentinus*

by V.Yu. Tsygankov (AtlantNIRO)

Analysis of the fishing dynamics, the course of sexual maturation, the size composition, etc. has enabled us to distinguish (167)
4 seasonal groups of *Illex argentinus*, i.e. a summer, autumn, winter, and a spring group (Nigmatullin, 1986). Their status is not clear. There are 3 hypotheses on how the groups emerged.

1. Seasonal groups are formed as a result of the disperal of young squids to different areas of the species range with different growth and development conditions, as a result of which the maturing squids arrive at the fishing grounds at different times; the groups are formed randomly, and represent a part of the same population. 2. The groups represent intrapopulational hereditary ecomorphs. 3. The groups are sympatric populations isolated by spawning time. It is essentially important to establish the status of the intraspecific groups of *Illex argentinus* in order to regulate the stock.

We have compared the squids of the autumn and winter groups on the basis of one of the esterase loci of the buccal complex, which is represented on electrophoregrams by three phenotypes of a 2-allele system. We studied two groups of squid samples taken in February—beginning of March (autumn group) and at the end of April—May (winter group). A comparison of the maturing and mature individuals from these samples revealed the presence of statistically significant differences between them in esterase frequencies, which points to the genetic difference between the autumn and winter groups of squids. The balanced nature of most of the samples of the 1st and 2nd groups makes the hypothesis on hereditary ecomorphs highly improbable.

Our results have helped to confirm the hypothesis on the existence of genetically isolated sympatric populations of *Illex argentinus* in the southwestern Atlantic.

UDC 594.582.2/.8(261.7)

Geographic variability in the feeding of *Sthenoteuthis pteropus* in the eastern Atlantic

by M.V. Chesalin (INBYuM)

Sthenoteuthis pteropus occupies a dominant place among the medium-sized nektonic predators that populate the epipelagic tropical zone of the Atlantic Ocean. It is the main link in the transformation of matter and energy from the macroplankton— (168) micronekton to the large predators (tunas, sharks, mammals). To establish the geographic variability in the food composition and feeding conditions of this species, we analyzed the stomach contents in 724 individuals with a mantle length (ML) of 18-30 cm, caught during the 10th and 18th trips of the "Professor Vodyanitsky" research vessel in January—April 1981 and December—March 1984-1985 respectively in the eastern Atlantic. The material was analyzed according to region (northeastern tropical, equatorial, southeastern tropical, Angola, open waters of the Gulf of Guinea) (Zuyev et al., 1985).

The average index of fullness of the squids was 1.1% of body mass. The significance of the basic food groups consumed by *Sthenoteuthis pteropus* was similar in all the regions studied, i.e. fish constituted about 2/3 of the total volume of food, about 1/2 of the ration consisting of Myctophidae; cephalopods constituted an average 1/4 of the food volume, and crustaceans 1.6-6.0%. However, the proportion of the different species consumed by the squids varied significantly with the region. The index of fullness averaged 1.1% in the northeastern tropical region. The significance of nyctiepipelagic Myctophidae was approximately 10% lower than in the rest of the regions, but then the proportion of young and small predaceous and flying fishes was substantially higher (up to 25%). Among the Myctophidae in the northern part of the region, *Myctophum asperum* dominated in the squid stomachs; *M. nitidulum* became the dominant species farther southward. Interzonal species of fish and cephalopods also play a significant role in the feeding of squids, constituting up to 18.7% of their food volume. *Onychoteuthis banksi* dominates (9.1%) among the cephalopods consumed by this species.

In the equatorial region, the squid stomachs contained mostly *M. nitidulum* (16.0% by volume), the proportion of flying and predaceous fishes diminishing to 10.8%. The proportion of stratal Myctophidae and *Vinciguerria* was also high (12.3% and 6.8% respectively). The fullness of the squids diminished to 0.9% as we moved along the equator eastward, and small *Myctophum affine* and the young of *Hygophum* began to predominate.

The highest average fullness of the squid (up to 1.8%) was observed in the southeastern tropical region. Of the Myctophidae, species of the genus *Hygophum* and *M. nitidulum* dominated (19.4% and 7.9% respectively). The proportion of cephalopods found in their stomachs (primarily the young of the same species) was also high (18.7%).

In the Angola region, the average fullness of the squids was (169)
fairly high (1.3%). Of the subsurface Myctophidae, *M. affine* predominated in the stomachs (14.3%), and *M. asperum* was not

encountered at all. The significance of the young of *Sthenoteuthis pteropus* in the feeding of this species dropped to 7.0%, while that of *Onychoteuthis banksi* increased to 15.8%.

In the open waters of the Gulf of Guinea, the average index of fullness was the lowest, 0.8%. Of the nyctiepipelagic Myctophidae, *M. nitidulum* and *M. affine* were encountered in the squid stomachs (17.3% and 7.8% respectively). In this region, we noted the highest frequency of occurrence and proportion of stratal species of Myctophidae and cephalopods (about 20%) and crustaceans (6.0%) in the stomachs of these squids.

On the whole, the food spectrum and the proportion of different organisms in the food bolus of *Sthenoteuthis pteropus* are determined by the composition and distribution of the macroplankton and small nekton.

UDC 594.582.2/.8(261.6)

Distribution and size-mass composition of the Patagonian longfin squid (*Loligo patagonica*) in the southwestern Atlantic

by Z.A. Chesheva (AtlantNIRO)

The Patagonian longfin squid is distributed from La Plata Bay (36°S lat) to Birdwood*Bank (55°S lat) and from 54° to 64°W long, i.e. in the infertemperal and eutemperal subzones of the South American biogeographic region according to the terminology of V.N. Semyonov. In the eutemperal subzone, the highest density of the squid population is confined to its southern part. *Loligo* is found here at depths of 10-380 m, mainly at 75-320 m. During

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*conjectural spelling - transl.

the daylight hours, the squids are concentrated mainly in the near-bottom layers of water, and at night they can be found in the 10-50 m layer over depths of 150-300 m.

The length of the mantle (ML) in 5-28 cm individuals is mainly 10-18 cm. Squids with a ML of 5-9 and 19-28 cm comprised not more than 3-7%. The males are larger than the females; the ML of the females did not exceed 22-23 cm. The males begin to mature at a ML of 6.5-7 cm, and the females at a ML of 7.5-8 cm. The first pre-spawning males have a ML of 7-8 cm, and the females 11-12 cm. (170) Practically all the males with a ML of 10-11 cm and females with a ML of 15-16 cm are at the pre-spawning stage. Squids caught on the shelf and in the upper part of the continental slope were of the same size, which is an indication of their redistribution within these zones.

In the southern part of the eutemperal subzone, the squids are larger than in the northern part; the average mantle length is equal to 14.08 and 11.10 cm respectively. The size of Loligo increases in the near-bottom layers of the shelf waters from May to September—October. In August, a large number of small individuals with a mantle length of 7-8 cm was noted in the northern part of the eutemperal subzone. These squids probably migrated to this area from the southern parts of the eutemperal subzone where the longfin squid breeds.

The females had a mass of 7-89 g (mainly 36-69 g), and the males 6-119 g (mainly 44-77 g). The size-mass ratio was determined on the basis of our analysis of 1098 female specimens and 1938 males. For females with a ML of 5-18 cm, $W=0.1601 \cdot L^{2.219 \pm 0.029}$, and for males with a ML of 5-21 cm $W=0.1641 \cdot L^{2.196+0.043}$, where W denotes the mass (g), and L denotes mantle length (cm). The difference in the weight of the males and females is statistically insignificant.

UDC 594.582.2/.8

Cholinesterase activity as one of the evolutionary characteristics of squids

by G.A. Shevtsov and L.M. Epshtein (TINRO)

Cholinesterases (CE) represent a group of enzymes that hydrolyze the choline esters of carboxylic acids at different speeds. Acetylcholine (AC), butyrylcholine (BuC), propionylcholine (PC) and acetyl- -methylcholine (MeC) were used as the choline substrates. If a cholinesterase hydrolyzes acetylcholine at the highest rate, it is referred to as an acetyl cholinesterase (ACE); if it hydrolyzes butyrylcholine at the highest rate, then it is a butyryl cholinesterase (BuCE), and if it hydrolyzes propionylcholine at the highest rate it is a propionyl cholinesterase (PCE). Our analysis of the optic ganglia of squids has shown that each family is characterized by a certain sequence of the maximum rates (171) of hydrolysis of the substrates, i.e. AC PC BuC MeC or Ac MeC PC BuC in Ommastrephidae, AC PC BuC=MeC in Gonatidae, and PC BuC AC MeC in Onychoteuthidae. In the majority of the squids studied, the rate of AC hydrolysis is the highest, and so this cholinesterase resembles the typical ACE, but it cannot be regarded as such due to the high rate of BuC. We can therefore assume that the centrifugate of an optic ganglion homogenate from any species of squids is composed of a series of cholinesterases, the quantitative ratio of which determines the species specificity of the esterases (Brestkin et al., 1975). This assumption is substantiated to some extent by Grigor'yeva's investigations (1983) in which two cholinesterases referred to by her as ACE and BuCE were isolated. In our material, the rate of PC hydrolysis in Onychoteuthis borealijaponicus is almost 1.5-2 times higher than that of BuC and AC. Apparently, PCE prevails in Onychoteuthidae. In his comparison of the properties of blood plasma esterases, Augustinsson (1969) came to the conclusion that PCE was the most primitive esterase, that it originated from the simplest esterases called alisterases*. In the course of evolution, BuCE made its appearance, followed by the more recent ACE.

Consequently, the Onychoteuthidae, in which PCE prevails, should be regarded as the more primitive squids, while the Ommastrephidae with the ACE characteristic of vertebrates should be considered more advanced in the evolutionary respect.

The primitiveness of the Onychoteuthidae is confirmed by the structure of their gladius. The gladius of the present-day squids consists of a stalk (rachis), a thin pinna and a terminal cone which is sometimes replaced by a cartilaginous hood (rostrum). The presence of a rostrum was always regarded as a characteristic feature of the extinct Belemnites (Naef, 1922). Rostra have recently been encountered in more than 10 species of present-day squids (Kabanov, 1983). Rostra are particularly developed in the family Onychoteuthidae which includes at least 5 rostromorphic genera (Kabanov, Filippova, 1975).

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*conjectural spelling - transl.

A comparative morphological analysis of the gladii in the present-day squids has shown that the families Onychoteuthidae, Gonatidae and Lycoteuthidae have the most primitive structure of the gladius. The rostrum in the first family resembles that of the *Belemnites* in position and exterior form, and is homologous to it (Filippova, Bizikov, 1983). Kabanov (1983) believes that (172) the rostrum is genetically the most recent addition to the squid skeleton.

This points to the relative primitiveness of the Onychoteuthidae which, apparently, comprise the oldest group of the present-day squids.

UDC 594.582.2/.8:597-153(265.1)

The enemies of *Dosidicus gigas* and *Sthenoteuthis oualaniensis* in the southeastern part of the Pacific Ocean

by A.S. Shchetinnikov (AtlantNIRO)

The material was collected in February-May 1981 and October 1982—March 1983 predominantly in the the region of the Peru Basin. The observations were conducted at night at light drift stations, and the squids were caught with manual fishing rods, scoop nets and fish spears from a vessel. The stomach contents were analyzed in 16 whitetip sharks measuring 1-1.8 m in length (including six with empty stomachs), 23 blue sharks 0.9-2 m long (5 with empty stomachs), 2 dusky sharks 1.7 and 1.8 m long, 147 mahimahi 17-118 cm in length (mode 70-95 cm) (22 with empty stomachs), 12 pompano dolphins 22-50 cm long (2 with empty stomachs), 28 snake mackerels 48-91 cm long (mode 50-70 cm) (11 with empty stomachs), 40 frigate mackerels 25-35 cm long (mode 30-34 cm) (16 with empty stomachs), 2 skipjack tunas 45 and 47 cm long, one bluefin tuna 1.2 m long, and one swordfish 1 m in length.

Dosidicus gigas. A practically whole squid of this species with a mantle length (ML) of 16.5 cm was found in the 1 m swordfish. The stomach of the 1.7 m dusky shark contained a 29.4 cm (ML) squid without a head and fins. Squids of this species were noted in the stomachs of 8% of the mahimahi, the remains of the squids comprising 6.1% of the weight of the food bolus. The mantle length of the consumed squids varied from 2.5 to 24.5 cm (mainly 17-21 cm). Dolphin fish usually swallow their prey whole. *Dosidicus gigas* with a ML of 14-17 cm were relatively often encountered in the stomachs of snake mackerels which attack their prey swiftly and, as a rule, "chop" it in half and then swallow it in parts. (173)

Sthenoteuthis oualaniensis. A young specimen with a ML of 0.8 cm was noted in the stomach of a 23.5 cm pompano dolphin. The stomach of the 1.2 m bluefin tuna contained a practically whole squid with a ML of 15.3 cm. *Sthenoteuthis oualaniensis* was rarely encountered (4.8% frequency of occurrence, 2.2% by weight) in the stomach of mahimahi (*Coryphaena hippurus*). On the whole, *Sthenoteuthis oualaniensis* is less commonly consumed by predaceous fishes in comparison with *Dosidicus gigas*, due to the low numbers of this species in the study area. At 4°S lat and 86°W long where the young of *Sthenoteuthis oualaniensis* abounded, we observed the hunt of the Galapagos *Xema sabini*. Up to 40 birds spread out along the periphery of the light field in the zone of dusk illumination and hunted the young of flyingfishes, 8-10 cm smallwing flying fishes, 6-8 cm lanternfishes and young *Stheno-*

teuthis oualaniensis with a mantle length of up to 15-18 cm; they were able to swallow squids with a ML of not more than 10-12 cm, which is probably the prey size limit for these birds.

Squids were not detected in the stomachs of frigate mackerels and skipjack tunas; however, according to visual observations, these tunas sometimes hunt young squids with a ML of up to 6-8 cm, while snake mackerels hunt *Sthenoteuthis oualaniensis* with a ML of up to 22 cm. Most of the enemies of these two species of squids are active nektonic predators, and so their absence in the stomachs of the whitetip and blue sharks indicates that their high activity makes them inaccessible to these sharks.

These data should be treated with a certain amount of caution, for we are not sure how naturally predaceous fishes behave in artificial light. Nevertheless, we can say that as consumers of the 34d-4th orders, the frigate mackerel, the skipjack tuna, the pompano dolphin and the Galapagos Sabine's gull are enemies only to young squids with a mantle length of up to 12-15 cm. The dolphin fish, snake mackerel and the bluefin tuna (consumers of the 4-5th orders) consume squids with a ML of up to 20-24 cm. The dusky shark and the swordfish, which stand at the top of the food chain as consumers of the 5-6th orders, can apparently feed on practically all sizes of squids.

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PART II

BIVALVIA AND GASTROPODA

UDC 594.124:(574.5:615.9)

Toxicological evaluation of cultivated mussels

by A.M. Avdeyeva, V.D. Tret'yakova and V.N. Geft
(AzCherNIRO)

In connection with the cultivation of commercial mussels in the Kerch Strait, it has become necesary to establish toxicological control over the content of the most common toxicants, metals and organochlorine pesticides (OCP), in their tissues.

The content of Cu, Fe, Al, Zn, Sb, Ni, Cd, Cr, Pb and Sn in the tissues of _Mytilus galloprovincialis_ was determined by the method of flameless atomic-absorption spectroscopy, and the content of α, γ-HCCH , DDT, DDE, ADD and biphenyl polychlorine by the method of gas-liquid chromatography.

We established that the content of the given metals (except for Cr, Cd and Ni) and organochlorine pesticides did not exceed the officially accepted limits for hydrobionts. A higher than usual content of Ni was noted in the tissues of mussels harvested in summer. We noted a seasonal relationship between the weight of the tissues and the concentration of the metals, i.e. as the weight of the tissues diminishes, the content of Fe, Cu, Al, Zn, Cd and Cr increases. Seasonal changes in organochlorine pesticies were not detected. The highest concentration of OCP was observed in the tissues of mussels harvested in September. No significant differences were observed in the content of metals and OCP in the tissues of mussels cultivated in the Kerch Strait and Sudak area.

Control over the content of metals and organochlorine pesticides in mussels is necessary for the ecological evaluation of the given area, and the presence of toxic substances in the hydrobionts, along with other indices, are the criterion of their nutritional value.

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UDC 594.141

Variability of certain physiological and biochemical characteristics of the freshwater mussel *Unio tumidus* in different habitats

by L.V. Aksamitauskene (IZiP AN Lithuanian SSR)

The material was collected in a natural environment in the Shventoyi R. and in the warm zone of the Elektrenai cooler reservoir of the Lithuanian State Regional Electric Power Plant (SREPP). The total body mass, the mass of the shell and soft body tissues and the quantity of mantle fluid were determined for each mollusk. The soft tissue was subjected to chemical analysis, homogenized, and then fixed in Folsch solution. In a natural environment and in the warm zone of Elektrenai, the mass of the shells in this species averages 45.5 and 37.13% respectively, the mantle fluid 29.60 and 37.5%, and the soft part of the body 24.9 and 25.37% of the total body mass. The increase in the quantity of mantle fluid through a decrease in shell weight in the Elektrenai Reservour is due to the adaptation of the mollusk to altered temperature conditions. The moisture content of the soft tissue hardly changes, remaining at a level of 81.47-84.87% of the body weight in the Shventoyi R. and 82.87-84.86% in the cooler-reservoir.

The total content of protein and minerals is equal to 13.6± 0.63%—14.91±0.48%, the content of fat 0.27±0.02%—0.56±0.05%, and the content of carbohydrates (defatted protein-free residue) 0.64±0.9%—2.04±0.19% of the fresh weight of the soft part of the mollusks from the Elektrenai cooler reservoir. In a natural environment, the soft part of the body contains 12.50±0.32%—15.56±0.4% protein, 0.42±0.1%—0.68±0.09% fat, and 1.13±0.17—2.23±0.2% carbohydrates.

More carbohydrates than fats accumulate in the soft part of the mussels both in a natural environment, and in the warm zone of the Elektrenai Reservoir. Furthermore, carbohydrates are a more mobile source of energy, its percentage varying to the greatest extent throughout the year both in the Shventoyi R. and in the Elektrenai Reservoir. We noted a decrease in the content of the main energy nutrients (lipids and carbohydrates) in the soft tissues of the Elektrenai mussels as compared with those from a natural environment.

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UDC 594.124(262.5)

Carotenoids of the Black Sea mussel

by L.V. Antsupova and Ye.M. Rusnak (Odessa branch of INBYuM)

We studied the seasonal age-related changes in the carotenoid pigments, the effect of various degrees of eutrophication on the synthesis of carotenoids in hydrobionts, as well as the differences in the content of carotenoid pigments in mussels of natural and artificial substrates.

We studied 1-8 cm mussels from areas varying in their anthropogenic load (pro-estuarine areas, water area of a port, coastal zone, areas of the sea farther from shore), as well as mussels cultivated under the conditions of an experimental mussel farm at Cape Bolshoi Fontan, Odessa.

In areas with a higher than usual anthropogenic load, the concentrations of carotenoids were substantially higher (3—5-fold) than in the mussels of relatively clean areas.

We have studied the seasonal changes in pigments, related to the physiological conditions of the mollusks. A sharp increase of these compounds was observed in the mussels during gametogenesis, whereas the concentration of carotenoids decreased drastically when the mussels were at rest. The content of these biologically active substances did not change much in the process of growth. The highest values are characteristic of young individuals.

We have studied the interrelation of the exterior colour of the mussels and the concentration of carotenoids in the soft tissues. To do this, we selected organisms of three phenotypes: organisms with a brown (A) and violet (B) colour, and organisms with alternating radial stripes (C) according to Shurova and Zolotarev (1984). We found that the soft tissues in phenotype B had a higher concentration of these compounds.

The mollusks grown on collectors under the conditions of an experimental mussel farm contained 2-4 times more carotenoids than those from natural colonies of the same area, and the concentrations of these substances depended on the location of the mussels in the clusters.

The results of our study have shown that the carotenoid pigmentation of the Black Sea mussel depends on many factors. A (177)
sudden increment of these biological substances in hydrobionts may be an indication of some adverse situation in the area of their habitat at a particular time. This fact can be taken into consideration when selecting a site for a maricultural enterprise.

UDC 664.951.7:664.957

Feed value of mussels from natural and artificial populations of the Gulf of Odessa

by L.V. Antsupova, T.A. Petkevich, V.K. Golovenko,
I.A. Stepaniuk, V.I. Lisovskaya (Odessa branch of INBYuM)

In order to evaluate the quality of mussels as a feed supplement for farm animals, we carried out a comparative study of the biochemical composition of mussels grown on different substrates. We analyzed small (20-40 mm) unmarketable mussels grown at the experimental mussel farm in the vicinity of Cape Bolshoi Fontan. Mussels from natural substrates of the same area were analyzed for comparison. The sampling of mussels of this size was carried out during different seasons.

The feed value of the mussels was established by determining their content of protein compounds, amino acids, lipids and their fractional composition, carbohydrates, provitamins A (carotenoids) and trace elements.

The meat of mussels cultivated at the experimental farm has higher protein values (by an average 1.5-3.0% of fresh mass) in comparison with those from natural substrates.

The following 19 free amino acids that form the reserve in protein synthesis were identified in mussels of different populations: cystine, cysteine, lysine, histidine, arginine, glutamic and aspartic acids, serine, glycine, glutamine, threonine, alanine, proline, tyrosine, tryptophan, methionine, valine, phenylalanine and leucine. Nine of these (lysine, histidine, arginine, threonine, tryptophan, methionine, valine, phenylalanine and leucine) are irreplaceable in feed mixtures, since they are not synthesized in the animal. The total pool of free amino acids in mussels averages 0.70% of the fresh mass; 40% of these are essential ones. The content of such essential amino acids as lysine, arginine, valine and leucine amounts to 0.20%. Mussels cultivated on collectors, particularly small ones, are characterized by a higher amino acid potential than the mussels of natural populations. The amino acid content of young mussels can go up to 1.5% of their fresh mass.

Mussels raised on collectors contain more lipids and carbohydrates than those of natural populations. Fractional analysis of mussel lipids revealed phospholipids, sterols, triglycerides, sterol esters and other classes of these important compounds.

During analysis of provitamins A in mussel meat, we found that mussels raised on collectors contained 2-4 times more carotenoids than the ones from natural populations of the same area.

No significant differences in the composition of chemical elements were observed between the mussels of natural and artificial populations. The mussels of the given area are characterized by high concentrations of copper, strontium, nickel and other trace elements.

We should note that the biochemical composition of the mussels depends on the physiological condition of the populations. During the periods of sexual activity, we observed an increase in the content of protein compounds, amino acids, lipids, carbohydrates and carotenoids, whereas the concentration of these substances during periods of rest decreased significantly.

Our investigations have shown that the mussels cultivated at the experimental mussel farm in the Gulf of Odessa area are a valuable product biochemically; they contain sufficient quantities of protein compounds with a full set of essential amino acids, and abound in lipids, carbohydrates, provitamins A and the necessary trace elements.

UDC 594.1(265.54) (179)

Long-term changes in the population dynamics of the larvae of commercial bivalves in the shallow bays of Peter the Great Gulf

by Ye.A. Belogrudov, V.A. Rakov and N.A. Shepel (TINRO)

For ten years we have studied the population dynamics and distribution of the larvae of *Patinopecten yessoensis*, *Chlamys nipponensis*, *Crassostrea gigas* and *Mytilus edulis* in the inlets of Posyet and Slavyansky bays. Temperature is the most significant factor determining the onset of spawning and its activity in the mollusks, the rate of embryonic and larval development, the growth rate and mortality of the larvae in the plankton and the intensity of their settling.

The larvae of P. yessoensis appear at the end of May—mid June at a water temperature of 10-12^{o}; they usually disappear from the plankton in the second half of July. The maximum density is 500-600 specimens/m^3. The larvae of Ch. nipponensis appear in July, and their density in shallow bays reaches 1000 specimens/m^3.

The appearance of C. gigas larvae in the plankton extends from the beginning of June (1982) up to the beginning of August (1974, 1983). The oyster larvae disappear from the plankton by the end of August or mid September. The maximum density is ten thousand specimens/m^3.

The longest breeding period is noted in M. edulis. The larvae of this species are encountered in the plankton from the end of May up to the beginning of September, forming a density of up to 3000-5000 specimens/m^3.

The most unfavourable season for the development of P. yessoensis larvae was observed in 1980; it coincides with the mass blooming of Noctiluca miliaris. The abrupt fluctuations in water temperature at the beginning of the reproductive period of the oysters are fatal to their larvae. Oyster larvae are concentrated in enclosed bays that heat up substantially in summer, while the larvae of the Yezo scallop and mussels congregate in the more open parts of the gulf. The distribution of the larvae depends highly on the local currents. When southeastern winds prevail in summer, conditions obstructing the transport of the mollusk larvae into the open sea are created. The results of our investigations can be used to predict the time and rate of settling of (180)
the larvae on commercial collectors at maricultural establishments.

UDC 594.124:(574.5:615.9)

Effect of copper ions on the protein composition of Black Sea mussels

by N.M. Beregovaya (INBYuM)

Mussels are one of the products of the fishing industry, as well as a principal member of the periphytic community. It is, therefore, of interest to us to study the effect of copper ions (general toxicants that affect numerous biochemical processes) on the protein composition of Black Sea mussels.

During exposure of the mussels to copper ions (1 mg/l^{-1} for two days), we noted a decrease in the content of total, salt-soluble and structural proteins. Of the three tissues studied (muscles, gills, hepatopancreas), the hepatopancreas underwent the most significant changes. Under the same conditions of exposure, we observed changes in the electrophoretic spectra of the salt-soluble proteins. These changes were seen mainly in the region of fast and slow fractions, manifested as changes in the mobility, number and intensity of certain fractions. For instance, the average number of fractions in the electrophoretic spectrum of the proteins in the gills and hepatopancreas was significantly lower ($P \leqslant 0.01$) than in the control specimens, whereas the appearance of new bands was noted for the muscle proteins.

The changes noted in the content of proteins and their composition in certain mussel tissues may reflect the degree of copper ion influence on the intensity of protein synthesis and the physicochemical properties of the protein, and can serve as an indicator of the quality of the environment.

UDC 594.124(265.72)

(181)

Some results of a biological study of *Perna viridis* in the coastal waters of South Vietnam

by S.V. Blinov (IBM DVNTs AN SSSR)

Considerable attention has been devoted in recent years to the ecology and biological characteristics of the green mussel (*Perna viridis*) in connection with its rapid cultivation in the countries of Southeast Asia. At the same time, we have no information on the green mussel that inhabits the coastal zone of South Vietnam.

The material was collected in February—May 1984 in Fukhan Province, Vietnam, during an expedition of the "Berill" research vessel. We studied the distribution of the mollusks in their natural habitats and on artificial substrates, the size and sex structure of their colonies, as well as some of their ontogenetic characteristics. The length of the shell, the total mass and the fresh mass of the soft tissues were determined. The sex and condition of the reproductive organs were determined by temporary preparations of gonad smears.

Two abundant mussel colonies were discovered in Thieucheu* Lagoon and Nyafu* Lagoon. This species inhabits the littoral and sublittoral zone up to a depth of 10-15 m. The littoral colonies consist of scattered groups of small individuals with a shell measuring not more than 50 mm in length. Large animals up to 130 mm in length predominate in the colonies of the sublittoral zone. We found that mussel colonies were particularly abundant in some parts of Thieucheu Lagoon, where the density of

*conjectural spelling - transl.

live mussels amounted to more than 2000 specimens/m^2 and the biomass exceeded 80 kg/m^2. Animals with a length of 90-100 mm predominated, though some individuals measured up to 140 mm in length. Substantial mussel concentrations were detected in the periphyton of the underwater structures of the bridge across the lagoon. Large (up to 130 mm) mussels cover practically the entire surface of the substrate up to a depth of 10-12 m. The density of the P. viridis colony in the periphyton exceeds 1000 specimens/m^2, and the biomass amounts to 40 kg/m^2.

The relationship between the length of the shell (L, mm) and the total mass (W, g) in mussels from natural habitats is (182) estimated by the equation $W_{tot}=0.0037\ L^{2.1188}$; in individuals living on substrates of anthropogenic origin (e.g. on wooden fishweirs), it is expressed by the equation $W_{tot}=0.0019\ L^{2.2896}$. The relationship between the length of the shell and the mass of soft tissues ($W_{s.t}$) is estimated by the equations $W_{s.t}=0.0079\ L^{1.6101}$ and $W_{s.t}=0.0059\ L^{1.6808}$ respectively.

With age, the ratio of soft tissue mass to total mass (%) diminishes in the green mussel, regardless of the type of substrate or living conditions. At the time of our study, this coefficient was equal to 18.0-19.8% in the largest mussels (110-130 mm long).

Analysis of the gonads of mature individuals showed that the majority of the mussels had spawned and were at the stage of sexual rest or starting the next stage of oogenesis by the beginning of April. At the same time, the plankton was found to contain only individual larvae of this species, which could be easily identified by a green border along the shell margin. Mass spawning and settling of the mussels in this area apparently took place in December 1983—January 1984. However, we know that the green mussel can spawn at any time of the year, and the spawning peaks during the different years do not usually coinicde (Walter, 1982). During mass settling, mussel larvae are capable of utilizing substrates of anthropogenic origin (posts, poles, ropes) and forming large colonies on them. In the process, the mussels reach a marketable size (60-80 mm) in 4-6 months (Bardach, 1972).

The Thieucheu area is a promising one for the cultivation of _P. viridis_. This lagoon is a highly sheltered and non-navigational body of water, which makes it easier to set up collectors and keep them safe.

UDC 639.42:639.64(262.5) (183)

Combined cultivation of mollusks and algae in Dzharylgachsky Gulf of the Black Sea

by Ye.I. Blinova, K.M. Kaminer, N.P. Volskaya, Yu.P. Began and O.A. Trishina (VNIRO, Odessa branch of AzCherNIRO)

Combined cultivation of the agar-containing alga _Phyllophora nervosa_ subf. _sphaerica_ and mussels of the species _Mytilus galloprovincialis_ was carried out in Dzharylgachsky Gulf in an area 8-9 m deep from 1982 up to 1985. Capron lines and cribs of different type (flat and volumetric frame ones made of netting) with _Phyllophora_ were fastened to a flexible raft. The cultivation horizon extended from the surface to the bottom. Mussels developed on _Phyllophora_ at all the depths in the water column, but not many were found on the bottom. Settling on the _Phyllophora_ thalluses, the mussel larvae attach themselves to the latter quite firmly by the byssus, which practically eliminates the possibility of their dropping off during a storm. Most of the mussels (90-95%) attach themselves to the algae, rather than the lines and cribs. Over a period of 11 months (from the beginning of June 1984 up to the end of April 1985), mussels with a mass 14.3 times greater than that of the algae developed in the flat crib at a depth of 2 m. For every 100 g of algae, we found 950 g of mussels 30-65 mm in length. The following table gives the size-mass composition of the mussels during combined cultivation in a flat crib made of netting at the 1-metre depth 13 months after it had been set up.

Size-mass composition of mussels cultivated together with *Phyllophora nervosa* subf. *sphaerica* from 26 March 1984 to 24 April 1985

Size of mussels, mm	Abundance of mussels per 100 g of algae		Mass of mussels per 100 g of algae		
	No. of specimens	%	g	%	
Less than 20	2583.1	80.4	1517.2	44.8	
20-25	234.8	7.3	290.2	8.6	
25-30	105.5	3.3	179.4	5.3	
30-35	129.3	4.0	438.0	12.8	(184)
35-40	126.6	3.9	693.9	20.5	
40-45	23.7	0.7	147.8	4.4	
45-50	10.6	0.3	121.4	3.6	
Total	3213.6		3387.9		

The mass of 30-50 mm mussels cultivated per 100 g of raw algae over a period of 13 months amounted to 1400 g.

A comparison of the size-mass composition of the mussels grown over the same period off the coast of the Tendra Peninsula on standard one-metre foam plastic collectors and in Dzharylgachsky

Gulf has revealed significant differences in the growth rate and biomass of the mollusks. For example, the mass of the mussels grown on a standard collector amounted to 719 g/m, whereas the mass of mussels on the lines with algae amounted to 1219 g/m; the mass of Phyllophora on the lines amounted to 34 g/m.

The mass of 30-50 mm mussels cultivated together with algae amounted to 41.3% after 13 months (see table), whereas the mass of mussels grown on foam plastic collectors amounted to 27% of the total mass of mussels.

Consequently, combined cultivation of mussels and algae ensures a fairly high year-round harvest of mollusks that are quite suitable for human consumption, or as a feed for animals. *Phyllophora nervosa* subf. *sphaerica* is a powerful attractant for the larvae of marine animals, primarily mussels, and it also stimulates their growth.

UDC 591.524.11(262.5) (185)

Prolific species of benthic invertebrates in Karkinit Gulf of the Black Sea and their habitat

by N.I. Bobko, P.N. Zolotarev, V.P. Malakhov, V.P. Petrov, A.V. Povchun, A.S. Povchun, V.V. Popov, Z.D. Sapronova, V.S. Sinichkin, Yu.V. Uvarov, A.G. Chursin and A.V. Shutenko (SEKBP)

Karkinit Gulf is one of the most productive regions of the Black Sea. In addition to sturgeons and other valuable species, this area has the most abundant mussel and oyster banks in the Black Sea. However, the zoobenthos of the deep-sea zone (>20 m) of the gulf and its habitat have not been studied since the 1930's.

We have summed up the results of bottom surveys carried out with the help of an "Okean-50" dredge (0.25 m^2) in October 1978, March and October 1979, and in June and September 1980; the results of hydrological-hydrochemical surveys carried out in October 1978 and in March, July and October 1979, and the results of a study of bottom sediments collected with a dredge and a direct-flow 73 mm coring tube in October 1979 and September 1980. The pH of the upper layer of the bottom substrate and the water near the bottom were measured with a platinum-electrode "pH-343" gauge in September 1980.

During the investigation period, *Mytilus galloprovincialis*, *Abra nitida milachewichi* and *Nephtys hombergii* abounded in the study area. The predominance of this or that species is determined by the significant differences in habitats in the different parts of the gulf. The highest concentrations of mussels are confined to the coarse-grained sediments (silted sand, shell rock) in the western part of the gulf at depths of 29-32 m, and along the coast at depths of 20-22 m, as well as off Tarkhankut Peninsula at depths of 30-32 m. The numbers and biomass of the mussels exceeded 500 specimens/m^2 and 500 g/m^2 respectively in all the areas in 1980. The pH values of the water near the bottom were 7.7 at Mezhvodnoye and 8.0 in the western part of the gulf; the pH of the bottom substrate varied from 7.4 to 7.8 in the western part of the gulf. The water temperature near the bottom was 6.3°C in March and 16-17°C in July and October at Tarkhankut; (186)
4.1-4.9°C in March, 9.0-12.0°C in July and 11.0-11.5°C in October in the northwestern part of the gulf, and 18-19°C in July and

$14^{\circ}C$ in October at Mezhvodnoye. The salinity in all of these areas fluctuated around 18‰. During the spring-summer period, the content of dissolved oxygen at the bottom was 7-8 ml/l throughout the entire water area. As the seasonal thermocline set in, its content diminished, and in the autumn amounted to 2.5-3.5 ml/l in the western part of the gulf, 4 ml/l at Tarkhankut, and 5-6 ml/l at Mezhvodnoye. Among other things, this resulted in losses of the bottom fauna due to lack of oxygen in the western part of the gulf in September 1978.

The polychaete Nephtys hombergii dominated in the central part of the gulf (41.4 ± 5.4 specimens/m^2; 2.4 ± 0.3 g/m^2), and Abra nitida milachewichi dominated in the northwestern part of the gulf (316.9 ± 57.4 specimens/m^2; 34.0 ± 5.9 g/m^2).

In Karkinit Gulf, the distribution of certain species of the macrobenthos (including commercial mussels) clearly depends on the composition of the sediments and the content of dissolved oxygen at the bottom during the summer-autumn period.

UDC 594.124

Diurnal rhythms of respiration in mussels

by P.G. Borovinsky (Odessa branch of INBYuM)

One of the principal problems encountered during the cultivation of mussels is the determination of their food requirements. The food requirements of mussels are closely related to their energy metabolism which can be determined by studying the respiration of these animals.

The diurnal respiratory activity in mussels was determined by the method of "closed vessels". 3-4 mussels of different size were placed in each respiration vessel. The experiment lasted 24 hours, and the exposure period was 3 hours. A total of 190 samples was processed.

Our study of the diurnal respiratory rhythms of mussels has shown that the highest activity occurs from 12:00 to 16:00 hours. The second, less pronounced, peak of metabolic activity is observed between 24:00 and 02:00 hours, and the lowest respiratory (187) activity is observed between 08:00 and 10:00 hours.

Our study of the diurnal rhythms of metabolism in mussels has shown that the difference between the maximum and minimum rate of oxygen consumption tends to increase in these animals as they grow in size. The differences in the rate of metabolism in 10-15 mm mussels observed in the morning (08:00-10:00 hours) and during the day (12:00-14:00 hours) amount to 0.04 ml O_2/h, and in mussels with a shell length of 50-55 mm they are equal to 0.22 ml O_2/h. These differences are significant. Furthermore, the nocturnal peak of activity in "large" individuals is less pronounced than in smaller mussels.

It follows from this that the derived data on the energy metabolism of mussels, which are based only on daytime observations, will be clearly overstated with regard to the actual metabolism over a 24-hour period, and this difference will increase proportionally to the increase in the weight and size of the mollusks. Naturally, the use of these data for calculating the food requirements of mussels will also result in overestimations.

Therefore, to determine the actual energy metabolism in mussels and their food requirements, we must conduct either diurnal observations, or introduce the necessary corrections in our calculations to suit the specific conditions of the experiment (season, temperature, salinity, etc.).

UDC 594.117:639.446

Experimental physiological study of the Yezo scallop at the early stages of ontogenesis under the conditions of mass cultivation

by Yu.E. Bregman, L.G. Makarova, G.M. Chan and G.I. Viktorovskaya (TINRO)

The cultivation of *Mizuhopecten yessoensis* is developing very slowly in the Maritime Territory due to irregularities in the supply of planting stock (spat). This served as the basis (188) for the development of biotechnological methods of obtaining larvae and spat in a controlled environment.

The spawning of adult scallops was induced by a gradual increase in water temperature (0.5-1°C per hour) from 5-6°C. The egg cells developed at a density of 100-200 specimens/ml in glass cylindrical jars. After 30-36 hours, the trochophores were transferred to other containers where they continued to develop at a temperature of 15±0.5°C. One-third of the water was changed every 2-3 days, and microalgae of the species *Pavlova lutheri* and *Platimonas viridis* were prescribed. The density of planting was gradually reduced from 5 veligers to one veliconch per ml. The average live mass of the larvae and spat was calculated from Chislenko's nomograms. Oxygen consumption was measured weekly by the method of closed vessels (7 experiments, each in 7-9 replications).

The development of the scallop progressed rapidly at $15^{o}C$. The embryos became active after 24 hours, and 48 hour later the veligers began to feed and their stomachs turned green. The larval period lasted about a month, andin another 40 days the spat had grown to a 1 mm size. The periods of maximum mortality were related primarily to the internal restructuring and alteration of the mode of life during the transition from veliconch to spat (metamorphosis) and from developed veliger to veliconch (development of foot and prodissoconch II). The total yield of spat from the fertilized egg cells amounted to 2%.

The body length of the scallop (1, mm) at the early stages of ontogenesis changes with age (t, days) in accordance with the exponential principle. Prior to settling ($t \leqslant 35$ days), $L_1=97.5 \cdot e^{0.028t}$. Its growth speeds up later on, i.e. $L_2=51.1 \cdot e^{0.048t}$; its specific velocity ($V_1=0.048\ d^{-1}$) increases approximately 1.5-fold. These two different stages of ontogenesis have their own corresponding ratios of oxygen consumption (Q, $mgO \cdot specimen^{-1} \cdot h^{-1}$) to live body weight (W, mg), i.e. $Q_1=(0.164 \pm 0.012) \cdot 10^{-2} \cdot W^{0.667 \pm 0.039}$ ($r=0.953$; $n=32$; mass $0.11 \cdot 10^{-4}-6.55 \cdot 10^{-3}$ mg), $Q_2=(2.63 \pm 0.021) \cdot 10^{-4} \cdot W^{0.4 \pm 0.025}$ ($r=0.963$; $n=13$; mass $6.55 \cdot 10^{-3}-1.98$ mg), as well as a different efficiency of utilization of food energy on growth (K_2), i.e. at first it is insignificant (0.03-0.1), but then it quickly increases to 0.208 after the scallop has settled.

The data on the metabolism and growth of juvenile specimens of this species have enabled us to calculate their energy balance (assuming that assimilability is equal to 0.9) and the dependence of the rations C ($cal \cdot specimen^{-1} \cdot days^{-1}$) on live body mass (W, mg), (189) i.e. $C=0.213\pm0.002\ W^{0.708\pm0.005}$. The estimated values of the rations are in good accord with the results of direct determination of food requirements.

The derived characteristics of the main physiological processes have been used to calculate the biological standards of maintenance for juvenile scallops during mass cultivation.

UDC 594.124:639.42

Demography, growth and productivity of *Mytilus edulis* in the process of cultivation

by V.A. Brykov (IBM DVNTs)*

We studied the dynamics of density, the survival, growth and the monthly productivity of *Mytilus edulis* during the cultivation of this species in Vostok Bay in the Sea of Japan during 1982-83.

The settling of the larvae on the collectors in 1983 began during the first ten days of July, and lasted up to the end of August. The maximum density of the settled mussels was recorded on September 1st, and amounted to 30,230 specimens per running metre of the collector. During the following three months, there was a significant decrease in population density, as a result of which the latter amounted to only 3600 specimens/m by the beginning of December. The abundance of mussels on the collectors did not change much after that, and by August 1983 the density amounted to 2770 specimens/m.

A study of the mortality of *Mytilus edulis* showed that the highest mortality occurred during the first four months after the larvae had settled on the collectors. The probability of

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survival to January 1983 was equal to 0.125, and the probability of survival to August 0.08. The survival of *Mytilus edulis* for the entire period of cultivation (14 months) was 0.046.

The length of the shell increases nonuniformly in the process of cultivation. High rates of linear growth are noted during the first 3 months after settling. The maximum increment was recorded (190)
in September, and it amounted to 7.6 mm/month. The growth rate slows down in winter (December-February); the average monthly increments during this period do not exceed 1.5 mm/month. Beginning in March, the rates of linear growth increase once again; as a result of this, the average size of *Mytilus edulis* amounted to 40.4±0.4 mm at the beginning of August 1983, and reached 48.7±0.4 mm by October.

The average mass of the settled mussels was approximately 0.1 g at the beginning of September 1982; by December, it had increased to 1.5±0.1 g. During the winter months, the increments in mass did not exceed 0.2 g/month. Beginning in March 1983, the rate of mass increment increased once again. The average monthly increments in August and September amounted to 2.4 and 2.6 g/month respectively. By the beginning of October 1983, the average mass of *Mytilus edulis* amounted to 9.5±0.2 g, while some individuals weighed 16.0-18.0 g during this period.

The productivity (rate of biomass increment) of *Mytilus edulis* on collectors is determined both by the population density, and by the rate of mass increment of the mussels. The monthly productivity varied considerably from one season to the next. It slightly exceeded 1900 g/(m·month) in autumn (September-November), whereas it amounted to only 191 g/(m·month) during the winter months (e.g. in January). The maximum rate of biomass increment was noted in June; it amounted to 5279 g/(m·month).

The installation for the cultivation of *Mytilus edulis* covered an area of 0.8 ha of the water surface. The maximum rated yield of this species was recorded at the beginning of August 1983; it amounted to 40 tons/(ha·year).

UDC 594.124(262.5)

Morphogenetic investigations on mud and rock colonies of mussels in the Black Sea

by K.V. Bulatov (INBYuM)

Mussel colonies were first studied mainly from morphological positions (Milashevich, 1916; Dragoli, 1966). The population genetics of mollusks are usually studied with the help of markers, (191) the genetic interpretation of which is simple and conclusive [biochemical variants of proteins and enzymes, variants of shell colour (phenes)]. We have identified three phenes of shell colour in Black Sea mussels; they are apparently determined by the co-dominant interaction of two alleles of the same locus (Bulatov, 1983; Ivanov, Bulatov, 1983).

In the rock (10-5 m depth) and mud (30-50 m depth) colonies of mussels studied from the Caucasus, Kerch Strait, Kara-Dagh, Sudak, the South Crimean shore, Sevastopol, Karkinit Gulf, Tar-khankut Peninsula, Zmeinyi (Snake) Is., the *Phyllophora* field, Varna and Constanta (more than 10,000 specimens from 18 points), we detected a strict zonality in the phenetic interchange of mussel colonies, which is related to the type of biotope, i.e.

dark violet (52-77%), striped (17-45%) and least of all brown (1-13%) individuals predominate in rocks, whereas mud colonies of mussels are made up of 8-27% dark violet, 37-60% striped and 10-50% brown individuals. This is due to the better survival of dark violet mussels in rock biotopes with age, and the better survival of striped and brown mussels in mud biotopes. On rocks, the dark violet individuals in the younger age groups (up to 3 years of age) surpass the rest in all the weight and size characteristics; such clear differences are not observed in a muddy biotope. The mussels of different phenes within individual colonies do not differ in their morphometric indices.

A long planktonic stage, an extremely high fecundity, the absence of selectivity in settling (Kiselyova, 1966) and the similarity in the phene ratios of the spat and underyearlings point to a substantial levelling flow of genes between the mud and rock colonies of mussels. Later, in the process of growth, the mud and rock groups undergo differentiation under the effect of diverse selection. Observations over a period of six years have shown that the given process is highly stable.

Suspended collectors for the cultivation of mussels should be set out for the spat settling from rock groups of mussels. This is particularly important for the northwestern part of the Black Sea where vast mud colonies of mussels are found.

UDC 594.151(262.5) (192)

Phenetic structure of *Cerastoderma glaucum* colonies from different regions of the Black Sea

by K.V. Bulatov and T.V. Mikhailova (INBYuM)

The colour characteristics of the shells (phenes) are the most commonly used markers of the genetic composition of mollusk populations. Analysis of extensive material has revealed marked polymorphism of the shell colour. Three discrete colour variants are differentiated, i.e. white, brown (homozygotes) and white-brown (heterozygotes). The inner surface of the valves is pigmented. The observed distribution of these phenotypes in the samples usually corresponds to that anticipated on the basis of the Hardy-Weinberg principle (single-locus diallelic inheritance of shell colour without dominance).

In the relatively deepwater *Cerastoderma glaucum* colonies in Karkinit Gulf (depth 32 m) and off Zmeinyi Is. (depth 26 m), white cockles comprise 4.63 and 9.36% respectively, while in the shallow waters of the innermost parts of bays in the Sevastopol area they constitute 30.83%.

White-brown individuals predominate in the samples from Karkinit Gulf. The observed distribution of heterozygotes (74.70%) greatly exceeds the expected distribution (48.70%). Unlike other areas, this one abounds in benthophagous fishes. The predominance of white-brown forms is probably why fewer of them are eaten up, since their "camouflage" is superior to that of the white and brown cockles on a sandy and muddy bottom. Consequently, the differentiated consumption of them by fishes may be a significant factor that influences the phenetic structure of individual cockle colonies. The better survival of the white-brown heterozygotes ensures stable polymorphism in the populations.

UDC 594.124:639.42 (193)

Growth of *Mytilus edulis* in trays in Avacha Bay

by A.I. Buyanovsky (Kamchatka branch of IBM DVNTs)

On 23 July 1984, we suspended four Japanese scallop-breeding trays in Avacha Bay to study the growth rate of southeastern Kamchatka mussels. The trays were set up in the water column at a depth of 1.5 m from the full water level. In them we placed mussels collected at the same depth from the fouling of a port structure located close to the place where the trays had been set up. Twenty mussels 50-.0-60.0 mm in length were placed in the first tray, 50 mussels 40.0-49.9 mm long in the second tray, 60 specimens measuring 30.0-39.9 mm in the third tray, and ninety 20.0-29.9 mm specimens in the fourth tray. Each individual was measured and numbered beforehand. The numbers were scalpelled onto the surface of the shell. The trays were removed on 22 July 1985, and the live mussels were measured again. Despite the fouling of the shells, the numbers on them were quite clear.

The Bertalanffy equation was used as the one characterizing the growth rate of the mussels. The coefficients were calculated by Valford's method (Alimov, 1981). The coefficient of correlation r_{Lt+1}/Lt proved to be equal to 0.85; L =65.7 mm; K=0.56. The following are the estimates for the first 6 years of life:

Age (years)	1	2	3	4	5	6
Length of shell (mm)	28.2	44.3	53.4	58.7	61.4	63.4

Further analysis of the spat grown on the collectors and the size structure of the starting colony, as well as the counting of annual markings by penetrating light (Hosomi, 1984) have shown that the estimated values are in line with the actual ones.

Consequently, the mussels in Avacha Bay have a relatively high rate of growth, reaching marketable size during the third year of life. From this point of view, the area can be regarded as suitable (194) for the cultivation of mussels.

UDC 639.42

Some data on the cultivation of mussels in Lake Donuzlav

by V.I. Vizhevsky (AzCherNIRO)

Lake Donuzlav is one of the few sheltered bays of the Black Sea that are suitable for the cultivation of mussels. Its hydrological characteristics (low turbulence, favourable depths from 3-7 m in the upper parts) make it possible to produce less expensive mussel products due to the use of simple technology, a small fleet and limited diving operations.

A 3-year study has revealed significant differences in the reproductive biology of the mussel population in the upper parts of Lake Donuzlav. For instance, while the Black Sea mussels are characterized by two peaks of reproduction, spring and autumn (Kiselyova, 1966; Ivanov, 1968), the ones in the upper parts of Lake Donuzlav have only one, clearly defined, autumn period of reproduction. In spring, mussel larvae were encountered in the plankton singly, brought in by the current from the sea. Perhaps the disturbance of the spring breeding period is due to the freshening of the water in the upper parts of Lake Donuzlav, which occurs at the same time as the spring spawning of the mussels.

In autumn (October-November), the concentration of larvae in the plankton varied from 50 to 1000 specimens/m^3. We noted that their distribution throughout the area was quite irregular; the maximum abundance of larvae was observed in the southwestern, deeper part of the lake. The concentration of larvae in the shallow northwestern part with depths up to 3 m did not exceed 100 specimens/m^3.

For collecting the spat and growing the mussels, we used 1.5-metre collectors made of ropes and bars, installed on linear rod carriers, as well as a continuous collector designed by AzCherNIRO. (195)
The number of mussel spat settling on the collectors corresponded to the number of larvae throughout the area. For example, in June 1984, the density of spat on the collector of the linear carrier amounted to 55,000 specimens/m^2 (19.9 kg/m^2) in the deeper part, and 14,500 specimens/m^2 (7.4 kg/m^2) in the shallow part with the average size of the mussels equal to 12.6 mm and 15.6 mm respectively. At harvesting time (September 1985), the yield of mussels from one running metre of a collector amounted to 5.3 kg (57 kg/m^2) with an average size of 54 mm and yield of marketable mussels (40 mm) of about 90%. On the rod and continuous types of carriers, the yield of underyearlings with 11-month exposure amounted to 11.6 kg/m (83.6 kg/m^2) and 21 kg/m (71.6 kg/m^2) respectively.

Consequently, the data obtained in the course of cultivation permit us to recommend the use of the Lake Donuzlav area for commercial cultivation of mussels.

UDC 594.117:639.446

Production of mature germ cells in the Yezo scallop under artificial conditions, and their functional characteristics

by G.I, Viktorovskaya and V.V. Yevdokimov (TINRO)

We have studied the effect of the temperature factor on gametogenesis in the Yezo scallop under artificial conditions during different seasons of the year. This was accomplished by placing sexually mature animals in aquariums with automatic control of certain environmental parameters, and then changing the temperature to see how it affected their reproductive process.

On the basis of the experimental data, we have developed a method that accelerates the maturation of germ cells in the Yezo scallop with the right temperature. We have succeeded in obtaining egg cells and spermatozoa in 66, 38 and 21 days in autumn, winter and early spring respectively, the seasons when scallops do not breed.

Temperature stimulation causes an accelerated increase in gonad mass, resulting in a higher index. The mass of the gonad increases because of the reproduction and growth of the cells. As a result of this, the acini of the gonad reach a substantial size by the end of the experiments, exceeding the initial size more than 1.5-fold. An obvious indicator of accelerated gonad development is the consistent increase in the average size of the cells and their nuclei. With temperature stimulation, spermatogenesis is activated and the maturity coefficient increases several-fold during the experiment.

Consequently, the increase in gonad weight and the size of the acini, as well as the accelerated growth with subsequent maturation of the the cells point to the fact that temperature stimulates gonad development.

The full value of the germ cells was proved by studying the ontogeny of the scallop in comparison with the development of scallops from cells maturing in the sea.

The successful experimental stimulation of gametogenesis in the scallop at the three main stages of gonad development gives us reason to believe that mature gametes can be obtained at any time of the year. This permits us to recommend the use of this method in aquiculture, which will definitely increase the efficiency of scallop reproduction.

UDC 639.4:639.64(265.54)

Results of the harvesting of certain commercial bivalves at algae plantations in Kit Bay (Sea of Japan)

by D.D. Gabayev, N.F. Demchenko and A.N. Shigimaga
(TINRO, Experimental Maricultural Station of PRIMORRYBPROM)

Sea tangle (*Laminaria japonica*) plantations constitute a vast collector for the larvae of commercial invertebrates such as the Yezo scallop (*Mizuhopecten yessoensis*), Swift's scallop (*Swiftopecten swifti* and the common mussel (*Mytilus edulis*). Right after the establishment of commercial plantations in Kit Bay in 1978, an abundance of *M. yessoensis* spat was found on the bottom; in mid July 1985, the average size of the shells was 134 mm and the average mass of meat amounted to 84 g. A commercial density of 5-10 specimens/m^2 was noted on a limited area with a fine-sandy bottom and (197) depth of 24 m in the vicinity of old plantations. The density of *S. swifti* and *M. edulis* was insignificant.

To determine the possibility of cultivating scallops and mussels commercially, 100 strings of scallop collectors were set out at a depth of 4.5-16 m between ropes of sea tangle at five stations of the algae plantation in Kit Bay on 10-24 July 1985. Plankton samples were taken once every ten days at the five stations from the 0-10 m horizon. Three months later, 18 strings of collectors were removed at four stations, and the Yezo scallops, Swift scallops and mussels counted. They were measured at three depths.

Despite the low density of *M. yessoensis* larvae in the plankton (from 14.2 to 16.2 specimens/m^3 in the process of our observations), the average abundance of this species per collector cone with an area of 0.1 m^2 amounted to 122 specimens. *S. swifti* numbered 1.4-3.5 specimens/m^3 in the plankton, and 50 specimens per cone. *M. edulis* settled at a rate of 125 specimens/cone on the average. The Yezo scallop is more abundant in the northern part of Kit Bay opposite the mouth of the Osinovaya R. in the 7.5-16 m horizon. More *S. swifti* settle in the eastern part of Kit Bay in the 12-16 m horizon, and possibly deeper. *Mytilus edulis* settles more in the southern and southwestern parts of the bay in the 4.5-10 m horizon.

The extremely destructive starfish were not found on the bottom, or on the collectors. The size of the Yezo scallop averaged 14.4 mm at a depth of 4.5 m. It was larger on the collectors close to shore, and smaller on the ones farther from shore. The size of the given mollusks diminished with depth, apparently because of later setting.

During our observations at the collectors, we found that the rhizoids of one rope with *Laminaria japonica* contained an average 17.3 specimens of *Mizuhopecten yessoensis*, 239.5 specimens of *Swiftopecten swifti* and 1742 specimens of *Mytilus edulis*. These numbers were much lower than on the scallop collectors.

The low biomass of year-old seedlings of sea tangle makes it possible to set up the scallop collectors and cages without additional floats, which greatly reduces the cost of growing the mollusks. Optimal growth temperatures, the absence of starfish and the insignificant setting of companion species make it possible to expand the cultivation of the Yezo scallop in the more northerly parts of the Maritime Territory on algae plantations.

(198)

UDC 594.124:(574.5:615.9)

Variation of the hemolymph parameters in the Black Sea mussel under the effect of the soluble fractions of petroleum products

by M.S. Galina and M.M. Dzhurtubayev (Odessa State University)

The resistance of mussels to petroleum contamination has been noted time and time again (Mironov, 1973, 1979, etc.). This applies in particular to the extract of soluble petroleum fractions used by us.

The petroleum products in our study were added to the water in the form of aqueous extracts (155-175 mg/l) at a rate of 10 ml of the solution per litre of seawater. The solution was renewed every 24 hours over the 10 days of the experiment. The mortality of the mollusks was compared with the control; it amounted to 60-80% on the 10th day.

The following parameters of the hemolymph were studied: the concentration of total protein, the activity of the transamination enzymes, as well as the content of lactic and pyroracemic acids in the hemolymph.

In the process of our study, we noted that the response of these hemolytic parameters to the stimulus introduced over the given period was of a phasic nature. Among other things, the maximum activity of the transamination enzymes, alanine transaminase (ALT) and aspartate transaminase (AST), was noted at the beginning of the experiment, and on the 6th and 10th days (162%, 165.6% and 137.7% of the control respectively for ALT, and 110%, 117.5% and 138.3% of the control for AST). The minimum activity of the transaminases was observed on the 4th and 8th days of the experiment, but it did not drop lower than the control level by much. An analogous phasic reaction was also noted for the concentration of total protein in the hemolymph, as well as for the content of lactic acid and pyroracemic acid in the hemolymph of the mollusks. On the other hand, the content of lactic acid was higher than usual, and the content of pyroracemic acid lower than in the control right up to the 8th day of the experiment. On the 10th day of the experiment, the ratio of the lactic and pyroracemic acid concentration in the hemolymph of the mussels became irregular, which may be an indication of some disturbance of the aerobic and anaerobic metabolic processes (1'99)
taking place in the organism. On the whole, this phasicity of the processes occurring in the hemolymph can be regarded as the result of the activation of the systems in the mollusk organism in response to the new stimulus.

UDC 594.124:581.526.325

Effect of mussel metabolites on the productive characteristics of the phytoplankton, studied by the method of multiple-factor experiments

by V.N. Galkina (ZIN AN SSSR)

The method of multiple-factor experiments has been used extensively over the past ten years to determine the effect of various environmental factors on the productive characteristics of the phytoplankton. In our case, this method was used to compare the effect of mussel metabolites and mineral biogenic salts on the phytoplankton found in the areas of mussel colonies. Our multiple-factor experiments were carried out according to the PFE-2^3* flow pattern (Ashmarin et al., 1975; Maximov, 1980). In them, we examined the effect of three factors (nitrates, phosphates and dissolved organic matter (DOC) of mussel metabolites) at two levels, the lower of which represented the background of these substances in seawater, while the upper one was created by additions of potassium nitrate and potassium phosphate, as well as a full complex of organic substances from mussel metabolites. The concentrations of the added substances amount to 100 $\mu g \cdot l^{-1}$ for nitrates, 25 $\mu g \cdot l^{-1}$ for phosphates and 0.5 $mgDOC \cdot l^{-1}$ for dissolved organic matter. From the results of the experiments, we have calculated the regression equations which enable us to form an opinion on the effect of each factor individually or combined. The changes in the values of photosynthesis in these experiments were determined on the background of fluctuations in all the other production characteristics (species composition, abundance of cells, total biomass, concentra-

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*acronym unknown - transl.

tion of chlorophyll, ACh*). Changes in these characteristics have been noted throughout the vegetative period in the Barents Sea. Altogether, we carried out 17 series of experiments, with 24 experiments in each series.

As a result of these experiments, we derived the following (200)
regression equations which express the dependence of photosynthesis ($mgC \cdot m^3$) on the effect of the different additives (x_1 - nitrates, x_2 - phosphates, x_3- DOC of mussel metabolites).

<u>April</u> $Y = -36 + 1.4x_1 + 2.0x_2 + 212.7x_3 - 0.03x_1x_2 - 1.6x_1x_3 - 5.3x_2x_3 + 0.03x_1x_2x_3$

<u>June</u> $Y = -8.7 + 1.9x_1 + 0.9x_2 + 144x_3 - 0.002x_1x_2 - 3.2x_1x_3 - 3.1x_2x_3 + 0.05\ x_1x_2x_3$

<u>July</u> $Y = +23.4 + 1.36x_1 + 0.2x_2 + 70.5x_3 - 0.008x_1x_2 - 4.4x_1x_3 - 3.2x_2x_3 + 0.1x_1x_2x_3$

<u>September</u> $Y = +74 + 30x_1 + 1.8x_2 + 68x_3 + 6.5x_1x_2 - 6.3x_1x_3 - 6.3x_2x_3 + 7.0x_1x_2x_3$

These equations show that nitrates and the dissolved organic matter of mussel metabolites have the most stable and noticeable effect on the phytoplankton, increasing production by 38-60% in comparison with the control. At the same time, the effect of the DOC of metabolites reaches its maximum value in spring, during the active development of microalgae and an abundant supply of mineral biogenic salts. Furthermore, the addition of mussel metabolites intensifies the effect from the addition of mineral salts, particularly phosphates. All this points to the biologically active properties of the substances excreted by mussels in the products of metabolism. However, analysis of the results of our

*acronym unknown - transl.

experiments has also shown that one should not proceed from the effect of any individual substance when evaluating the effect of organic matter. In the given case, we should regard this process as the result of the effect of a whole complex of substances from mussel metabolites, which regulate the structure of the phytoplankton community and stimulate its development.

Consequently, the method of multiple-factor experiments can help us to analyze the relationships between organisms in greater detail.

UDC 639.446:591.524.11 (201)

Effect of the mariculture of *Patinopecten yessoensis* on the meiobenthos of Alekseyev Bay in the Sea of Japan

by V.V. Galtsova, O.N. Pavlyuk and V.S. Levin
(ZIN AN SSSR, IBM DVNTs)

Commercial breeding of *Patinopecten yessoensis* has been underway in Alekseyev Bay for the past several years. The purpose of this study was to determine how the mass concentrations of the dominant species affect the meiobenthos. Our material consisted of samples collected in 1985 under submerged scallop trays and in parts of the bay that are free of commercial plantations. The samples were collected at a depth of 10-15 m by a diver equipped with a 20 cm^2 tubular bottom sampler (5 cm core sample). Four parallel samples were taken simultaneously at each station. All of the small benthic animals measuring 0.1-2 mm were counted. The results are given in the table below.

Foraminifers, nematodes, harpacticoids, ostracods and water mites formed the constant component of the meiobenthos (eumeiobenthos);

the temporary component (pseudomeiobenthos) consisted of juvenile (202)
forms of bivalves and polychaetes. The density of the meiobenthos under the submerged scallop trays was by an order of magnitude higher than in the areas free of scallop plantations. Foraminifers, nematodes and ostracods were more concentrated under the submerged trays, whereas sea mites were more abundant in the areas free of plantations. 30-82% of the total density of the meiobenthos can be attributed to the free-living marine nematodes. The influence of the dominant species on the habitat of the associated fauna is particularly noticeable in this group. As we know, the determinant species, being the central species of a community, is not only an edificator that determines the environment of associated organisms; it also alters the spatial structure of the community to some extent.

Group	Areas under trays		"free" areas	
	$N \pm m_N$	(thou. spec./m^2	$N + m_N$	(thou. spec./m^2
Foraminifera	-	406.5±103.2	12.5±3.1	-
Nematoda	1151.2±345.4	1594.3±450.3	54.2±15.3	258.3±75.5
Harpacticoida	136.6±40.9	331.5±94.3	91.7±25.5	25.0±6.1
Ostracoda	24.9±7.0	54.9±16.5	8.3±2.1	8.3±2.1
Halacarida	8.3±2.1	8.3±2.1	12.5±3.6	33.3±8.9
Eumeiobenthos	1321.0±395.2	2395.5±624.2	179.2±51.8	324.9±95.4
Bivalvia (juv)	12.5±3.6	27.4±7.1	8.3±2.1	-
Polychaeta	74.9±21.3	33.3±8.9	-	-
Pseudomeiobenthos	87.4±24.2	60.7±16.2	8.3±2.1	-
Meiobenthos (total)	1408.4±401.4	2456.2±720.4	187.5±51.3	324.9±95.4

Earlier investigations have shown that a specific hydrochemical complex with a higher than usual content of dissolved organic matter and carbohydrates forms at plantations of mussels which excrete metabolites into the environment. This, in turn, leads to an abnormal increase in the population density of 2-3 prolific species of nematodes, which results in a sharp increase in the numbers of the whole group (Galtsova et al., 1985).

One can assume that specific physicochemical conditions which are conducive to the flourishing of certain associated groups of animals and the inhibition of others also form at scallop plantations.

UDC 594.124(262.5)

Dynamics of the distribution of mussels in the northwestern part of the Black Sea

by L.S. Garba (Odessa State University)

V.N. Nikitin (1958, 1961, 1964) describes the location of mussel colonies in the northwestern part of the Black Sea, and divides it into two parts, a somewhat larger western part and a smaller eastern one. The boundary between them extends close to the exit of the Dnieper-Bug Liman in the north, and at the 31°10' meridian in the south.

(203)

Both biocoenotic groups were found to have the same composition of the benthic fauna both in the western, and in the eastern part; however, the quantitative distribution of the microzoobenthos differed significantly. The average density of the benthic fauna amounted to 698 specimens/m^2 and the average biomass to 630 g/m^2 in the western part, and to 275 specimens/m^2 and 335 g/m^2 respectively in the eastern part. According to V.N. Nikitina (1961), the nutrient-abundant currents passing above the western part of the mussel colonies are responsible for the almost double density and biomass of mussels in comparison with the eastern part.

The quantitative distribution of the macrozoobenthos in the western and eastern regions has undergone significant change. Its biomass in the Danube-Dniester interfluve in September 1983 dropped to 1.2 g/m^2, and its density amounted to 900 specimens/m^2. Polychaetous worms comprised the dominant group of benthic fauna in this area. Mussels were encountered singly at several stations, their maximum biomass amounting to approximately 3 g/m^2.

The biomass of macrozoobenthos in the eastern part in August 1984 was almost 100 times higher than in the western part. The average biomass of mussels was equal to 90 g/m^2 in the Dniester area, and 302 g/m^2 in the vicinity of the Tendra Peninsula.

Consequently, the distribution of mussels in the northwestern part of the Black Sea increased from east to west in the 1960's. The opposite is observed at the present time, i.e. the density and biomass of mussels in the eastern part of the northwestern shelf of the Black Sea is considerably higher than in the western part.

This redistribution was caused by water pollution (particularly the Danube River), an increase in eutrophication, as well as mortality due to lack of oxygen.

(204)

UDC 594.1

Linear growth of *Modiolus difficilis* in Vostok Bay of the Sea of Japan

by A.Yu. Gogolev (IEMEZh)*

Growth data are used extensively for solving problems related directly to the industry, and for comparing individual populations. We have studied the effect of abiotic factors on the rate of linear

*Institute of Evolutionary Animal Morphology and Ecology - transl.

growth in the commercial mollusk Modiolus difficilis and the variability of this parameter within the boundaries of Vostok Bay in the Sea of Japan.

The age of the mollusks was determined from shell sections, while the growth rate was determined by the retrospective method which had been proven suitable for this purpose earlier (Gogolev, 1984).

The growth rate of Modiolus difficilis diminishes noticeably in freshened areas, but no statistically significant differences are observed from the age of 14 years. Wave action causes a slight decrease in growth rate, and significant differences are observed from the age of 18 years at a depth of 2-3 m, and from the age of 14 years at a depth of 6-7 m. The growth rate increases consistently with an increase in depth from 1 to 7 m, the differences in the growth rate of Modiolus difficilis at a depth of 2 m and 6-7 m becoming statistically significant from the age of 7 years. We have traced this tendency in two colonies on muddy-sandy substrates, but observed no differences on hard substrates. The decrease in growth rate at small depths is probably due to freshening and wave action. Modiolus difficilis is more stable on solid substrates, and so waves do not have much effect on its growth rate in this type of habitat. A comparison of these animals from colonies on hard substrates and muddy ones has shown that they grow more rapidly on hard substrates.

Consequently, the optimal conditions for the growth of Modiolus difficilis are formed in closed, fully saline bays at a depth of 6-7 m. Under such conditions on muddy substrates in Vostok Bay, Modiolus difficilis reach a length of more than 140 mm; their rate of growth is estimated by the equation $L_t = 120(1-e^{-0.158(t-0.2)})$, where t denotes the age in years.

(205)

A comparison of the derived curves of group linear growth shows that the rates of growth of Modiolus difficilis remain stable during the first 6-7 years, whereas the variability caused by the described abiotic factors manifests itself in older mollusks. This permits us to utilize the initial segment of the curve of group growth to characterize Modiolus difficilis of this particular region, and to compare them with other populations.

UDC 639.27:639.4

Some questions related to commercial exploitation and cultivation of marine invertebrates, with gastropods and bivalves taken as an example

by A.N. Golikov and O.A. Skarlato (ZIN AN SSSR)

The majority of large commercial invertebrates forms aggregations or congregations, i.e. permanent or temporary concentrations determined by spawning or the availability of food. This results in patchy distribution, which makes it dfficult to determine their numbers. Relative success has been achieved in the study of the distribution of crustaceans. It is difficult to study the quantitative distribution of commercial gastropods and bivalves because of their ecological peculiarities.

When analyzing the results of a quantitative survey, it is important to examine the size-weight structure of populations, which will provide us with material by which we can determine the growth and production of the individuals forming these populations.

Organisms in natural ecosystems are distributed nonuniformly as to the density of their colonies and biomass; it is, therefore, necessary to determine their resources not by random sampling, but by systematic analysis of their abundance in areas of different size, depending on the value and nature of the distribution of these animals.

Almost all the species of gastropods and bivalves are edible; many of them are marketable species, while others can be used in mariculture. The most important stages in the breeding of mollusks (206) are the production of the spat and the protection of the growing generation from predators. Therefore, it is best to raise species with leaf-oriented larvae (mussels, scallops, etc.) or colour-oriented larvae (oysters) at the setting stage, or species with direct development of spat (whelks), with subsequent cultivation on suspended trays or collectors protected from predators.

The exploitation and breeding of mollusks and other invertebrates should be carried out with the analysis of the energy flowing through the natural or cultivated populations taken into account. It is important to calculate the portion of production required for the replacement of the initial biomass. We have found that the optimal rates of removal of large bivalves and gastropods from natural populations vary from 10% (more commonly) to 30% (less commonly) of their resources annually. Such rates of removal (preferably in the post-spawning period) can ensure the restoration of the mollusk stock to the initial level.

UDC 594.124

Respiration and excretion of metabolites as indicators of the functioning of mussel populations

by S.A. Goromosova and V.A. Tamozhnyaya (INBYuM)

The level of oxygen consumption and the dynamics of excretion of end and intermediate products of metabolism, particularly ammonium, free amino acids and total carbohydrates, were used as the quantitative characteristics of the activity of mussel populations. The other indicators were the content of dissolved organic matter (DOC) and pH, which reflected the overall level of excretion and its chemical nature. The level of respiration and excretion of metabolites were compared according to season and under various extreme conditions. The above characteristics were determined in a periphytic community at the stage of mussel dominance for a period of one year, and also under experimental conditions with a pure mussel population. (207)

The level of the metabolic processes was closely related to the season, water temperature, the content of oxygen in the water and the physiological condition of the mollusks. In summer, for example, there was a significant increase in the excretion of ammonium, amino acids and carbohydrates in comparison with the winter level, and the total content of DOC and acid metabolites also increased. The respiration of a population is also characterized by distinct seasonal rhythms. Respiration is minimal in winter, increases sharply in March-April, and is directly related to the increase in water temperature and gamete maturation. With the decrease in the oxygen content of the environment in summer, mussels resort partially to anaerobic metabolism, which is accompanied by an increase in the level of metabolite excretion. During the oxygen deficiency in winter, the excretion of metabolites by mussels diminishes.

The exposure of mussels to a hypoosmotic environment (9‰) results in a lower pH both in the mantle fluid, and in the water, with increased excretion of DOC. Reverse processes occur with an increase in salinity to 32‰.

We observe a decrease in the respiration rate and excretion of organic matter when the mussels are exposed to organometallic toxins, the degree of the response reaction depending both on the nature of the biocide, and on its concentration. Qualitative differences are observed in the properties and degree of toxicity of copper and arsenic. Copper ions induce a strong isolating reflex in mussels, and, as a result, the metabolites accumulating in the mantle fluid are not excreted into the environment. Organic arsenic compounds lead to other changes, i.e. a decrease in the content of dissolved organic matter both in the mantle fluid of the mussels, and in the toxic environment. Acid metabolites accumulate under all extreme conditions, and this results in a significant decrease of the pH level.

Consequently, systematic determination of the above-mentioned characteristics in the habitat of the mussels or other marine invertebrates is an adequate reflection of the physiological condition of the organisms and their functional state at a given period of time.

UDC 639.4:639.3.045:639.33 (208)

Methods of transporting the Black Sea mollusks *Mytilus galloprovincialis* and *Mya arenaria* in connection with their acclimatization

by V.F. Grigoryev, O.A. Leis and I.N. Zodoyenko (TsPAU Glavrybvod)*

With an increase in the scale of cultivation of marine mollusks and their acclimatization, it becomes necessary to develop methods of transporting them.

Based on the experimental work of TsPAU and the Institute of Zoology of the Kazakh Academy of Sciences and according to the recommendations of the Kazakh Scientific Research Institute of Fisheries, it is advisable to settle Black Sea mollusks in the Aral Sea in order to enrich its hydrofauna as the salinity of its waters continues to increase. The biological grounds for these measures have been approved by the Ichthyological Commission.

The Aral waters with a salinity ranging from 18.4-31.2‰ are conducive to the development of the larvae, spat and adults of Black Sea mussels (Malinovskaya, Nilov, 1981). These assumptions have been confirmed by the results of our investigations.

We have established that mollusks can be transported in isothermal containers in a damp environment by aircraft, and in fish cars containing Black Sea water for 2.5-3.0 days at a water and air temperature of 15-20°C.

With the different ways of transporting the mollusks in containers, the mortality rate (%) is as follows: *Mytilus galloprovincialis* on *Phyllophora* 0.4%, the spat of mussels on collectors 1.6%,

*Central Commercial Acclimatization Board of the Main Administration for the Preservation and Replacement of the Fish Stocks and Fishery Managment of the USSR Ministry of the Fishing Industry - transl.

Mya arenaria on frames 4.6%, and the mortality for transportation in fish cars by rail is 5.1% for *Mytilus galloprovincialis* and 6.1% for *Mya arenaria* when the mollusks are transported in net retainers, and 15.8% and 11.3% respectively when they are transported in net pouches.

The mollusks used in the experiment measured 8–70 mm, except for the mussels on the collectors which were 4–15 mm long.

The mortality of the mollusks transported in retainers of railway fish cars is slightly higher than that of mussels transported in containers by aircraft for the same period. However, the long trip from the Black Sea to the Aral Sea by rail (5–6 days) increases the mortality of the mollusks 3—5-fold. The use of refrigerator cars for this purpose is economically unprofitable due to high rental costs.

The best way to transport Black Sea mollusks at the present time is on a natural substrate (*Phyllophora*) and on collectors in isothermal containers by aircraft. Control sampling of benthic specimens by the diving method has been planned for 1986 to establish the results of the settling and reintroduction of Black Sea mollusks in the Aral Sea.

UDC 594.446

Functional characteristics of the reproductive system in Swift's scallop *Swiftopecten swifti*

by L.A. Denisova (IBM DVNTs)

Marine bivalve mollusks are characterized by a diversity of reproductive types. In addition to gonochoristic types, there are functional-hermaphroditic and labile-dioecious species. The study of the functional characteristics of the reproductive system in bivalve mollusks on the basis of the sex structure of their natural colonies, as well as experimentation in this field, is of definite theoretical and practical interest to us.

We have studied the sex structure of the local population of Swiftopecten swifti in Melkovodnaya Bay in the Sea of Japan. The total abundance of these animals amounted to 205 specimens. The sex of the mollusks was determined from temporary gonad smears, and the age of the mollusks from the annual growth zones on the external surface of the shells.

This species reaches sexual maturity at the age of 3 years. Most of the animals begin their reproductive activity as males (protandry). In the older age groups, however, we observe an increase in the proportion of females, which make up approximately 50% of the 6—7-year-old animals. This, apparently, is related to sexual inversion in the mollusks. (210)

To verify this assumption, we selected 90 3—4-year-old male Swiftopecten swifti. The sex of the animals was determined visually, by the colour of the gonads, which are bright orange in the females and cream-coloured in the males. For a whole year, the mollusks were kept in trays suspended in the water column at a depth of 6 m. After the sex had been determined again, we found that 14 of the 45 animals that had survived had undergone a sex change, i.e. they became functional females.

We can, therefore, say that some Swiftopecten swifti change from male to female in the process of ontogenesis. At the same time, sexual inversion in this species occurs in between breeding seasons. As to its reproductive characteristics, Swiftopecten swifti can be classified as a labile-dioecious protandrous species with a consecutive change in the sexual phases.

UDC 594.124

Mytilus galloprovincialis in the periphyton of artificial substrates in the Gulf of Odessa

by M.M. Dzhurtubayev (Odessa State University)

Our material was collected during the spring-summer period of 1983-1984 at three points along the Odessa coast, at the breakwater off capes Lanzheron (Komsomolsky beach), Malyi Fontan (hydrobiological station of Odessa State University) and Bolshoi Fontan (16th station). The samples were collected with the use of lightweight diving equipment, a 20x20 cm scraper and a pouch made of miller's gauze at the 0.5 m, 1.0 m and 1.5 m depths 10, 20 and 40 metres from shore. Seventy-five samples were collected in all. They were processed by the standard method.

Mussels were encountered at all the depths only at the hydrobiological station, where they were somewhat more protected from wave action and mussel-hunting vacationers. There were practically no mussels to be found at the 0.5 m depth at any of the control (211) points in the vicinity of Bolshoi Fontan. At the surface near the breakwater of Komsomolsky beach, they were encountered only at the point farthest out to sea, where the density amounted to 600-800 specimens/m^2, and the biomass up to 1600 g/m^2. On the whole, this area shows a clear tendency towards an increase in the numbers of periphytic mollusks from the coast seaward and from the surface towards the bottom. The increase in mussel numbers with depth is particularly rapid (2—9-fold) at the coastal control points (10 m from the coast). This increase is more pronounced at Komsomolsky beach and Bolshoi Fontan. The mussels at Bolshoi Fontan were extremely silted up; silty deposits were abundant both on the mollusks themselves, and on the substrate between them. The silt had a characteristic odour of hydrogen sulfide, but not many dead mussels were found. This is apparently due to the fact that the mollusks were located above the bottom where the water circulation was stronger and the supply of oxygen higher. Here we also found the highest numbers of periphytic organisms such as polychaetes (nereids) and crustaceans (amphipods, isopods, etc.).

Small mollusks dominated in the periphyton during the period of investigation. From 85 to 93% of all the mussels measured up to 35 mm in length. Relatively large mussels over 50 mm constituted only 3.0-5.5% of the total numbers. There was practically no seasonal change in the average length of the mollusks; they measured 28.9 mm in summer and 28.5 mm in autumn (M-values here and below). On the whole, the average density of mussels for the area amounted to 1924 specimens/m^2 in summer and 2113 specimens/m^2 in autumn, and the biomass amounted to 5980 g/m^2 and 6130 g/m^2 respectively.

Despite the fact that hydrotechnical structures (breakwater, etc.) made of smooth concrete cannot be regarded as optimal substrates for periphytic mollusks, the density and biomass of mussels off the Odessa coast can be quite high. Estimates show that, under favourable conditions, they can amount to 8000 specimens/m^2 and 20 kg/m^2 respectively or more. However, these levels are not usually attained due to wave action and, primarily, the collection of mussels by vacationers. In connection with this, the public is being asked to refrain from this practice.

(212)

UDC 594.117:(574.5:539.16)

Effect of gamma radiation on the oogenesis of the bivalve mollusk *Patinopecten yessoensis*

by S.M. Dzyuba, L.N. Mishchenko, Yu.A. Ivanovsky and V.N. Kulepanov (TINRO)

It has been shown in the past (Ivanovsky, 1985) that irradiation of *Patinopecten yessoensis* with ^{60}Co gamma rays resulted in an increase of its soft tissue mass after a certain length of time. This effect was detected after irradiation with doses of 5.25-15 Gy in one- and two-year-old mollusks, and with 4-7.5 Gy in spat. A dose of 50 Gy completely inhibited their growth, and often proved lethal for these animals. We are now faced with the question of whether it would be possible to apply the method of radiative stimulation in mariculture. However, before doing so, we must first establish the effect of irradiation on the germ cells and on the reproductive capacity of the mollusks.

We subjected the gonads of *Patinopecten yessoensis* to histological analysis after the animal had been exposed to radiation doses of 7.5, 15 and 50 Gy. Spat and one- and two-year-old mollusks were used in the experiment.

One year after exposure of spat to a dose of 15 Gy, a large proportion of the experimental mollusks were found to be sterile. There were no parenchymatous elements in their gonads, and the intestinal loop was surrounded only by connective tissue perforated by fibrillary strands; the organ as a whole was growing smaller. In individual animals, the gonad consisted of unbranched or weakly branched genital tubules stemming from the base of the foot. This is apparently the site of the main pool of gonadal trunk cells, which ensures the growth of the gonad in juvenile scallops and helps to regenerate it after radiation damage. When spat was irradiated with a dose of 7.5 Gy, no destructive processes were detected in the gonads at the level of light microscopy, which may be due to a less pronounced rate of cell destruction.

In one-year-old female scallops, the gonads normally contain small oogonia and oocytes; at the age of 2 years, they (213) already contain large oocytes and individual cells that have completed their growth.

During irradiation of scallops of this age, we noted that some of the germ cells synchronously entered mitosis and meiosis on the 1st-4th day after irradiation with doses of 7.5 and 15 Gy. As a result, at least twice as many small oogonia and oocytes appeared in the gonads in comparison with the control. Apparently, irradiation takes the cells out of the dormant state, stimulating their transition to the following stage of differentiation. The fact that the number of ^{3}H-thymidine—labelled cells did not increase significantly at this time is a characteristic one. On the basis of this, we can say that the increase in cellularity among the oogonia must be due to their emergence from the C_2 stage of the cellular cycle, and the emergence of the small oocytes from the premeiotic interphase after the completion of DNA synthesis. Inhibition of cell reproduction set in after this, and the oocytes growing in the gonad began to deteriorate. Chromatin condensation and chromosome deformation were noted in the small oocytes;

in the large oocytes, we observed coagulation of the karyoplasm, exfoliation of the cytoplasm from the external cell membrane, and the appearance in it of large vacuoles, faintly stainable spheres and thick strands of fibril bundles.

A month after exposure of the mollusks to radiation doses of 7.5 and 15 Gy, their gonads did not contain a single oocyte, and with a dose of 50 Gy the oocytes disappeared on the 15-17th day. The germ cells in the gonads consisted exclusively of oogonia.

The autoradiographic method showed that DNA synthesis sharply decreased in the germ cells during the first hours after exposure of the animals to doses of 15 and 50 Gy; after that, it was of an undulatory nature, reflecting both the decrease in cells, and the regenerative processes. With exposure to a dose of 7.5 Gy, the decrease in cells was less pronounced, and the regenerative processes more intense.

Consequently, the effect of the increase in soft tissues as a result of gamma radiation with a dose of 15 Gy may be due to radiative sterilization of the mollusks, but the question of whether the genital products remain intact when the scallop is irradiated with smaller doses remains unanswered.

UDC 594.117:(574.5:615.9) (214)

Bioconcentration of cadmium by the hepatopancreas in *Mizuhopecten yessoensis*

by Z.S. Yevtushenko, O.N. Lukyanova and N.N. Belcheva
(IBM DVNTs AN SSSR)

The relationship between the concentration of heavy metals and body size has been studied in various species of marine invertebrates. The bivalve mollusks (according to Bowden's data) are characterized either by a decrease in Cd concentration with an increase in shell size, or by a constancy of Cd concentration in all the size groups of mollusks.

Like a number of other members of the Pectinidae family, Mizuhopecten yessoensis is distinguished from other bivalve mollusks by higher Cd concentrations in the soft tissues and individual organs. We determined the Cd content in the organs of 5 size groups of scallops with a shell size from 2.5 cm to 17.5 cm (1-8 years old). We also determined the Cd content in the organelles, cytoplasmic proteins and lipids of the hepatopancreas and gills in different size groups of this species. The mollusks were collected in the littoral zone of Furugelm Is. and Posyet Bay in the southern part of the Peter the Great Gulf in the Sea of Japan.

The Cd content in the organs of the different size groups of Mizuhopecten yessoensis varied significantly, from 0.8 ± 0.2—5.8 ± 1.2 µg/g dry wt in the muscle, mantle and gills, 39.0 ± 2.2—400.0 ± 10.0 in the hepatopancreas, to 119.0 ± 8.6—644.0 ± 43.6 µgCd/g dry wt in the kidneys. While no increase in Cd concentration was noted in the muscle, mantle and gills with shell growth, a significant increase was noted in the hepatopancreas and kidneys as the mollusk grew. The regression equation for the content of Cd in the hepatopancreas in relation to shell size is $175.1 + 43.6x$, $(r=0.98)$.

To determine the dependence of intracellular Cd localization on shell size, we carried out subcellular distribution of hepatopancreatic and gill homogenates from different size groups of this species into nuclei, mitochondria, microsomes and cytosols, and determined the content of Cd in them. In the hepatopancreas, the bulk of the Cd was detected in the cytoplasm. This is characteristic of all the different groups of this species, though we should note that 71.7% of the Cd is concentrated in the cytoplasm of scallops with a 2.5 cm shell (1 year old), and 98.8% in 8-year-old scallops. This difference is even more significant when calculating the specific concentration per mg of protein (0.12 μgCd/mg of protein in one-year-old scallops and 1.40 μgCd/mg of protein in 8-year-old scallops). The same ratio is characteristic of the gills as well, though the concentration of Cd in this organ is by an order of magnitude lower than in the hepatopancreas. To determine the nature of Cd binding in the cytoplasm, we separated the cytoplasmic proteins on a Sephadex G-75. While determining the content of Cd in proteins of different molecular weight from the hepatopancreas, we observed a clear relationship between the increase of Cd in low-molecular proteins of the metallothioneine-type and the growth of the scallop shell (1.5 μg Cd with a shell size of 8.0-9.0 cm at the age of 2 years, and 22.0 μg Cd with a 16.0-17.0 cm shell at the age of 8 years). The same relationship is observed when calculating the specific Cd concentration in protein fractions per mg of protein (0.15 μgCd/mg of protein at the age of 2 years, and 0.81 μgCd/mg of protein at the age of 8 years).

The nature of the relationship between Cd and the membranes in the organs of the scallop can be determined indirectly from the concentration of this metal in the lipids of the extracts. The Cd concentration in the lipids of the hepatopancreas diminishes significantly with the growth of the shell (8.2 μgCd/g of lipids with a 8.0-9.0 cm shell, and 1.1 μgCd/g of lipids with a 16.0-17.0 cm shell).

Consequently, the bioconcentration of Cd in the hepatopancreas of Mizuhopecten yessoensis with age occurs mainly because of the binding of metal by the cytoplasmic proteins.

(216)

UDC 639.4

Prospects of utilizing commercial bivalve mollusks for mariculture in the Maritime Territory

by A.V. Zhirmunsky (IBM)

The physicogeographic conditions of the Maritime Territory (Primor'ye), particularly Peter the Great Gulf, were the prerequisite for the development here of the most diverse invertebrate fauna encountered in the seas of the USSR, among which the bivalve mollusks play the leading role in coastal benthic communities. A number of species which were, are, or can be exploited commercially is found in this region.

However, for a commercial species to become an item of mariculture, we must fulfill a number of conditions related to its biological characteristics on the one hand, and to the development of the biotechnology of cultivation, the technology of preparing the products and sales economics on the other. A most important factor in the development of mariculture is the amount of interest shown in the project by industry, which depends on the presence of reserve fish stocks (which can be utilized without breeding), the availability of manpower, market demand, and the targets and assistance planned by the Ministry of the Fishing Industry.

Judging by our experience in experimental and experimental-commercial cultivation, the common mussel is the most promising invertebrate for the Maritime Territory. Up to 50 tons/ha of these mollusks (fresh, with shell) can be harvested in a one-year cycle from an area of thousands of hectares in this region. The Institute of Marine Biology has developed a simple and reliable biotechnology (Brykov et al.) which is currently being tested at the collective farm named after the 21st Congress of the CPSU.

Second priority should be given to the Yezo scallop; the cultivation of its spat has already been mastered at the Primorrybprom maricultural enterprise in Posyet Bay. On the other hand, the biotechnology and economics of producing marketable scallops have not been developed yet. The giant oyster (*Crassostrea gigas*) is the third most promising mollusk.

The following are some of the potential bivalves that are suitable for cultivation: the Japanese bay scallop, Swift's scallop, Gray's mussel, the sand-burrowing striped *Mactra* (chinensis*), the Sakhalin *Spisula*, the Philippine *Venerupis** (ruditapes*, etc. (217)

The significant fluctuations in the numbers of larvae in the plankton from year to year are the the biological characteristic that restricts the development of widescale mariculture. However, this difficulty can be overcome by raising larvae in basins with regulated environmental parameters, as is being done in Japan and England, and then transferring the spat to maricultural plantations.

UDC 639.42

Influence of the macrostructure of the substrate on the setting of mussel larvae

by S.V. Zagranichnyi (VNIRO)

The influence of the substrate material and the structure of its surface on the setting rate of mussel larvae has been the

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*conjectural spelling - transl.

subject of a large number of investigations. Their results have shown that the most intensive setting occurs on substrates with a rough and shaggy surface. The substrate material apparently plays a smaller role, and no distinct characteristics have been established in connection with this.

The investigations conducted in Kapsel inlet of Sudak Bay in the Black Sea during 1984-1985 have enabled us to establish yet another important factor that influences the setting of mussels, i.e. the surface macrostructure of the substrate.

We studied the setting of mussels on collectors made of 100x40x10 mm foam plastic plates interwoven with a nylon rope 6 mm in diameter. A separate count was taken of the mussels settling on the foam plastic and the mussels settling at the points where the rope and plates abutt. We examined 102 plates on which 1026 mussels had settled.

Despite the fact that the foam plastic plates have a highly shaggy and rough surface with an area hundreds of times larger than the area of the rope-plate junctions, the number of mussels that settled on the plates and at the junctions was practically the same, 520 and 506 respectively. The mean value of the difference between the number of mussels settling on a plate and at a (218)
rope-plate junction was equal to 0.235 ± 0.779, and did not differ significantly from zero.

Our results have brought us to the conclusion that the presence of large (compared with the mussel larvae) slits, knots, joints, etc. on the surface of the substrate is highly conducive to the setting rate of mussel larvae. Experiments have confirmed this. Collectors consisting of knotted nylon ropes were used in the experiment. Clusters of settling mussels formed exclusively at the knots, while the setting rate increased with the number of knots per running metre of the collector. Underwater observations of the fouling of various hydraulic structures and stationary fishing gear have also confirmed that mussels form clusters primarily at the junctions of various components of a structure.

This tendency is of great practical importance, and should be taken into account when making collectors for mussel cultivation, or designing artificial reefs and marine hydraulic structures.

UDC 594.1(262.5)

Fluctuations in the numbers and biomass of soft-shelled clams (*Mya*) and mussels (*Mytilus*) in the northwestern part of the Black Sea

by Yu.P. Zaitsev, V.A. Salsky, V.B. Nikitina and N.S. Chilikina (Odessa branch of INBYuM)

In numbers and biomass, *Mya* and *Mytilus* are the principal bivalve mollusks on the northwestern shelf of the Black Sea.

Over the past years, asphyxiation of benthic organisms at depths from 5-8 to 30-40 m has been periodically observed in summer due to hypoxia in the near-bottom layers of water, which occurs during the warm months as a result of eutrophication and density stratification of the waters. As a result, the numbers and biomass of the benthic species began to undergo substantial fluctuations with the minimum observed in July—September. (219)

We have traced the numbers and biomass of *Mya* and *Mytilus* in the area influenced by the outflow from the Dnieper-Bug liman.

It has been established that these parameters reach the maximum values by June—July. Then, as a result of hypoxia, masses of the mollusks die off; the biomass of Mya decreased by more than 99% over a period of 1-2 months, and the biomass of Mytilus by 85-98%. Practically the only survivals are the animals from the edge of the water where, because of the surf, the oxygen content of the water does not undergo any marked seasonal changes.

After the onset of homothermal conditions in autumn and as a result of the mixing of waters by waves, the content of oxygen in the asphyxiation zones is restored to the normal level. These zones become occupied by the larvae of mollusks (and other benthic organisms) which are carried by the currents from the edge of the water and other areas not affected by hypoxia. The mollusks develop successfully up to the following warm season, when the same phenomenon occurs again. As a result of these fluctuations in oxygen content, the mussels and clams at these depths consist almost exclusively of young individuals.

This characteristic of the seasonal population dynamics of these mollusks should be taken into consideration when planning their exploitation and the development of mariculture in the given and similar areas of the northwestern shelf.

UDC 639.42(262.5)

An experiment in intensive cultivation of mussels in areas of the Black Sea that have undergone eutrophication

by Yu.P. Zaitsev and A.I. Ivanov (Odessa branch of INBYuM)

The high biological productivity of the northwestern part of the Black Sea is determined by the biogenic runoff of the large rivers (Danube, Dniester, Dnieper) flowing into it.

Over the past years, this area has undergone eutrophication which, on the one hand, has led to hypoxia in the near-bottom layers of water and, as a result, to mass asphyxiation of the benthic organisms (Zaitsev, 1977, 1985; Salsky, 1977; Ivanov, 1979); on the other hand, it has led to a spurt in the abundance of phytoplankton in the upper layers of the pelagic zone (Nesterova, 1983). (220)

Proceeding from this ecological situation, we decided to raise mussels in the water column (Ivanov, 1971, 1983) in order to remove them from the zone of oxygen deficiency at the bottom into the nutrient-abundant zone near the surface. Our experiment was carried out off the Odessa coast (Cape Bolshoi Fontan). We set up 1200 collectors 2.5 and 3.5 m long 1-4.5 m from the surface of the water above depths of 7-10 m. After 10 months of cultivation, the mussels averaged 22.3 mm in length, and the largest individuals measured 54 mm. The average yield of mussels from one net collector amounted to 57 kg (maximum 81.8 kg), and from a wooden collector 54 kg (maximum 73.8 kg). The yield of mussel meat during the harvesting period in autumn varied from 25 to 31%.

Mussel production was estimated at more than 500 tons of mollusks or about 140 tons of mussel meat from one hectare of collectors on the average (density of collectors 1 per m^2). This level of production is by an order of magnitude higher than in other parts of the Black Sea (Sakovets, 1985), which is due to a high degree of eutrophication in the northwestern part of the sea.

Our investigation has shown that a high rate of mussel cultivation is possible in highly trophic waters. At the same time, we can achieve both an economic effect (a high yield of mussels), and an ecological one, i.e. the transformation of excess plankton and detritus into feed and foodstuffs. These products in their natural and processed (paste) forms are in great demand on poultry, cattle and animal farms of the Odessa Region.

(221)

UDC 551:46:593.7+594.124(262.54)

Influence of abiotic factors on the concentration of mussels and jellyfish in the Sea of Azov

by V.P. Zakutsky, A.P. Kuropatkin, Yu.M. Gargopa and V.M. Shishkin (AzNIRKh)

The current changes in the hydrologic-hydrochemical conditions of the Sea of Azov have caused a number of ecological transformations. For example, the salination of the waters led to the formation of an independent mussel biocoenosis in the sea, while the jellyfish became an indispensable component of the plankton. Expeditionary material has been analyzed by methods of mathematical statistics in order to determine the effect of abiotic factors on the growth of   the _Mytilus_ range, and on the numbers and biomass of the jellyfish.

Correlation analysis has shown that a direct relationship existed between the annual salinity of the sea in the preceding year and the abundance of jellyfish during the year in question ($r=0.79\pm0.08$). At the same time, the biomass of jellyfish was correlated to the greatest extent with the salinity of the Sea of Azov itself during the same year ($r=0.82\pm0.07$).

The area of the mussel biocoensis is directly dependent on salinity ($r=0.75$), the areas of the zones with the most favourable salinity (over 11-12‰) ($r=0.77$), temperature ($r=0.59$) and wind action (r=0.76), and is inversely related to river runoff (r=0.78). The age of the mussels varies from 4-6 years. Consequently, the statistical relationship between the area of the mussel biocoenosis and the above-mentioned factors is most significant if the above predictors are taken into account for the five preceding years. We have found that the wind and temperature factors have a particularly significant effect during the spring-summer and summer periods. The observed negative correlation between the area of the mussel biocoenosis and river runoff is maximal if the volume of runoff for the ten preceding years is used in the calculations.

Using X_1 as the predictor of the average wind velocity in summer, X_2 as the average annual area of the zones with a water salinity of more than 12‰, X_3 as the sum of water temperatures during the spring-summer period, X_4 as the average annual salinity of the sea itself during the five preceding years and X_5 as the average annual river runoff, our results have enabled us to derive the regression equations that describe the relationship between the area of the mussel biocoenosis and these factors (Y). (222)

$$Y = 1{,}706X_1 + 0{,}041X_2 - 2{,}3 \quad (1)$$
$$R = 0{,}81; \quad F = 4{,}1; \quad S_y = \pm 0{,}63 \text{ thou.км}^2 \qquad \frac{S_y}{\sigma_y} = 0{,}63$$
$$Y = 0{,}173X_3 + 0{,}913X_4 - 19{,}4 \quad (2)$$
$$R = 0{,}77; \quad F = 3{,}7; \quad S_y = \pm 0{,}69 \text{ thou.км}^2 \qquad \frac{S_y}{\sigma_y} = 0{,}69$$
$$Y = 1{,}518X_1 - 0{,}1515X_5 + 4{,}1 \quad (3)$$
$$R = 0{,}82; \quad F = 4{,}1; \quad S_y = 0{,}62 \text{ thou.км}^2 \qquad \frac{S_y}{\sigma_y} = 0{,}62$$

Similar linear and nonlinear equations that approximate the dependence of jellyfish biomass (Y) on the salinity of the Sea of Azov (X) during the year in question have the following form:

$$Y = 3{,}37X - 38{,}35 \quad (4)$$
$$R = 0{,}82; \quad F = 3{,}1; \quad S_y = 2{,}38 \text{ mil.т.} \qquad \frac{S_y}{\sigma_y} = 0{,}57$$
$$\ln y = 17{,}35 \cdot \ln x - 43{,}15 \quad (5)$$
$$R_y = 0{,}89; \quad F = 3{,}3; \quad S_y = 1{,}82 \text{ mil.т} \qquad \frac{S_y}{\sigma_y} = 0{,}46$$

The above statistical models belong to the category of adequate ones with respect to accuracy and efficiency, and can be used to determine any possible changes in the biocoenosis of the mussels and biomass of the jellyfish in the Sea of Azov.

UDC 594.124:(574.5:615.9)

Mutagenic and toxic effect of heavy metals on the larvae of *Mytilus galloprovincialis*

by T.F. Zvezdina (INBYuM)

Heavy metals are one of the principal contaminants of the sea environment, and the threat of pollution by them is steadily increasing. The heaviest pollution load is borne by the coastal areas that are convenient for the cultivation of mussels and other invertebrates. This being the case, it has become extremely necessary to test the effect of heavy metals on the species suitable for mariculture, particularly at the early stages of their development. (223)

Spawning was induced in mussels under laboratory conditions, and immediately after fertilization the animals were placed in beakers with solutions of $ZnCl_2$ (10.0, 1.0, 0.1, 0.01 mg/l; control) and $Pb(NO_3)_2$ (5.0, 0.5, 0.05, 0.005 mg/l; control). Temporary, pressed specimens stained with acetoorcein were prepared from the trochophores of the mussels (the largest number of mitoses). The mutagenic effect was determined by the anaphase method; disturbances of the chromatid type (single bridges and fragments) and chromosome type (double bridges and fragments) were registered.

Approximately 300 specimens were examined in all, and about 4000 anaphases and telophases were analyzed.

Mutagenic effect of various concentrations of Zn and Pb on the trochophores of mussels

Concentration of Zn^{++}, mg/l	Average number of disturbances (%)	Concentration of Pb^{++}, mg/l	Average number of disturbances (%)
control	5.35±1.25	control	5.35±1.25
0.01	9.94±3.71	0.005	8.02±4.23
0.1	8.33±4.41	0.05	5.09±5.23
1.0	8.38±4.65	0.5	15.40±10.21
10.0	12.60±0.93	5.0	13.44±2.60

The total number of disturbances for zinc differed from the control beginning with the minimal concentration of 0.01 mg/l; the percentage of disturbances did not increase after that right up to the concentration of 10 mg/l, at which the number of disturbances was significantly higher than at other concentrations (see table). The total number of disturbances for lead differed from the control in the same way, beginning with the concentration of 0.005 mg/l; the percentage of disturbances at concentrations of 5 and 0.5 mg/l differed significantly from the number of disturbances at lower concentrations.

The toxic effect of lead and zinc ions manifests itself in disturbances of metamorphosis, i.e. the larvae die at the stage of trochophore, and the shells develop abnormally in the veliger larvae. The mitotic activity and growth rate of the mussel larvae decrease significantly with an increase in the concentration of lead and zinc.

Consequently, the salts of heavy metals have a noticeable mutagenic and toxic effect on the early stages of mussel development even with insignificant concentrations. This should be taken into account when assessing the environment during the selection of sites for mussel farms. (223)

UDC 639.42

Data on experimental commercial cultivation of mussels (*Mytilus galloprovincialis*) in the Kerch Strait

by A.P. Zolotnitsky, A.N. Orlenko, L.F. Shtyrkina, V.I. Vizhevsky and V.V. Timofeyev (AzCherNIRO)

Investigations related to the development of the biotechnology of commercial mussel farming have in recent years been conducted on a wide scale in the Black Sea. However, these investigations were usually of an experimental nature, and so it has now become necessary to test the results under conditions closest to the commercial ones.

In 1983, AzCherNIRO, together with the V.I. Lenin r/k* of the Crimean RKS*, organized an experimental commercial plantation in the Kerch Strait; the plantation covered an area of 2.5 hectares, and mussels were grown there for 1½ years. One hundred and twenty-seven carriers of 3 types were set up in all.

A study of the size-weight composition of the mussels during the different seasons of the year has shown that the biomass of the mussels grown on collectors is determined by the first spring generation of spat. The larvae of the autumn and second spring generations settling after that are quickly eliminated.

With a high density of setting spat, a significant mortality of the mollusks is observed in the process of growth. On the whole, regardless of the area of the substrate, the elimination of mussels on the collectors at the early stages of ontogenesis can be described by the exponential function $N_t=N_0 \cdot e^{-kt}$, where N_0 and N_t denote the abundance of the mollusks during the initial period of setting and

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*acronyms unknown; r/k probably stands for rybokombinat (fish-processing plant), while RKS may be the acronym for rybokonservnyi sovkhoz (a state-owned enterprise involved in fishing, mariculture and the processing of its catches) - transl.

during the period t (days) from the time setting began, and k the coefficient of the instantaneous rate of elimination which (225) varied from 0.0106 to 0.0144. However, when a certain density is attained (determined mainly by the area of the substrate), the abundance of mussels stabilizes.

Our observations of the changes in the abundance and biomass during the period of cultivation have shown that the efficiency of cultivation, with all other conditions being equal, depends on the area/length ratio (S/1) of the substrate. On carriers with a higher S/1 ratio, we observed a higher abundance and biomass of mussels in comparison with a linear carrier. At the same time, the average length and mass of one specimen and, consequently, the percentage of mussels of marketable size (50 mm and larger) were greater on the linear carriers. Among other things, the density of mussels on the continuous carriers with a S/1 ratio of 0.35 at the end of 1½ years of cultivation amounted to 1100-1400 specimens/m and the biomass 7-10 kg/m with the abundance of marketable mussels constituting 35-40%, whereas these indices amounted to 300-500 specimens/m, 2-4 kg/m and 70-80% respectively on the linear carrier with a S/1 ratio of 0.09.

On the basis of these data, we have introduced the necessary corrections into the standards by which the biotechnology of mussel cultivation in the Black Sea is tested commercially.

UDC 594.1(262.5)

Expansion of the area of distribution and the population dynamics of the bivalve *Mya arenaria*, a new ecdemic species in the Black Sea

by A.I. Ivanov (Odessa branch of INBYuM AN UkrSSR)

Over the past years, profound changes have taken place in the fauna and flora of the Black Sea due to man's influence on oceanological conditions. In vast areas of the northwestern part of the Black Sea, mass asphyxiation occurs as a result of hypoxia in the near-bottom layers of water (Zaitsev, 1977, 1979; Bryantsev, Fashchuk, 1979; Ivanov, 1979). The stock of numerous commercial fishes has declined sharply (Tkacheva, 1979). At the same time, the fauna of the Black Sea is being rapidly replenished by new species of animals (Puzanov, 1967), including mollusks (Drapkin, 1953; Beshevli, 1967; Ivanov, 1969).

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The bivalve mollusk *Mya arenaria*, which settled in the Black Sea in the 1960's, is of commercial importance.

Detailed investigations based on a standard network of stations (Ivanov, 1969) have been conducted annually since 1966 throughout the northwestern part of the Black Sea in order to control the expansion of the new ecdemic, and also to study its population dynamics and size composition. The material was collected with an "Okean-50" bottom grab with a coverage of 0.25 m^2. Four samples were taken at each station. 980 stations were executed annually in the given area. This particular paper contains the results of investigations from 1971 to 1975.

The new ecdemic was quickest to adapt to the freshened areas of the northwestern part (the Dnieper area around Kinburnskaya Kosa, Tendrovsky Zaliv and Zhebriyanskaya Bukhta near the Danube delta). The density of *Mya arenaria* in 1971 amounted to 47 specimens/m^2 in the Dnieper area, and 72 specimens/m^2 in Tendrovsky Zaliv. On the whole, the density of *Mya arenaria* in 1971 amounted to 37 specimens/m^2 and the biomass 193 g/m^2 in the northwestern part of the Black Sea. The area of distribution of *Mya arenaria* in the Dnieper—Danube interfluve continued to expand up to 1973. Its frequency of occurrence in 1973 was the highest, constituting 71.7%. After that, its area of distribution and abundance decreased as a result of hypoxia and mass asphyxiation of the demersal population observed in the northwestern part of the sea after 1973. In 1975, the frequency of occurrence of *Mya arenaria* amounted to 25.4% in the Dnieper-Danube interfluve, and 11.8% in the northwestern part of the Black Sea as a whole. The average density decreased from 58 specimens/m^2 in 1972 to 39 specimens/m^2 in 1975. The total biomass of the species decreased accordingly from 570,300 tons in 1972 to 170,600 tons in 1975. Consequently, after the rapid development of *Mya arenaria* during the initial years of settlement in the Black Sea, its area of distribution, abundance and biomass underwent significant changes as a result of mass asphyxiation.

(227)

UDC 551.464.5:594.124(262.5)

Influence of water salinity on respiration in Black Sea mussels

by A.I. Ivanov and P.G. Borovinsky (Odessa branch of INBYuM)

Salinity is one of the main factors that determine the choice of sea area for mussel farms.

Since there is no unanimous opinion regarding the optimal values of salinity for mussels, it has become necessary to determine the optimal salinity for normal mussel activity on the basis of a sensitive characteristic such as energy metabolism, which was measured by the intensity of respiration in the mussels.

The experiments were carried out at a constant temperature of 20±0.2°C. The energy metabolism in the mollusks was studied at water salinities of 6.88, 10.86, 13.99, 19.80, 26.87, 31.16 and 36.97‰. During the acclimatization of the animals to water of a specified salinity in aquariums (at least a month), the animals were given food supplements and the water was changed twice a week. The level of oxygen consumption by the mussels was determined by the method of "closed vessels". The period of exposure was 2-2.5 hours. Mollusks with a shell length of 10 to 55 mm were placed in respiration vessels, 4-6 specimens to a vessel, in accordance with their size. 699 samples were processed in all.

The minimum consumption of oxygen is observed in mussels at a salinity of 6.88‰. With an increase of salinity to 19.80‰, we observe a continuous increase in oxygen consumption by the animals. The rate of this process is inversely proportional

to the rate of respiration. With a further increase in salinity from 19.80‰ to 36.97‰, the level of energy metabolism diminishes. It should be said that the consumption of oxygen by the animals is close to the maximum level with a salinity of 26.87‰, whereas the level of metabolism at the highest salinity was close to that observed at salinities of 6.88-10.86‰. Obviously, a water salinity of 19-27‰ is the optimal one for mussels. The above-mentioned irregularity in oxygen consumption by the animals with an increase in salinity to 19.80‰ is conveyed by the fact that the increase in the respiration rate in the salinity range of 6.88-13.99‰ is (228)
greater than in the 13.99-19.80‰ interval, i.e. in salinities approximating the optimal ones. Consequently, the respiration rate changes significantly at water salinities below 14‰.

The values of optimal salinity and its lower limit for mussels, derived by us during a study of the energy metabolism in the latter, coincide with analogous data obtained by other methods (mortality, cessation of filtering). The lower limit of salinity for mussels is 14‰ according to A.K. Vinogradov (1982), 14‰ according to G.A. Kiselyova (1966), and 13‰ according to P. Lyubet (1964).

Thus, when selecting an area for mussel farming, we must make sure that the water salinity in the area is not less than 14‰.

UDC 639.42

Preliminary results on the cultivation of mussels off the southern coast of the Crimea

by V.N. Ivanov and K.V. Bulatov (INBYuM)*

During 1983-1984, the experimental mussel farm of INBYuM in the vicinity of Laspi-Batiliman Bay conducted observations on setting and growth of mussels on 8-metre foam plastic collectors. The spring-setting mussels of 1983 grew at a rate of 5 mm a month during the first summer; their growth slowed down to 1 mm/month during the autumn-winter period. The growth rate during the spring-summer of 1984 increased again to 6 mm/month. In twelve months, the average length of the mussel shells reached 40.58$\pm$ 1.08 mm, the total weight of the meat and valve 4.77$\pm$0.37 g, and the weight of the meat itself 2.51$\pm$0.22 g. The weight of one running metre of the collector was 4.135 kg. After 15 months (in August), the length of the mussels amounted to 56.94$\pm$1.06 mm, the total weight 11.48$\pm$0.65 g, and the weight of the meat 6.12$\pm$ 0.44 g; in these mussels, the maximum percentage of meat to the total weight of the meat and valve was 53.35$\pm$0.54%. The collector weighed 4.700 kg/m. The mussels of the black-violet phene (Bulatov, 1983; Ivanov, Bulatov, 1983; Bulatov, 1984) surpass the (229) striped and brown mussels in all the weight-size characteristics studied.

The mussels from collectors greatly surpass the mollusks from the mud and rock colonies of the same region in growth rate and meat content. For example, the mussels from collectors grow to a length of 59 mm in 15-17 months, while the "wild" mussels

*Institute of South Sea Biology - transl.

reach a length of 58 mm in four years. The maximum percentage of meat in the rock mussels was $46.40 \pm 1.74\%$.

The autumn-setting mussels of 1983 showed the lowest rate of growth, reaching 40 mm in 14 months and 50 mm in 17 months. The slower growth rate of the "autumn" mussels is apparently due to their longer presence in an unfavourable autumn-winter environment.

The growth rate of the mussels in Laspi-Batiliman Bay is practically the same as in the Sevastopol and Sudak bays (Slavina, 1965; Zagranichnyi et al., 1983; Suprunovich, 1983) and higher than in the Kerch Strait and the northwestern part of the Black Sea (Zolotnitsky, Shtyrkina, 1983; Began et al., 1983; Ivanov, 1983).

In the course of growth, the ratio of the phenes in the mussels on collectors changes in favour of the black-violet ones, approximating the phenetic composition of the rock colonies.

Thus, the preliminary results of mussel cultivation in Laspi-Batiliman Bay indicate that this area is a suitable and promising one for the cultivation of mussels on suspended collectors. It is more profitable to cultivate spring-setting black-violet mussels.

The results of mussel cultivation in this area can be used for the organization of maricultural establishments off the southern coast of the Crimea, since the Laspi-Batiliman area is typical of this coast.

UDC 639.42 (230)

Setting characteristics of Mytilus galloprovincialis and Mytilaster lineatus spat on artificial substrates in Laspi-Batiliman Bay

by I.I. Kazankova (INBYuM)

Data on the dynamics and rate of setting of the Black Sea mussel *Mytilus galloprovincialis* are necessary in order to predict the yield on collectors of various types.

During the summer months, we studied the spatfall of *Mytilus galloprovincialis* and *Mytilaster lineatus* on artificial substrates; the latter included foam plastic and rope slabs, as well as glass sheets covered with tight rows of cotton thread measuring 1.5 mm in diameter. The slabs and sheets were examined every 10-15 days. Our observations showed that the threaded surface hardly differed from the rope and foam plastic ones with respect to the setting rate of the mollusks, and even surpassed them during certain periods. During the period in question, the setting of the larvae progressed nonuniformly. In *Mytilus galloprovincialis*, the maximum rate of setting was noted in July; it gradually decreased to a minimum by the end of August, and then again began to increase from the beginning of September. In *Mytilaster lineatus*, setting was highly insignificant in July, and then increased sharply in August, reaching its maximum level in September.

The setting of the mytilids occurred nonuniformly at different depths. For example, *Mytilus galloprovincialis* showed a tendency to speed up setting with depth. This relationship proved to be more complex in *Mytilaster lineatus*, i.e. setting gradually increased from 3 to 10 m, and then decreased with a further increase in depth (up to 20 m).

According to our preliminary data, there were no significant differences in the rate of mussel spatfall on foam plastic and rope surfaces at the initial stages.

In addition to the above-mentioned substrates, we also studied the setting of mytilid larvae into mussel clusters located on flat polyethylene slabs. We did not detect any significant influence of the adults on the setting of the mussel spat.

(231)

UDC 639.4

The prospects of artificial cultivation of Unionidae

by O.P. Kazlauskene and D.P. Sinyavichene (IZIP AN LithSSR)

Considering the fishing industry's need for feed of animal origin, particularly for young fish, we conducted a study of the nutritional value of unionids for the young of rainbow trout during the period from 1982 to 1984.

The results of experiments carried out under aquarium conditions have shown that the addition of mollusks to the feed (20% dry wt in our experiment) helps to increase its consumption and the growth of young trout. The growth rate of the young fish on mollusk feed was significantly higher than than in fish given feed with spleen. Increased consumption of mollusk feed by the fish has led us to believe that mollusks contain substances that stimulate the appetite of fish.

Experiments were conducted in 1984 to study the feeding of young rainbow trout at the "Zheymyana" fish hatchery. In this case also, the growth of the fish given mollusk feed was significantly higher than in those given feed containing spleen (174.3 and 131.3% respectively).

Determination of the content of energy, protein and amino acids in the dry mollusk and spleen substance has shown that the mollusks are not superior to spleen in chemical composition. On the contrary, dry spleen contains 20% more energy and protein, 2.5 time more of the scarce amino acid lysine, and twice as much histidine.

The chemical properties of the young trout raised on mollusk and spleen feeds are similar, but those given mollusk feed have a slightly higher dry weight and protein content (6.3 and 3.7% respectively).

Analysis of our data showed that the young fish given mollusk feed had a higher weight gain (20.4% higher) and a higher rate of accumulation of dry matter (36.2% higher), energy (34.1%), protein (31.6%) and especially lysine (55.4% higher).

Consequently, despite the lower content of energy and protein (232)
in the mollusks and despite the scarcity of lysine, the increase in the rate of consumption of mollusk feed resulted in a higher growth rate and more rapid accumulation of nutrients in the young trout.

Unionids (freshwater mussels) can be regarded as one of the most desirable ingredients of feed mixtures during trout cultivation, especially at the early stages of ontogenesis.

However, our experience in the industrial use of unionids has shown that their reserves are quickly undermined in this case. This is not to be tolerated, due to their major role in the purification of water bodies, the decrease in natural unionid populations and the threat to their existence as a result of environmental pollution and the overharvesting of mollusks and host fishes.

The utilization of unionids in the national economy will be practicable only when establishments for their cultivation have been organized. We now have the prerequisites for accomplishing this, i.e. the biological principles of artificial cultivation of unionids have for the most part been developed (Saint-Hilaire, 1940; Vlastov, 1948; Vlastov, Yerokhina, 1950; Roberts, 1983). The creation of specialized mollusk breeding establishments will enable us to enrich the malacofauna of natural water bodies and to produce high-quality feed primarily for the fishing industry.

UDC 593.93:639.446

Factors influencing the predation efficiency of starfishes at benthic plantations of the Yezo scallop

by V.Z. Kalashnikov and V.S. Levin (IBM DVNTs AN SSSR)

The prolific species of large starfishes *Asterias amurensis* and *Distolasterias nipon* often occupy the same biotopes as the Yezo scallop *Mizuhopecten yessoensis* in the sublittoral zone off the coast of the Maritime Territory (Primor'ye). Observations at bottom plantations have shown that the most accessible prey for starfishes consists of young scallops (yearlings, underyearlings) during their acclimatization to a benthic mode of life. (233)
With the density of young scallops at 50-80 specimens/m^2 and the density of starfishes at 0.9-1.0 specimens/m^2, the predators

completely changed to feeding on scallops within several days after their appearance. After that, Mizuhopecten yessoensis developed an effective escape reaction and, though starfishes continued to pursue it, cases of capture became rare and the predators gradually went back to feeding on their usual food. The proportion of scallops in the diet of the starfishes can increase after storms in which the wave action reaches the bottom.

Extremely dense congregations of the Yezo scallop (over 1000 specimens/m^2) initiated the immigration of starfishes into the area. The high density of scallops enabled the predators to capture and hold 2-3 year-old individuals and up to 10 under-yearlings at one time. With a "normal" setting density of the young scallops (5-20 specimens/m^2), we did not note any increase in the abundance of starfishes above the usual. As the Yezo scallop grew, it became less active on the whole. In the relatively deepwater areas (20-22 m) protected from wave action, we noted a stable, practically invariable density ratio of the Yezo scallop and both species of starfishes over a period of five years.

At plantations of mature Mizuhopecten yessoensis that are exposed to unusually heavy storms, we noted cases of mass invasion of large Distolasterias nipon (length of ray 13-30 cm) which in one case formed a local congregation (approximately 8000 m^2) within the boundaries of a plantation covering an area of several hectares, and in another occupied an artificial Mizuhopecten yessoensis colony entirely. In the first case, the starfishes destroyed 57% of the Mizuhopecten yessoensis yearlings (shell height 12.0±1.4 cm) in the area occupied by them within a short time.

In the second case, a plantation of marketable scallops (10-12 cm) was completely destroyed within two years; the rate at which the scallops were eaten up steadily increased on the whole, but it was significantly higher in summer, which coincided with the wave action caused by the southern winds.

Consequently, *Asterias amurensis* and *Distolasterias nipon* can actually be detrimental to *Mizuhopecten yessoensis* plantations, but their predation efficiency depends on the age of the mollusks, their physiological condition and the density ratio of both starfishes. The given predator—prey system includes balanced coexistence, sporadic attacks and active feeding. The state of the (234) starfish—scallop system may be influenced by the wave shock load on the bottom, which can lead to migration of the predators and suppression of the prey. The possibility of a sharp increase in the intensity of predation by the starfishes under the effect of external stress factors should be taken into account when determining the suitability of areas for *Mizuhopecten yessoensis*.

UDC 639.27/.29:664.959(262.5)

Biochemical prerequisites of utilizing Black Sea invertebrates as a source of biologically active substances

by R.P. Kandyuk (Odessa branch of INBYuM)

When mariculture is being established and developed, research into the hydrobionts being cultivated becomes an urgent task for modern marine biochemistry.

The rational approach to utilizing the biological resources of the world's oceans lies in the use of sea products not only as food for man and animals, but also as a source of the most diverse chemical compounds for the production of medicines and other preparations.

The localization and metabolism of sterols, biologically active substances found in marine invertebrates, should definitely be studied when dealing with questions related to the mechanism of action and the application of these substances.

The results of long-term investigations of sterols in commercial invertebrates (crustaceans and mollusks of the Black Sea) have shown that they contain large quantities of these biologically active substances and can serve as raw material for pharmaceutical preparations, as well as a source of dietetic natural seafood.

During the development of therapeutic diets at the USSR Academy of Sciences Institute of Nutrition, it was found that mussels were beneficial to those suffering from diseases of the liver and gallbladder, diabetes mellitus, sclerosis and anemia (235)
(Zenkevich et al., 1968).

The sterols of invertebrates produce a hypocholesterinemic effect, which is of definite interest to medical science. The sterols in crustaceans are responsible for the hardness of the chitinous cover.

During the study of sterols from mollusks under maricultural conditions, we examined the distribution of this parameter in mussel organs and tissues, and found that it was concentrated in the hepatopancreas and gills, which points to the specific functional role of this biochemical component, and to the possibility of directed utilization of mollusks in the pharmaceutical industry.

UDC 594.117:574.583

Role of the seasonal dynamics of plankton in the diet of the Yezo scallop in the Busse Lagoon (Southern Sakhalin)

by T.N. Kolganova and N.G. Khrushkova (SakhTINRO, State Pedagogical Institute, Yuzhno-Sakhalinsk)

We compared the feeding spectra of different age groups of the Yezo scallop from two areas of the lagoon and 1—3-year-old nursery scallops with the seasonal development of the plankton for 1978-1980.

The main colonies of mollusks are concentrated in the south-western and eastern parts of the lagoon, exactly where the trays with the young scallops were suspended.

During the winter, the density of the phytoplankton amounts to $0.3 \cdot 10^6$ cells/m^3, the zooplankton up to $10 \cdot 10^3$ specimens/m^3, the bacterioplankton up to $2 \cdot 10^{12}$ kl/m^3, and the nannoplankton up to $7 \cdot 10^9$ kl/m^3. In spring (April-May), there is usually a spurt of development of diatomaceous algae (with a density of up to $40 \cdot 10^6$ cells/m^3), green Flagellata from the nannoplankton (density up to $37 \cdot 10^9$ cells/m^3) and bacterioplankton ($3\text{-}5 \cdot 10^{12}$ cells/m^3) in the lagoon. With a low density of the zooplankton (up to 1500 specimens/m^3), the eggs and larvae of copepods dominated, constituting up to 50% of the total number of all the species in the eastern part of the lagoon. At this time, the diges- (236)
tive tract of all the age groups of the Yezo scallop contained diatoms of the Centricae class, copepod eggs, as well as peridinians of the genera Dinophysis and Peridinium, tintinnids and ostracods in the mollusks from the eastern part of the lagoon.

In August, the density of the phytoplankton constituted up to $70 \cdot 10^6$ cells/m^3. Up to 80% of all the species consisted of small diatoms, predominantly naviculoid forms. The density of the zooplankton went up to $70 \cdot 10^3$ specimens/m^2 in the eastern part of the lagoon, and up to $30 \cdot 10^3$ specimens/m^3 in the southwestern part. The larvae of demersal invertebrates (predominantly bivalves), tintinnids and copepod eggs and larvae dominated, constituting up to 75% of the total numbers of the species. The above-mentioned groups of plankton also predominated in the stomachs of the mollusks, constituting 80-100% of the numbers of all the planktonic organisms.

In autumn (September-October), the density of the phytoplankton decreased to $5\text{-}10 \cdot 10^6$ cells/m^3, but there was a spurt of development of nannoplankton and microplankton, i.e. Flagellata (up to $130 \cdot 10^9$ cells/m^3) and bacterioplankton ($2.0\text{-}3.5 \cdot 10^{12}$ cells/m^3). The density of the zooplankton also decreased (to $30 \cdot 10^3$ specimens/m^3 in the southwestern part of the lagoon). Of the diatoms, the demersal *Cocconeis*, *Navicula*, *Coscinodiscus* and *Pinnularia* predominated in the digestive tract of the mollusks (90% of the organisms), and tintinnids were the dominant zooplankton.

Thus, the change in the forms of plankton in the digestive tract of the mollusks corresponded to their seasonal development in the lagoon. On the whole, the proportion of plankton with a definite form in the digestive tract of all age groups of the Yezo scallop from trays and from natural colonies weighed much less than the formless organic detrital matter. As we know, the Busse Lagoon belongs to the semi-enclosed type of water bodies, and the processes of detritus formation are developed there. The dominance of detritus in the diet of the mollusks is determined by its predominance in the overall quantity of suspended matter in the water of the lagoon.

(237)

UDC 594.124

Content of prostaglandins and their predecessors in *Mytilus galloprovincialis* from collectors

by O.D. Korotchenko, M.V. Nekhoroshev, S.V. Isai and V.N. Ivanov (TIBORKh DVNTs AN SSSR, INBYuM)

The purpose of our investigations was to determine the quantity of prostaglandins (PG) and the fatty acid composition (FA) in *Mytilus galloprovincialis* cultivated on collectors at INBYuM's biological station in the vicintiy of Batiliman and harvested in August 1984. Six-month-old mussels 2-2.5 cm long were used for analysis.

Prior to this, we demonstrated the presence of PG-like activity in 40 species of marine invertebrates of the Sea of Japan, including the bivalve mollusks. The content of PG in mussels was determined by the method of UV-spectroscopy (see table 1).

Table 1. Content of B-type prostaglandins in mussels

Gonads			Whole organism except gonads			Intervalvular fluid
PG, %	μg/mg of tissue	μg/mg Σ PG	Σ PG, %	μg/mg of whole org.	μg/mg Σ PG	μg/mg Σ PG
0.4	0.03	12.5	0.03	0.004	48.3	2.7

Qualitative and quantitative determination of the fatty acid composition of the total lipid extract was carried out by the method of gas-liquid chromatography on a capillary column. We established the presence of 26 saturated and unsaturated fatty acids with 12-22 atoms of carbon and 1-6 double bonds. For instance, the content of FA with C_{12}-C_{22} (saturated, mono- and diene) fluctuates from 0.01 to 13%, calculated in terms of the total methyl esters of the fatty acids (MEFA). The content of polyunsaturated fatty acids (PUFA), the predecessors of PG, is given in table 2.

(238)

Table 2

A c i d	Content of PUFA, % of MEFA
20:3	0.74
20:4 w 6	4.2
20:4 w 3	0.20
20:5 w 3	18.5
22:4 w 6	0.47
22:5 w 6	0.52
22:5 w 3	0.70
22:6 w 3	19.6

Thus, we have shown that the lipids of Mytilus galloprovincialis contain a series of important biologically active substances such as polyunsaturated fatty acids and prostaglandins.

UDC 594.32

Study of the migration of Rapana* in the Karadag Reserve (Black Sea)

by N.S. Kostenko (Karadag branch of INBYuM)

Due to the organization of experimental facilities for the cultivation of mussels in the areas bordering on the Karadag Reserve, special attention should be devoted to the question concerning the distribution and migrational characteristics of

*genus? unknown - transl.

the self-acclimatized predator Rapana within the zone of the reserve.

The investigations of 1982-1984 have shown that the distribution of Rapana is highly irregular in the Karadag area. The density of the mollusk on individual clumps amounts to 10 specimens/m^2. This predator prefers depths from 10-12 m (boundary of solid substrates and sand) to 25-30 m (sand replaced by silt). Young Rapana are encountered mainly at depths of 20-22 m in the zone of Venus* sand. Close to shore, Rapana is encountered on (239) precipitous rocks (Ivan Razboynik, Vorota Karadaga, Khoba-Tepe Ridge and capes) with mussel brushes covering a total area of about 16,000 m^2. Vertically, Rapana moves from the water line to the bottom (14-15 m).

In view of the significant negative importance of Rapana in the coastal ecosystem, we undertook to study the migrations of this predator within the boundaries of the reserve. Study areas were selected in the shallow zone (Kuz'michev kamen') and very deep zone (Bukhta Barakhty) of the area, the distance between them being 3 km.

Oval 12-15x8-10 mm tags made of polyvinyl chloride plastic with a hole along the bevelled margin were used to mark the Rapana. A hole was drilled on the umbo of the shell so as not to damage the body of the mollusk. The tag with a number seared on it was attached to the shell with a copper wire. The tagged Rapana (100 specimens) with a height of 77-102 mm were released in the centre of the study area, within a 10x10 m square roped off with braided cord and located at a depth of 12 m. A buoy

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*conjectural - transl.

was set up in the centre of the study area; that was the point from which the movement of the Rapana was reckoned after a marked braided cord had been attached to it. The observations were carried out in three stages. One hour after being released, seven Rapana turned up in another location, 0.5-2.8 m from the centre of the area. Their underwater speed of migration along the sandy bottom was approximately 20 cm/min. After two hours, three of the seven Rapana had covered a distance of 1.2-2.7 m. Another 13 Rapana, which had been 0.5 to 4.8 m from the centre of the study area, began to move. After three hours, we observed that four of them had moved slightly (0.2-0.9 m) towards the centre, three had remained motionless, while the other seven had covered a distance of 0.5-2 m. After 4 days, we found one dead Rapana in the centre, 6 specimens 12 m from the centre, and the remaining 46 mollusks 0.3-10 m from the centre. The average rate of diurnal migration of the Rapana amounted to 1.6 m, and the maximum was 3 m. In the study area near Kuz'michev kamen', two Rapana were found 50 m from the study area on the seaward side 20 days after being released. Some Rapana burrow in the sand. To keep track of them, we found it convenient to use a foam plastic buoy with the tag.

We repeated our search for tagged Rapana in 1983. We discovered 5 of the specimens released in this area in Barakhta Bay, (240)
and 15 near Kuz'michev kamen'. No new locations of tagged Rapana were discovered, despite the fact that mapping of the shelf zone of the reserve was carried out in 1984.

Consequently, taking the above migrational characteristics of the Rapana into account, we can say that mass removal of the latter in mussel-abundant areas is the most effective method of controlling this predator.

UDC 594.124:(574.5:615.9)

Combined effect of mercury and DDT on the process of water filtration in Black Sea mussels

by E.F. Kostylev (Odessa branch of AzCherNIRO)

We studied the effect of mercury dichloride and the organochloride pesticide DDT in 1-1000 μg/l concentrations on the process of water filtration in adult Black Sea mussels.

The rate of filtration was determined by an indirect method using a suspension of greyish green clay. The experiment lasted 4 hours.

The appearance of these contaminants in the water immediately reflects on the process of filtration. High concentrations of these toxicants evoke an escape reaction which manifests itself in the mollusks' attempt to isolate themselves from the environment by closing their valves tightly and stopping water filtration. Low concentrations of these toxicants are particularly dangerous, since they do not evoke the escape reaction.

Mercury and DDT in concentrations of 1-10 μg/l stimulate the filtration of water by the mussels. The rate of filtration during the first hour of the experiment (gill contact) with these concentrations of the contaminants reached 124.7-133.7% (compared with the control) with exposure to mercury dichloride, and 135.7-154.1% with DDT. It should be said that these maximum levels were already noted after 30 min into the experiment in the water contaminated with DDT. These peaks appeared only after 3.5 hours in the water contaminated with mercury dichloride.

(241)

With an increase in the concentration of these toxicants, the process of filtration slowed down, and this was clearly defined in the case of mercury dichloride.

Our study of the combined effect of mercury and DDT on the filtration of water by mussels was carried out in the range of concentrations that do not evoke the escape reaction in the mollusks.

We noted an increase (stimulation) of the filtration process in water contaminated with a mixture of mercury and DDT. With an equal quantity of these toxicants in the water (5.0:5.0), the overall rate of filtration was almost 1.5 times higher than with other mercury/DDT ratios.

It is interesting to note that the specific properties of each of the two toxicants were reflected in the nature of the filtration of the contaminated water by the mussels. On the curve of filtration rate, we observe two "peaks" determined by 1) the action of DDT (after 0.5 h) and 2) the action of mercury (after 2.0-4.0 h). This is probably due to the specific characteristics of the toxic effect of mercury and DDT on hydrobionts. As a neuroparalytic toxicant, DDT acts on the nerve endings in the gills, inducing a rapid response reaction. The inhibiting effect of mercury on the enzyme system manifests itself later on.

UDC 594.124(262.5)

Dependence of water filtration in Black Sea mussels on ecological environmental factors

by L.L. Krasota (Odessa branch of AzCherNIRO)

The purpose of our investigations was to study the effect of temperature, salinity and the content of dissolved oxygen in the water on the rate of water filtration by Black Sea mussels. The nature of the water filtration process in adult Black Sea mussels (about 50 mm long) was determined by our own modification of an indirect method using clay under aquarium conditions. The experiment lasted 4 hours. The rate of biological clarification of the suspension by the mussels was expressed in % of potential clarification. (242)

A study of the seasonal variability of the filtration rate has shown that the mollusks display the highest filtering activity during the winter-spring period. On the whole, the filtering activity during this period was 37.2-39.4% as compared with 17.8-23.1% in the summer-autumn period.

The seasonal changes in filtration are due not only to the seasonal variations in the mass and physiological condition of the mollusks, but also primarily to the change in abiotic factors, i.e. water temperature and salinity and the content of dissolved oxygen.

The filtration rate in mussels kept in warm water (20^{o}) was almost three times lower than in those kept in cold water ($10^{o}C$).

A change in salinity affects the filtering activity of the mollusks by stimulating the nerve endings in the gills. A 5‰

decrease in salinity results in a statistically significant 1.8-fold average increase in the filtration rate as compared with the filtration rate in mussels kept in water with the initial level of salinity (15‰).

We have also noted that the filtration rate in mussels kept in clean water depends on its content of oxygen. In aquariums with a low content of oxygen (1-2 ml/l), the mussels were forced to filter water more actively (1.8 times more rapidly) than the mollusks kept in aquariums with a high content of dissolved oxygen (8-9 ml/l).

Our data on the effect of ecological factors on the filtration of water by mussels can be used during the development of environmental quality standards for mussel farms.

(243)

UDC 594.124:628.394(26)

Effect of sewage from soda plants on the filtering activity and respiration of cultivated Black Sea mussels

by L.L. Krasota, E.F. Kostylev and I.P. Tret'yak
(Odessa branch of AzCherNIRO)

The sewage of soda plants (still waste) contains a large quantity of various salts (100-200 g/l) with calcium salts prevailing among them. The sewage includes an abundance of suspended matter which clogs the gills of fish, coats the benthos and destroys animals and plants. The bottom sediments that form from this suspended matter are highly resistant and sometimes totally unaffected by the processes of self-purification.

We have studied the effect of still waste on the filtration and rate of oxygen consumption by mature Black Sea mussels, which determine the metabolic processes in the mollusks.

In the experiments, the sewage was diluted with seawater in 1:10, 1:50, 1:100, 1:250, 1:500 and 1:1000 dilutions.

The nature of water filtration in the mussels was determined by a modified method based on the use of greyish green clay (length of experiment 4 hours). The rate of respiration in the mussels was determined by the method of closed vessels (length of the experiment 7 days).

In the aquarium experiments, we found that water filtration by the mussels was very weak with a 1:10 ratio of still waste and seawater.

A 50-fold dilution of the still waste accelerated the filtration process somewhat. With a 1:100 dilution, the filtering activity of the mollusks increased to 58.0% on the average. No toxic effect was observed with a 135-fold or greater dilution of the still waste. A 1:250-1:500 dilution brought the water filtration in the mussels close to that of the control group of mollusks, the filtration rate averaging 91.3-91.5%. A 1000-fold dilution (244) of the still waste stimulated the filtration process, the rate of filtration averaging 225.9%.

The process of respiration is related to filtration, since the oxygen required for this enters the organism from the filtered water. With a 10-fold dilution of the still waste, the respiration rate by the end of the first day of the experiment had increased sharply as a result of the stimulation of the gill nerve endings. However, a high salt content later produced an inhibitory effect. The mussels closed their valves tightly and soon died. With a 50—1000-fold dilution of the still waste, regardless of the degree of dilution, the nature of the change in the respiration rate of the mussels in the course of the experiment was similar, i.e. the respiration rate decreased during the first day of the experiment, and then increased on the second and third days. Afterwards, this value decreased, showing a tendency toward attenuation of the range of fluctuations in the respiration rate.

In a 100-fold dilution of the still waste, the respiration rate of the mollusks during the investigation period was on the whole similar to that of the control group (91.2%). With a 1:1000 dilution, the highest degree of respiratory stimulation was observed during the first days of exposure.

UDC 594.124

Study of the filtration rate of the Black Sea mussel (*Mytilus galloprovincialis*) in relation to food concentration, body mass and water temperature

by L.S. Kruk (AzCherNIRO)

Mytilus galloprovincialis, which is one of the most prolific species in the coastal zone of the Black Sea, plays an important role in the utilization and destruction of organic matter. Furthermore, this species is of great interest to mariculture. In connection with this, we undertook to study its filtering activity in relation to various environmental factors. (245)

The material was collected in the Kerch Strait in 1984-85. The filtration rate was determined by an indirect method based on the difference in the concentration of *Nitzschia closterium* at the beginning and at the end of the experiment. Since preliminary 4-hour experiments revealed an exponential decrease in the concentration of suspension, the rate of filtration was calculated by Gould's formula (Gould, 1951). The experiment usually lasted one hour, during which the concentration of the algae in the experimental vessels decreased by not more than 30%.

Our study of the filtering activity in relation to the density of the suspension in a wide range of concentrations (1-50 mil. $\text{cells}\cdot 1^{-1}$) has shown that the maximum filtration rate is attained with a concentration of 2-3 mil. $\text{cells}\cdot 1^{-1}$, after which it begins to decrease. A characteristic feature is that the ration continues to increase as the filtration rate decreases, and it reaches its maximum level with a density of 6-7 mil. $\text{cells}\cdot 1^{-1}$.

Our study of the filtration process in different size groups ranging from 0.01 to 1.69 g dry weight of the soft tissues has shown that the rate of filtration is described by the parabolic function $F=mW^n$, where F denotes the filtration rate of the mollusks ($1\cdot h^{-1}$), W - body weight (g), and m and n are coefficients. During our study of the filtering activity of the mollusks at different times of the year at water temperatures of 7.5-22°C, we found that the rate of filtration was the lowest at a temperature of 7.5°C. The maximum values of 4.2 and 3.9 $1\cdot g^{-1}\cdot h^{-1}$ were reached at temperatures of 14 and 18°C, and a low of 2.1 $1\cdot g^{-1}\cdot h^{-1}$ was reached at a temperature of 22°C.

Consequently, 14-18°C is the optimal water temperature for the Black Sea mussel. Our data can be of interest when selecting locations for mussel farms, and during quantitative determination of the energy flow through mussel populations on collectors.

UDC 594.124:(574.5:615.9) (246)

Morphological parallelisms in the reaction of mussel gonads to toxicants, a high level of eutrophication and congestion during mussel cultivation

by O.Yu. Kudinsky (Odessa branch of INBYuM)

Mytilus galloprovincialis is one of the most prolific forms of the Black Sea macrozoobenthos. The rapid decrease in its stock in the northwestern part of the Black Sea due mainly to asphyxiation has stimulated the cultivation of this valuable commercial species. Successful and profitable mussel farming is practicable only on condition that the factors adversely affecting natural populations will not cause any significant damage to the mollusks raised at maricultural establishments.

As a result of asphyxiation, the quality of the water deteriorates substantially, not only because of acute hypoxia, but also because a whole complex of toxic gases appears in the near-bottom layers of water. We thought it necessary to study the reproductive system of the mussels, mainly the morphofunctional changes in the gonads, at the early stages of asphyxiation.

Our histological study of gonads from mollusks collected 2-3 weeks prior to detection of asphyxiation by hydrochemical methods has shown that the following abnormal phenomena occur during the early stage of asphyxiation: a) abortive expulsion of the genital products; b) blocking of the expulsion with subsequent resorption of the residual vitellogenous oocytes; c) replacement of a part of the gonad by a connective-tissue reticulum.

In a parallel study, we examined mussels collected in shallow areas in narrow coastal zones with a high level of eutrophication, which are separated from the sea by a large concrete breakwater. Histological analysis has shown that the fecundity of these mussels decreases sharply to total infertility in a substantial part of the females with a shell length of 30-40 mm (normally the most productive).

When raising mussels in the water column on rope and foam plastic or wooden collectors, the mollusks are found in highly diverse conditions within a dense multilayer cluster. In the inner layers of these clusters where the water exchange is less adequate, the food supply is smaller, the metabolic processes are weaker and the self-infection by parasites is high, the gonads of the majority of mussels display the same tendencies as do the mussels exposed to asphyxiation or a high degree of eutrophication. We should note that the gonads in all three groups of mussels are characterized by very similar regnerative processes which are expessed in mass initiation of proliferation zones of a new generation of oocytes.

The degradation of the gonads in these mollusks during exposure to toxicants, a high degree of eutrophication and cultivation conditions, as well as the regenerative processes in the reproductive system, merit further detailed study, since they can be used to characterize the resistance of populations to adverse effects.

UDC 594.124

Utilization of sexual and parasitological characteristics of mussels for biological testing of maricultural areas

by O.Yu. Kudinsky and Ye.V. Kholodkovskaya (Odessa branch of INBYuM, Odessa Agricultural Institute)

During the development of conchiculture, we are faced with the problems of selecting areas suitable for the organization of maricultural establishments. The suitability of an area is determined by numerous factors; its adequacy for maricultural purposes can be determined by studying the physiological condition of the species to be cultivated. The characteristics of the reproductive system as the one most dependent on the environmental parameters and the parasitological condition of the natural population within the study area can be used as the major indices. We used the number indicating the proportion of gametes in the total volume of the gonad (which we call the DOG-coefficient*) as the integral index of gonad condition. Furthermore, we calculated the extensiveness of infection by microsporidia, since (248)
microsporidioses develop more severely in mollusk hosts found in unfavourable environmental conditions.

The DOG-coefficient reflects the condition of the mollusk, and varies in relation to sex, the phase of the sexual cycle and the season. In the course of the sexual cycle, the DOG-coefficient changes from 0.00 in mussels in the state of sexual rest to 0.84 in females prepared to spawn and 0.87 in males. The DOG-coefficient in mollusks infected with microsporidia is significantly lower than in healthy ones. For instance, the

*Dolya Obyoma Gamet (literally Proportion of Gamete Volume) - transl.

DOG-coefficient of healthy mature females (ZA_2 by Lyube's* scale) averaged 0.52. At the same time, this coefficient amounted to 0.29 (confidence probability P=0.999) in mussels infected with microsporidiosis.

To assess the areas in the summer of 1980, we collected samples of mollusks from the Odessa Gulf in the vicinity of the "Put' Il'yicha", "Kolkhoz im. P.P. Shmidta" and "Chernomorets" fisheries. Our investigations have shown that the best conditions are found on the territory of the "Put' Il'yicha" fishery where the DOG-coefficient averaged 0.41 as compared with 0.34 at the "P.P. Shmidt" fishery and 0.26 at the "Chernomorets" fishery. The confidence probability of these differences is 0.996.

A characteristic to be noted is that the differences in the extensiveness of infection with microsporidia are inversely proportional to the DOG-coefficients. At the "Put' Il'yicha" fishery, this value is equal to 3.8% as compared with 20.0% at the "Chernomorets" fishery (confidence probability of difference 0.984).

UDC 639.42(268.46)

Prospects of commercial cultivation of mussels in the White Sea

by E.Ye. Kulakovsky (ZIN AN SSSR)

Investigations are currently being carried out in the White Sea to determine the feasibility of organizing mussel farming on a commercial scale there. Experiments have shown that it is basically possible to utilize some of the areas of the White Sea for this purpose (Kulakovsky, Kunin, 1983). In cooperation with "Karelrybprom", an experimental mussel farm was established in

*conjectural spelling - transl.

(249)

1983 on an area of one hectare. This type of project is an important prerequisite for the transition from experimental to commercial cultivation. One of the goals of this pilot establishment is to develop the main biotechnological methods for mussel cultivation in the White Sea on a close-to-commercial scale.

Having analyzed mussel development on artificial substrates of this pilot mussel farm over a period of two years, we have come to a number of conclusions. First of all, maximum attention should be paid to the recommendations resulting from years of experimentation during the transition to a commercial scale of production, i.e. when introducing scientific developments. For example, under the conditions of the White Sea, the carriers for artificial substrates are placed in specified places, primarily to protect them from ice push. The selected site should also have good water exchange. The carriers of substrates and the substrates themselves should be placed so as not to alter water exchange to any great extent. At this experimental mussel farm, the biotechnology of mussel cultivation derived as a result of experiments was modified significantly, which resulted in a situation where a large number of carriers and, therefore, arti-substrates became concentrated in a relatively small area. During the second year, the water exchange at this site decreased by one-half. The decrease in water exchange increased the fouling and overall "silting up" of the mussels, particularly in the central part of the mussel farm where conditions unfavourable for mussel development had formed. The condition of the mussels on marginal substrates did not differ from that observed under experimental conditions.

The experimental mussel farm was "cleaned up" in September 1985, i.e. some of the substrate mussels were transferred to another place. The purpose of these measures was to achieve normal development of the mussels throughout the farm. In connection with this, it is extremely important to study the formation and development of biocoenoses on artificial substrates in order to achieve efficient control over the condition of the mussels and to select suitable new places for mussel cultivation.

The tactics of "mosaic mariculture" should be used for commercial development of mussel farming on the White Sea; in other words, a number of large mussel farms should be established. In this case, there will be no excessive "overloading" of this (250)
or that suitable site, and the development of mussels on artificial substrates will meet the requirements of mariculture.

UDC 594.1:591.524.12

Distribution of the larvae of some commercial bivalve mollusks in the northeastern part of Peter the Great Gulf

by V.A. Kulikova, N.K. Kolotukhina (IBM DVNTs AN SSSR)

We have studied the population dynamics and distribution of the pelagic larvae of *Mytilus edulis*, *Crassostrea gigas* and *Mizuhopecten yessoensis* in the northeastern part of Peter the Great Gulf from Anna Bay to Nakhodka Bay in order to determine the prospects of their cultivation.

Plankton samples were taken at 34 stations every ten days from June to September in 1984-1985, from the surface to a depth of 10 m. They were collected by means of a Juday plankton net with a 0.1 m^2 opening and a cone made of No. 38 gauze. Only larvae at the veliconch stage were taken into account. The larvae were counted under a binocular lens.

In 1984, Mytilus edulis larvae were encountered at all the stations from the end of June up to the end of September. Their density varied from several tens of specimens to 460 specimens/m^3. The highest densities were noted from the end of June up to the first ten days of July. The largest concentrations were observed in the western part of Vostok Bay and in the central sector between Vostok and Nakhodka bays. In 1985, Mytilus edulis larvae were encountered during the same periods, but the maximum shifted to July 10-12th. They were not encountered at all the stations, and the densities were several times lower than in 1984.

In 1984, Mizuhopecten yessoensis larvae were observed from the end of June up to the end of July, and their density varied from 1 to 86 specimens/m^3. The largest number of larvae was recorded on July 10-11th in Srednyaya inlet (Vostok Bay), Anna Bay and in the Cape Kozin area, east of Vostok Bay. In 1985, (251)
there were hardly any Mizuhopecten yessoensis larvae in the plankton; single specimens were noted only at individual stations.

In 1984, Crassostrea gigas larvae were encountered in the plankton from the end of June up to the middle of August, but their numbers were not high. Only on the western coast of Vostok Bay (near capes Peshchurov and Pashinnikov) did the density reach 64 specimens/m^3. In 1985, Crassostrea gigas larvae were noted throughout the observation period at nine stations only, their density amounting to 1-2 specimens/m^3.

On the basis of the above information, it is apparent that the numbers of larvae of commercial bivalve mollusks in the plankton in 1985 were insignificant in comparison with the preceding year. This is probably due to the fact that the climatic conditions in 1985 were different from those of previous years. The snowy and severe winter, the thick ice cover in the small bays and inlets and the frequent typhoons accompanied by torrential rains could have greatly altered the hydrology of the coastal waters and, in turn, affected the success of reproduction.

A number of authors has noted a similar situation during certain years for other coastal areas of the world's oceans. In their opinion, the reproductive processes of invertebrates and larval survival are adversely affected during certain years by poor temperature conditions and salinity fluctuations.

The low numbers of *Mizuhopecten yessoensis* and *Crassostrea gigas* larvae are insufficient for providing collectors with spat in the given areas; on the other hand, the high concentration of *Mytilus edulis* larvae in the plankton permits us to recommend most of these areas for the collection of spat.

UDC 639.42:551.464.7

Transformation of the biochemical parameters of a water environment under the influence of oyster cultivation

by A.V. Kucheryavenko (TINRO)

Experimental-commercial cultivation of *Crassostrea gigas* has been in progress since 1975 in Novgorodskaya Bay (Posyet Gulf, Sea of Japan). The concentration of organic matter in the (252)
seawater and its biochemical composition are an important

indicator of the potential productivity of the waters, which can be used to detect the changes that take place in the seawater under the influence of the mollusks cultivated there. Indeed, we have found that oysters can excrete a large quantity of dissolved organic matter (DOC). For example, the concentration of DO carbon at the oyster breeding sites is 0.5-2.0 mg/l higher than in the adjacent area, and varies from 14.5 mg/l to 10.0 mg/l from May to September. The carbon content of suspended organic matter (SOM) in some parts of Novgorodskaya Bay differs slightly, averaging 0.155 mg/l/year.

Compared with other parts of the bay, the carbon content of SOM is higher in the area of oyster plantations; the maximum concentration is reached during the second half of June (0.280 mg/l). The protein content of SOM is highest in July-August (0.220 mg/l) because of spatfall. At all other times, the concentration of protein substances is higher in the areas adjacent to the oyster plantations.

Long-term observations on the activity of proteolytic enzymes and the activity of the electron-transport system have shown that, despite the differences in the quantity and composition of organic matter, the recycling of protein substances and the oxidative recycling of organic matter in the suspended fraction in the waters of Novgorodskaya Bay takes place in practically the same manner on oyster plantations and in the waters surrounding them. This may be the result of the adaptation of the artificially created biosystem to the action of a large number of cultivated oysters.

UDC 574.586:639.42(268.46)

Initial stages in the development of a mussel biocoenosis under the conditions of aquiculture in the White Sea

by Yu.A. Laius (ZIN AN SSSR)

As we know, the development of periphytic biocoenoses follows the course of a biotic succession, and the first stages of this succession take place prior to the setting of the larvae of macroorganisms. (253)

The formation of the periphytic community was studied in August 1983-1985. Microscope slides were used as the substrate; they were placed in the sea in the area of a mussel farm for 4, 10, 17 and 24 hours, and for 3, 5, 7, 10, 14, 17 and 21 days.

Minute, predominantly Gram-negative rod-shaped and curved bacteria were the first to appear on the surface of the slides (after 4-8 hours). Electron-microscopic analysis has enabled us to detect various types of attachment of these cells to the surface. Cultures of copiotrophic and oligotrophic bacteria were isolated from slides exposed for 4 hours. The physiological properties of these bacteria are quite diverse. The majority of the forms were aerobes with an oxidative type of metabolism. Psychrotrophic and halotolerant bacteria predominated.

With longer exposure of the slides in the sea (2, 3, 5, 10 days), a large number of stalked bacteria, cocci, spirilla, crawling bacteria, as well as spirochaetes (closely associated with diatomaceous algae in their distribution) and actinomycetes was noted in addition to the rod-shaped bacteria. After 5-day exposure, protozoans were encountered in the periphytic community. By the 14-20th day, the slides were covered with a continuous layer of diatomaceous algae where colonial forms of *Melosira*, *Navicula* and *Berkeleya* predominated. By this time, organisms of the meiobenthos, mainly nematodes, had also appeared on the slides, and they were followed by polychaetes and the larvae of mussels.

The results obtained on the slides will later be defined more specifically with the properties of the substrates used during mussel cultivation taken into account.

UDC 594.124:628.394(26)(262.5) (254)

Fluctuations in the numbers of *Mytilus galloprovincialis* under the anthropogenic influence

by G.V. Losovskaya and V.A. Sal'sky (Odessa branch of INBYuM)

The numbers of the Black Sea mussel (*Mytilus galloprovincialis*) are quite readily affected by the negative aftereffects of man's economic activities which lead to eutrophication and the asphyxiation of the given fauna on the western shelf of the Black Sea.

The fluctuations in mussel numbers are particularly evident in the estuarine areas of the northwestern part of the sea where, beginning from 1973, occurrence of hypoxia and asphyxiation have been noted almost every year. For example, in the Dnieper area (including the Odessa bank), high values of average abundance and biomass (902 specimens/m^2, 770.4 g/m^2) were recorded for this species in 1977-1978, while the same indices were by an order of magnitude lower in 1975 (following the mass asphyxiations of

1973-1974), and 5 times lower in 1983 (after the 1982 asphyxiation which encompassed almost the entire area of the Dnieper-Dniester interfluve). A high average abundance of *Mytilus galloprovincialis* (671 specimens/m^2) was also noted in the Dniester area in 1977-1978; it was lower by an order of magnitude in 1975, and 50% lower in 1983 (the fluctuations in biomass were insignificant). No fluctuations in mussel numbers were observed in the Danube area during 1975-1983; the average abundance and biomass of this species were not high (18-85 specimens/m^2, 22.9-107.4 g/m^2).

These sharp fluctuations in mussel numbers (which decrease by an order of magnitude during asphyxiations, but then return to normal after the development of the young) reflect on the structure of the mussel population of the northwestern part of the sea, which over the past years has been characterized by the predominance of young individuals and a small percentage of market-size mussels. Furthermore, the proportion of mussels in the biocoenosis is gradually diminishing in the zones of severe asphyxiations, which is resulting in its degradation to the extent of replacement by communities with a lower species diversity and low biomass.

UDC 594.12(268.45) (255)

Size structure as an indicator of the condition of mussel colonies

by V.V. Lukanin, A.D. Naumov, V.V. Fedyakov (ZIN AN SSSR)

Regular observations were conducted from 1977 to 1985 on five mussel banks in Kandalaksha Bay of the White Sea. Parallel studies of individual mussel colonies throughout the sea were also carried out. Approximately 600 samples were processed. The mollusks were measured with an accuracy of up to 0.1 mm, and grouped into size classes 5 mm apart.

Four types of size-frequency distribution have been established for mussels. The first type of distribution is described by a function approximating a concave hyperbola. The second type can be approximated with certain allowances to a normal distribution with positive asymmetry, and the third type to a normal distribution with negative asymmetry. As for the fourth, bimodal, type, it represents a combination of the third and first types, or the third and second types. These types of size structure correspond to certain stages in the development of a mussel colony.

The size structure dynamics of ephemeral pseudopopulations of mussels on filamentous algae and in some surf areas can be described as regular seasonal appearances and disappearances of colonies with the first type of distribution.

The alternation of structures of the first and second types is observed in the majority of stable littoral colonies on hard substrates. The transition from the first type to the second type of structure is relatively long, and depends on the growth of the mollusks. The reverse process takes a short time, as long as it takes the young to settle.

Littoral banks on soft substrates and sublittoral colonies usually develop along the same pattern, but under certain conditions can form colonies with the third type of structure.

The increase in silting that occurs in this case (in areas with weak currents) prevents the spat from setting, which results in gradual degradation of the bank. The life span of this type of colony in the White Sea is, on the average, 3-6 years longer than the maximum life span of the mollusks.

Another fate awaits sublittoral banks which are found in places with strong bottom currents. The muds that accumulate here are washed out prior to the complete destruction of the colony, which again creates the conditions required for the setting of the larvae. The latter leads to bimodal size distribution. (256)

Consequently, the White Sea mussel colonies can be divided into four groups according to the size structure dynamics of the edificator species. However, the development of each specific bank is described by one of the above-mentioned patterns only in the case where the environmental conditions remain more or less the same from year to year. Abnormal environmental factors over a long period of time can alter the direction of development in mussel colonies.

UDC 594.115:639.446

Relationship between the filtration and feeding rate and body weight in *Mizuhopecten yessoensis* as an object of mariculture

by L.G. Makarova (TINRO)

The rate of filtration was determined by an indirect method based on the change in the concentration of suspended matter. The concentration of suspended food particles was determined by the method of wet combustion (Agatova, 1983), and was expressed in calories per litre of water. The experiments were carried out in September-October at a temperature of 10°C. The initial concentration of the feed was 2.46 ± 0.22 $cal \cdot l^{-1}$; it decreased by 15-20% in the course of the experiment. In each case, 39 determinations were carried out with 66 mollusks.

The rate of water filtration by Mizuhopecten yessoensis increased from 0.17 $l \cdot h^{-1} \cdot specimen^{-1}$ to 41.3 $l \cdot h^{-1} \cdot specimen^{-1}$ with an increase in body weight from 0.337 to 855 g (height of shell from 12 to 180 mm), while the intensity of filtration decreased from 0.5 to 0.05 $l \cdot h^{-1} \cdot g^{-1}$ respectively.

Our results have enabled us to calculate the relationship between the rate of filtration (F, $l \cdot h^{-1} \cdot specimen^{-1}$) and the body weight (W, g) of the animal, which is expressed as $F = (0.366 \pm 0.03)W^{0.70 \pm 0.04}$ (correlation coefficient r=0.943). (257)

The consumption of food (C, $cal \cdot specimens^{-1} \cdot days^{-1}$) by the Yezo scallop increases from 7 to 1600 $cal \cdot spec^{-1} \cdot d^{-1}$ with an increase in body weight (W, g) from 0.337 to 855 g. This relationship is approximated by the equation $C = (15.92 \pm 0.98)W^{0.68 \pm 0.08}$ (r=0.832).

To calculate the feeding values at other water temperatures, we determined the average value of the coefficient Q_{10}, which turned out to be 2.53 in the 5-20°C range.

The biomass of the feed necessary to cover the food requirements of the scallop, which is determined from the ratio of the specific values of the ration and the rate of water filtration, is equal to approximately 1.8 $cal \cdot l^{-1}$.

The derived relationships between the filtration and feeding rate and the body weight of the Yezo scallop have been used to calculate the food requirements of the mollusks while they were being kept in an artificial environment, and, together with the data on the dynamics of the suspended organic matter in the waters of bays, to determine the potential load in the areas of maricultural establishments.

UDC 594.124

Growth and productivity of *Crenomytilus grayanus* in the periphyton of an artificial substrate and in natural communities of Posyet Bay in the Sea of Japan

by O.N. Mandryka (LGU)*

The possibility of *Crenomytilus grayanus* colonizing an anthropogenic substrate and growing more rapidly in the periphyton in comparison with natural mussel colonies (Krasnov et al., 1979; Selin, 1980; Mandryka, 1983) has sharpened our interest in establishing farms specializing in the artificial breeding of this commercial species.

The following are the results of a study of the linear growth and rate of the bioenergy cycle of a mussel periphyton with an interval of 5 years due to its succession. The material (258)
on the periphyton was collected in Vityaz' Bay in 1977 and 1982, and from the rocky substrates of Pos'yet Bay (for comparison) in 1976, 1977 and 1982; 1220 specimens were processed in all.

The growth of mussels from different habitats were characterized by the Putter-Bertalanffy equation throughout their life span with analysis of the following parameters: the maximum

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*Leningrad State University – transl.

linear size, the threshold age and the growth constant. With the help of the growth/age coefficient, we compared the productive potentials of the mussel concentrations studied.

The maximum age of the mussels in the periphyton of an artificial substrate was 10 years in 1977, and 15 years in 1982. During this period, the periphytic community acquired the whole complex of species characteristic of natural colonies of *Crenomytilus grayanus*, and reached the climax. We must not extrapolate the equation calculated on the basis of the data on the younger age groups (up to the age of 10 years) for the entire period of growth of *Crenomytilus grayanus* which can surpass the age of 100 years. The empirical curve of group linear growth for *Crenomytilus grayanus* in a 15-year-old periphyton that has attained the climax aquires a bend by this time, while the parameters of the Putter-Bertalanffy equation for the mollusks in the periphyton approximate the growth indices for this species on rocky substrates.

Despite the high linear growth rate of the periphytic mussels during the first ten years of life, the rate of circulation of matter in them is not higher than in mollusks of the same age group from natural congregations. The growth/age coefficient is the same for the periphytic mollusks of Vityaz' Bay from depths of 12 m (G/A=0.292) and 18 m (G/A=0.294), and for the slow-growing mussels off Cape Kreyserok (G/A=0.297), and it is even higher (G/A=0.357) on the rocky substrate in Vityaz' Bay. In the natural mollusk colonies off Cape Kreyserok and from Vityaz' Bay which differ in their size-age composition, the G/A-coefficients, calculated with all the age groups taken into account, are identical, and amount to 0.173.

Consequently, the productive potentials of the periphyton are not higher than in natural _Crenomytilus grayanus_ colonies of the same age. The G/A-coefficient is more stable than the values of linear growth. This should be taken into consideration in the artificial breeding of this commercially important mollusk.

(259)

UDC 594.151(262.5)

Growth dynamics of Black Sea cockles

by T.V. Mikhailova (INBYuM)

Cockles, bivalve mollusks of the genus _Cerastoderma_, are included in the "List of animal species which constitute the natural resources of the continental shelf of the USSR". The cockle industry is prospering in some European countries. Cockles represent an important link in the overall trophic structure of the demersal population of the sea. Their spat is consumed by bottom-feeding fishes.

The most intensive growth of the cockles is observed during the first half of the year, when the underyearlings grow to 12-14 mm. After that, their growth decreases by almost one-half. The growth curve, which is plotted on the basis of the average values of shell length, already resembles the one characteristic of animals with slowing growth during the first year. By the beginning of the reproductive season in May, the underyearlings have a shell length of about 15 mm on the average, they mature and spawn.

During the periods of unfavourable conditions (low water temperatures in winter, lack of oxygen in summer), the mortality of the cockles is quite high in all the age groups, and is especially high in first-year mollusks. The mortality of these animals is usually more prone to drastic fluctuations in comparison with the breeding rate which is usually proportional to the number of spawners. Consequently, the optimal strategy of the species is intensive growth of the underyearlings and early maturation.

The highest growth rate is observed in autumn. The growth rate diminishes during intensive spawning. The animals stop growing at the end of July—August. Characteristic dark zones of growth lag form at this time; they are clearly discerned in the shell structure and hinge elements, and are located at the very edge of the valves. In animals collected in other months and even at the beginning of July, they are found at some distance from the shell margin. At the same time, the sculptured annual rings on the outside of the shells correspond to the structural zones of temporary growth lag.

(260)

Salinity and depth are the primary factors that have a significant effect on the growth rate. A low salinity (2-4‰) and great depth (20-30 m) slow the growth of cockles.

UDC 594.117:(574.5:615.9)

Effect of copper and zinc on the ontogenesis of *Mizuhopecten yessoensis*

by G.V. Moiseyenko and V.V. Shcheglov (TINRO)

The biological and ecological aftereffects of heavy metals are attracting a great deal of attention due to their high toxicity and retention in the environment. Copper and zinc comprise a significant part of the heavy metals [that pollute the environment]; contamination with these metals has reached regional proportions. Finding their way into the seawater, these compounds adversely affect all the organizational levels of life and especially the early stages of ontogeny of the hydrobionts, which are the most sensitive periods of development.

We have studied the effect of copper and zinc on the Yezo scallop which is a promising commercial invertebrate in the shelf zone of the Sea of Japan. Our experiments were carried out with sexually mature adults (3-4 years old), spat (1.5-3 months), and the embryonic and larval stages. The toxicity of these metals was judged by the percentage of survival. Spawning was induced by heat stimulation. The egg cells were washed several times with sterile seawater and artificially fertilized. The density amounted to 1000 per ml for embryos, and 20 per ml for larvae. Each experiment was repeated 3-4 times. Our investigations have shown that the Yezo scallop is highly sensitive to copper. Zinc induced a similar toxic effect at higher concentrations. Comparative analysis has shown that the Yezo scallop is more sensitive to these toxicants in comparison with other bivalve mollusks. The minimum effective concentrations for young Yezo scallops amounted to only 0.015 mg/l for copper and 1.0 mg/l for zinc. (261)
The average lethal concentrations (LC 50) with 24-hour exposure amounted to 0.20 ± 0.016 mg/l for copper and 5.660 ± 0.520 mg/l for zinc.

We found that the resistance of the larvae and embryos to these toxicants differed with the stage of development (cleavage-active embryo—trochophore—veliger larva). The highest effect of the toxicants was observed at the initial stages of development. The larval stages (trochophore, veliger larva) displayed a high resistance to the effect of the toxicants. We noted an increase in vitality at the early stages of ontogenesis under the effect of low concentrations of zinc (0.01 mg/l). We also noted a high resistance to the toxicants in the planktonic forms of the embryonic development of this species. At the stage of cleavage, LC 50 amounted to 0.1 mg/l for copper and 5 mg/l for zinc with 24-hour exposure to the toxicants. At the cleavage—active embryo stage, copper is 5-7 times more toxic than at the later larval stages (trochophore, veliger larva). The early stages of embryogenesis are the most susceptible to the toxicants; the toxic effect is 10-15 times lower at the stages of larval and spat development. Copper is 35-40 times more toxic than zinc in its effect on the Yezo scallop. The mature specimens showed the highest resistance to the toxicant. With a copper concentration of 0.05 mg/l, the physiological activity of the animals deteriorated after 12 hours, and they died after only 48-96 hours.

UDC 594.121+594.124

Sex structure and individual fecundity in *Mytilus galloprovincialis* and *Ostrea edulis*

by V.L. Monin and A.P. Zolotnitsky (AzCherNIRO)

The study of the sex structure and fecundity of commercial bivalve mollusks in the Black Sea is of interest to us in connection with the reproduction and rational exploitation of natural populations, as well as the cultivation of mollusks.

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During this particular investigation, we determined the quantitative sex ratio and individual fecundity of the Black Sea mussels and oysters during the natural reproductive seasons. The mollusks were differentiated into males, females and hermaphrodites on the basis of spawning results and the results of an analysis of a residual gonad suspension.

In mussels of different size taken from pier foulings in the Kerch Strait in 1983-1984, the male/female ratio was close to 1:1. At the early stages of ontogenesis, there was a slight predominance of males, but the females predominated among the older individuals. Hermaphrodites constituted 1.4% of the individuals in 1983, and 0.6% in 1984.

The induction of maturation in the females by means of temperature and hormonal stimulation has shown that the number of spawned eggs increases from 2 to 20 million with the size and weight of the body. The relationship between these indices is adequately approximated by the exponential function which numerically is expressed as $E = 0.423 \cdot W^{1.057}$ (n=31, r=0.861), where E denotes the number of spawned eggs (millions of specimens), and W the weight of the mollusk with the valve (g).

The linear equation $E=0.485 \cdot W$ can be used for practical purposes.

In Black Sea oysters collected in the vicinity of Cape Bolshoi Utrish, the sex ratio in 1984 differed significantly from that of the mussels. Males dominate among the young individuals (92% among the yearlings), which permits us to assume that protandrous hermaphroditism exists in the oysters. With age, the proportion of males decreases, and the number of females and hermaphroditic individuals increases, which is probably due to sex reversal. In five-year-olds, the male numbers decrease to 54%, and the female numbers increase to 42%. In the group of three-year-olds, we observe a sharp increase in hermaphroditic individuals (up to 23%), which is most likely due to the transition of most of the oysters to egg production.

The number of eggs spawned depends on the size and age of the oysters. The relationship between fecundity and body weight in them is described by the equation $E = 0.0514 \cdot W^{0.945}$ ($n=19$, $r=0.946$) or $E = 0.23 \quad 0.036W$ ($n=19$, $r=0.912$).

A comparison of the individual fecundity of these molluska shows that per unit of body weight (with the valve), the mussels spawn almost 10 times more eggs than the oysters.

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UDC 639.41

Production and cultivation of *Crassostrea gigas* larvae and spat in the Black Sea

by O.B. Monina (AzCherNIRO)

Over the past ten years, the Pacific oyster has become an important item of aquiculture. This species has been successfully introduced and cultivated in numerous countries. However, its cultivation on a commercial scale still depends largely on the import of breeding stock.

So far, five shipments of mollusks have been delivered to the Bolshoi Utrish area from Pos'yet Bay.

Based on a growth and survival study of these oysters, we can say that their introduction in the Black Sea has been successful.

The possibility of reproducing the replants is one of the most important factors governing successful acclimatization. The results of observations on the condition of the reproductive system and the breeding of Pacific oysters in a natural environment have shown that these process take place without any visible abnormalities. This is substantiated by the larvae and spat that set in the Bolshoi Utrish lagoon.

Investigations were begun in 1982 to establish the possibility of breeding Crassostrea gigas larvae and spat in an artificial environment. As a result, methods of obtaining larvae and raising them at the early stages of development have been evolved. Temperature stimulation of mature mollusks was used to obtain the gametes. The first active trochophores measuring 40-45 μm appeared 30-40 minutes after the onset of spawning, and the shell began to form after 36 hours. The average values of shell height in veliger larvae amounted to 67.7 μm, and the average length was 51.6 μm. At this stage of development, the larvae were released into 5 m^3 plastic troughs where they were raised up to the time of setting on collectors. The first pediveligers were noted in the trough 15 days after fertilization. On the average, they measured 202 ± 0.3735 μm in height and 197.9 ± 0.212 μm in length. The larvae settled on the collectors at a shell length of 300-350 μm and water temperature of 23.5°C. The numbers of the spat amounted to 843 specimens/m^2. The settled spat measured 7 mm (264) on the average after 40 days of exposure. Further cultivation of the spat was carried out in the lagoon. After 15 months of cultivation, 80% of the spat had attained marketable size (80 mm and larger).

As a result of our investigations, we have been able to obtain Crassostrea gigas larvae and spat in the Black Sea. For the first time, we have succeeded in raising artificially bred spat to marketable size. These data can be used in the biotechnology of production of breeding stock during the cultivation of Pacific oysters in the Black Sea.

UDC 594.124

Biochemical characteristics of mussels from the Karadag area

by A.L. Morozova, L.P. Astakhova, I.A. Graf, T.P. Kondrat'yeva, L.M. Rudenko, Ye.N. Silkina (Karadag branch of INBYuM)

We determined the content of glycogen, total protein and total lipids in mussels taken from a natural environment in the Karadag area, from a coastal rocky substrate and the wooden stakes of a deep trap net. The specimens measured 3-4 and 5-6 cm, and had dark and light-coloured valves; they were taken from a depth of 1-1.5 m once a month from May to October.

The glycogen content varied from 140 to 6300 mg%, the total protein from 0.1 to 4.7 g%, and the total lipids from 32 to 260 mg%. The content of total protein decreased, reaching its minimum level at the end of July—August. The protein content again increased in September. The maximum concentrations of glycogen and lipids were noted in May and August, and the minimum ones in June—July.

The content of these substances is related to the habitat and size of the mussels. The content of total protein and lipids in the rock forms of mussels is slightly lower than in those living on the stakes of trap nets. The rock forms of mussels contain twice as much glycogen than those from trap net poles. In June, the content of total protein and lipids in the rock mussels was higher than in those from trap net poles. The autumn increase of protein and lipids in these mussels was more intensive than in the rock forms. The relative content of glycogen and total protein in 3-4 cm mussels was higher than in the 5-6 cm ones. (265)

The content of glycogen, protein and lipids did not differ with the pigmentation of the valves.

An electron microscope was used to examine the ultrastructure of the muscle tissue in the mussels.

Our year-long study of the biochemical and morphological characteristics of the mussels has enabled us to determine the best time for removing the mussels from the collectors.

UDC 594.117

Some ecological features of the genus *Chlamys* (Bivalvia, Pectinidae) in the Far Eastern seas

by V.G. Myasnikov (TINRO)

Our investigation was based on the material of undersea observations carried out from the "TINRO-2" manned submersible in the Bering Sea, the Sea of Japan and off the Kurile Islands in 1980-1984.

In areas of dense concentrations of the scallop, the species composition of the macrobenthos is poor in comparison with the other parts of the shelf. The scallops form the biocoenosis together with brittle stars of the families Ophiactidae, Ophiolepididae and Gorgonocephalidae, and sea-urchins of the genus *Strongylocentrotus*. Off the coast of the Maritime Territory, *Chlamys rosealbus* is often encountered in areas almost completely occupied by Brachiopoda, the density of which is higher by an order of magnitude. The scallop was encountered less commonly with sea-lilies of the genus *Heliometra*, sponges, starfishes, sea-cucumbers and hydroids. In the Bering Sea and near the Kurile Islands, the scallop is often found amidst the virgate and large cup-shaped sponges*, where starfishes of the families Asteriidae, Asteropectinidae and Solasteridae are also encountered.

The periphytic fauna of the scallop is diverse. It consists of the sponges *Mycale adhaerens* and *Myxilla parasitica*, and less (266)
commonly hydroids, *Balanus*, bryozoans, algae, polychaetes, actinians and the spat of bivalve mollusks. In the Maritime area, the gastropod *Velutina* and its egg deposits are often encountered on the valves of *Chlamys rosealbus*. Off the Koryak coast and in Olyutorsky Bay, the periphyton of *Chlamys behringianus* consists mainly of sponges and bryozoans. A much poorer periphyton of the scallop is noted off Karaginsky Is., where it consists of hydroids of the genus *Eunephtya*; gastropod egg deposits and ascidians of the family Pyaridae are also noted.

The organisms living beside, or directly on the scallop can compete not only for space, but also for food. At the same time, the periphyton of the scallop, as well as the ophiurans, can further obstruct the flow of water. In the vicinity of the northern Kurile Islands, *Ophiopholis aculeata* covers practically all the light-coloured scallops in some areas, and raises a whole

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*Species name not known - transl.

"network" of its pubescent rays above the bottom. Broom (1976) gives ophiurans as the main serious competitors of Chlamys opercularis for space.

The most active consumers of the scallop include crabs, benthophagous fishes and starfishes, which are constantly encountered in the places where scallop congregate. Broom (1976) also indicates that the green crab Carcinides maenas feeds on Argopecten irradians from the Atlantic. The same author notes that starfishes are the main enemies of the scallops in the deeper areas. In the areas studied by us, the shells of dead mollusks covered the bottom completely in some places, and most of the shells were intact, which points to the active feeding of starfishes on the scallop.

UDC 594.124

Development of Mytilus edulis in a laboratory culture

by T.Kh. Naidenko (IBM DVNTs AN SSSR)

The common mussel, Mytilus edulis, inhabits different seas of the northern and southern hemispheres, and consists of a multitude of geographic subspecies. It is interesting to compare (267) the embryonic and larval development of M. edulis from different habitats.

The work was carried out on the "Vityaz" (Sea of Japan), at the Kamchatka branch of the Institute of Marine Biology (Avacha Bay, Pacific Ocean) and at the "Kartesh" biological station (White Sea) in June-July 1984-1985. The gametes were obtained by thermal stimulation, by placing sexually mature mussels in water with a temperature of 20-25 $^{\circ}$C. The long-term experiments included the progeny from one pair of mussels from batches where the percentage of fertilized egg cells was at least 95%. The technique of raising the embryos and larvae of bivalve mollusks has been described in detail (Loosanoff, Davis, 1963; Chanley, 1975). Unlike other authors, we mixed the culture of developing embryos from fertilization to setting at a rate of 60 rpm. Monochrysis sp. and Nephlochloris sp. were used as food. The density of the larvae amounted to 15-20 specimens/ml at the early stages, and 1-2 specimens/ml at the later stages. The temperature of larval development was 18-120°C on the "Vityaz" and at the Kamchatka site, and 16-17°C at the "Kartesh" station, and within the optimal limits for the larvae of this species (Brenko, Calabrese, 1969). All the conditions of larval development in cultures (feeding, changing of water, mixing) were similar.

The diameter of the spawned eggs was 70 μm in the mussels from the "Vityaz" and Kamchatka site, and 56 μm in the White Sea mussels. The colour of the eggs differed with the location, i.e. they were whitish-pink in the Vityaz population, yellowish in the Kamchatka population, and yellowish-pink in the White Sea population. The period from fertilization to the onset of the first division varied from 15 to 76 minutes in different cultures, which greatly exceeds the several minutes usually observed in each culture. By the blastula stage, the asynchrony of development characteristic of bivalve mollusks usually diminishes, and the developing embryos leave the membrane. This instance is easily observed in culture by the onset of embryo rotation. The period at which this stage begins varies from 18-20 hours in the Vityaz larvae to 7 hours in the Kamchatka larvae. The veliger larva forms in 1.5 days from the time of fertilization in White Sea mussels, and in three days in Kamchatka and Vityaz mussels. Veliconchs were noted by the appearance of the umbo on the sixth day in White Sea larvae, on the ninth day in Kamchatka larvae and on the 10th day in Vityaz larvae measuring 140-150 μm. Upon the appearance of the veliger larvae, we already note that the Kamchatka larvae have a more rounded form and more convex valves (268) in comparison with the Vityaz larvae. The convexity of the umbo and valves is particularly evident in the Kamchatka veliconchs. The velar tuft in the Kamchatka larvae was longer and more luxuriant. The greater convexity of the valves and umbo in the Kamchatka larvae and the corresponding increase in the volume of the mantle cavity may be an adaptation that enables the larvae of the Kamchatka mussel to remain in the unstable salinity conditions of Avacha Bay for a longer period.

300 μm pediveligers appeared in the White Sea culture 16 days after fertilization, and 240-250 μm pediveligers appeared in the other cultures on the 28-29th day.

Thus, we noted significant differences in the duration of larval development of *Mytilus edulis* from different habitats. The highest rate of development was observed in the larvae of the White Sea mussel. The external structure of Kamchatka *Mytilus edulis* larvae differs from that of the White Sea and Sea of Japan populations. The vertical distribution of the mussel larvae from different habitats is also of a different nature.

UDC 594.124

The structure of mussel colonies, their distribution, and the prospects of commercial utilization of mussels in the coastal waters of eastern Kamchatka

by V.V. Oshchurkov, S.V. Blinov and A.I. Buyanovsky
(Kamchatka branch of IBM DVNTs, IBM DVNTs)

To determine the possibility and prospects of commercial utilization of *Mytilus edulis* in the Kamchatka region, we conducted a study of this species on natural and anthropogenic substrates in some parts of Avacha Bay during 1982-1985. We collected and processed about 800 quantitative samples from the periphyton and benthal zone. We determined the species structure of the colonies, the size characteristics of the mollusks and their individual mass. Year-round sampling of the mussels in three study areas was carried out to establish the population dynamics and size composition of the mollusks. (269)

This species does not form substantial colonies on the open ocean coast of southeastern Kamchatka. A study of the majority of bays and inlets has shown that mollusk colonies occupy the middle and lower horizons of the littoral, rarely descending to a depth of 1.0-1.5 m. The size of the mollusks did not exceed 30 mm, and 5-10 mm ones predominated. Comparatively extensive mussel banks are confined to the estuarine areas. The proportion of large individuals increases in these biotopes. The biomass in some congregations of mussels amounted to 11 kg/m^2, and the average was 4.4$\pm$2.9 kg/m^2. The largest mussel colonies have been found on various anthropogenic substrates, i.e. port structures, the water conduits of heat and electric power plants, and on floating navigational enclosures. The mussel is found at depths from 1 m to 20-25 m in colonies on the chain anchor of buoys. The average shell length of the mollusks on anthropogenic substrates amounted to 29.2 ± 2.4 mm. Some individuals measures 85-92 mm in length. The average biomass of mussels from foulings was considerably higher than that on natural substrates (20.6 ± 6.0 kg/m^2). The biomass of the mollusks reached 57-62 kg/m^2 at depths of 5-15 m. In one of the inlets of Avacha Bay, the total biomass of the mussels amounted to about 700 t in the benthal zone, and 5500 t in the foulings. Consequently, the basis of the mollusk colony is formed by the individuals inhabiting artificial substrates. The mussels found in fouling have practically no enemies. The starfishes that feed on mollusks in the benthal zone are not found in periphytic communities.

The recruitment of this species in the Kamchatka waters is irregular. In 1983, for example, the maximum density of larvae in the plankton did not exceed 80 specimens/m^3, while the density of the spat on collectors amounted to 18,000 specimens/m^2. The bulk of the spat that sets dies during the autumn—winter.

One of the biological characteristics of the mussel in the Kamchatka waters of the Pacific Ocean is the poisoning of the mollusks. Biochemical investigations carried out at the Kamchatka branch of the Institute of Marine Biology revealed the presence of saxitoxin in mollusks collected in September 1983 and in July—September 1984. The mussels showed no traces of the toxin during the winter and spring periods.

The abundance of mussels in inlets, particularly estuarine-type inlets, is due to the fact that they are protected here from the surf on the one hand, and to the high concentration of phytoplankton resulting from a high content of biogens throughout most of the year (June—November) on the other. At the same time, hypereutrophication apparently increases the probability of mussel poisoning. All of these ecological factors should be taken into consideration when discussing the prospects of mussel cultivation in the bays and inlets along the Pacific coast of Kamchatka.

UDC 551.465.5:639.42

Hydrometeorological prerequisites of the distribution of mussel larvae and suspended organic matter in the area of mussel plantations in the Kerch Strait

by B.N. Panov and I.N. Tribrat (AzCherNIRO)

The main factor determining the distribution of mussel larvae concentrations in the southern part of the Kerch Strait is water circulation, which depends mainly on the wind conditions. In the case where Black Sea currents prevail, we note a large concentration of larvae and suspended organic matter (SOM) in the central part of the strait. No regularities are noted with variable currents, and some tendency towards an increase in concentrations in the direction of the western shore is noted with Azov currents.

With the current distribution of mussel plantations in the coastal zone, the periods of Azov currents are the most favourable for the setting of larvae on collectors. During the intensive growth of the mussels, a large quantity of detrital SOM may accumulate in the vicinity of the plantations. At this time, the Black Sea currents will be the most favourable ones. The Black Sea currents in the strait are associated with the stable winds of the southern quarter, and the Azov currents are associated with the northern winds.

The relationships established will enable us to select the optimal distribution of plantations, and to efficiently determine the intensity of aggregation of the larvae on collectors.

UDC 639.42 (271)

The dynamics of mussel spatfall in Sudak Bay of the Black Sea

by M.V. Pereladov (VNIRO)

To determine the optimal periods for setting out mussel spat collectors, we conducted observations in Sudak Bay from 1981 to 1985 to study the dynamics and intensity of mussel spatfall and the elimination of spat on artificial substrates found in the water. Collectors located in different hydrological zones of the bay were observed throughout the year. Standard commercial collectors made of a nylon screen with foam plastic slabs intertwined in them served as the substrate for settling.

Mussels in Sudak Bay settle throughout the year with pronounced peaks in spring, summer and winter. The rate of the background spatfall does not exceed 5-50 specimens per running metre of a collector, and cannot ensure the required number of marketable mussels on the collectors.

Winter spatfall takes place in November—January, and is the most stable in time and intensity. During this period, the water temperature is the same throughout the bay, varying from 7 to 10°C. The intensity of spatfall reaches 5000 specimens/m of the collector, and does not depend on the location of the collectors. The elimination of the spat of this generation is determined only by the availability of a substrate.

Spring spatfall takes place in April—May, and its intensity rarely exceeds 1000 specimens/m of a collector. The elimination of the spring spat is determined by the degree of development of filamentous green algae on the collectors. The temperature of the surface layers of water during spring spatfall varies from 8 to 18°C in different parts of the bay. The highest rate of spatfall is observed in cold-water areas which form in places of stable coastal upwellings.

Summer spatfall takes place in August—September when the water temperature throughout the bay is 20-25°C. The rate of spatfall at this time is 4000-5000 specimens/m of a collector. Practically all the spat of this generation dies within 2-3 weeks (272) after settling. We observe a direct relationship between the survival of the summer spat and the drop in water temperature. Another cause of the spat losses is the competition for the substrate with _Mytilaster lineatus_ which usually settles 2-3 weeks before the mussels at a rate of 100,000-200,000 specimens/m of a collector.

The setting out of collectors during the summer after the spring spatfall leads to the fouling of collectors with hydroids, and this greatly reduces the settling rate of the following generations of spat.

Consequently, October—November is the best time to set out collectors for mussel spat in Sudak Bay.

UDC 639.42

Experiments on the cultivation of mussels on the Komandorski Islands

by M.V. Pereladov and K.S. Sidorov (VNIRO)

The plans to establish an experimental station for studying the biology and behaviour of the sea-otter on Medny Is. have raised the problem of providing these animals with sufficient nutritious feed. Mollusks are one of the main items in the sea-otter's diet. Because of the limited reserves of mollusks in the coastal zone of the Komandorski Islands, a series of experiments was carried out in 1983-1985 to study the possibility of raising mussels on collectors in the semi-freshened waters of the Gladkovskaya Lagoon on Medny Is., the benthos of which is characterized by large mussel banks. Collectors made of different types of synthetic netting were set out on linear carriers in various hydrological zones of the lagoon.

The mussels inhabiting the lagoon (*Mytilus edulis*) breed in June. The first larvae appear in the plankton at the beginning of July, and it is at this time that the mussel larvae begin to settle on the collectors. By the middle of September, the mussel spat grows by an average 2-5 mm, spreading evenly over the entire length of the collector. By the following spring, the spat grows to 10-15 mm, and 21-22 months after spatfall, the average size of the mussels on the collectors is anywhere from 36.4 mm to 44.5 mm, depending on the hydrological conditions of the different parts of the lagoon. The maximum size of the mussels on the collectors after 21 months of cultivation is 56.5 mm. Cultivated mussels measuring 50 mm weigh 10 g; the yield of raw meat at the prespawning stage averages 46% of the weight of the mollusk.

The central part of the lagoon, characterized by stable hydrological conditions and the lowest degree of mixing by the wind, is the zone best suited for the mussel carriers. Due to substantial freshening of the surface layer of the lagoon, the collectors must be submerged 1.5-2 m beneath the surface throughout the entire period of cultivation. The most intensive spatfall was observed on collectors made of nylon ropes of different weave, and the poorest spatfall was noted on strips of cut netting and on unravelled polymer-fibre ropes with a slippery surface. Preliminary data on the settling and growth of the mussels indicate that 3-5 kg of feed mussel can be obtained per running metre of a collector in the Gladkovskaya Lagoon with a 1.5-year cycle of cultivation.

A comparative study of the mussels inhabiting natural banks on the Bering and Pacific coasts of the Komandorski Islands has shown that the average size of a modal group in littoral mussel populations does not exceed 28.5 mm at an age of 5-7 years. The yield of meat from "wild" mussels does not exceed 30% of the weight of the mollusk.

Thus, mussels for feeding sea-otters can be raised on Medny Is. in the Gladkovskaya Lagoon.

UDC 594 (274)

Seasonal variations in the condition of mollusks from different biotopes, based on the condition factor

by A.N. Petrov (INBYuM)

We have analyzed the seasonal changes in the condition factor of three prolific species of Black Sea mollusks (*Pitar rudis*, *Polytitapes aurea rostata* and *Gouldia minima*) from two sectors of one of the Sevastopol bays, which are found at different distances from the epicentre of hypoxia caused by the mass dying away of *Zostera*. The condition factor was calculated on the basis of monthly samples collected throughout the year, and represented the ratio of the logarithms of shell length and the dry weight of the tissues. The use of this form for the calculation of this factor enables us to compare the condition of the mollusks without paying much attention to the difference in their size.

All three species display a significant decrease in the values of the condition factor during the spawning period, followed by an increase during the autumn—winter period, when energy substances accumulate in the tissues of the mollusks. The relative changes in the condition factor constituted up to 30% for *G. minima*, the values throughout the year always being lower in the first sector that was closer to the epicentre of hypoxia. The spawning period, determined by a decrease in the condition factor, included two peaks, in July and in October. Maximum values of the condition factor were observed in March-April, which may be due to the spring spurts in the abundance of phytoplankton used by the mollusks for feeding. A similar pattern was observed in the seasonal dynamics of the condition factor in *P. rudis*, i.e. two pronounced lows in June and October during the spawning period, followed by an increase in the condition factor in winter. The values of the condition factor were 20-25% lower in the mollusks of the 1st sector than in those of the 2nd sector. In *Polytitapes aurea rostata*, we noted one annual spawning peak (June—July) with minimum values of the condition factor; we later observed a gradual increase in the condition factor (40% over the initial value) with the maximum value observed from October to the end of March, followed by a decrease (275) as the mollusks prepared for the new breeding season. The differences in the values of the condition factor of the animals in the different sectors, although less pronounced (especially in autumn—winter) in comparison with the other two species, constitute up to 15-17% during the spawning period.

The above results, despite their approximateness, demonstrate the possibility of utilizing one of the simple quick methods of determining the condition of mollusks during the spawning period, depending on the ecological-sanitary conditions of the study area, which can prove useful during the monitoring of coastal benthic communities and during the cultivation of mollusks at maricultural establishments.

UDC 594.124

The dynamics of gonadal maturation and the fecundity of *Mytilus galloprovincialis* females in Laspi Bay

by A.V. Pirkova (INBYuM)

By studying the dynamics of gonadal maturation and the fecundity of mussels as an item of mariculture, we can determine the generative potential of mussel plantations.

Since the water temperature in the spring of 1985 was below the spawning level for a long period, 92% of the rock and collector mussels were at the spawning stage in March and in the first half of April, but the genital products were not cast out. The spring spawning peak was prolonged to the end of July, at which time 70% of the individuals were still spawning. The minimum number of mussels (18%) was at the spawning stage in August. The proportion of spawners constituted 30% in the middle of September, and increased to 40% in October, thus indicating the onset of the autumn peak.

A clearly defined first spawning peak was observed at the beginning of July in the mud mussels. The minimum number of mud mussels (6%) with gonads at the spawning stage was noted in August. The beginning of the second peak coincided with that of the rock and collector mussels.

(276)

Consequently, gonadal maturation and spawning in mussels from different biotopes takes place at the same time.

Mussels at different stages of development were encountered alongside the spawners. Most of the spawners belonged to the 45-55 mm size group.

The seasonal fecundity of the female mussels on the collectors was determined by repeated temperature stimulation of spawning. For mussels in the 25.6, 33.5, 33.9, 45.2, 48.9, 53.2 and 55 mm size groups, the fecundity was equal to $15\cdot10^4\pm0.2\cdot10^4$, $37\cdot10^4\pm0.25\cdot10^4$, $37.8\cdot10^4\pm0.4\cdot10^4$, $55.5\cdot10^4\pm0.9\cdot10^4$, $82\cdot10^4\pm 0.1\cdot10^4$, $184\cdot10^4\pm0.5\cdot10^4$ and $191\cdot10^4\pm0.3\cdot10^4$ egg cells respectively. Consequently, the fecundity of the collector females is directly related to their size.

UDC 594.124:574.5.001.8(268.46)

Statistical characteristics of the distribution of *Mytilus edulis* in the vicinity of the Keretsky Archipelago in the White Sea

by V.B. Pogrebov (Leningrad State University)

To study the distributional characteristics of commercial invertebrates, the material should be collected in a wide range of environmental conditions, and then the data processed mathematically by the methods of multivariate statistics. In this particular study, we examined the distribution of the common mussel in an inlet with a pronounced thermohaline gradient in summer. The material was collected in June—July 1983-1984 at horizons -1, 0, 1 and 2 m depths from 0.0625 m^2 areas (368 samples).

This inlet cuts into the Karelian shore of the White Sea, and is of a fjord nature. Its banks are composed of granites, and the littoral is narrow. The salinity in the area varies from 2 to 24‰, and the temperature from 15 to 22°C. On the whole, this body of water is typical of the coast in this area, and can be regarded as a natural model of a shallow marine ecosystem.

Mussels were found at 81% of the stations examined. The (277)
average density of the mollusk colonies at the given horizons amounted to 10,656±11,725 specimens/m^2 with a biomass of 42± 41 g/m^{-2}. The mussels comprised 6% of the total biomass of the communities detected there, and 62% of the total biomass of the animals.

The distribution of the mollusks on the surface of the substrate is aggregated as to numbers (degree of structure W=0.7-4362.0) and predominantly sporadic as to biomass (W=0.1-21.4). The mathematical model of the distribution of the numbers of the animals on the substrate is a negative binomial; the distribution of biomass is adequately approximated by Poisson's law.

Two-factor analysis of variance ("fixed" model) revealed that the vertical and horizontal coordinates of the stations had a significant effect on the biomass of the mussels, and that the effect of their interaction was also significant (P=0.001). Analysis of the matrix of the coefficients of paired correlation and the calculation of the partial coefficients of correlation between the values of temperature, salinity and length of drying, which are related to the coordinates of the stations, have revealed that the factors are highly colinear. A comparison of the ecological amplitude of the species and the range of the recorded gradients have permitted us to introduce the daily average salinity in a given water column (S,‰) and the length of the drying period (T, $h \cdot d^{-1}$) as explanatory variables for the plotting of an empiricostatistical model of distribution of mussel biomass (B, g/m^2). For each of the factors, we tested polynomials of the second degree, which usually enable us to adequately describe the common bell-shaped distribution of species according to environmental gradients. The optimal number of independent variables was determined by the maximum value of the corrected coefficient of determination during the procedure of consecutive step-by-step elimination of predictors from the model of the highest complexity.

The functional model based on the multiple regression of ecologically important gradients is expressed as

$$B = -201.0702 + 18.7135S + 13.4016T - 1.1987ST.$$

Standard error of regression Su=54.23, coefficient of determination R^2=47% with the significance level of the zero hypothesis P=0.01.

The use of analogous models enables us to visualize the biomass (and apparently production) of the species as a function of a small number of key ecological factors. Regression equations concisely and without any great loss of information describe the (278)
distribution of hydrobionts, and their graphic depiction enables us to establish the main tendencies of the response of organisms to environmental changes. We believe that these models can prove useful for prognostic purposes and for determining the combination of abiotic variables that optimize the biomass and production of hydrobionts during the transition to industrial methods of mariculture.

UDC 594.1(265.54)

Population structure and seasonal density changes in the bivalve mollusk *Ruditapes philippinarum* of Vostok Bay in the Sea of Japan

by S.K. Ponurkovsky (IBM DVNTs AN SSSR)

We have studied the size and age structure of the *Ruditapes philippinarum* population and the seasonal changes in its density in Vostok Bay in the Sea of Japan. The material was collected from July 1984 to September 1985. The samples were taken with a 1/16 m^2 frame. A total of 168 samples (6283 specimens) were collected.

We have established that *Ruditapes philippinarum* is found at depths of 0-4 m on the rubbly-pebbly bottom in the coastal waters of Vostok Bay. The mollusks form mass congregations at a depth of up to 1 m. The distribution of the animals in the population is of an aggregate nature. The average annual density of a colony of these mollusks is 613.6 ± 15.8 specimens/m^2, and the average biomass of the mollusks 4030.5 ± 125.1 g/m^2. The maximum density of *Ruditapes philippinarum* was noted in August 1984 (1038.9 ± 91.2 specimens/m^2), and the lowest density in April 1985 (291.9 ± 30.9 specimens/m^2). The density of the colony and the biomass of the mollusks do not undergo significant change in the summer.

We have noted significant differences in the age and size structures of the population at different horizons. During the summer of 1984, the main part of the colony at the 0 m horizon was made up of one-year-old mollusks with a shell length of 1-15 mm (95%). We did not encounter any individuals older than 3 years at this horizon. 5—6-year-old individuals predominated at a depth of 0.5 m (67%). Individual spat were usually noted at the other levels. (279)

Thus, the absence of older age classes at the 0 m horizon, as well as the significant decrease in the density of the congregation in spring, permits us to assume that the population dynamics of Ruditapes philippinarum in Vostok Bay are greatly affected by ice conditions.

UDC 594.1:574.5.001.8

Vertical migration capacity of bivalve mollusks

by Yu.V. Prosvirov (INBYuM)

Large areas of lifeless substrate form as a result of dumping. It is interesting to trace the mechanism by which communities form in these areas, and to establish which takes priority in this process, the settling of the young and adults from the water column, or the vertical and horizontal migrations. The purpose of this experiment was to examine the

capacity of the bivalve mollusks Venus gallina and Pitar rudis to perform vertical migrations through various layers of substrate taken from the habitat of the mollusks (A) and foreign substrate (B). The experiment was carried out in glass cylinders with a diameter of 15 cm, which were placed in an aquarium with running water. The mollusks and substrate A were collected in the Uchkuyevka area from a depth of 15 m. Substrates A and B are similar in their granulometric composition (the 0.315 mm fraction forms the basis of these substrates), but they differ in their chemical composition. SiO_2 predominates in substrate A, and CaO in substrate B. The mollusks were covered with 5, 15, 25, 30 and 35 cm of substrate. All the mollusks passed through the 5 cm layer of substrate A. 80-90% of *V. gallina* and 0-25% of *P. rudis* passed through the 15 cm layer of substrate A. 30% of *V. gallina* and 25% of *P. rudis* passed through 25 cm of substrate A. 25% *V. gallina* and 0% *P. rudis* passed through 35 cm of substrate A. 0-10% of *V. gallina* and 0% *P. rudis* passed through 15 cm of substrate B, and no *V. gallina* or *P. rudis* passed through 25, 30 and 35 cm of substrate B.

As we can see, there is a significant difference in the capacity (280) of species from the same biotope to perform vertical migrations. This can be attributed to the fact that *V. gallina* is also encountered in the more shallow zone and, because of this, has adapted to being buried during stormy conditions.

The type of substrate used to bury the mollusks proved to be an important factor. If dumping involves substrate from the habitat of the animals, many of the bivalve mollusks are capable of passing through it to the surface. If foreign substrate is dumped, the mortality will be considerably higher.

UDC 594:639.4:576.8(26)(262.5)

Microbiological safety characteristics of mollusks cultivated in the eastern part of the Black Sea

by S.G. Puchenkova (AzCherNIRO)

Commercial cultivation of mollusks for food purposes calls for control over the microbiological safety of the product and the establishment of bacteriological standards for assessing its quality. In order to solve these problems, we tested the

MNIIG* methods of determining the microflora indicative of the quality of the mollusks. As a result of this, we now have data on the qualitative and quantitative composition of the microflora found in mollusks cultivated in the coastal waters of the Crimea and Caucasus.

The organisms studied by us included the Black Sea mussel *Mytilus galloprovincialis* and oyster *Ostrea edulis*, as well as the Pacific oyster *Crassostrea gigas* acclimatized in the vicinity of Cape Bolshoi Utrish. At the same time, we analyzed the seawater, the bottom deposits under the mussel plantations and the biodeposits on the shells of the mollusks. In the course of our work, we analyzed a total of 470 samples in which we determined the total microbial number (TMN), as well as the indices of the *Escherichia coli* group of bacteria (ECGB), fecal colibacilli (FCB), enterococci, fecal streptococci (FS), *Aeromonas* and sulfite-reducing *Clostridium*. The pathogenic microflora was determined at the sanitary and epidemiologic station of the Kerch port.

The areas of marine invertebrate cultivation in the eastern part of the Black Sea proved to be microbiologically safe. The content of indicator microflora in the seawater of areas like Sudak Bay, Laspi Bay, Lake Donuzlav and Cape Bolshoi Utrish was determined as individual or tens of microbial cells per dm^3, and the TMN constituted hundreds of cells per cm^3. The indices of ECGB and enterococci for the mussels of these areas vary from less than 1 cell/g to 24 cells/g, and the indices of FCB and FS are lower by an order of magnitude on the average, and

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*Moscow Scientific Research Institute of Hygiene - transl.

the TMN constituted 10^2-10^4 cells/g. The oysters in the Bolshoi Itrish area had the following microbiological characteristics during the different seasons: TMN 10^2-10^4 cells/g, indices of ECGB 0.45-13 cells/g, indices of enterococci 0.6-24 cells/g, FCB from less than 0.45 cell/g to 5-6 cells/g, and FS up to 6.2 cells/g.

The TMN of seawater in the vicinity of mussel plantations in the Kerch Strait did not exceed several thousand cells per cm^3. The content of ECGB and enterococci usually amounted to several tens of cells per dm^3, except in some cases where it increased to 240 cells/dm^3 and more, probably due to sporadic contamination. The TMN of mussels cultivated in the Kerch Strait was 10^3-10^4 cells/g, in some cases up to 10^5 cells/g, and the indices of ECGB and enterococci at different times of the year varied from less than 1 cell/g to 60 cells/g, in some cases up to 240 cells/g and more. The ratios of FCB:ECGB and FS:enterococci averaged 0.4. The spores of sulfite-reducing _Clostridium_ in 0.1 g of mollusks were grown very rarely. _Vibrio parahaemolyticus_ was detected in individual cases. Anaerogenous _Aeromonas_ were isolated in some cases. No enteropathogenic microflora was detected. The bottom sediments and the biodeposits on the shells of the mollusks abounded in sporous and cytochromoxidase-positive microflora, but the content of intestinal microflora was insignificant.

Our investigations have provided us with the microbiological characteristics of the mussels and oysters cultivated in the Black Sea, and have enabled us to develop the microbiological specifications for mussels in the area of their cultivation.

UDC 594.121(265) (282)

Main stages in the expansion of the range of the Pacific oyster, *Crassostrea gigas*

by V.A. Rakov (TINRO)

The Pacific oyster *Crassostrea gigas* originates from the Sea of Japan and the Pacific coast of Honshu. In Japan, Korea and the southern part of the Maritime Territory, *C. gigas* shells have been discovered in marine Pleistocene and Holocene deposits. The earliest exploitation of the natural oyster resources and the cultivation of oysters began here 3000-4000 years ago. The development and formation of the present-day range of the Pacific oyster occurred in several stages.

1. In the Middle Ages, the range expanded as a result of the import of oysters from the Yellow Sea to the shores of the East China Sea and Taiwan, and later to the shores of the South China Sea.

2. At the beginning of the 20th century, this species was introduced to the Pacific coast of North America via the Hawaiian Islands. In 1912-1913, it found its way to British Columbia in Canada, and at the beginning of the 1920's to the states of Washington and California. Here, *C. gigas* underwent naturalization to such an extent that it could be cultivated on a commercial scale.

3. The first attempts to transport the oysters from Japan to the southern part of Australia and Tasmania were made in 1947-1948. Since 1955, this species has become naturalized off the coast of Tasmania, and since the end of the 1960's off the

eastern coast of Australia and around New Zealand. The northern boundary of the range off the eastern shores of Australia has of late been gradually moving in the direction of the equator. The Pacific oyster was recently introduced on some of the islands of Oceania.

4. At the end of the 1950's, *C. gigas* was transported from the Pacific coast to the Atlantic coast of the USA, to the states of Alabama and Massachusetts.

5. The final stage in the expansion of the *C. gigas* range, which is currently in progress, began at the end of the 1960's, and is due to the import of this mollusk to the shores of Western Europe, Africa and South America. In a short period of time, (283) the oysters have formed natural populations in some countries, and large-scale commercial cultivation has developed on the basis of these populations.

Since 1980, this species of oysters has been introduced in the Black Sea for the purpose of commercial cultivation.

The expansion of the species range was caused mainly by transoceanic, interoceanic and regional transplantations of the Pacific oyster.

UDC 594.1(262.5)

Reproduction of *Mytilaster lineatus* and *Modiolus phaseolinus* in the Black Sea

by N.K. Revkov (INBYuM)

Mytilaster lineatus forms mass congregations in the coastal zone, and *Modiolus phaseolinus* is the dominant species in the deepwater association with the maximum biomass in the 70-80 m range.

We have analyzed the condition of the gonads in the given species from different populations. We examined samples of Mytilaster lineatus from three points along the Crimean shore of the Black Sea (Laspi area, Kazach'ya inlet and Streletskaya inlet) at the time of mass maturation of the mollusks, and samples of Modiolus phaseolinus from the Bosporus area and the Caucasian coast .

The maturation of Modiolus phaseolinus does not depend on the location of the habitat, and occurs when a shell length of 5.5 mm has been attained. The maturation of Mytilaster lineatus takes place at a length of 5.5–7 mm, and depends on the degree of pollution in the area. Both species are stably gonochoristic, with the average diameter of ripe oocytes equal to 0.055 mm and the sex ratio 1:1.

Mytilaster lineatus breeds in the Black Sea once a year when the surface waters heat up in summer. On the basis of our own data and the literature, we have come to the conclusion that Modiolus phaseolinus breeds throughout the year in the Black Sea, which is a reflection of the relative stability of its deepwater habitat.

UDC 594.124 (284)

Some ecological characteristics of Mytilus edulis in different parts of its range

by O.G. Reznichenko (IOAN)

Two ecological groups of mussels can be distinguished in the waters of the USSR, the Atlantic group (AG) and the Pacific group (PG). The first group lives mainly in the Barents and

White seas, and the second group in the Sea of Japan, Sea of Okhotsk, Bering Sea and off the coast of the Pacific islands and mainland. The principal zone of the Atlantic group is the littoral + upper littoral; it is the same for the Pacific group, but with a clear tendency towards transition to the upper sublittoral. The optimal depth for both groups is the sublittoral (up to 3 m). Whereas the Pacific group never forms significant congregations deeper than this, the Atlantic group often forms substantial concentrations (about 1 kg/m^2) at depths over 10 m (even up to 45 m). On the whole, the lower boundary of occurrence of the Atlantic group exceeds that of the Pacific group by an order of magnitude; the mussels of the Pacific group can function only in periphytic biocoenoses at this depth. Various solid substrates and plants are the favourite substrates of the mussels in both parts of the range. However, a biomass of 10-20 kg/m^2 is common for the Atlantic group on muddy and clayey-sandy substrates, whereas the Pacific group does not assimilate the latter at all, or its biomass on such substrates is lower than in the Atlantic group by 2-3 orders of magnitude. The benthic congregations of mussels from the Atlantic group are four and two times more abundant in the average and maximum biomass respectively than the congregations of the Pacific group, but they are half as abundant with respect to the maximum biomass of the periphytic mussel community. The discrepancy between the values of the quantitative abundance of this species in the benthic and periphytic biocoenoses is not as pronounced in the Atlantic group. In suspended mariculture, the mussels from the Pacific group reach marketable size twice as quickly. The mussels from the White Sea and Sea of Okhotsk are alike in their life span (7-13 (25) and 8-18 years respectively), whereas the maximum life span of the Sea of Japan mussel (4-5 years) is equal to the minimum life span of the Barents Sea mussel (3-5 years). The littoral congregations of the Pacific group are often ephemerals (annually survive only up to freeze-up, after which they die off entirely), and they do not have the clearly defined spatial structure typical of the Atlantic group.

There are other differences between the Atlantic and the Pacific group of *Mytilus edulis* apart from the specific habit of the mussel communities. The primary factors determining these (285)
differences include the bottom topography, depth, temperature, salinity and ice action. It is remarkable that we found hardly any *Mytilicola** copepods (one of the most constant and serious parasites of this mussel outside USSR waters) in either of the groups.

UDC 594.124(262.5)

The rate of generative growth in Black Sea mussels

by Z.A. Romanova (INBYuM)

The goal of our investigations was to determine the rate of generative growth in *Mytilus galloprovincialis* at the scientific-experimental maricultural establishment in Laspi Bay (Black Sea). The rate of generative growth enables us to determine the dynamics of the utilization of nutrients and energy for the formation of egg deposits, and to compare this process in animals of different taxonomic groups.

*Name of genus(?) transcribed from the Russian - transl.

The samples were taken monthly throughout 1984-1985. The rate of generative growth was determined by the loss of dry body weight or its energy equivalent during the spawning period. The spawning period was the period during which the genital products were cast out repeatedly until the gonad had been emptied completely. The spawning period lasted from 30 to 90 days, depending on the season and on the fullness of the gonad prior to spawning.

Analysis of the condition of the gonads throughout the year has shown that the mussels have two peaks of reproduction, a spring and an autumn one, and the time at which these peaks set in is determined by the environmental conditions. The mussels that settled on collectors reached sexual maturity at the under-yearling stage with a shell length of 17 mm and overall fresh weight of 430 mg.

The gonad index (the ratio of the dry weight of the gonads to the total dry weight of the soft tissues) depends on the weight of the mollusks and the stage of gonadal development. In the annual cycle, it varies from 0.7 to 19.4% with the maxi- (286)
mum rise during the period of active breeding. A decrease in the gonad index was noted towards the end of the spawning period.

The maximum caloricity of the gonads is noted during spring and summer spawning (5.12 and 4.58 $kcal \cdot g^{-1}$ dry weight respectively. The caloricity of the soft tissues during these periods is 5.18 and 4.58 $kcal \cdot g^{-1}$ dry weight.

The rate of generative growth in 1—1½-year old mussels varies from 0.4 to 4.7 mg/d, or from 3.7 to 37.7 $cal/spec^{-1}/d^{-1}$.

The quantitative dependence of the rate of generative growth P_g cal/spec^{-1}/d^{-1} on the energy equivalent of the soft tissues C cal/spec^{-1} is expressed by the following exponential equation:

$$P_g = 0.0076 \cdot C^{0.97}$$

Mussels 1-1½ years old utilize from 16.7 to 45.9% of the energy stored up in their bodies in one spawning period. These data a quite comparable with those obtained earlier for rock mussels (Kazach'ya Bay) and mud mussels (northwestern part of the Black Sea).

UDC 594.1(262.54)

The bivalve mollusk *Mya arenaria*, a new commercial invertebrate from the Sea of Azov

by M.Ya. Savchuk (Berdyansk Pedagogical Institute)

In September 1975, an experimental study of *Mya arenaria* from the northwestern part of the Black Sea was carried out in one of the lagoons at the southern tip of the Berdyansk sand bar. As a result of further investigations, we found that its larvae appeared in the Sea of Azov and settled in the shallow areas close to shore (Savchuk, 1980). In the ten years since that time, we have observed the extensive spreading and naturalization of this commercial species new to the Sea of Azov.

The undersea investigations in the coastal shallow areas of (287) the northwestern part of the Sea of Azov and the surveys conducted farther from shore from AzNIIRKh research vessels (S.N. Nekrasov) have shown that the soft-shell clam is currently encountered from the Belosaraiskaya and Dolgaya sand bars near Taganrog Gulf to Arabatskaya Strelka.

In Berdyansk Bay, the soft-shell clam is encountered everywhere, both on uncluttered parts of the bottom, and amidst periphytic biocoenoses. In shallow lagoons connected with the sea where we observe strong currents and the transport of loose material, this species is found up to the very edge of the water where it burrows to a depth of 25 cm. At some stations, the density of Mya arenaria congregations amounted to 380-1315 specimens/m^2, and the biomass 2600-6130 g. On some sand bars that were exposed during off-water, the density of the congregations amounted to 140 specimens/m^2, and the biomass 4240 g. The largest specimens had a shell length of 100 mm, a height of 59 mm and a convexity of 37 mm. The weight of the soft part of the body in relation to shell weight in the 60-70 mm size group (based on length) was equal to 46%, while the cooked meat/empty shell weight ratio was 29%. Consequently, one ton of these clams yields 290 kg of delicacy meat which contains more protein than mussel meat.

The extensive distribution of Mya arenaria in the Sea of Azov is of great economic interest to us. It has remarkable taste qualities, and can be utilized and cultivated on a commercial scale in the southern seas of the USSR.

UDC 594.124(262.5)

Population structure and relative growth of mussels in different types of congregations

by I.A. Sadykhova (VNIRO)

Mussels collected in 1982 and 1983 in the northeastern part of the Black Sea were studied to determine their relative growth and characteristics of the size-age structure. The samples were collected on natural banks from a rocky bottom at a depth of 10-12 m, on piles at a depth of 1.5-2 m and on piles in the 0-20 cm subsurface layer. Divers collected the material from 0.1 m^2 areas on the mussel banks, and the mussels on the piles were collected from 0.03 m^2 areas. Two areas of the substrate were taken into account for each station, one with the minimum and one with the maximum density not more than 1.5 m from each other. The derived average and unit data were processed statistically.

Analysis of the data has shown that the mussels from the piles grow 1.5-2 times more quickly on the average than those living on the bottom, reaching a length of 60 mm by the age of 3 years (this length is attained in 5-6 years on the bottom substrate). The "freer" distribution of the mussels on the piles results in a larger shell compared with individuals of the same size from benthic populations (coefficients of relative height increase of shell B_1=0.86 and relative width increase of shell b_2=1.05 in mussels from piles, and b_1=0.48 and b_2=0.5 respectively in mussels on the bottom). The very nature of the isometric width increase of the shell in pile congregations also determines its greater convexity and greater potentials for increasing the meat yield at any size. Indeed, the rate of growth of the soft tissues in pile mussels remains significantly higher throughout their life (b_3=2.67, compared with 2.2 in the benthic mussels). It is interesting to note that the relative rate of increase of the shell substance does not differ significantly in the mussels from these biotopes (b_4=2.6 and b_4=2.7). At the same time, mussels growing on collectors, as we have learnt from the literature, have a relatively lighter shell in comparison with those growing on the bottom. Apparently, the mussels on piles are as if in an intermediate ecological-physiological habitat.

In pile populations, the abundance of mussels per unit of area decreases with depth because of intensive settling of the larvae in the subsurface layer. Constant distribution with a mode of 20 mm is characteristic of this biotope. At a depth of 1.5-2.0 m, the size distribution on those same piles varies with the season, i.e. it is unimodal with a modal class of 50 mm in May (prior to settling), bimodal with modes of 20 and 50 mm at the end of August, and it acquires the form of a plateau in October because of the elimination and growth of the spat. The size distribution at a depth of 12 m is markedly unimodal, with a mode of 75 mm. The populations on piles are characterized by smaller threshold sizes, i.e. individuals larger than 70-75 mm are practically never encountered here, whereas benthic populations con- (289)
sist at least 20% of 80-100 mm individuals. Perhaps the faster growth of the pile mussels governs their more rapid physiological aging, as a result of which 3—4-year-old individuals that have attained a size of 70 mm no longer have any physiological potential.

UDC 594.1:594.3

Effect of predaceous gastropods on the structure of a *Ruditapes philippinarum* population

by N.I. Selin (IBM DVNTs AN SSSR)

The habitats of several species of gastropods are confined to colonies of the prolific bivalve mollusk *Ruditapes philippi*-

*Institute of Marine Biology of the Far Eastern Scientific Centre of the USSR Academy of Sciences - transl.

narum which is successfully exploited and cultivated in a number of countries of Western Europe and Southeast Asia. Field observations have shown that interrelations of the "predator-prey" type are the most common for predators such as Cryptonatica janthostoma, Nucella heyseana, Boreotrophon candelabrum and Tritonalia japonica. In connection with this, we studied the influence of these species of mollusks on the structure of the Ruditapes philippinarum population in Vostok Bay of the Sea of Japan.

During the summer of 1984, total sampling of the valves of dead Ruditapes philippinarum was carried out in the coastal waters of the bay. We counted the total number of shells, as well as the number of whole valves and valves perforated by the predator. In the cases where an unpaired valve was found, only its right part was taken into account. The hole in the shell and the feeding behaviour served to identify the species of the predator. This was accomplished by means of lab experiments in which Ruditapes philippinarum were kept in aquariums with each of the species of gastropods studied. The length of the Ruditapes philippinarum valves and the height of the gastropod shells were measured with a slide gage. The size composition of the prey and predators was analyzed in one of the most typical parts of the bottom near the Vostok biological station of IBM DVNTs AN SSSR . In all, we exa- (290)
mined more than 10,000 valves of dead Ruditapes philippinarum and 35 quantitative samples collected with 1/16 and 1 m^2 frames.

Our results indicate that:

1) All of the gastropod species studied are active predators.

2) Gastropods attack Ruditapes philippinarum of all the size groups characteristic of the given habitat.

3) Gastropods prey mostly on 1—2-year-old Ruditapes philippinarum, the perforated shells of which constituted 78-89% of all the mollusk shells of these age groups that were collected.

4) A certain size range of Ruditapes philippinarum corresponds to each species of gastropod.

5) The number of unsuccessful attacks by gastropods increases with the body size of the prey.

6) The larger the prey, the more frequently gastropods of the same of different species attack together.

7) Approximately 60% of the valves collected bear traces of successful attacks by predaceous gastropods. This indicates that predaceousness serves as one of the main factors that determine the structure and regulate the numbers of the coastal congregations of Ruditapes philippinarum in Vostok Bay of the Sea of Japan.

UDC 594.1

Populational and ecological analysis of Spisula sachalinensis and Mactra chinensis (Bivalvia, Mactridae)

by N.I. Selin and S.V. Yavnov (IBM DVNTs AN SSSR)

In order to exploit the large bivalve mollusks Spisula sachalinensis and Mactra chinensis efficiently, we must study their populational and ecological characteristics in detail. In connection with this, we analyzed the size and age structure of Spisula sachalinensis and Mactra chinensis populations, their depth distribution and growth in Vostok Bay of the Sea of Japan in July—August 1985. The mollusks were counted at depths of 1, 3, 5, 7, 9 and 11 m. In each case, the population density and biomass of the animals were determined with a 1 m^2 frame (291) which was placed on the sand parallel to the shoreline 30 times in succession. The average values of the given characteristics were determined for the horizon. The length of the mollusk shells was measured with a slide gage; the total raw weight of the mollusks was determined on BДKT-500 scales. The individual age of Spisula sachalinensis and Mactra chinensis was determined from the growth inhibition annuli on the surface of the shell and the structural markings on the cross-section of the valve.

The results of our study have brought us to the following conclusions:

1. In Vostok Bay, Spisula sachalinensis and Mactra chinensis inhabit the sandy parts of the upper sublittoral at a depth of 1.5-11 m.

2. As the distance from the shoreline increases, the density of the mollusk population gradually decreases; the maximum biomass of Spisula sachalinensis (about 280 g/m^2) characterizes the 7 m horizon, and the maximum biomass of Mactra chinensis (111 g/m^2) the 5 m horizon.

3. The main reproductive part of the Spisula sachalinensis and Mactra chinensis populations, which determines the self-reproductive characteristics of the benthic population of these mollusks in the bay, is confined to a depth of 3-9 m.

4. A high content of immature mollusks and individuals of other age groups in the populations indicates that Spisula sachalinensis and Mactra chinensis populations are renewed regularly, and are stable. This indicates that it would be possible to exploit these species on a commercial scale.

UDC 594.124+639.42:581.526.325 (292)

Qualitative characteristics of the food spectrum of *Mytilus galloprovincialis* on collectors

by M.I. Senicheva (INBYuM)

The organization of mussel farming in Laspi Bay made it necessary to study the composition and quantitative development of the phytoplankton as a food supply for mussels and to determine their food spectrum.

The investigations carried out in the bay from June 1983 to October 1985 have shown that the composition and abundance of the phytoplankton differ within the same season during different years, depending substantially on the direction and velocity of the currents, as well as on the tidal phenomena.

The highest concentration of phytoplankton is noted in spring and autumn, and the minimum concentration in winter. During the summer of 1983 and 1984, weak development of phytoplankton was observed due to the clearly defined density stratification of the waters. On the other hand, the frequent drops in water level due to wind and the influx of cold abyssal waters into the bay in the summer of 1985 caused the rapid development of algae, the biomass of which reached its maximum level during this period. The bulk of the phytoplankton was concentrated in the 0-10 m layer, and varied within the range of 22,000,000-460,000,000 cells/m^3 and 25-425 mg/m^3.

The food spectrum was studied from January 1985 by selecting mussels from the collectors 1-3 times a month and examining their stomach contents and feces under a microscope. When the stomach contents were examined under a light microscope, we saw only the remains of cells or the valves; most of the food bolus appeared to consist of detritus. This is why we studied the food spectrum with the help of a fluorescence microscope, which enabled us to establish that the food bolus is composed basically of half-disintegrated and disintegrated planktonic algae (the chlorophyll of which gives off a red light) and heterotrophic algae (give off a green light), many of which have been identified to the species.

The stomachs of the mussels were found to contain more than 40 species of diatomaceous, peridinian, yellow-green and green algae, as well as fragments of macrophytes, infusorians, planarians, nematodes, individuals parts of copepods and sagittae, pine pollen, a mass of bacteria and transparent (apparently fatty) (293) drops measuring 1-2.5 μm.

The stomachs of 20-59 mm collector mussels contained mainly algae which at that time dominated in the plankton (10-80 μm oval forms of peridinian algae, yellow-green algae and pennate forms of diatoms measuring 14-200 μm). In May, however, the stomachs were filled with *Prorocentrum micans* and pine pollen which were very scarce in the plankton at that time. This obviously is an indication of the high water dynamics in the bay, which is responsible for bringing food from a much larger area to the area of mussel cultivation.

During the periods when there were no dominant species in the plankton, the food of the mussels was more diverse, consisting of up to 30 components of plant and animal origin.

The contents of the feces during the different seasons consisted mainly of the same algae as encountered in the stomachs, but they were at different stages of digestion, many of them still luminescing. The feces were sometimes filled with whole or barely disintegrated cells of various algae. According to our observations, there is a direct relationship between their content in the stomachs and in the feces. When food is abundant, particularly in spring, the mollusks probably have an easier time assimilating cells with soft membranes which abound in the plankton at that time, while the cells with thicker membranes are partially excreted undigested, whereas they are encountered fully disintegrated in the stomachs during the other seasons.

UDC 594.117(265.54)

The growth of different generations of the Yezo scallop

by A.V. Silina and L.A. Pozdnakova (IBM DVNTs AN SSSR)

Age groups were distinguished on the basis of the annuli on the valves of *Patinopecten yessoensis* from Peter the Great Gulf and Olga Bay in the Sea of Japan. The method of reverse (294) computation was used to determine the height of the shell of each individual in the preceding years. The height was measured by the surface of the upper valve of the shell from its apex to the point of concentration of the growth lines that form annually during the summer when the water temperature in the bottom layer exceeds 16-18°C (end of July—August). The average values of shell height in each age group of the Yezo scallop were calculated for each generation separately, and for the entire population (based on all the individuals of a sample).

Some generations were extremely scanty due to the unfavourable conditions for spawning or larval development in this area during the year of hatching (up to 0-1% of the sample); other generations dominated in the population (55 of the 204 specimens). We encountered populations of relatively young scallops (mainly of 4—7-year-old individuals) in Andreyev Bay of the Ussuri Gulf, in Lake Vtoroye of Nakhodka Bay and in Starka Strait of the Amur Gulf, and populations of old individuals (mostly 8-12 years old) in Olga Bay and near the Stenin and Bolshoi Pelis islands of the Amur Gulf. The oldest (18—20-year-old) scallops were found in Olga Bay, and 15-year-old individuals were found near the Stenin and Bolshoi Pelis islands of the Amur Gulf.

The growth curves of the different generations in the same population differ with the age (juvenile or mature stage) at which the habitat was conducive or detrimental to their growth. The growth rate and size of the yearlings are particularly variable, depending on the periods and conditions of spawning, development and settling of the larvae. After periods of inhibited or accelerated growth, the growth process usually levels off somewhat.

The linear growth of the young and old generations of scallops differs noticeably. For instance, in the old scallops (for the population of this area) in Lake Vtoroye of Olga Bay and in Lazurnaya Bay of the Ussuri Gulf, the height of the shell from the age of 2-3 years is less than the average values in each age group calculated for all the scallops of the population. It may be that certain abiotic or biotic conditions in these areas do not allow the large individuals to survive. For example, it is more difficult for them to remain on the surface of a soft muddy substrate (as in Lake Vtoroye of Nakhodka Bay). In the Vityaz' inlet of Posyet Bay and in the vicinity of Stenin Is. where the bottom is sandy or sand mixed with mud, the old 11—13-year-old scallops are mostly large.

(295)

UDC 594.1:574.5.001.8

Linear growth of some marine bivalve mollusks from the family Veneridae

by A.V. Silina and A.M. Popov (IBM DVNTs AN SSSR)

Ruditapes philippinarum is a subtropical-lower boreal Pacific Asian species. It is a commercial bivalve mollusk which has been cultivated in Japan for over 30 years; it is also being successfully cultivated off the Pacific coast of North America.

This paper discusses methods of studying the linear growth of this species, and examines its growth in some areas of Peter the Great Gulf of the Sea of Japan.

Dark-gray and light-gray concentric striae are clearly seen on the outer surface of both valves in *R. philippinarum*. It has been established that the dark striae are formed in winter. Microscopic examination of radial cuts (from the apex to the lower margin) after polishing revealed that the valve was composed of two layers, the outer one lighter than the inner one. During the formation of the winter stria, the inner dark layer penetrates the outer light layer. During microscopic examination of acetate replicas prepared from shell sections in oblique transmitted light with 50—250-fold magnification, the elementary layers of growth can be discerned. They are wider in the parts of the shell formed in summer, and considerably narrower closer to the winter ring and in the ring itself (dark in the cross-section of the shell).

This method enabled us to establish the age and rate of linear growth in R. philippinarum from two sectors of Vostok Bay and from the Ussuri Gulf. R. philippinarum displays the slowest rate of growth in the most freshened area (at the mouth of the Volchanka R.) both in the first years of life, and at a more mature age. For example, the height of its shell is 5.6±0.3 mm at the age of one year, 9.8±0.6 at two years, 13.0±0.7 at three years, 15.3±1.1 at four years, and 17.1±1.4 mm at five years. Farther from the mouth of this river, in Vostok Bay, the linear growth rate of these mollusks is noticeably higher, particularly during the first two years of life. The highest growth rate is (296) noted in the third study area, the Ussuri Gulf, which is more open than Vostok Bay. The growth rate of these mollusks is particularly high after the age of 3 years. For example, the height of the shell in the mollusks of this area measures 19.0±0.8 mm at the age of three years, 23.4±0.9 mm at 4 years, and 26.8±0.8 and 29.5±0.9 mm at 5 and 6 years respectively. The marketable size of this species (according to Japanese authors) is 30x20 mm; this size is attained in 6 years in the first area, and in 3-4 years in the Ussuri Gulf. The largest specimen encountere by us in the Ussuri Gulf measured 53x37 mm at the age of 10 years. The largest specimens from Vostok Bay (near the mouth of the Volchanka R.) measured 36x25 mm at 13 years, and 46x32 mm at 15 years.

The same methods were used to study the linear growth of the shell in *Protothaca jedoensis*, a subtropical Pacific Asian species, and *P. euglypta*, a lower boreal Pacific Asian species. *P. jedoensis* has a much higher growth rate than *P. philippinarum* in the Ussuri Gulf. The height of its shell is 9.0±0.5 mm at the age of one year, 18.3±0.5 mm at two years, 25.8±0.7 at three years, 31.3±0.8 mm at four years, and 34.8±1.0 mm at five years. The growth of *P. euglypta* is significantly slower than in the other two species. The growth of this species is practically the same off Furugelm Is. of Posyet Bay in the Ussuri Gulf. The height of its shell measures 6.9±0.5 mm after the first year, 16.3±0.7 mm at 3 years, and 22.9±0.8 mm at 5 years.

UDC 594.141

Developmental characteristics of the reproductive system in the freshwater mussel *Unio tumidus* from the cooler reservoir of the Lithuanian State Regional Electric Power Plant (SREPP)

by D.P. Sinyavichene (IZIP AN LitSSR)

We studied the dynamics of the gonadosomatic index (GSI) and the reproductive periods of one of the commercial mollusks, the freshwater mussel, due to the environmental changes effected by the thermal loads in the cooler reservoir. (297)

The work carried out in 1982-1985 to study the gonads during different periods of the reproductive cycle and the dynamics of the gonadosomatic index of different age groups of *Unio tumidus* from the warm waters of the cooler reservoir of the Lithuanian SREPP, as well as from the natural biotopes of the Shventoyi R.

and Lake Dringis, has shown that the altered thermal regime causes changes in some of the stages of oocyte development, which leads to more intensive vitellogenesis. In maturing females from the reservoir, oocytes of the older generation reach their ultimate size in the middle of February with an average diameter of 169 μm. At this time, the gonads of *Unio tumidus* from the Shventoyi R. and Lake Dringis are in a state of relative sexual inertia. The oocytes in the river and lake mussels attain their definitive size at the end of April. Their diameter measures 194 μm.

Mass spawning of the freshwater mussel in the zone of strong warm water influence takes place from the middle of March up to the end of May at a water temperature of 22.4–25.5°C. This is several months earlier than in the natural environments of the Shventoyi R. and Lake Dringis. The *Unio tumidus* from the Shventoyi R. begin to spawn at the end of April—beginning of May at a water temperature of 9.0–11.2°C.

During the year, the GSI varies from 2.3 to 29.5 in the reservoir, and from 2.6 to 38.6% in the Shventoyi R. The GSI reaches its maximum value just before spawning, when most of the gametes are represented by oocytes at the 4th stage of maturity, and the minimum value during the period of relative rest. Similar GSI values are also noted in the mussels from Lake Dringis. The GSI of the ovaries in maturing individuals averages 36.4% in May.

A comparison of the results of our investigations on the dynamics of the GSI and the period of reproduction has brought us to the conclusion that the gametes in *Unio tumidus* mature earlier at higher temperatures, while the relative mass of the gonads prior to spawning is smaller than in natural bodies of water (Shventoyi R. and Lake Dringis). It is typical for the mussels of the cooler reservoir to spawn in several batches. As we know, the normal development and maturation of the reproductive system from one spawning to the next calls for a certain sum of effective temperatures. This sum of effective temperatures amounts to 2914 degree-days for the mussels found in natural habitats in the Shventoyi R., and 55,704 degree-days for those inhabiting the cooler reservoir.

UDC 594.124 (298)

Monitoring the functional state of mussels by the change in the motor activity of the valves under normal conditions and during exposure to toxicants

by L.N. Slatina (INBYuM)

The mobility of any animal is an important physiological indicator of its functional state. Proceeding from the fact that the mussel belongs to the filtering hydrobionts, we can assume that it is quite sensitive to changes in the chemical composition of the water. The purpose of our investigation was to examine the importance of the group of sulphur-containing proteins in the regulation of the periodic activity of the mussel valves. The periodic activity of the valves was recorded on the ribbon of a 24-hour drum of a modified hydrometeorological barograph. The sulfhydryl groups were blocked with thiolic toxins, i.e. cadmium chloride and the sodium salt of p-chloromercuty benzoate (PCMB) in concentrations of $1 \cdot 10^{-6}$–$1 \cdot 10^{-4}$ g/ml, and the normal condition was restored with cysteine in a concentration of $1 \cdot 10^{-5}$–$1 \cdot 10^{-6}$ g/ml.

Our experiments showed that the blocking of the sulfhydryl groups alters the rhythm of the periodic activity of the valves. With a $1 \cdot 10^{-6}$ g/ml concentration of $CdCl_2$, we began to observe a change in the rhythm 7 hour after exposure to the chemical. The valves remained open for a long time, and closed for a brief period. Exposure to a concentration of $1 \cdot 10^{-5}$ g/ml of $CdCl_2$ altered the rhythm of the valves after 3-4 hours. The valve closure curve acquired an absolutely atypical form, the resting period varying from 45 min to 1 hour. With a concentration of $1 \cdot 10^{-4}$ g/ml, the resting periods became shorter, and the valves remained open and tense. The animals died when kept in this solution for more than 24 hours. Similar results were obtained when PCMB was added to the water. Whereas the results of our experiments were brought on by the blocking of the sulfhydryl groups, the addition of cysteine to the water produced the opposite effect. Cysteine neutralized the effect of the thiolic (299) toxins. The effect of cysteine was noted only after 7 hours of exposure to it; before that, we noted only the aftereffect of PCMB and $CdCl_2$. The results of our experiments indicate that the rhythm of the periodic activity of the valves in mussels is greatly affected by the state of the sulphur-containing ligands of proteins, the blocking of which alters the rhythm of valve activity, while the restoration of it restores the initial normal rhythm of activity.

Thus, our experiments have demonstrated the toxic effect of minimum biologically active concentrations of $CdCl_2$ and PCMB on the functional state of Black Sea mussels. Our investigations have shown that a concentration of 10^{-6} g/ml can alter the normal rhythm of the motor activity of the mollusks. The results of our investigation can be applied as a comparatively simple and sensitive biological test for the purpose of monitoring the quality of the water; biologically active substances (amino acids) can also be used to activate the protective physiological and biochemical reactions of mussels exposed to unfavourable environmental factors.

UDC 594.124

Variability of the growth rate of *Mytilus edulis* within its area of distribution

by I.N. Soldatova (IOAN)

A comparative study of the growth rate of *Mytilus edulis* in different parts of its range and different biotopes has been carried out on the basis of our own data (Sea of Japan) and the literature (northwestern part of the Atlantic Ocean, straits of Denmark, the North Sea, the Barents Sea and the White Sea). Linear growth was described with the help of Bertalanffy's equation $\mathbf{l(t)} = \mathbf{L_\infty(1-e^{-kt})}$, where $\mathbf{l(t)}$ denotes the length of the shell (mm), $\mathbf{L_\infty}$ the definitive size (mm), $\mathbf{k}$ the growth rate factor, and $\mathbf{t}$ time (years). The overall variability range of $\mathbf{k}$ differs by almost an order of magnitude (0.10-1.10). Its average value for the benthic sublittoral mollusk colonies in the centre of the range (straits of Denmark, North Sea) is in the neighbourhood of

(300)

0.4. The same value is also characteristic of the populations at the southeastern boundary of the *Mytilus edulis* range (Peter the Great Gulf, Sea of Japan). The minimum value of **k** (0.1-0.13) is noted at the northwestern outskirt of the range (coast of Greenland). The mussels found in the littoral zone are characterized by a smaller rate of growth than in the sublittoral zone. For example, the difference is 3—4-fold in the North Sea. The transition from the benthic zone to the "pelagic" zone (periphyton) stimulates the growth rate. Our own observations have shown that the value of **k** is 24% higher and L 17% higher in the Sea of Japan mussel from the periphyton as compared with mussels from the benthic zone. The differences in the growth rate are greatest in the spat and young sexually mature animals. The higher than usual rate of growth in the "pelagial" is due to the favourable hydrodynamic conditions. This is precisely why the growth rate is highest in the "pelagial" during mussel cultivation (**k** = 1.1; North Sea). The temperature determines the duration of growth throughout the year, which varies almost 3-fold, from 3-4 months in Greenland waters to 10-11 months in Copenhagen Bay.

This mollusk is also characterized by a high variability of the relative rate of growth in length, height and width, which leads to significant differences in the form of the shell in different areas.

UDC 594.124 (262.5)

Seasonal variations in the rate of energy metabolism in the Black Sea mussel (*Mytilus galloprovincialis*)

by V.V. Timofeyev (AzCherNIRO)

In order to expand commercial cultivation of mussels in the Black Sea, we must study various aspects of the life of this species.

The purpose of this investigation was to study the rate of the energy metabolism of this species at different times of the year.

The material was collected from the pier foulings in the Kerch Strait during 1984-1985. Mussels measuring 11-73 mm and weighing 0.05-36.7 g were kept for a day in water matching the natural habitat. The rate of oxygen consumption was determined by Winkler's method of closed vessels. The relationship between the amount of consumed oxygen and body weight was approximated by the exponential equation $\mathbf{Q} = \mathbf{a} \cdot \mathbf{W}^{\mathbf{k}}$, where $\mathbf{Q}$ denotes the rate of oxygen consumption by the mussel ($ml \cdot h^{-1}$), $\mathbf{W}$ the mass of the mollusk (g), and "a" and "k" are equation parameters. (301)

Our investigations have shown that significant changes in the level of consumed oxygen take place throughout the year. The level of metabolism is the lowest in winter. With an increase in water temperature, the rate of the metabolic processes also increases. The highest rate of energy metabolism is attained in spring, during the maturation of the gonads, at a temperature of 14-15^{o}C. At this time, the coefficients "a" and "k" are equal to 0.632 and 0.809 per gram dry weight of the soft tissues respectively. After spawning, the rate of oxygen consumption was lower than at 14-15°C, despite the increase in temperature. Consequently, the intensity of energy metabolism is determined largely by the condition of the reproductive system.

At a temperature exceeding 20°C, the intensity of energy metabolism decreases, and in the equation correlating the rate of oxygen consumption and weight we note a decrease not only in the coefficient "a", but also in the exponential coefficient "k" which is equal to only 0.585 at 22°C (in July).

Thus, the optimal temperature for the active life of the Black Sea mussel is close to 20°C, which is typical of boreal species. This information can be of use in the selection of sites for mussel farms.

UDC 594.124(262.5) (302)

Biochemical polymorphism based on 6-PGD in the Black Sea mussel *Mytilus galloprovincialis*

by Yu.A. Uss (INBYuM)

The polymorphism of the principal commercial mollusk and main item of mariculture in the Black Sea, *Mytilus galloprovincialis*, must be studied in order to organize an efficient mussel industry and develop a selective approach to the process of cultivation.

The 6-PGD spectrum was analyzed in 540 specimens by electrophoresis in a vertical block of polyacrylamide gel. The mussels were collected in different areas of the Black Sea; they included rock mussels (126) and mud mussels (90) from the Laspi-Batiliman Bay area, rock mussels (129) from the Sevastopol area, and mud mussels (200) from the region of the Golitsin seamounts.

The spectrum of the given enzyme is genetically determined by a single locus, and is dictated by the combination of the 3 co-dominant alleles A, B and C (in diminishing order of mobility). The locus of 6-PGD in Mytilus galloprovincialis is polymorphic (95% criterion). The frequency of the dominant allele "B" varies from 0.927 to 0.949 in different samples. The frequencies of alleles "A" and "C" vary from 0.0155 to 0.025 and from 0.0275-0.0725 in different samples. A comparison of the correspondence of the theoretical and empirical distributions based on criterion x^2 has shown that the distribution of the specific genotypes corresponds to the Hardy-Weinberg principle, which has confirmed the hypothesis on the genetic basis of the characteristic and the correctness of its genotyping.

The x^2 heterogeneity test (Workman, Niswander, 1970) for assessing the significance of the differences between several samples has demonstrated the presence of heterogeneity in the allele frequencies ($x^2=7.955$; $x^2_{0.05}=7.8$) and homogeneity in the genotypic frequencies ($x^2=4.851$, $x^2_{0.05}=7.8$).

A comparison of the mud and rock forms on the basis of the mean values of the genotypic and allelic frequencies with the help of the x^2 heterogeneity test has shown that they do not differ on the whole, either in the allele frequencies ($x^2=0.186$, $x^2_{0.05}=3.8$), or in the genotypic frequencies ($x^2=0.849$, $x^2_{0.05}=3.8$).

The average heterozygosity for the given locus is $0.100\pm$ (303)
0.004. In two samples (rock mussels from Batiliman Bay and mud mussels from the Gokitsin seamount), we observe a small shortage of heterozygotes (0.054 and 0.0725 respectively).

Improvement of the separation procedure enabled us to differentiate (in addition to the three main alleles) another three alleles in a heterozygous state with a frequency of 0.0025-0.0039 in three samples, i.e. Batiliman (rock and mud populations) and from the Golitsyn area.

When comparing the frequencies of the heterozygotes and homozygotes in three size groups from different areas (20.0-40.0 mm, 40.1-50.0 mm and 50.1 mm and over), we observed a tendency towards a decrease in the frequency of the heterozygotes and an increase in the frequency of the homozygotes with an increase in size.

UDC 594.124+639.42:574.5:(574.5:57.08)

Biological deposits of cultivated mussels

by Yu.A. Uss, V.K. Shalyapin and M.V. Nekhoroshev
(INBYuM)

Due to the organization of different types of maricultural establishments, it is necessary to assess their potential effect on coastal ecosystems. With this aim in view, we studied the accumulation of biological deposits of mussels and their composition in the vicinity of the INBYuM mussel farm (Academy of Sciences of the Ukrainian SSR).

The apparatuses for collecting the biological deposits were placed in the corner part of the plantation leeward to the existing insignificant current (3-6 cm/s). The turbulence in the bay did not exceed 1-2 points, and the water temperature during the experiment varied from 16.9 to 17.2°C. Hydrometeorological conditions such as these can be regarded as close to optimal for field experiments of this type.

The apparatuses for collecting biological deposits (special design) were placed in two points 10 m apart under collectors 8 m in length. Samples of the biological deposits of the mussels were collected 5 times over a period of 26 hours. On the basis of these data, we calculated the rate of accumulation of the bio- (304)
logical deposits, which constituted 5.3±2.1 mg dry wt/h·m^2 for the first point, and 6.3±2.8 mg/h·m^2 for the second point. The percentage of proteins in the biological deposits amounted to 2.5±0.7 dry wt, while the percentage of carbohydrates and lipids amounted to 0.9±0.2.

The mussel farm covers an area of 2660 m^2. Consequently, the biological deposits of the mussels provide a minimum 8.6±3.5 g of protein and 3.1±1.2 g of carbohydrates and lipids daily.

UDC 639.446:594.124:620.193.8(265.54)

The importance of *Mytilus edulis* found in the fouling of plantation equipment to the tray cultivation of scallops in Peter the Great Gulf (Sea of Japan)

by V.I. Fadeyev and I.A. Kashin (IBM DVNTs)

The commercial species of mussel *Mytilus edulis* is an important component of the fouling of anthropogenic substrates (vessels, wharves, buoys) in the coastal waters of Peter the Great Gulf. Despite its high biomass (up to 50 kg/m^2), the mussels from the fouling of anthropogenic substrates are difficult to utilize due to the fact that these animals can accumulate the toxic substances contained in the anticorrosive and antifouling agents used to protect these structures. The intensive development of mariculture in Peter the Great Gulf has led to an increase in the area occupied by hydrobiotechnical structures (HBTS) for suspended cultivation of hydrobionts. Highly toxic agents are not used as protective coverings for HBTSs.

The composition and intensity of the fouling of HBTSs and the role of this species as a structural component of the periphyton were studied at experimental and commercial plantations in three parts of Peter the Great Gulf: Alekseyev Bay (Popov Is.), Nerpa inlet (Slavyansky Bay) and Vityaz' inlet (Posyet Bay). We examined the fouling of the cultivation equipment (trays of different design, collectors) and the elements of the supporting HBTS (buoys, ropes and anchors). The given HBTSs differed in the (305) degree of protection from wave action (protection of HBTSs from wave action increased in the order Vityaz' Bay—Slavyansky Bay—Alekseyev Bay) and the depth at which the cultivation equipment was placed (at depths of up to 15-18 m in Alekseyev and Slavyansky bays, and at depths of up to 20-26 m in the vicinity of Vityaz' Bay).

Mytilus edulis was found in the fouling of both the cultivation equipment, and in the elements of the supporting HBTS at all the depths studied. In the three areas examined, it is the dominant component of the periphyton up to a depth of 12-15 m (in biomass and the density of the population). The maximum values of biomass are noted at depths from 0 to 5-7 m. For example, it amounts to 3360 g/m^2 on floating objects in Alekseyev Bay (89% of the total biomass of the periphyton), and averages 400 g/m in the fouling of the ropes (50% of the biomass of the periphyton). The biomass of *Mytilus edulis* on the cultivation elements varied from 400 to 3400 g/m^2, depending on the depth and location of the HBTS. The biomass and density of the mussel population tends to decrease with the degree of protection of the HBTS from wave action. For example, the biomass of *Mytilus edulis* amounts to 1800 g/m^2 in the fouling of the trays at a depth of 5-7 m in the most unprotected area (Vityaz' Bay), and 3350 g/m^2 at the same depth in the most protected area (Alekseyev Bay). A decrease in biomass is also noted in the same area with an increase in depth. The biomass of *Mytilus edulis* decreases from 3350 g/m^2 (depth 5-7 m) to 1200 g/m^2 (16-19 m) in Alekseyev Bay, and from 1840 g/m^2 (5-7 m) to 270 g/m^2 (14-16 m) in Vityaz' Bay.

Mass development of this species in the fouling of HBTSs makes them much heavier, increases the irregularities of their elements, and this reduces their storm-resistance. When developing on the cultivation elements (where the density sometimes attains 10,000 specimens/m^2), *Mytilus edulis* competes with the scallop for food. At the same time, the common mussel from the fouling of HBTSs can be a bonus product during the cultivation of scallops. Depending on the design of the HBTS, from 400 to 900 kg of mussel can be collected from one scallop-breeding unit.

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UDC 594.124(262.5)

Quantitative characteristics of filter feeding in Black Sea mussels

by G.A. Finenko (INBYuM)

On the basis of an ecological-physiological study of the filter feeding in mussels, we have established the main tendencies that characterize the relationship between the filtering activity of the mussels and the biotic and abiotic factors.

We conducted a quantitative study of the relationship between the filtration rate and the total (as well as fresh and dry) mass of the soft tissues of the mussels at four temperatures (7, 11, 18 and 22°C). The degree of the dependence of the filtration rate on the mass of the mollusks (**m** in the parabolic equation $F=pW^m$) is fairly constant at all the temperatures studied, and is equal to 0.42-0.50, calculated in terms of dry mass of the tissues. The intensity of water filtration increases from 0.175 $l \cdot g^{-1} \cdot h^{-1}$ at 7° to 0.470 $l \cdot g^{-1} \cdot h^{-1}$ at 17°, and decreases to 0.168 $l \cdot g^{-1} \cdot h^{-1}$ at 22°C. The optimal filtering temperature in mussels lies within the 15-18° range.

The concentration of suspended matter is a major factor governing the rate of filtration and the consumption of food by the animals. At low concentrations (up to 3 $mg \cdot l^{-1}$), the rate of filtration increases; an increase in the amount of suspended matter from 3 to 7 mg/l^{-1} results in a decrease of the filtering activity of the animals to a certain minimum which remains constant with a further increase in concentration. The nature of the relationship between the rate of filtration and feeding conditions determines the amount of food consumed by the animals. The ration of the mussels increases with all the concentrations studied ($\approx$ up to 12 $mg \cdot l^{-1}$); the decrease in filtration at a concentration exceeding the "threshold" one slows down this process, and the ration attains a plateau at 3-5 $mg \cdot l^{-1}$ in small 2—5-gram mollusks. In large mussels (>10 g), even a relatively low rate of filtration leads to an increase in the ration at high food concentrations. The efficiency of assimilation of algae is high (70% of the ration), and does not depend on the size of the animals or concentration of food.

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In addition to live algae, mussels can actively filter phytogenic detritus and utilize it as food. The filter feeding on detritus is identical to feeding on algae, i.e. the nature of the organic material does not affect the filtering activity of the mollusks to any great extent. Algae and detritus should be regarded as a single food pool for filtering mollusks, a food pool which provides a more constant supply of energy than each of its components separately.

UDC 594.124+639.42(262.54)

The mussel stock in the Sea of Azov and its utilization in marine aquaculture

by L.N. Frolenko, M.Ya. Nekrasova and S.K. Spichak
(AzNIRKh)

The mussel was exceptionally rare in the Sea of Azov prior to regulation of the flow of the Don R. As a result of the latter, the waters of the sea became more saline, and the mollusk was provided with the optimal conditions for its development, and so it began to spread throughout the area of the sea. At first, it adapted to the areas with a high salinity (11.5-12.7‰) and compact substrates (Zhelezinskaya Bank, Kazantip areas and Biryuchy Islands).

In 1978, the total mussel stock amounted to 550,000 tons; mollusks of marketable size predominated in the population (62%, or 334,000 tons).

Due to lack of oxygen and freshening of the waters in 1979, the mussel stock decreased 3-fold to 180,000 tons, including 53,000 tons of marketable mussels (29% of the total population). High mussel losses were noted on Zhelezinskaya Bank (epicentre of asphyxiation).

Investigations in 1980 showed that the mussel stock in the Sea of Azov was being renewed after the 1979 losses, and the total stock was almost at the 1978 level. On the whole, the mussel stock for the entire sea amounted to 453,000 tons, and the commercial stock 116,000 tons. (308) The mussel stock in June 1981 remained at the 1980 level with a slight deviation towards an increase. The total mussel stock in 1982-1984 amounted to 240,000-280,000 tons, and the commercial stock 10,000-20,000 tons.

The high abundance of mussels in the Sea of Azov permits us to recommend 1/4-1/8 removal of the commercial stock. However, the use of the drag nets for this purpose destroys the benthic biocoenoses and depletes its natural stock. At the same time, the mussel banks are found in areas with the highest concentration of Azov fishes, and so the mussel industry can prove detrimental to the food supply and the entire habitat of the fishes in this zone. On the other hand, the experience of the Soviet Union and other countries in the development of maricultural establishments has shown that the mussel is a promising item of mariculture. However, the cultivation of the mussel as a seafood in the Sea of Azov is limited because of the absence of wintering grounds. In order to create the latter, the bottom of the bays and limans must be deepened.

The advantage of cultivating mussels as feed for other animals has been proven. A mussel farm for the production and cultivation of spat can be established in Obitochny Bay which covers an area of 5-10 hectares and yields an estimated 2000-4000 tons of underyearlings a year.

The recruitment of the mussel population is determined by the summer spawning, when up to 100 and more larvae settle on each 1 cm^2 of the collector.

Observations have shown that a salinity of not less than 11‰, a temperature of 20-25°C and a density of not more than 50 specimens/cm^2 can be regarded as optimal for the setting of larvae and the growth of the spat.

The setting of spat on collectors can yield up to 1000 tons/hectare under good conditions of growth, and 200 tons under poor conditions. The underyearlings collected can be used as feed for agricultural animals, or they can be transported as replants to parts of the Black Sea that do not freeze over, and raised to marketable size.

UDC 639.41:582.251.4 (309)

<u>Determination of the optimal concentration of food for the larvae of the Black Sea oyster *Ostrea edulis*</u>

by T.V. Khrebtova (AzCherNIRO)

During artificial cultivation of the Black Sea oyster, we studied the influence of *Pavlova lutheri* on the growth, survival and development of the larvae. The larvae from a single female oyster were raised for ten days under the conditions of low food concentration ($2 \cdot 10^4$ kl/ml), average food concentration ($4 \cdot 10^4$-

$5 \cdot 10^4$ kl/ml) and high food concentration ($6 \cdot 10^4$–10^5 kl/ml). The control larvae were not fed.

With a low concentration of food, the specific growth rate of the larvae was not high (0.0076). The highest specific growth rate (0.0121) was observed in larvae given an average concentration of food. With a further increase in the amount of food, the relative growth rate of the larvae was somewhat lower.

The survival rate of the larvae decreased as the amount of food increased ($r = -0.74$). During the first four days, a few (up to 5%) of the larvae died in all the variants of the experiment. This was followed by a high survival rate (4th–8th days), after which the mortality rate increased. At the end of the experiment, the survival of the control larvae amounted to 64%, which pointed to the high viability of the larvae of the given spawning period. With an average concentration of food, the survival rate of the larvae was relatively high (48–74%) and did not differ significantly from the control. A low survival rate (35–40%) was characteristic of the larvae raised on a high concentration of food. The differences between these data and the survival rate in the control are statistically significant ($P < 0.05$).

Larval development with low and high concentrations of food was slow and asynchronous. The yield of veliconchs amounted to 39% of the total number of larvae in the experiment. The maximum yield of veliconchs (86%) was noted with an average concentration of food. Practically no larval development was observed in the control (yield of veliconchs 1%).

The distribution of the larvae according to the length of the valves was normal in all the variants of the experiment (level of significance 5%). (310)

The behaviour of the larvae and their distribution over the cultivation equipment varied throughout the period of cultivation. With low and average concentrations of food, as well as in the control, the larvae kept mainly to the surface layer. With a high concentration of food, the larvae sank after 3-4 days to the bottom layer where their conditions worsened, i.e. pseudo-feces, food remains and the valves of dead larvae accumulated in this layer.

Thus, the optimal food concentration for oyster larvae varies from $4 \cdot 10^4$ to $5 \cdot 10^4$ cells/ml, which corresponds to 3.76-4.70 mg/l of P. lutheri algae calculated in terms of fresh biomass. At the same time, the food supply of the larvae is quite high, from $7 \cdot 10^3$ to $25 \cdot 10^3$ cells per larva. During artificial breeding of Black Sea oysters, we must adhere strictly to the optimal concentration of food for the larvae, and not overfeed them, since this would result in wasted food and contamination of the cultivation environment, as well as the suppression of the larvae themselves.

UDC 594.124(265.54)

Composition of trace elements in the soft tissues of the giant Pacific mussel (Crenomytilus grayanus) from Peter the Great Gulf

by N.K. Khristoforova, V.Ya. Kavun (Pacific Institute of Geography; IBM DVNTs AN SSSR)

Crenomytilus grayanus is one of the most common commercial mollusks in the Far East. However, we know very little about the composition of the trace elements of this mollusks, the soft tissues of which are wholly utilized as a food.

We are interested in the range of concentration of certain elements in the soft tissues of this mussel, some of which (Fe, Mn, Zn, Cu) are biologically important, while others (Cd, Pb) are toxicants which pollute the environment.

The mussels were collected in June 1982 (after the first wave (3.11) of spawning) at 11 stations varying in the level of anthropogenic intervention (from background to impact). From each station we selected 7-10 equal-sized individuals of both sexes, and analyzed each of them separately. The maximum length of the shells varied from 11.9 to 13.8 cm, which corresponds to an age of 14-23 years. Sampling of the mollusks was repeated in June 1983.

The table below gives the minimum and maximum content of the elements in the bay mollusks, as well as the range of the most common (modal) values of their concentrations.

Compared with the oysters which are known to accumulate copper and zinc (up to hundreds and thousands of μg/g), as well as scallops which accumulate cadmium (up to tens and hundreds of μg/g), *Crenomytilus grayanus* can be called "moderate concentrators", which is apparently due to their low level of metabolism, characteristics of biochemical organization and low rate of growth. Only the concentrations of iron and zinc are significant in these mussels (tens of µg/g); even the maximum contents of Mn, Cu, Cd and Pb do not exceed 10 µg/g.

Concentrations of trace elements, µg/g dry weight

	Fe	Mn	Zn	Cu	Cd	Pb
			June 1982			
Maximum	42.3–110.3	1.6–6.6	68.1–92.3	3.1–7.3	2.6–7.9	2.1–3.7
Modal	61.8–85.0	2.1–3.4	73.0–88.0	4.4–5.5	3.8–5.8	2.5–3.3
In dumping area	229.7	650.8	247.0	15.9	64.0	5.0
			June 1983			
Maximum	119–201	2.3–92	81.3–134	4.9–7.8	4.2–15.5	–
Modal	137–165	4.2–6.1	93.0–121.0	5.7–6.5	6.3–9.7	–

However, in the zone of extreme anthropogenic pressure (e.g. a dumping area), the concentrations of these elements in the mussels increase remarkably (several-fold for Fe, Cu, Zn and Pb, by and order of magnitude for Cd, and by 2 orders of magnitude for Mn).

The second sampling in June 1983, which was characterized (312)
by different hydrochemical conditions and turbidity of the bay waters, altered our idea regarding the content of trace elements in these mollusks. The basic range of their concentrations in the soft tissues of Crenomytilus grayanus increased in 1983 as compared with 1982 (approximately 2-fold for Fe and Mn, 1.3-fold for Zn and Cu, and 1.6-fold for Cd).

UDC 594.117+639.446(265.54)

Mineral composition of the scallop cultivated in the Maritime Territory (Primor'ye)

by N.K. Khristoforova, L.G. Makhnyr' and Ye.N. Chernova
(Pacific Institute of Geography, DVNTs AN SSSR)

The Yezo scallop has been the object of commercial utilization and artificial breeding for a long time. In Peter the Great Gulf, it is cultivated in Alekseyev Bay (Popov Is.), Severnaya Bay (Slavyanka Gulf) and Minonosok Bay (Posyet Gulf). The purpose of this investigations (sanctioned by TINRO) was to study the mineral composition of tray and bottom cultures of mollusks from different maricultural establishments, and to establish the age and sexual differences of the scallops, as well as the content of trace elements in their tissues in relation to the chemicoecological differences of their habitats.

The table below gives the average concentrations of iron, manganese, zinc, copper and cadmium (μg/g dry wt) in the soft tissues as a whole, in the liver, gonads and in the muscles of scallops collected in May 1982.

In the mollusks replanted on the bottom, the highest content of elements in the whole tissues is characteristic of the scallops from Severnaya Bay. This is particularly evident from the concentration of metals in the liver. The most perceptible in the liver of these scallops is the increase of the cadmium content; it is about twice as high as in Alekseyeva Bay and 1.5 times higher than in Minonosok Bay. However, this does not affect the content of cadmium in the muscles of either the females or the

(313)

males collected on the bottom (cadmium concentration less than 1 μg/g). On the whole, the muscles also have a low content of manganese and copper. Only the content of iron, and especially zinc, amounts to tens and even hundreds of μg/g equally in the bottom and tray cultures of scallops.

Sampling site	Age, conditions	Sex	Organ	Fe	Mn	Zn	Cu	Cd
Popov Is., Alekseyev Bay	4 years bottom	♂	whole	327.4	4.0	73.7	5.4	14.1
			liver	604.2	5.0	106.2	8.1	57.2
			gonads	122.3	4.0	44.7	4.9	1.5
			muscle	4.5	4.0	53.6	2.0	1.0
		♀	whole	436.1	7.6	133.2	7.1	8.0
			liver	649.3	7.5	105.8	19.1	53.6
			gonads	121.7	10.0	175.0	10.9	2.1
			muscle	28.0	4.0	59.2	9.2	2.2
	2 years trays	♂	whole	232.5	4.6	108.4	7.7	7.6
			muscle	21.0	4.0	69.1	2.0	1.0
Slavyanka Gulf, Severnaya Bay	5 years bottom		whole	705.8	9.8	87.3	12.5	34.5
			liver	1004.6	14.3	147.0	22.2	102.6
			gonads	192.9	4.6	68.6	4.4	1.2
			muscle	14.8	4.0	59.7	2.0	1.0
		♀	whole	1096.8	20.4	123.1	9.5	24.9
			liver	879.2	18.6	148.6	21.3	101.6
			gonads	215.6	13.6	176.6	10.0	2.3
			muscle	38.4	4.0	56.5	2.0	1.0
	2 years trays		whole	181.0	5.8	206.0	4.5	21.3
			liver	540.3	13.7	179.0	15.1	53.5
			muscle	33.1	4.0	112.3	2.0	4.8
Posyet Gulf, Minonosok Bay	3 years bottom	♂	whole	109.4	5.0	79.2	4.4	5.2
			liver	742.0	7.1	80.2	26.8	73.4
			gonads	138.3	4.0	46.3	4.9	1.0
			muscle	29.7	4.0	55.1	2.0	1.0
		♀	whole	326.8	5.4	97.5	2.0	9.2
			liver	495.3	4.0	95.1	17.7	77.6
			gonads	123.7	14.6	196.6	10.0	2.3
			muscle	35.0	4.0	74.6	2.0	1.0
	1 year trays		whole	178.2	6.2	102.8	5.2	12.5
			muscle	18.8	4.0	56.5	2.0	1.6

Despite their high rate of metabolism, the young tray scallops are characterized by a lower content of minerals, which is apparently due to their considerable distance from the bottom and to the lower penetration of the mantle cavity by suspended mineral particles, as well as to their sexual immaturity. (314)

As for the sexual differences in the mineral content of the entire soft tissues of the scallops, they are clearly defined for iron, manganese and zinc in all the cases, i.e. the concentrations of these elements are higher in the females. However, analysis of the gonads has shown that copper and cadmium also always prevail in the reproductive organs of the females.

UDC 639.42:(574.5:57.08)

Methods of determining trophic characteristics in mussels

by Ye.A. Tsikhon-Lukanina (IOAN)

The determination of trophic characteristics such as food composition, the rate of food consumption and food assimilability is an important prerequisite of successful mussel farming and the development of the theory on ecosystems.

Food composition should be analyzed in animals recently removed from a body of water, not in fixed animals. The food sample should be taken from the anterior region of the digestive tract, since the digestive diverticula fall into the stomach; small food particles do not actually find their way into the intestine. The factor of trophic significance (**I**, %) is best calculated by the equation

$$\mathbf{I} = (\mathbf{V} + \mathbf{w})/2 \qquad (1)$$

where **V** (%) is the relative value of the food component, and w (%) its frequency of occurrence. It is also necessary to observe the food capturing mechanism in mussels of different ages, beginning with recently settled ones.

The rate of food consumption (C) can be determined by the equation

$$\mathbf{C} = \mathbf{F} \cdot \mathbf{V}/(1-\mathbf{a}) \qquad (2)$$

where **F** denotes the fullness of the digestive tract of the recently caught animal, **V** the frequency of fullness, and **a** food assimilability.

Food assimilability (**a**) is examined by the direct method using the equation (315)

$$\mathbf{a} = \frac{\mathbf{c}^1 - \mathbf{F}^1}{\mathbf{c}^1} \cdot 100 \qquad (3)$$

where $\mathbf{c}^1$ is the amount of food consumed, and $\mathbf{F}^1$ is the amount of indigested food. Either seston concentrated on a membrane filter or a filtrate of periphytic organisms and detritus from rocks along the coast or from macrophytes can be used as food. At first, the large organisms are removed by filtering the suspension through gauze No. 38.

The advantage of the recommended methods of studying the trophic characteristics is that their values are determined on the natural food consumed by the mussel in its natural environment.

UDC 594.124:620.193.8:626.88(262.5)

Role of the mussel in the circulation of matter in the coastal waters of the Black Sea

by Ye.A. Tsikhon-Lukanina, T.A. Lukasheva and G.G. Nikolayeva (IOAN)

The everincreasing area of anthropogenic substrates in the seas and oceans has made it necessary to study their fouling. Mussels constitute the main form of macrofouling on these substrates in the coastal zone. They are the most active elements of the communities that form on anthropogenic substrates. We, therefore, decided to study their colonies in one of the areas of the Black Sea (Rybatskaya Bay) where numerous hydraulic structures have been built over the past ten years (1974-1984).

We determined the indices characterizing the mussel population (on 1 m^2) on anthropogenic substrates in 1974 and 1984. We found that the average mass of one individual had decreased 3-fold, and the biomass 2-fold. The density of the population had increased almost 1.5-fold. The smallest individuals are the most abundant in the population at present, not like in 1974 when the mussels of average weight prevailed; the largest individuals formed the maximum biomass during both these years. The largest quantity of food is currently consumed by the spat and mussels of (316)
average weight, instead of by the medium-sized and large mussels as in 1974. The total amount of food consumed from 1 m^2 was virtually the same in 1974 and 1984.

The area of anthropogenic substrates in the bay has increased from 20.0 to 212.5 m^2 over the past ten years. As our calculations have shown, the mussels consumed 1.5 tons of seston in dry weight, or 12.2 t in fresh weight, in 1974, and 15.0 t and 124.8 t respectively in 1984. The proportionality of the increase in the area of anthropogenic substrates and the total consumption of seston by the mussels indicates that the development of the mussel population is limited not by the quantity of food, but by the presence of anthropogenic substrates. Consequently, the introduction of the latter into coastal waters promotes an increase in the numbers of mussels and, as a result, more rapid circulation of matter in the bay.

UDC 594.117:(574.5:615.9)

Effect of cadmium on the metabolism of membrane lipids in the tissues of *Patinopecten yessoensis*

by V.P. Chelomin, N.N. Bel'cheva and Z.S. Yevtushenko
(Pacific Ocean Inst., IBM DVNTs AN SSSR)

We studied the effect of cadmium on the composition and metabolism of membrane lipids (nucleus, mitochondrium, endoplasmatic reticulum) of the cells of the liver and gills in *Patinopecten yessoensis*, a commercial marine mollusk. Exposure of the animals for a month to an environment containing up to 2.5 μM of cadmium did not lead to any significant changes in the composition of the main lipids of the mitochondrial membranes, but there were some variations in the content of phosphatidylcholine, phosphatidylserine and phosphatidylinosite in the microsomal membranes of the gill cells. As experiments with (^{14}C)-acetate have shown, the rate of membrane lipid metabolism was greatly suppressed in the animals exposed to cadmium. The inhibition of (^{14}C)-acetate incorporation tino individual lipids (cholesterol, fatty acids, phosphatidylcholine, ceramide aminoethylphosphonate, phosphatidylserine and phosphatidylinosite) bears a clearly defined membrane and tissue specificity. The rate of metabolism of microsomal lipids in the cells of the gills was suppressed to a greater extent than in the mitochondria. The incorporation of (^{14}C)-acetate into microsomal lipids (phospholipids, cholesterol, fatty acids) decreased by 40-50% in the experimental animals, whereas it decreased by 20% in the mitochondrial lipids. The inhibition of membrane lipid metabolism was also observed to the same extent in the cells of the liver. In the microsomes of the liver, the suppression of (^{14}C)-acetate incorporation into cholesterol and fatty acids was much less evident than in the nuclear and mitochondrial membranes. (317)

The distribution of (^{14}C)-acetate in the individual phospholipid classes has shown that cadmium in the cells of the gills suppresses the biosynthesis of ceramide aminoethylphosphonates, phosphatidylserine and phosphatidylinosite to a greater extent than it suppresses the main phospholipids (phosphatidylcholine and phosphatidylethanolamine). The opposite is noted in the case of the liver cells.

UDC 594.124(265.54)

Dynamics of spatfall in the common mussel (*Mytilus edulis*) in Vostok Bay of the Sea of Japan

by M.Zh. Chernyayev (IBM DVNTs)

During July-September 1984, we collected material on the settling of *Mytilus edulis* larvae in Vostok Bay of the Sea of Japan, using experimental collectors consisting of 300 m lengths of 50 mm capron cable (area 150 cm^2), interconnected in a series by means of fish line. From the moment the larvae began to settle on the substrate, the collectors were removed every ten days, and the mollusks on each of the 8 lengths at a depth of 1-8 m counted and measured in length. The results were used for analyzing the size structure of the spat, and for deriving information on the dynamics of abundance, the rate of settling and the survival of the larvae.

The settling of larvae onto the experimental collectors began on July 1st at a surface water temperature of 13.3°C, and lasted (318) up to the beginning of September. Analysis of the dynamics of spatting has shown that the maximum number of larvae settled on the substrate during the first 20 days of July at all the depths, with significant quantitative differences noted for the different depths. For example, the maximum numbers of larvae settling during the second ten days of July amounted to 227, 305 and 146 at the 1 m, 4 m and 8 m depths respectively. The general nature of the vertical distribution of the mollusks indicates that the settling of larvae was the most intensive at a depth of 4-6 m. Beginning with the third 10-day period of July, the numbers of spat sharply decreased at all the depths. The survival rate of the larvae that settled on the model substrates in 3 months varied from 13% at a depth of 4 m to 54% at a depth of 2 m. The substantial elimination of larvae during this period may be due to natural mortality, predators and "flotation", i.e. the ability of the mollusks to change their biotope at the postlarval stage. Natural mortality was not observed at any of the depths, since our samples did not contain any valves from dead mollusks. The design of the experimental collectors virtually eliminated the vertical migration of the settled larvae. Young mussels were found in the stomach of the gray triggerfish, a potential predator that affects the abundance of mussels. The decrease in mussel abundance due to "flotation", as well as the possibility of this process, have not been researched yet.

Consequently, the settling of mussel larvae in Vostok Bay is characterized by one peak of abundance, which transcends into the second ten days of July; at the same time, the total abundance of settled mussels greatly depends on the depth of the substrates.

UDC 594.124(262.5)

(319)

Age structure of mussel populations in the northwestern part of the Black Sea

by N.M. Shurova (Odessa branch of INBYuM)

Black Sea mussels of the species *Mytilus galloprovincialis*, being the object of commercial utilization and mariculture, require constant control over the condition of their population. Their age structure is an important parameter of this condition, which reflects the annual recruitment of the population, the mortality at different age levels, and the survival of the mussels in different ecological conditions. It became possible to study this parameter only after a reliable method of determining age in mussels on the basis of the internal structure of their shells had been developed.

The mussel colonies in the coastal areas of the Dnieper-Danube interfluve at depths of up to 20 m consist of 3-8 age classes. The maximum age at the same depths in the central part of the northwestern region of the Black Sea is 11-12 years, and it increases to 20 years with depth. The life span is 21 years at a depth of 20 in the Karkinit Gulf, and 28 years at a depth of 6 m in Dzharylgachsky Bay. The coefficient of mortality of the mussels in different parts of the northwestern region of the Black Sea varies from 0.19 to 0.97, the minimum being noted in mussel colonies with the longest life span.

These differences in the life span of mussels in different areas are determined largely by the salinity of the water. The relationship between the values of maximum age (T, yr) and the average annual values of water salinity (S, ‰) is described by the following equation when the correlation coefficient is equal to 0.97: $\mathbf{T = 0.0278 \cdot e^{0.3706 \cdot S}}$.

In addition to the mortality rate, the annual recruitment also affects the age structure of a population. Judging by the age class ratios, the 1970-1980 period was characterized by normal recruitment of the population. Since 1981, the mussel population of the northwestern part of the Black Sea has had a lower recruitment rate. It was particularly low in numerous areas in (320)
1982, which was the cause of the abnormally low numbers of this age group in the years that followed.

UDC 594.124(262.5)

Effect of the density of mussel colonies in the north-western part of the Black Sea on their growth rate

by N.M. Shurova and V.N. Zolotaryov (Odessa branch of INBYuM)

Mussels of the species *Mytilus galloprovincialis* collected in different areas of the northwestern part of the Black Sea in 1983-1985 served as our study material. The age of the mollusks was determined by the growth layers on the radial sections of their shells. The median line of 3-year-old mussels (L_3, mm) was adopted as the growth rate coefficient. The density of the mussel colonies was determined by their average biomass (B, kg/m^2).

An inverse relationship between the growth rate of mussels living at depths of 15-33 m and the density of their colonies was noted for the southern part of the Karkinit Gulf ($n=12$, $r=-0.899$, $r > r_{0.001}$), i.e. $L_3 = 45.4 - 3.525 \cdot B$.

No correlation between the average size of 3-year-old mussels from depths of up to 10 m and the density of their colonies was noted for the shallower areas of the northwestern part of the Black Sea (Dniester and Odessa banks, Sanzheyka, Tendra area).

These data indicate that the growth rate of mussels in the southern Karkinit area is limited to some extent by the density of their colonies, whereas no such relationship is observed in the coastal areas. This phenomenon can be attributed to the differences in the food supply of the mussels, i.e. the maximum development of phytoplankton in the coastal freshened areas of the northwestern part of the Black Sea and the decrease in its supply with depth.

UDC 594.124

RNA content in *Mytilus galloprovincialis* as an indicator of its functional condition

by S.A. Shcherban' (INBYuM)

The concentration of RNA is closely related to the processes of biochemical synthesis. The purpose of our investigation was to determine the dynamics of RNA content in the mantle of mussels during the warm period of the year. We examined mussels from three size groups (30, 50 and 70 mm in length) growing on collectors of the experimental mussel farm in Laspi Bay.

In addition to the RNA content, we determined the concentration of DNA and the content of protein in the somatic tissue, since their ratios to RNA are the most stable indicators of biological, primarily protein, synthesis.

The results of our investigations in 1985 boil down to the following:

1. The dynamics of RNA content in the somatic tissue was established. The lowest concentration of RNA is observed in May at a water temperature of 12.5°C. It amounts to 0.275 mg/100 mg dry tissue. With the gradual increase in temperature in June and July (water temperature 13.8° and 17°C respectively), the content of RNA also increases, amounting to 0.36 mg/100 mg in June, and 0.77 mg/100 mg in July. The maximum concentration of RNA is reached in August-September (1.77 mg/100 mg) at an average temperature of 21°C. The concentration of RNA dropped noticeably

in October when the water temperature was 15.1^{o}C, at which time it amounted to 1.48 mg/100 mg dry tissue.

2. The content of protein was determined in percentage of the dry weight of the tissue. This characteristic proved to be quite stable in all the size groups throughout the period of our investigation. It varied within the 3.9-5.65% range.

3. We derived data on the temperature/seasonal relationship of the RNA/protein ratio for the given groups, which correlate with the dynamics of the RNA content.

4. The RNA/DNA indices were used as a special criterion of the functional state of the mussels.

As a result of our work, we have established that the given (322)
biochemical characteristics are related to the temperature and seasonal factors that determine the metabolic rhythms of the mussels.

These characteristics can serve as biochemical criteria of the physiological condition of marine hydrobionts.

COMMERCIAL ECHINODERMS (323)

UDC 593.953

Ecology, distribution and prospects of commercial utilization of sea-urchins of the genus *Strongylocentrotus* in the coastal waters of eastern Kamchatka

by A.G. Bazhin and V.V. Oshurkov (Kamchatka branch of IBM DVNTs AN SSSR)

In 1985, during the expedition of the Kamchatka branch of the Institute of Marine Biology of the Far Eastern Scientific Centre of the USSR Academy of Sciences (IBM DVNTs AN SSSR) to study the shallow-zone communities on the eastern Kamchatka shelf, the species composition and distribution of 3 species of regular sea-urchins (*S. polyacanthus*, *S. droebachiensis* and *S. pallidus*) were studied. The first two species dominate in the phytal zone of the eastern Kamchatka shelf, and play a significant role in the structuring and metabolism of benthic communities. They are encountered everywhere on solid and mixed substrates, but the highest, commercial concentrations of them are found at the lower boundary of the macrophytic zone. The main concentrations of *S. pallidus* are found at depths exceeding 50 m, and only in certain areas characterized by the upwelling of cold abyssal waters (Kamchatka Gulf, Cape Afrika) is this species encountered at smaller depths. The density of the sea-urchins did not exceed 40 specimens/m^2 with a biomass of 0.5-0.6 kg/m^2.

Hydrobiological diving surveys have shown that *S. polyacanthus* is the most common species inhabiting the shallow zone (from 2-3 to 12-15 m) of the open coast of Kamchatka. In areas with a higher than usual water exchange, the biomass of this species in certain areas of rocky substrate amounted to 8.3-14.2 kg/m^2 with a density of 64-68 specimens/m^2. At the same time, the test of some specimens measured 96-98 mm in diameter and some individuals weighed 325-330 g. The average biomass of this species amounted to 2493.5 g/m^2 in Avacha and Kronotsky bays.

S. droebachiensis colonies were found in areas affected by river runoff. The density of these sea-urchins was 200 specimens/m^2, and their biomass was 3.5-5.1 kg/m^2. The maximum diameter of the test did not exceed 70 mm. The average biomass was 1285.0 g/m^2. (324)

We have found that the sea-urchin populations in the vicinity of the Northern Kuriles (Shumshu Is.) and the southeastern coast of Kamchatka (from Cape Lopatka to Cape Krestovyi) (where the main concentrations of the sea-otter are located) are in a depressed state; their biomass has dropped to 326.0 g/m^2, and the main congregations of them are concentrated at depths of over 10 m and consist of small individuals.

On the basis of our investigations, we have established that S. polyacanthus is the most promising commercial invertebrate in Avacha Bay and in the northern and southern parts of Kronotsky Bay. Due to the fact that this large species lives at small depths and forms dense concentrations, it can be exploited commercially with the use of diving equipment. In view of its frequent occurrence in trawl nets with commercial bottom fishes, S. pallidus can also be utilized in the national economy. Compared with the other species, S. droebachiensis is less common in the waters of Eastern Kamchatka and, therefore, unprofitable as a commercial species.

UDC 593.953:628.394(26)(265.54)

Characteristics of embryonic and larval development of the commercial sea-urchin *Strongylocentrotus intermedius* in seawater from different areas of the coastal zone of the Sea of Japan

by V.M. Busev (TOI DVNTs)

We undertook the task of studying the suitability of seawater from different areas of the sea for the development of the embryos and larvae of the sea-urchin.

The seawater was taken at stations 1, 2, ...7, located in sequence from a point removed from all possible sources of anthropogenic contamination (station 1 - control) to an area adjacent to a densely populated part of the coast. (325)

Our study of the time-related characteristics of the initial stages of development has shown that a substantial lag is observed in the first cleavage division in the sea-urchin embryos developing at the same temperature in seawater from stations 6 and 7 as compared with the control (by 12.2 and 19.2 minutes respectively). The lag is less significant in the seawater from station 5 (5.5 minutes), and practically no lag is observed in the embryos in seawater from stations 2, 3 and 4 (-1.2, 0.0 and 1.2 minutes).

An estimate of the percentage of anomalies of the first cleavage division (polyspermy) did not reveal any clear correlation between the frequency of this defect and the proximity of the sources of anthropogenic contamination, which had been observed during analysis of the first cleavage division.

In about 24 hours, practically all the larvae developing at the same temperature in seawater from stations 1, 2, 3 and 4 reached the stage of late gastrula-2 and were uniformly developed. At the same time, the larvae in seawater from stations 6 and 7 did not develop simultaneously. Some of the larvae (17.5%) in the seawater from station 7 were still at the stage of intermediate gastrula-2, lagging by about 5.5 hours in their development, and 14.5% of the larvae were at the stage of early gastrula, lagging by about 7 hours. In the seawater from station 6, 8% of the larvae were lagging by 5.5 hours, and 1% by 7 hours. A 5.5-hour lag was noted in 4% of the larvae, and a 7-hour lag in 2% of the larvae in the seawater from station 5. At this stage of development, there was a slight increase in the frequency of appearance of the resting mesenchymal blastula in larvae developing in seawater from stations 6 and 7. As for the anomalous exogastrula, it appeared very rarely, depending not so much on the source of the seawater, as on the choice of the parents of the sea-urchins.

Consequently, seawater from areas subjected to anthropogenic contamination slows down the process of the first cleavage divi- (326)
sion in embryos and the formation of the gastrula in larvae of the sea-urchin, and it also reduces the synchrony of development at the stage of gastrula.

UDC 593.953:574.5.001.8

Effect of estradiol-dipropionate on oogenesis in the sea-urchin

by G.S. Varaksina (IBM DVNTs)

We studied the effect of estradiol-dipropionate on oogenesis in *Strongylocentrotus nudus* at the beginning of development and at the stage of active gametogenesis in order to determine the possibility of obtaining germ cells outside the breeding season.

Our study was carried out with sexually mature animals. Over a period of one month, the females were twice injected with 100 μg of an oily solution of estradio-dipropionate. The injection of estradiol-dipropionate at the beginning of development (November) brought about a change in certain morphometric characteristics, i.e. the gonad index increased ($p < 0.005$) and so did the weight of the gonad ($p < 0.005$). The size of the oocytes exceeded the control by 40-55%, and the nuclei became 2.5 times larger. The proportion of parietal oocytes decreased to 66.2%, and the number of large free cells increased 5-fold; one-third of these were mature egg cells which were not observed at all in the control.

Our analysis of the frequency of oocyte distribution according to size has revealed significant differences. The spread in oocyte diameter is wider in the experimental animals. The oocytes are much larger than in the control group, and they are characterized by a more pronounced heterogeneity.

The injection of estradiol-dipropionate at the stage of active gametogenesis (April) effected a 50% increase in the mass of the ovary and a corresponding increase in the gonad index, as well as a 3.5-fold increase in the size of the acini and a 3-fold increase in the size of the gametes. The cellular composition of the gonad changed accordingly. Mostly mature gametes were found in the acini. Spawning was observed in some (327) of the sea-urchins. Normal larvae developed from the gametes obtained by the experimental procedure.

Consequently, the injection of estrogen greatly accelerated the processes of vitellogenesis, and led to the formation and accumulation of a large number of normal mature gametes in the gonad. Furthermore, this hormone apparently contributes to the restructuring of internal physiological mechanisms, which makes the organism more susceptible to factors that induce spawning. This makes it possible to utilize estradiol-dipropionate for speeding up the maturation of gametes, which will enable us to use the gametes of sea-urchins more extensively for practical and scientific purposes.

UDC 593.953:628.394(28)(265.54)

Reproductive characteristics of sea-urchins during exposure to anthropogenic contamination

by M.A. Vashchenko, T.Kh. Naidenko, V.M. Busev and P.M. Zhadan (TOI, IBM DVNTs AN SSSR)

The subject of this particular study consisted of sea-urchins of the species *Strongylocentrotus intermedius* and *S. nudus* which are widely distributed in the coastal waters of the Sea of Japan.

The specimens were caught in July and August 1984 and in August and September 1985 in areas differing in the level of contamination, i.e a highly contaminated area (1), a moderately contaminated area (2), a slightly contaminated area (3), and uncontaminated areas (4, 5) (control stations). The areas selected had basically the same depth, substrates and temperature conditions.

Each sample consisted of 40-50 animals. Our investigations included: 1) determination of the gonad index (GI) and the maturity of the gonads (separately for males and females), 2) histological analysis of the gonads, 3) observation of the development of the progeny of five parental pairs from each sample (from fertilization to metamorphosis), 4) determination of the content of heavy metals (HM) in the gonads, egg cells and sperm.

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The lowest degree of gonad maturity and the lowest GI values are characteristic of sea-urchins from station 1, and the highest ones were observed in the sea-urchins from station 3. The GI and degree of gonad maturity in the sea-urchins from stations 4 and 5 were significantly higher than in those from stations 1 and 2, and somewhat lower than in those from station 1.

Histological analysis showed that the majority of the animals from stations 2-5 was at the stages of active gametogenesis, prespawning and spawning. Histopathological changes (active processes of gamete destruction and morphological disturbances of auxiliary cells) were detected in the gonads of the sea-urchins from stations 1 and 2. The most pronounced histopathological changes were observed in the sea-urchins from station 1. There were practically no gametes in the gonads of some sea-urchins.

The number of anomalies at the stages of embryogenesis and early larval development was correlated with the degree of contamination of the seawater. Only the larvae of the sea-urchins from one of the control stations underwent metamorphosis successfully.

The results of the HM determination show that the quantitative ratios of the Fe, Mn, Zn, Cu and Cd concentrations in the gonads and genital products depend on the sex of the animal. The maximum content of heavy metals was noted in the gonads, egg cells and sperm of the sea-urchins from station 1.

Consequently, serious disturbances were noted in the condition of the gonads and development of the progeny in the sea-urchins from stations 1 and 2. These disturbances were probably caused by the prolonged exposure of the animals to the toxicants found in the waters of the given areas.

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UDC 593.961.1(265.54)

Characteristics of the reproductive cycle in the Far Eastern trepang *Stichopus japonicus* from Vityaz' Bay of Peter the Great Gulf in the Sea of Japan

by G.P. Voronova (IBM DVNTs AN SSSR)

On the basis of histological studies, we have established four stages of gonad maturity in the annual reproductive cycle (September—April) of the Far Eastern trepang from Vityaz' Bay of Peter the Great Gulf in the Sea of Japan.

The 1st stage covers growth and maturation. At the beginning of this stage, the gonads are difficult to detect; they have the form of two compact pale pink or white tubules extending from a common base. These genital tubules with individual offshoots on each measure from 0.5 to 2.5 cm in length. In sections of them, we can see a parietal layer of embryonic epithelium. The gonads increase in size by the end of this stage. A developed spermatogenic zone and a developed spermiogenic zone are noted in the testes, and late vitellogenic parietal and free oocytes occupy most of the space in the ovaries. Resorbing gametes and accumulations of phagocytic cells are occasionally observed in the gonads.

The 2nd stage is the prespawning stage (May-June). The gonad continues to grow. It turns an intense pink in the females, and white in the males. The lumens of the testis are filled with a spermiogenic zone bordered with a developed spermatogenic layer. The genital tubules of the ovary contain large, almost equal-sized oocytes surrounded by follicular cells. Medium-sized parietal vitellogenic oocytes are still present in individual parts of the tubules. Oocytes undergoing resorption are very rarely encountered at this stage.

The 3rd stage is the spawning stage (from the end of June to September, with the peak in July-August). With the onset of summer, the gonads attain their maximum size, turning a bright orange in the females and remaining white in the males. The length of the gonads is 1.5-2 times greater than the length of the body. The gonad wall is thin. The thick spermiogenic zone in the testes is separated from the wall of the gonad by one (330)
layer of spermatogenic cells. The swollen genital tubules of the females contain large vitellogenic oocytes ready to mature.

In individual parts of the gonad, we still find parietal oocytes, but no resorbing gametes are encountered. The gametes are cast out at this stage.

The 4th stage is the postspawning stage (July-September, with the peak in August). The deflated translucent postspawning gonad hardly differs in length from the spawning gonad. In the testes and ovaries, there are still a few gametes remaining. They undergo resorption and are utilized by the phagocytic cells shortly afterwards. The depleted genital tubules, beginning with the terminal regions, disintegrate, as if dissolving in their own contents. The remaining upper part of the gonad shrivels, turns a rusty colour, and falls off. As the old gonads die off, new ones form from their base.

UDC 593.953+594.124:628.394(26)

Reproductive disorders in sea-urchins and mussels during exposure to a cadmium-polluted environment

by S.M. Gnezdilova, I.G. Lipina, V.B. Durkina and
Ye.M. Karaseva (IBM DVNTs AN SSSR)

Due to the increase in the cadmium level in the coastal waters of the shelf, it is becoming increasingly important to study the effect of this contaminant on the life of commercial invertebrates. This particular paper provides data on the effect of Cd which has a specific effect of the reproductive function and gametogenesis of _Strongylocentrotus intermedius_ and _Mytilus edulis_.

The method of atom absorption was used to measure the content of Cd in the gonads of animals exposed to cadmium solutions.

When sea-urchins were kept in water containing 100 μg Cd/l for 130 days, the content of Cd in the gonads of the females amounted to 7.1 μg/g dry wt, and the content of Cd in the male gonads was (331) 12 μg/g dry wt. The content of Cd in the ovaries and testes of the control animals was 0.6 and 0.7 μg/g dry wt respectively. The mussel has a higher cumulative capacity than sea-urchins; it accumulates up to 277 μg Cd/g dry wt in the gonads (exposure 40 days, content of Cd in the water 500 μg/l).

By means of histomorphometric methods, we have established that qualitative and quantitative changes occur in the gonads of the animals in the process of gamete differentiation when they are exposed to Cd for a long time. In sea-urchins, exposure to the toxicant leads to the destruction of the oocytes and auxiliarly cells on the one hand, and to an increase in the number of oogonia in comparison with the control on the other. The temporary increase in the number of gametes, which can be regarded as a compensatory reaction of the animal, cannot restore the reproductive function of the gonad completely, since the increasing resorption encompasses not only individual gametes, but also numerous acini. On the whole, the gonads of the experimental animals develop more slowly than in the control animals.

In addition to gamete resorption, the formation of mature egg cells is noted in the ovary of mussels exposed to cadmium solutions. The maturation of oocytes in the ovary is not characteristic of mussels. In a natural environment, the maturation of oocytes in this species takes place outside the gonad.

This fact indicates that not only the reproductive systems begins to malfunction, but also the neurohumoral regulation of gametogenesis and maturation specifically.

The changes occurring in the process of gamete formation lead to the formation of abnormal genital products, which becomes obvious when observing the development of the progeny. The embryos and larvae obtained from the gametes of sea-urchins kept in water containing cadmium lag in development during incubation in clean water, and have a higher percentage of anomalies. The presence of Cd in the water at the early stages of ontogenesis (embryonic and larval development) causes an increase in the number of anomalies and the mortality of the animals.

Therefore, irregularities in gametogenesis and embryogenesis are noted in sea-urchins and mussels within a wide range of sublethal Cd concentrations. This leads to lower reproduction and the appearance of abnormal larvae in these commercial invertebrates, which can in turn affect the structure of the aquatic communities.

UDC 593.9(268.45)(268.46) (332)

<u>Distribution of echinoderms in the coastal waters of the Barents and White seas in relation to environmental factors</u>

by V.Ye. Dzhus and Ye.A. Frolova (MMBI)

The echinoderms of the northern seas of the USSR (sea-urchins, sea-cucumbers) are promising items of the fishing industry, are the predators of commercial invertebrates and cultivated organisms (predaceous starfishes), and play an important role in the macrobenthos (some ophiurans, urchins). The distribution of echinoderms in the coastal waters of the Barents and White seas has been studied since 1978 with the use of diving and photographic equipment at depths of up to 30 m, and with the use of the "Zelenetskaya-2" stereophotostation and the "Yarnyshnaya" manned submersible at depths of up to 150 m.

Sea-urchins of the species Strongylocentrotus droebachiensis are the most numerous in the coastal zone. A slight freshening of the water leads to a sudden decrease in the density of populations. Urchins prefer a rocky substrate and tidal zones with higher than usual hydrodynamic activity. They are distributed in groups with a density of up to 30-40 specimens/m^2, which decreases to 5-6 specimens/m^2 on mixed substrates. Large urchins occupy the upper areas which abound in algae. The young keep to the deeper parts, seeking shelter in the hollows of the crustose Lithothamnion algae. The similar S. pallidus prefers depths of over 50 m and rocky-silty substrates. Off the western coast of the Rybachy Peninsula and in the vicinity of the Aynovsky Islands, this species is encountered together with S. droebachiensis at depths of 15-20 m, comprising approximately 5% of the animals. The boreal species Echinus esculentus is also encountered in places with higher than usual hydrodynamic activity, near capes projecting into the sea, on rocky substrates at depths of over 15-20 m, where it forms a density of up to 0.5 specimens/m^2.

Of the starfishes, Asterias rubens is common with a density of up to 1 specimen/m^2. The highest density (up to 8 specimens/m^2)

was noted on the mussels banks and in the vicinity of mussel plantations. It prefers rocky substrates. Crossaster papposus is less common, forming a density of 1-2 specimens/200 m. Young (333) individuals are encountered at depths of 5-10 m, their density amounting to 2-3 specimens/10 m^2. They prefer the vertical surfaces of rocks. The active, relatively fast-moving predator Solaster endeca is rare (about 1 specimen/400 m^2). However, there are cases where several of them congregate to eat up fish caracasses. Urasterias lincki has been encountered in the White Sea at depths of 40-120 m (density up to 0.75 specimens/m^2).

The brittle star Gorgonocephalus arcticus is encountered at depths of 30-60 m on muddy and rocky substrate (up to 1 specimen/15 m^2). Large concentrations of Ophiura robusta (up to 600 specimens/m^2) were found at a depth of 42 m on the muddy-sandy bottom in the area adjacent to the neck of the White Sea. The sea-cucumber Cucumaria frondosa is encountered on craggy steep walls at depths of 15 m and more (up to 1 specimen/m^2). This species is often encountered in places abounding in Chlamys islandicus.

The stock of echinoderms in these areas was also estimated.

UDC 593.953(268.45)

Contribution to the reproduction of the sea-urchin Strongylocentrotus droebachiensis of the Barents Sea under aquarium conditions

by V.S. Zenzerov and V.Ye. Dzhus (MMBI)

Sea-urchins constitute an important part of the biocoenoses in the sublittoral zone of the sea. They are of great interest to us as a source of biologically active substances (BAS) and as a possible source of food.

With the help of diving equipment, we collected sea-urchins each month (from 1983 to 1985) in one of the inlets of the Murman Coast for biological and histological analysis. Material from 1979-1982 was also used in our study.

On the basis of the gonadosomatic index (GSI) and the enterosomatic index (ESI), we have come to a number of conclusions regarding the seasonal dynamics of the feeding and sexual activity of the animals. Basically, the sea-urchin off the coast of Murman spawns at the end of March at an average water temperature of 0^{o} to $+1^{o}C$. (334)

We also conducted experiments on the artificial fertilization of eggs from sea-urchins caught during the winter-spring period. The fertilized eggs were incubated in a special appartus. A high percentage (up to 88%) of fertilization of the egg cells was noted in the course of the experiment. Mature egg cells prevail in the females during this period.

Five hours after fertilization, we observe the appearance of the first cleavage furrow with the formation of two blastomeres; sixteen hours later, the embryo is at the stage of 16 blastomeres, and the early blastula begins to form by the twentieth hour. A prism forms by the seventh day from the onset of incubation, and a larva (pluteus) forms by the twelfth day.

A histological analysis of development has shown that the processes of histogenesis and organogenesis proceed without any pathological changes, and that the main stages of embryogenesis and early postembryonic development correspond to the morphological data obtained earlier by other researchers (Ivanov, 1946; Varaksina et al., 1974; Horstadius, 1969).

The temperature of the seawater in which the incubation of fertilized eggs was carried out approximated that of a natural environment, varying from 1.5 to 4°C throughout the experiment.

Our results can be used in the solution of problems related to the replenishment of the sea-urchin stock in the Barents Sea.

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PARASITES AND OTHER PESTS OF COMMERCIAL INVERTEBRATES

UDC 595.132:595.142.2:597-169(268.45)

Role of polychaetes in the life cycle of *Hysterothylacium aduncum*, a parasite of fish and invertebrates of the White Sea

Ye.D. Val'ter (Moscow State University)

A great deal of attention in our investigations is devoted to questions concerning the biology of the Anisakidae and their interrelations with hosts of different systematic groups. The most researched so far is the development cycle of *Hysterothylacium aduncum*, one of the most common parasites of animals, including a number of commercial invertebrates such as *Pandalus borealis* and others. However, not all the biological aspects of this parasites have been covered. It has already been established that five species of polychaetes of the family Polynoidae (*Antinoëlla sarsi*, *Eunoë nodosa*, *Cattyana cirrosa*, *Harmothoë imbricata*, *Lepidonotus squamatus*) have a direct bearing on the development cycle of *H. aduncum*.

Our principal observation site and source of polychaetes was the Yeremeyevsky rapids and the Velikaya Salma strait near

the biological station of Moscow State University. The Yeremeyevsky rapids are characterized by steady invasion by H. aduncum. The invasive elements (eggs and larvae) are present here in the right numbers during the summer-autumn period. It is during this period that the mature nematodes begin copulation in the stomach or intestine of the fish, after which the fertilized eggs are deposited in the sea where they hatch into 2nd-instar larvae after 10-12 days. The larvae can remain in a free state in the water for up to 1-2 months. The period of egg production by the females may last for up to several months (from June to September). This is a sufficient length of time for the invertebrates (polychaetes, etc.) to become infested. In the body cavity of the polychaetes, the 2nd-instar larvae moult a second time, turning into 3rd-instar larvae which require several months for growth and development. Having attained the limit of their development, the larvae remain, (336)
with the rare exception, at the third stage. The polychaetes have a life span of 4-5 years. Consequently, the larvae of the parasite can remain viable inside of them for up to several years, which results in the cumulation of infestation. The predatory nature of these annelids and the cannibalism encountered occasionally contribute to this. Consequently, the stages of development of the parasites inside the polychaetes and the means of their penetration may differ, i.e. the larvae penetrate the polychaetes with the water, mude, etc., or via the invertebrates infested with 2nd- and 3rd-instar larvae that are consumed by the polychaetes. Normally, the females of H. aduncum deposit their eggs in the lumen of the digestive tract of fish. Meanwhile, other

unaccountable circumstances are also encountered in nature. As we know, during gutting of fish on the shore or fishing from a boat, the viscera are discarded into the sea where they are swallowed by birds, fish and other animals, or sink to the bottom, settling on algae, hydroids, sponges or into rock crevices. Under these circumstances, the parasites escape from the cut stomachs. Among them, there may be sexually mature fertilized females of H. aduncum. According to our observations, the females stay alive for up to 20 days. The casting out of the eggs lasts 4-5 days. The eggs are either spread by the water, or they collect between the rocks and in the rhizoids of algae where there is no strong current. By analogy with the Isopoda, the infestation of the Polychaeta is also possible via eggs containing 2nd-instar larvae and by free larvae. The latter, clinging to a rough substrate or to each other, are capable of congregating in large numbers (20-30 specimens and more) and attracting benthic animals (e.g. polychaetes) with their abrupt oscillatory movements. This is why we have been able to detect such a large number of larvae (54, 150, 170 specimens) of different stages and sizes (0.25-0.28 mm 2nd-instar and 2.7-25.9 mm 3rd-instar) in the polychaetes. 2-6 larvae of the parasite are usually encountered in polychaetes. Thus, in the development cycles of the Anisakidae, in this case H. aduncum, polychaetes can act as both intermediate hosts, and as intermediate and reserve hosts simultaneously, i.e. polyvalent hosts.

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UDC 594.582.2/.8

Comparative ecological characterization of the parasite fauna of the background species of the Ommastrephidae in the southwestern Atlantic

by A.V. Gayevskaya, Ch.M. Nigmatullin and O.A. Shukhgal'ter (AtlantNIRO)

In the southwestern Atlantic (34-47° S) in December 1983—May 1984, eleven species of parasites (one species of Coccidia, 4 species of Cestoda, one species of Trematoda and 5 species of Nematoda) were detected in the four background species of squids (Ommastrephidae) which include representatives of all three life forms of the family.

1. Slope-shelf squids. *Illex argentinus* (377 specimens, mantle length (ML) 6-36 cm, overall infestation 48%, 5 species of parasites), encountered on the shelf and continental slope. The larvae of *Phyllobothrium* sp. are common (40.8%, 1-31 specimens). Occasionally, we encounter 1-2 specimens of *Anisakis* larvae of the 1st and 2nd types (1.4 and 7.4%), as well as larvae of *Contracaecum* sp. (4.9%) and *Porrocaecum* sp. (0.9%). We observed no significant differences in the composition of the helminths or the infestation indices of the squids of the purely shelf summer-spawning (*Phyllobothrium* sp. - 43.4%, 1-31 specimens) and slope-shelf winter-spawning groups (54.3%, 1-12 specimens). Infestation of the winter group of squids by *Phyllobothrium* sp. begins at a mantle length of 6-10 cm (8.1%), 56.4% infestation is observed at a ML of 16-20 cm, and 72-86% infestation at a ML of 28-36 cm. The infestation of *Anisakis* sp. II varies from 2% at a ML of 6-10 cm to 22-28% at a ML of 28-36 cm, while

that of *Anisakis* sp. I varies from 2.2% at a ML of 24-28 cm to 14.3% at a mantle length of 32-36 cm. These changes are the result of the increase in the total food ration of the squids in the course of their development and the transition at a ML of 25-28 cm from feeding on crustaceans to feeding predominantly on fish.

Martialia hyadesi (21 specimens, ML 26-30.5 cm; 100%; two species) is encountered on the continental slope and on the edge of the shelf. 100% infestation with Coccidia (probably *Aggregata*) and 47.6% (1-4 specimens) with the larvae of *Phyllobothrium* sp. was observed.

2. The neritic-oceanic *Todarodes angolensis* (18 specimens, ML 20-29.5 cm; 77.8%; 6 species) is encountered in the pelagic zone of the Falkland Current system. We found that it was in- (338)
fested with the metacercariae of didimozoids* (22.2%, 1-5 specimens), the larvae of the cestodes *Tentacularia coryphaenae* (16.7%, 1-2 specimens) and *Phyllobothrium* sp. (38.9%, 1-7 specimens), as well as the larvae of the nematodes *Porrocaecum* sp. (22.2%, 1-4 specimens) and *Anisakis* sp. I and II (11% and 1 specimen in both cases).

3. The oceanic subtropical *Ommastrephes bartrami* (35 specimens, ML 16-40.5 cm; 100%; 7 species) was infested with the metacercariae of didimozoids* (91.2%, 1-250 specimens), the larvae of the cestodes *Scolex pleuronectis* (55.6%, 1-500 specimens), *Tentacularia coryphaenae* (24%, 1-2 specimens), *Nybelinia lingualis* (28%, 1-2 specimens) and *Phyllobothrium* sp. (8%, 1-3 specimens), as well as the larvae of the nematodes *Porrocaecum* sp.

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*conjectural (transliterated) spelling - transl.

(42%, 1-2000 specimens), *Anisakis* sp. I (5.7%, 1 specimen) and II (11%, 1 specimen) and *Spinitectus* sp. (in one squid, 4 specimens).

The given representatives of the three life forms have fairly separate biotopes (different water masses) and belong to different communities. Apparently, the structure of the parasite fauna of these communities also differs. From the slope-shelf species to the oceanic one, the qualitative composition of the parasites broadens and the dominant forms of helminths are replaced by others, *Phyllobothrium* sp. being the only common one. At the same time, the species of helminths common to the three life forms (*Phyllobothrium* sp., *Porrocaecum* sp. and *Anisakis* sp.) are index forms in some communities, and incidental forms in others (marginal effect"). Squids are the third intermediate or reserve hosts of the given helminths, and they are infested by the latter trophically. The variability in the composition of the helminths and the infestation indicies of squids from different communities is due mainly to the presence and abundance of definitive hosts (sharks, xiphoid fishes, tunas, sea mammals). The squid—parasite relations are also indicators of the relations between the squids and their enemies, the definitive hosts of the helminths. According to our data, their composition is maximal in *T. angolensis* and particularly *O. bartrami*, and is minimal in *I. argentinus* and *M. hyadesi*. Judging by the mass infestation of *M. hyadesi* with coccidians and the absence of the latter in *I. argentinus*, the spatial and trophic aspects of the ecological niches of the slope-shelf squids differ substantially, primarily because of the closer relationship of *M. hyadesi* with the bottom.

UDC 594.121 (339)

Pathological changes caused by shell disease in the European oyster *Ostrea edulis*

by V.V. Gubanov (Odessa branch of INBYuM)

The causative agent of the shell disease is the sea fungus *Ostracoblabe implexa* Born. et Flah, which belongs to the specific ecological group of fungi called the perforators of mollusk shells.

To establish the pathological changes caused in oysters by the shell disease, we studied the degree of shell and tissue infection in diseased oysters during 1980-1984. We also determined the amino acid composition of the shell and excrescences on the valves of the oysters, and carried out histological analysis of the oyster tissues and microscopic analysis of shell sections. The material for our study was selected from natural oyster beds and an oyster farm. A total of 2508 specimens was examined.

The first symptoms of the shell disease, which are difficult to diagnose, consist of small 1-2 mm spots which appear on the inside of the shell at the point where it is penetrated by the mycelium of the fungus. In response to the stimulation caused by the mycelium of the fungus, the epithelial cells of the external surface of the median fold of the mantle drastically increase the synthesis of protein fractions that form the organic base of the shell. As a result, a thin, bright green conchiolinic excrescence forms on the infected parts of the valves. Utilizing the organic components of this excrescence for its development, the mycelium continues to grow, stimulating in turn the further growth of the excrescence. The formation of these massive excrescences causes the mollusks to greatly increase their expenditures on the synthesis of their protein base, since the total content of amino acids in the excrescences constitutes about 42% of their dry weight (4.2% in the shells of healthy oysters).

Judging by the localization of the excrescences and their size, the disease in some mollusks can become chronic and last for several years. During this period, the excrescences attain a thickness of about 4 mm, occupying a large part of the shell (340) surface. In oyster spat, especially those grown on collectors, the excrescences are formed mainly in the region of the hinge, or at the point of adductor attachment. When individuals of older age groups are infected, the excrescences can also appear in the marginal region of the shell.

Microscopic analysis of shell sections from diseased oysters has enabled us to establish the microstructural irregularities of the shell and the individual differences in the development of the disease in various specimens. The shell sections of certain individuals showed layered structures consisting of thin layers of conchiolin alternating with calcite. Apparently, the formation of an excrescence can be stopped under certain conditions.

The other pathological changes were the separation of the hinge margin of the shell into layers, and the exfoliation of the calcite layer in its central part.

Many of the infectious and invasive diseases of oysters first of all affect the condition of their reproductive system.

The larvae in the mantle cavity of oysters with fairly pronounced excrescences confirm that they are still capable of breeding at the early stages of the disease. The effect of the shell disease on fecundity in oysters is still unclear.

Consequently, the changes in the morphology and microstructure of the shell are the most characteristic manifestation of the shell disease in oysters. The further development of the disease is accompanied by nonspecific pathological changes, i.e. weaking of the adductor, atrophy and thinning of the tissues. The specificity of the shell anomalies can be used for diagnosing the shell disease in oysters.

UDC 595.133:595.384.12 (341)

An interesting discovery of mature acanthocephalans in the humpback shrimp, *Pandalus hypsinotus*

by L.M. Kovalenko (TINRO)

In May 1985, we examined 47 specimens of *Pandalus hypsinotus* 11.5-15 cm long, caught in Peter the Great Gulf in the Sea of Japan at a depth of 150-300 m. The incidence of infestation was 10.7%, and the degree of infestation was 1-10 specimens. Sexually mature acanthocephalans were found in the stomachs of the five shrimp examined. This has never been noted in the literature. Altogether, we found 25 thorny-headed worms (8 mature males and 15 females, five of which contained fully-formed eggs).

The acanthocephalans discovered belong to the species *Echinorhynchus gadi*, which is commonly found in fish. However, our worms differed from those described earlier in that they were somewhat smaller, the males 8.6-9.5 mm compared with

12.8-15 mm (Petrochenko, 1965) and 20 mm (Lüeh, 1911), and in females 18.0-28.7 mm compared with 35-40 mm (Petrochenko, 1965) and 45-80 mm (Lüeh, 1911). The eggs of our specimens measured 0.11-0.14 mm, compared with 0.10 mm in those described earlier.

As we know, invertebrates are the intermediate hosts of E. gadi, and fish are the definitive hosts. We consider the discovery of mature acanthocephalans in Pandalus hypsinotus as a chance occurrence. Shrimps cannot be the definitive hosts of thorny-headed worms, since the latter are strictly specific to their definitive hosts. Most likely, the shrimps had swallowed a dead fish containing live thorny-headed worms. The latter, having found themselves in a nonspecific environment, did not develop further, though they did manage to stay alive in the gastrointestinal tract of the shrimps.

UDC 595.122:594.124 (342)

Infestation of mussels from different parts of the northwestern part of the Black Sea with the trematode Proctoeces maculatus

by N.A. Koval'chuk (Odessa branch of INBYuM)

The Black Sea mussel (Mytilus galloprovincialis) is an intermediate host in the development cycle of the trematode Protoeces maculatus (fam. Fellodistomatidae). The development of the parthenogenetic generations of this parasite takes place in mussels. The development cycle has been described in detail by Machkevsky (1980, 1983). A high degree of infestation and a capacity to affect a large part of the vital organs of this mollusk are characteristic of infestation of mussels with the sporocysts of this trematode. The parthenitae of trematodes also have a significant effect on the reproductive capacity of mussels. A high degree of infestation with sporocysts results in substantial atrophy of the soft tissues, autolysis of the adductors and a decrease in the content of glycogen in the mussels (Shchepkina, 1982).

To study the distribution of *P. maculatus* in the northwestern part of the Black Sea, we conducted a survey of mussels from different areas of the Odessa, Tendra, Yegorlytsky, Dzharylgachsky and Karkinit gulfs, including those grown on collectors.

Samples of mussels were taken throughout 1982-1985. A total of 2555 mussels was examined by the method of total parasitological dissection.

According to the data of our survey, the range of this trematode in the northwestern part of the Black Sea is limited to the Yegorlytsky, Tendra, Dzharylgachsky and Karkinit gulfs. These gulfs are distinguished by comparatively small depths, weak circulation and a higher than usual water temperature during the summer. Trematode sporocysts were not detected in the mussels from the Odessa Gulf.

The infestation of the mussels from natural populations varied significantly during the period of investigation. The minimum and maximum values of incidence constituted 1.3-13.6% in the Dzharylgachsky Gulf, 3.7-23.1% in the Yegorlytsky Gulf and 4.25-9.3% in the Tendra Gulf. The low incidence of infestation in 1985 (1.3% in Dzharylgachsky Gulf, 4.25% in Tendra Gulf, 4.6% in Yegorlytsky Gulf) compared with other years is apparently

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due to the mortality of the infested mussels in winter with its unfavourable abiotic conditions (prolonged freeze-up, low temperature of the water, etc.).

The degree of trematode infestation of the mussels from natural populations in Dzharylgachsky Gulf varied from 46,000 to 720 during different years. In some cases, infestation could be determined visually. When infestation with parthenitae is high, complete or partial castration of the mussels sets in, and it becomes difficult to determine their sex.

Our examination of the mussels grown on collectors enabled us to establish the minimum age at which infestation takes place. In Dzharylgachksy Gulf, for example, trematode parthenitae were found in mussels younger than five months, the incidence of infestation being 40.5%.

The results of our surveys can be used to assess the suitability of certain areas for mussel farming.

UDC 639.42(268.45)

The parasitological situation at an experimental commercial mussel farm in the White Sea (second year of cultivation)

by V.G. Kulachkova (Zoological Institute of the USSR Academy of Sciences, Leningrad)

Parasites can prove to be a serious negative factor, and cause substantial economic losses for maricultural establishments.

This particular paper deals with the parasitological situation at a mussel farm established in 1983 in Chupa inlet by Karelrybprom during the second year of mussel cultivation (*Mytilus edulis*).

From June 17 to September 18, 1985, we examined 1652 mussels collected from a standard profile in the upper and lower parts (344) of the substrates. The mussels measured from 0.8 to 5.5 cm, and their age varied from 2 to 4+ years. The mollusks older than two years had migrated to the collectors from the surrounding biocoenoses.

During the second year, the mussels at the mussel farm showed a slight increase in the numbers of ectocommensals (*Peniculistoma mytili*, *Ancistrum mytili*, *Tisbe furcata*). For example, *P. mytili* was noted in 76.7% of the mussels in 1984, and in 89.3% of the mussels in 1985. The frequency of occurrence of *A. mytili* increased accordingly from 90% to 98.1%, while the average number of infusorians per mollusk increased from 38.5 to 68.2 specimens. The crustacean *T. furcata* began to occur more frequently (1-6 specimens in 6.9% of the mussels).

We established a definite relationship between the rate of increase of commensals and the place of settling of the mussels at the mussel farm. Compared with 1984, the number of infusorians in 1985 increased substantially in the upper horizon (the frequency of occurrence of *P. mytili* increased by 15.5%, and that of *A. mytili* by 16.8%), while the number of *T. furcata* in the lower part of the substrates increased from 8 to 13%. Consequently, the conditions most conducive to the existence of both species of infusorians are found in the mussels from the upper part of the substrates, while the best conditions for the crustaceans are found in the mussels from the lower part of the collectors.

We noted the complete absence of trematode larvae in the mussels at the mussel farm, while the mussels from natural populations in the neighbouring inlets were found to contain 4 species of metacercariae, the incidence of which varied from 20 to 100% depending on the species, and the highest degree of infestation amounted to 120 specimens (Kulachkova, 1985). The fact that the collectors were suspended above the bottom was probably one of the major factors preventing the infestation of the mussels with trematode larvae. Haplosporidia were detected in one mollusk in 1984. There were no cases of haplosporidiosis in the mussels of the mussel farm the following year.

On the whole, the parasitological situation at the experimental commercial mussel farm by the end of the second year of mussel cultivation remained favourable.

UDC 595.122:594.124(262.5) (345)

Possible ways in which the Black Sea mussel can become infested with the parthenitae of *Proctoeces maculatus*

by V.K. Machkevsky (INBYuM)

This particular paper is devoted to generalization and analysis of the possible ways in which the Black Sea mussel, a promising item of mariculture, can become infested with the parthenogenetic generations of the trematode *Proctoeces maculatus* (fam. Fellodistomatidae) which causes proctoecosis, a serious disease of mussels.

The miracidium is the invasive migrant larva of the parthenogenetic generation of trematodes. There are two ways in which the miracidium can infest the first definitive (intermediate) host, the mussel: an active way, and a passive way. We studied the biological and behavioural characteristics of the miracidium of *P. maculatus*, which is capable of infecting its host, the mussel. We also studied the specific behavioural features of the hosts of the *P. maculatus* marita, which disseminate the eggs of the parasite throughout the environment, ensuring the contact of the invasive organism of the parasite with the mussels.

Our investigations were carried out in Yegorlytsky Gulf (Yegorlytsky experimental commercial maricultural establishment), in the saline Donuzlav lake (mussel farm of a fishery co-operative) and in the Laboratory of Ecological Parasitology of INBYuM. The following data were obtained as a result of our investigation.

1. A mature marita placed in seawater produces a batch of 25-30 eggs containing fully formed active miracidia within 30 minutes.

2. Stimulation of the hatching of miracidia from the eggs by varying temperature, illumination and salinity proved futile. Having used up their supply of nutrients, the miracidia died after 2.5-3 days. We can conclude from this that the mussel is infested not by a larva actively searching for a host, but by some other means.

3. Under laboratory conditions, the use of an alkaline buffer altered the pH of the environment, which brought on the hatching of the miracidia. This enabled us to study the structure of the larva in greater detail. We came across an apical gland, the (346)
secretion of which enables the larva of the parasite to move through the tissues of the host.

4. We found that the P. maculatus metacercariae extracted from the gastropods Rissoa membranacea and Rissoa parva (the latter proved to be a new supplementary host) contained mature eggs with live miracidia. The eggs deposited in the seawater by the metacercariae opened their egg caps and hatched into miracidia when a carotene-ptyalin filtrate with distinct alkaline properties was added to them. This points to the fact that the hatching of miracidia takes place in the digestive tract of the mollusk.

5. We established the characteristic seasonal variations in the biology of the P. maculatus hosts that ensure the circulation of this parasite in a mussel biocoenosis.

6. On the basis of these data, we are examining the possible ways in which the Black Sea mussel can become infested with parenthitae. The two basic ways are through fish and through gastropods. Mussels are infested by swallowing trematode eggs which are of the same size as the food particles in the host's diet.

UDC 594.1 (346)

Parasites of the commercial mollusk Ruditapes philippinarum in Peter the Great Gulf of the Sea of Japan

by A.V. Rybakov (IBM DVNTs)

Ruditapes philippinarum is a valuable commercial invertebrate which is the third highest-ranking bivalve harvested in Japan (after the oyster and mussel). The stock of this species in the USSR is not being utilized so far, but with time, it can become an item of the fishing industry and, possiby, mariculture.

At the same time, we should keep in mind that, unlike the traditional scallops and mussels, *Ruditapes philippinarum* is highly (347) infested with parasites, some of which are of great practical significance.

The parenthitae of trematodes are the most pathogenic for *Ruditapes philippinarum*, and we have found three species of these parasites. The sporocysts of *Cercaria tapidis* localize in the tissues of the gonad (mean incidence of infestation 3.01%). The gonad of infested mollusks degenerates, and is replaced by a loose fibrous connective tissue. Complete castration is a characteristic feature. In highly infested individuals, the sporocysts can penetrate the digestive gland and other internal organs, as well as the ctenidia. Infested mollusks appear to be highly emaciated; their gonads are translucent and grayish in colour.

The sporocysts of *C. pectinata* localize in the sini venosi of the gonad (0.43%). The latter acquires a flocculent consistency; with a very high degree of infestation, the gonad becomes translucent and turns a yellowish colour, but total castration is rarely observed even in this case. Even in sections of highly infested gonads, we can usually see acini with normal patterns of gametogenesis. The third species, *Cercaria* sp. Shimura et al., was found only once (0.11%) in the digestive gland of *Ruditapes philippinarum*.

Mollusks highly infested with trematode parthenitae are extremely sensitive to unfavourable environmental factors, i.e. they are the first to die during the freshening of waters or a lack of oxygen, and the mortality of infested mollusks is very high during the winter. The infested mollusks become so emaciated, that they are unable to close their shells, and various unwanted organisms (polychaetes, crustaceans, etc.) find their way into the mantle cavity; they eat out the gonad, ctenidia and mantle, and speed up the death of the mollusks. Predators can attack more easily because infested *Ruditapes philippinarum* become inactive and are easily washed out of the substrate by the tidal currents.

In addition to the parthenita, 5 species of metacercariae were found in *Ruditapes philippinarum*; these include larvae from the genus *Acanthoparyphium* which apparently belong to a new species (cysts localize in the tissues of the legs, incidence of infestation 82.02%), *Gymnophallus megalocoela* (mantle, 0.11%), *Meiogymnophallus minutus* (body wall, 67.39%), *Renicola* sp. (ctenidia and all internal organs, 73.14%) and unidentified degenerating larvae (mantle muscle, 0.11%). The degree of infestation (348) with these species of metacercariae, except *M. minutus*, is low, which means that they are apparently almost indifferent to the host. The pathogenicity of *M. minutus* has not been studied.

Many Flagellata and Infusoria, probably free-living for the most part, have been found in the mantle cavity and on the ctenidia of *Ruditapes philippinarum*; infusorians from the genus *Trichodina* have been found alongside them. The mantle cavity was found to contain individual commensal nematodes of the family Monchysteridae, as well as numerous free-living nematodes.

Furthermore, the mantle cavity and the ctenidia are parasitized by copepods of the genera *Modiolicola* and *Herrmannella* (possibly H. longichaeta), and the pericardial cavity by highly modified parasitic copepods of the species Phyloconcha emygdalae. The numbers of copepods are usually low.

UDC 593.4+595.142.2:639.42

The boring sponge and polychaete as pests of mussel plantations

by L.P. Tkachuk (INBYuM)

The investigations carried out in 1984 have shown that two species of commensal animals, the sponge Cliona vastifica and the polychaete Polydora ciliata, are potential pests on plantations of the Black Sea mussel (Mytilus galloprovincialis). Investigations in this field were continued in 1985. Our work was aimed at determining the degree of infestation of the valves in relation to the size (age) of the mussel, and studying the influence of these pests on the body mass of the mollusk.

The investigations were conducted in May-July in the following areas: Laspi-Batiliman, Novyi Svet, Karadag and Zavetnoye (Kerch Strait). We examined the shells in mussels from natural populations and in mussels artificially cultivated on collectors. Altogether, we studied 950 specimens by opening and examining them. Prior to opening, the fouling was removed from the valves and the latter were dried on filter paper; after removal of the byssus, the valves were weighed. After opening, (349) we weighed only the valves of the shells, and measured their length and width.

The sponge affects 60-100% of the collector mussels, depending on their size, and basically 100% of of the mussels of natural populations. Shell perforation is more common in the mussels of older age groups, the degree of perforation being higher in the mussels of natural populations than in mussels grown on collectors (1/2-2/3 and 1/5-1/9 of the valves respectively). Furthermore, upon examination of natural mussels affected by the sponge in 1985, we noted gonad tissues of the mollusks caught in the mouth of *Cliona vastifica* in 5.0-79.2% of the mussels examined. As we know, the sponges feed on dead microscopic algae, bacteria and protozoans. Their development may have been suppressed by low temperatures, and so the sponges turned to feeding on mussel tissue (due to a shortage of their usual foods). Another possible explanation is that the sponges themselves are highly sensitive to temperature changes, and can lock their osculum under extreme conditions. Therefore, the mussel tissue could have been seized accidentally with the stream of water. In any case, however, the tissue will be destroyed, since all organic particles that find their way into the sponge are destroyed by the toxic substances secreted by it.

Boring polychaetes were also noted in the valves of the mussel shells. Penetrating into the shell, they cause blisters to form on its interior surface. As in 1984, we found blisters occupying 1/2 of the cavity of the mussel. It should be said, however, that the perforation of mussel shells by the polychaete is a relatively rare occurrence in the given areas, being noted in only 3.0-10.2% of the mussels examined from a natural population. Highly perforated shells are not only unsightly, but they also have a damaged muscle insertion (Kinne, 1983). The polychaetes penetrate the shell in the region of the adductor or the byssal contractile muscle, which leads to atrophy and deterioration of the muscle tissue (Lebour, 1907; Field, 1923). Other authors (Pillai, 1965; Kent, 1979, etc.) have reported physiological disturbances (stress) in mussels, as well as abnormalities of their genital products (a decrease in fecundity, low viability of the larvae and slow growth).

Consequently, both the sponge and the polychaete are indeed potentially dangerous pests of mussel farms.

UDC 594.124:639.42(262.5) (350)

The parasite fauna of Black Sea mussels in natural populations and in mariculture

by Ye.V. Kholodkovskaya (Odessa Agricultural Institute)

A comprehensive ecological-parasitological survey of mussels has been going on in the northwestern part of the Black Sea since 1980. The natural populations of a number of gulfs (see table), as well as mussels grown on rope collectors and in trays, have been examined. Approximately 2000 mollusks have been studied by the method of total parasitological dissection. The parasite fauna of the mussels from the Dzharylgachsky and Yegorlytsky gulfs is the most abundant in pathogenic species.

In the cultivated populations from the Odessa Gulf (without the commensals), we found one parasite, the microsporidium of Steinhausia mitilovum (incidence of infestation 3.6%), whereas the mussels in Yegorlytsky Gulf were found to contain 4 parasites: (351)
Hexamita sp. (66.7%), Steinhausia mitilovum (8.3%), Gargarius*

*conjectural spelling - transl.

(2.8%) and Proctoeces maculatus (8.3%).

Incidence of infestation of Black Sea mussels (%) with parasites and commensals

PARASITES	GULFS				
	Dzharyl-gachsky	Yegor-lytsky	Odessa	Karkinit	Tendra
Flagellate *Hexamita* sp.		18.9	1.0	31.6	17.9
Microsporidium of *Steinhausia mitilovum*	2.8	12.4	5.2	0.8	
Infusorians *Ancistrum mytili*	17.2	17.5	26.4	15.8	41.3
Peniculistoma mytili			5.8		
Sponge *Cliona vastifica*	4.8				
Turbellarian *Enterostoma mytili*	21.2		3.0		
Trematode *Proctoeces maculatus*	2.6	10.3			
Polychaete *Polydora* sp.	1.2				

We can see from the above data that the Dzharylgachsky and Yegorlytsky gulfs have the least favourable parasitological conditions. Only after further research into the effect of parasites on the qualitative and quantitative composition of the soft tissues of infested mollusks will we be able to tell just how promising mussel farming can be in this region.

UDC 593.96

Parasite fauna of the Far Eastern trepang (*Stichopus japonica*)

by Ye.M. Tsimbalyuk (TINRO)

The prospects of developing the cultivation of *Stichopus japonicus* have brought about the recent intensive research of this species.

The TINRO Laboratory of Parasitology of Marine Animals conducted a parasitological survey of the trepang in the areas of its cultivation in Peter the Great Gulf from 1972 to 1985. One thousand and thirty-two specimens were examined; 738 (71.5%) were infested with parasitic turbellarians, and 27 (2.6%) with copepods. The turbellarians included the species *Anoplodium mediale* and *Xenometra arbora*, and the copepods consisted of *Humesulus lobatus* (in the lungs) and *Scambicornis affinus* (in the wash water).

We found *X. arbora* interesting; they localized strictly in the middle ascending limb of the intestine, firmly attaching themselves to the wall. Pathohistological analysis of the affected parts of the intestine of the trepand showed that certain degenerative changes are observed when the turbellarian attaches itself to the wall of the intestine, including pycnosis of the epithelial nuclei, degeneration of the epithelial cells and the appearance of a layer of connective tissue. Mitoses are observed in the cells of the connective tissue, which points to the possibility of tissue hypertrophy. Turbellarians parasitize only during the spring (April) and, less commonly, autumn periods, i.e. when the intestine is in its normal condition (full length). (352) During its resting period in summer (aestivation) when seasonal evisceration takes place, the remaining part of the intestine does not contain any parasites. I quite agree with the assumption that chemical stimulation is the primary cause of the autotomy of the internal organs (evisceration) (Jespersen, Liitzen, 1971; Levin, 1982). In this case, it could have been the metabolites that formed as a result of the vital activity of the turbellarians.

Infestation with turbellarians takes place when the trepang attains a weight of 39-40 g (average weight of a mature trepang 200-300 g). The highest incidence of infestation of the trepand with turbellarians is observed in Minonosok Bay (91.0%), and the lowest incidence in Starka Strait (44.4%). The highest degree of infestation was noted in Novgorodsky Bay (200 specimens).

The quantitative characteristics of infestation of the trepang with turbellarians vary from year to year. The highest infestation was noted in 1982 (97.7%), and the lowest in 1979 (64.0%).

Parasitic copepods were encountered singly.

Parasitological research of the trepang cannot be regarded as complete. Further investigations of this species should include biochemical and histological analyses.

UDC 594.582.2/.8:595.121

Illex argentinus as an intermediate host in the life cycles of cestodes

by O.A. Shukhgal'ter (AtlantNIRO)

Illex argentinus is one of the most prolific species of squids in the southwestern Atlantic. We have studied 377 specimens of this species with a mantle length (ML) of 6-36 cm, which were caught in 1984.

The cestode fauna of this squid consists of *Phyllobothrium* larvae with an overall incidence of 48%. They localize in the

(353)

organs of the digestive tract. The individual finds in the mantle cavity and funnel were apparently incidental ones, since these cestodes migrate actively even after the host has been caught. The *Phyllobothrium* larvae fall into 3 types according to the form of the bothridia: 1) with smooth oval bothridia, 2) with undulate bothridial margins, 3) with scalloped bothridial margins. We have studied the morphological characteristics of 143 specimens of *Phyllobothrium* larvae from 85 hosts. The cestodes of the 1st group (25.5%) measure 0.6-9.0 mm, those of the 2nd group (69.8%) 1.0-26.5 mm, and those of the 3rd group (5.0%) 1.0-21 mm. The cestodes fall into three size groups: small (up to 2 mm), medium (2-6 mm) and large (over 6 mm). The most commonly encountered are the small (1.0-1.5 mm) and large larvae (10.0-15.0 mm).

Phyllobothrium larvae localize in the stomach, caecum and rectum in squids with a ML of 6-14 cm, and mainly in the rectum and to some extent in the stomach in squids larger than 23 cm. Mostly small larvae are encountered in squids with a ML of up to 20 cm (71.9% of the total number); large and small larvae are encountered in squids with a ML of 20-24 cm (58% and 36% respectively), and large and small larvae are also encountered in squids with a ML of more than 24 cm (89.1% and 3.3% respectively).

Small *Phyllobothrium* larvae find their way into the squids via planktonic invertebrates, the main food of small squids. The squids of older size groups become infested with large *Phyllobothrium* larvae primarily from small bony fishes. However, the presence of a transitional size group of larvae, which constitutes 4-8% of the cestode fauna in all the studied size groups of squids is an indication of the growth of small *Phyllobothrium* larvae in the squid.

Consequently, the different size-age groups of *Illex argentinus* apparently contribute in different ways to the life cycle of *Phyllobothrium* cestodes, either as a second or a third intermediate host.

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