EXTRACTED from HYDRORES 7 (8)

SEVASTOPOL MARINE RESEARCH

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INSTITUTE OF BIOLOGY OF THE SOUTHERN SEAS

Aleksander O. Kovalevsky.

The Institute of Biology of the Southern Seas (IBSS), situated on the shore of Sevastopol Bay in Sevastopol's city centre, is the oldest Russian institution of the kind providing investigations in applied and basic sciences. It employes some 500 staff in Sevastopol and 250 in its Karadag and Odessa Branches altogether.

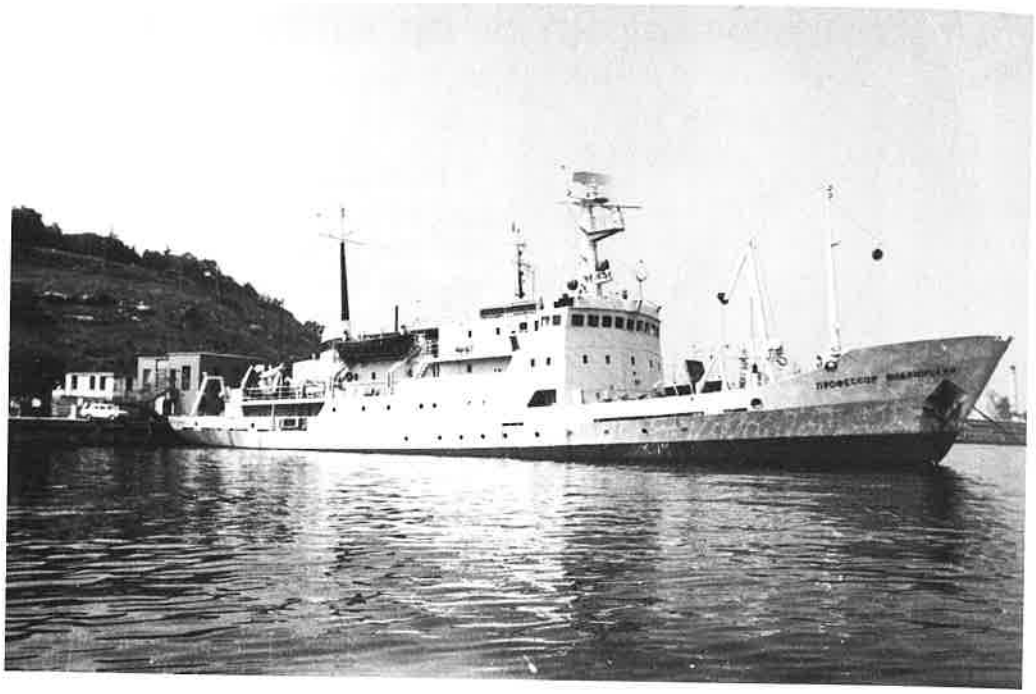
IBSS was founded in 1871, those days it was the Sevastopol Biological Station. The idea of its foundation belonged to a young zoologist N.N. Miklukho-Maklay, later a famous traveller and ethnographer. His initiative was supported at the 2nd Congress of Russian Naturalists, and then this was put into practice.

The Station was established in the period when the great evolutionary theory aroused particular interest for studying marine flora and fauna in their diversity. The Sevastopol Biological Station became the centre where Russian zoologists and botanists improved their know-how and were engaged in the most prominent contemporary investigations, hundreds of young people gained their first knowledge and took their first steps in science there. At the same time problems of national economy and fleet were studied within its walls.

The period of the World War I and the following Revolution cut any opportunity to carry out scientific works at the Station; investigations were resumed only in 1923. They concerned annual changes in vertical distribution of temperature, salinity and density, the problem of hydrogen sulphide in the Black Sea was approached, though nowadays the enigma of hydrogen sulphide still makes experts in hydrobiology and hydrochemistry uneasy.

During the World War II the city of Sevastopol was completely ruined, the Station did not make an exception. It was by a special decree of the Government that in the very first post-war months Sevastopol was put under restoration and soon rose from the ashes as the fabulous phoenix. The Station was reconstructed and equipped to satisfy the requirements of contemporary science.

In 1963 the Sevastopol Biological Station was reorganized into the Institute of Biology of the Southern Seas. At present IBSS includes 17 departments, its Odessa Branch 4 and the Karadag Branch 2 departments. The Institute performs researches in hydrobiology,



Research vessel «Professor Vodyanitsky», belongs to IBSS, Sevastopol displacement 1600 t, a take 22 scientists.

oceanography, ecology, radiobiology, seaweed cultivation and management, mariculture etc.

From its very beginning the Sevastopol Biological Station focused attention on training practice of students from different universities and istitutes. At present this tradition is successfully upheld, and students from Kiev, Moscow, Odessa, Krasnodar and Dniepropetrovsk do their practical work at IBSS.

The Institute library holds more than 150.000 volumes in addition to audio-visual materials, microfilms and comprehensive selection of newspapers and periodicals. The library also makes books available through inter-library loans to other libraries.

Two research vessels, «Academician Kovalevsky» and «Professor Vodyanitsky», are employed in the investigations. The R/V are used in geophysical, hydrographical and biological researches in different parts of the world. They have a crew of 32 and can carry scientific staff up to 28 people each.

A small part of the Black Sea is located under the cupola of the Institute's Aquarium. It is a favourite entertainment of the city residents. Besides, none of the guests from the famous Crimean sanatoriums misses a chance to come see curious fishes and other sea inhabitants.

So you are welcome also!

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ECOLOGICAL PROBLEMS OF MUSSEL MARICULTURE AT THE BLACK SEA

Abstract

The study of energy and substance fluxes is the productive-ecological basis for mussel mariculture arrangement at the Black Sea. Their optimization in ecosystems allows to rehabilitate the environment quality and to obtain commercial production.

Ecological conditions of the Black Sea are favourable for mussel inhabitance. Mussels are ubiquitly distributed forming mass aggregations. Quite recently mussels numbered almost 10 mln t, but during last years their number decreased essentially (IVANOV A., 1987). And nowadays the mussel catches are not profitable economically and ecologically as well.

Mussel is a popular research object. Vast scientific literature is devoted to main features relating to the ecology and biology of mussels *Mytilus galloprovincialis* Lam. at the Black Sea (for example, MIRONOV G., 1948; IVANOV A., 1971; KONSULOVA, 1981; SKARLATO et al., 1985; Biology and Cultivation of Molluscs, 1987; IVANOV V. et al., 1989; ZAIKA et al., 1990).

Mussel mariculture is perspective at the Black Sea (Moiseev et al., 1985; SKARLATO et al., 1989) due to a vast shallow shelf in the northwestern region, sufficient food and high mussel reproductive potential. However only some experimental farms were organized by scientific research institutes in the Crimea, Caucasus, north-western and Bulgarian regions. Main factors constraining mussel (oyster) production are the absences of good gulfs and lagoons for mariculture at the Black Sea. In connection with this the experience of mariculture-skilled countries cannot be applied to our basins.

Mussel mariculture at the Black Sea is to be developed as mariculture of open waters and oriented on the designing of storm-resistant constructions with the account of significant current effects. No less important role in restrain of mariculture development plays the competition of coastal industrial and recreational utilization, the traditional loss of non-fish marine products eaten by the population, sea pollution and its eutrophication.

Molluscs-filtrators in natural biocenoses are important for stabilization of the environmental natural conditions. That's why some researchers associate mariculture not only with foodstuff production but with a feasible improving of the sanitary-ecological status of inshore waters (MIRONOV O., 1985; MOROZOVA et al., 1985; KOSTILEV et al., 1987; MARJANOVIC, 1983).

In ecosystems including marifarms productive-destructive processes are intensified significantly. Synthesis of organic substances and sea purification from pollutants and eutrophying elements have their united substance-energetic basis - the substance turnover and energy flux in ecosystems of different complexity.

In perspective, besides the water pollution monitoring the main management mechanism for medium formation and commercial capacities of sea coastline may be the controlled ecologically balanced rearing of marine organisms and their harvesting in significant biomasses as sources for food, forage, medical raw material, organisms-meliorators, i.e. mariculture. The main mariculture motto developed by scientists of the Institute of Biology of Southern Seas (USSR, Sevastopol) is THE REPRODUCTION OF THE ENVIRONMENTAL QUALITY DURING THE MARINE PRODUCTION OBTAINING.

Genetic-selective studies with mariculture objects are of great significance now when species diversity decreases not only in the coastal region but in the pelagial also. The fate of genofond and of rare and reproductive species in mass number is equally actual for researches and for industrial programmes relating to the mariculture as well.

Though ecological problems of the industrial mussel mariculture development under growing anthropogenic influence are diverse we attempted to group the main problems into three directions:

1. Evaluation of aquatorium bioenergetic potential for mariculture aims. Problems connected with the maximal productivity obtaining and profitable utilization of trophic properties in some regions.

2. Pollution of the environment, mariculture production, toxicant impacts on molluscs as well as the study of a mussel role in pollutant transformation and detoxication during the biogenic migration, assimilation and release from the biotic turnover.

3. Ecological problems of the environmental re-eutrophication in regions with industrial mariculture, ecosystem functioning monitoring including marifarms.

In principle the account of rate and current direction, detailed knowledge on larval and food distribution, density and depth profile variations in collectors' placing, mollusc energetic budget with seasonal and ontogenetic changes in feeding and other functional indicators permitted to suggest a complex of biotechnical measures for each region optimizing mollusc scope for growth as well as labour expenditures to support the mariculture farming.

O. Kinne (1981, 1983) discussing aquacultural ecological problems underlined the inevitability of pollution includid into the biotic turnover and stressed the urgency of developing those mariculture technologies which transformed different elements and substances of anthropogenic origin into useful products. Problems of toxicants concentrations and their effects are associated with the study on mechanisms of biogenic migration, organism variability and evolutionary changes in ecosystems (Patin, 1985).

At the Black Sea especially in the northwestern shallow region the medium pollution entailed deep ecological changes followed by mass mortalities in bottom fauna (Zaitsev et al., 1987). Similar picture but in a less scale was marked at the Adriatic Sea (Fanuko, 1989). These processes are extremely important in mussel mariculture as they induce an essential decrease in reproductive capacities of natural mussel settlements.

Up to now at the Black Sea there were no registered poisonous effects of the «red tides». But this danger does exist due to still growing intensive blooming of unicellular algae and noctiluca. Molluscs-filtrators with proper biomass are able of regulating the seston number in the medium. Therefore it is perspective to develop biotechnical procedures providing an active role of mussels in conditions of mariculture farming for to stabilize sanitary-ecological status of the region with the experimental farming.

Theoretical basis for these investigations is in the balance modelling geochemical cycles of some eutrophying elements, knowledge of biochemical mechanisms and kinetics in physiological processes: filtration, assimilation and transformation of suspended dissolved organic substances. Many authors marked an active role of mussel mariculture farms as an artificial reef facilitating environmental melioration (Artificial Reffs for Fishery, 1987; FAO Fish Report, 1986).

Ecologically balanced bi- and polyculture, but not monoculture, are perspective for mariculture development at the Black Sea. The planning of investigations and development of practical recommendations directed to rational organization and management of production processes at marifarms of different types are the subject for active discussion in theoretical papers devoted to aqua- and mariculture (Sapozhnikov, 1985; Silkin and Khailov, 1988; Laws, 1986).

Some mediterranean countries demonstrated vast abilities of mariculture in foodstuff production and in aspect of nature protection while working with molluscs (Bussani, 1983; Paquotte and Rey, 1988).

There are all grounds to expect that in the near future the mussel mariculture and mariculture of other marine organisms will be widely distributed and developed as the system of rational utilization of nature.

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REARING OF VIABLE JUVENILES OF THE BLACKSEA TURBOT IN EXPERIMENTAL CONDITIONS

Abstract

Procedures and conditions on the Black Sea turbot Psetta maeotica (Pallas) rearing from artifically fertilized eggs upto the age of 240 days in experimental conditions are described. Transition to a bottom mode of life occurs at the age of 45-50 days, metamorphosis completes on days 70-80. At the age of 8 months the mean length of Black Sea turbot was 13.85 cm, body weight was 59.5 g.

The Black Sea turbot *Psetta maeotica* (Pallas) is a representative of sandy and silt-sandy communities. It is met to 130-140 m depth. Due to territirial restriction of species area the mean long-term data show that the total stock of turbot at the Black Sea is not high and accounts 103-158 thousands of centner (Popova and Vinarik, 1979). Main conditions providing stable stock are the prolonged life cycle (approximately 20 years), complex age structure of reproductive part of population and greatly high fecundity.

Nowadays the Black Sea turbot stock is in a depressive state. The main reason is the extensive fishing of all Black Sea countries, especially Turkey and Soviet Union and jprobably environmental pollution.

In 1974 to preserve this valuable fish species the Soviet Union limited the turbot fishing in the period of their mass spawning.

In 1985 complete prohibition was declared for ten years. We consider the artificial rearing of turbot juveniles at fishculture farmings and their next transportation into suitable sea regions to be cardinal rehabilitation measure to increase turbot quantity.

Main cultivation difficulties are connected with the creation of special technical constructions supplied with regulations of environmental parameters and with the lack of data on biology, ecology and adaptive abilities of turbot at early stages of ontogenesis. During last the years the morpho-ecological peculiarities at early ontogenesis were studied, developmental periodization was conducted, morpho-ecologo-physiological specifications of some stages were revealed, stages that were characterized by increased elimination under rearing (Chepurnov et al., 1985) were defined. During a longterm staying in pelagial (45-50 days) larvae passed 8 developmental stages during which changes occurred not only in body building and in functions of some organs but also in responses to abiotic factor impacts. The larval extreme vulnerability was exhibited with transmission from stage to stage: active feeding beginning (3.5-4 days of age); caudal, dorsal and anal fins' differentiation commence (13-14 days); skull orbital part alteration in process of an eye migration (30-35 days). A stage-specificity in developmental processes was expressed in shifts of optimal culturing conditions. The most important among them were temperature, salinity and food supply.

Temperature.

Tolerant temperature ranges for embryogenesis were limited by 12-21°C, optimal incubation temperature for turbot eggs was 14-17°C. More than 50% of all larvae were hatched viable. Optimal scope for growth and utilization of yolk sack content was limited by 15- 18°C. Temperature range concentration was noticed at each next developmental stage. Similar picture was shown for other plaice species (Irvin, 1974). If tolerant diapason for embriogenesis amounted 9°C, then at metamorphosis it reduced to 3-4°C with a shift to a field of higher significant values (19-23°C).

The developed juveniles possessed the ecological plasticity. They may be cultivated at a diaposon of extended temperatures.

Salinity.

Salinity affects significantly the turbot fertilization. The highest number of normally developed eggs was observed when the fertilization occurred at water salinity 16-20‰. Maximal number of viable hatched prelarvae was obtained under incubation at water salinity 17.3-18‰. The salinity increase or decrease disturbed the water-salinity balance, decreased the number and body length of normally-developed prelarvae and increased the yolk absorption rate. The prelarval osmoresistance expanded to 15-20‰, however the linear and weight growth efficiency as well as the utilization of yolk sack content were maximal at 17.5-18.5‰.

Food organisms.

The most wide-spread food organisms are highly technological marine organisms such as saline rotifers *Brachionus plicatilis* and brine shrimps *Artemia salina*. However in case of the unbalanced biochemical content, in particular, insufficient quantity of highly unsaturated fatty acids (HUFA) (BEN-AMOTZ et al., 1987), these organisms appeared to be unadequate to feeding requirements of larvae and thus they cause high mortalities of the larvae at the stage of exogenic feeding and at later stages. The dietary value of rotifers is improved by using modified temperature-density technologies and feeding of cultivated organisms by a mixture of algae of different systematic groups: *Chrysophyta, Bacillariophyta* and *Pyrrophyta*.

At late stages larvae were fed by calanoids *Acartia clausi* except the common-used *Artemia salina*. *Acartia clausi* were reared either in polyculture with harpacticoides *Harpacticus littoralis* or in synchronous monoculture (KHANAICHENKO, 1989). *Acartia clausi* synchronous culture permits to variate the copepod ration with its developmental stage, facilitates to select available size groups for feeding fish larvae of different stages. The Acartia generation time was 9 days, maximal density reached 8 nauplii/ml and 1 adult/ml at optimal 21°C in Pyrrophyta and Chrysophyta algal mixture at a concentration of no less than $5x10^3$ cells per organism.

Black Sea turbot rearing methods.

Eggs of the sampled females were dry and semi-dry-fertilized and brought in thermostative beakers to the shore laboratory. Eggs at 4-8 cell-stage were stored in incubators at the maintained temperature regime in account of 700-800/l. The eggs were incubated at 15°C and 18‰ salinity. The hatched prelarvae (15-20/l) were stored in 200-400 l tanks weakly aerated. The water-through system did not circulate since larvae were unable of resisting the water flow during first two-three days. Temperature was raised from 15°C to 17°C.

The 3-days old larvae have an open mouth, a differentiated intestine, pigmented eyes and a small swim bladder. The latter starts to be filled with air after the appearance of forming blood elements. At that time unicellular algae (0.001-0.01 mln cells/ml), rotifers (1/ml) and copepod nauplii (0.1-0.3/ml) were added to the tanks. The highest mortalities at turbot rearing was marked when larvae were set on active feeding (Fig. 1). Probably, one of the main reasons for that was deterioration of environmental hydrochemical parameters. That's why the 4-5 days old larvae were in weak water flow and 5 days later water circulation was increased to 2-3 tank volumes per day.

The 8-9 days old larvae were fed by *Artemia nauplii* at density of 0.5- 1.0/ml and copepods at density of 0.1-0.2/ml. When the turbot larvae increased in size they might be fed by meta-nauplii Artemia at density of 0.2-0.5/ml. New food manner is followed by changes in the intestinal system. At the first stages larvae digested food stomachlessly. On 12-13 days the stomach separated anatomically, gastric glands commenced to differentiate. Caudal, dorsal, anal and then abdominal fins developed, swim bladder inflate proceeded, body height reached 40-45% of body length.

On 16-17 days the body length was 7.0-7.5 mm, a right (upper) eye migration began, body slope changed at swimming. The temeprature must be raised to 20- 22°C for to have successful metamorphosis.

On 23-25 days the larvae reached 8-12 mm a length and were transferred to tanks of 0.8-1.0 m^3 volume. By this period the most complex processes of morphogenesis completed: the right eye placed on top of a head, body flattened, the hight amounted 55-60% of a body length. Larvae floated with a left side up and for short time descended to prebottom layer. Bottom life behaviour and a fry period was watched on days 45-50. The feeding behaviour of larvae changed: they might be fed by inert food (fish or mussel

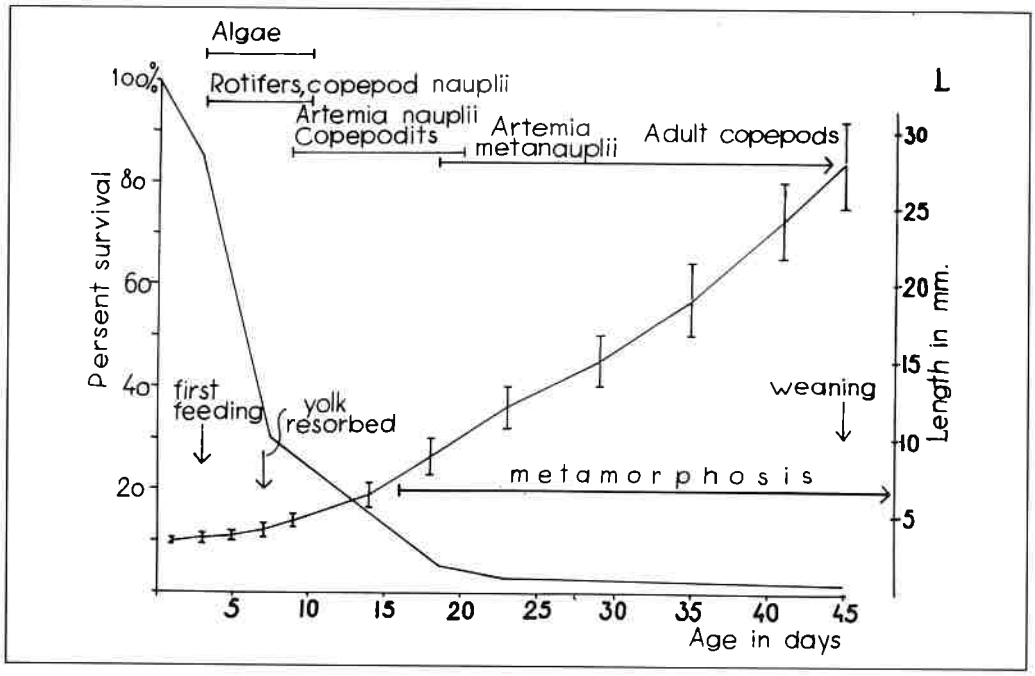

Fig. 1 - Survival and length growth (with S.D.) of Black Sea turbot larvae reared in 1989.

Fig. 2 - Black Sea turbot Psetta maeotica at the age of 7 months.

flash) twice a day. The metamorphosis completed during a fry period on 70-80 days, body length was 50- 60 mm.

Features of metamorphosis completion were: swim bladder reduction, definite eye position on left side of the head, primordial dorsal fin extended to a level of a front ridge of the right eye.

Metamorphosed juveniles may be transferred into open (outdoor) basins. To release juveniles into the sea is expedient in the age of 3-4 months with body weight - 8-12 g, body length - 7.5-9.0 cm.

In 1989 during 8 months the laboratory-reared Black Sea turbot juveniles were stored in closed water system at 15-13°C. They were fed by fish and mussel flash. During this period they sized as one-year fishes, body length was 13.85 cm, body weight - 59.5 g (Fig. 2). Thus it may be supposed that at higher temperature the Black Sea turbot can reach commercial sizes (35-40 cm) during two years. These data are in good accordance with those obtained at turbot rearing (Liewes, 1984).

Up to now the experience of artificial fish cultivation is practically absent at the Black Sea. Our results testify to the feasible reproduction of valuable, endemic for the Black Sea-Azov region, flatfish. With intense rearing of Black Sea turbot and other fish species one may solve not only problems of commercial production but also the problem of species diversities maintainance to preserve the ichthyofauna of the Black Sea.

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CLIMATIC AND PHYSICO-GEOGRAPHICAL CONDITIONS FOR MUSSEL MARICULTURE AT THE BLACK SEA

Abstract

Climatic and physico-geographical peculiarities of some regions define feasibilities of mussel mariculture development at the Black Sea. Diurnal and seasonal changes of thermochaline water structure in the region with experimental mussel marifarming are given.

From a morphological viewpoint the Black Sea is a significantly isolated water body with limited water exchange through shallow-watered straits connected with the Mediterranean and Azov seas. The summarized yearly effluents are evaluated as 370 m^3 (approx.). This defines positive freshwater balance and low salinity relative to World Ocean waters (BLATOV et al., 1984). Water masses with relatively homogeneous characteristics are involved into the system of cyclonic currents induced by prevailing sea winds.

Sharply differed in temperature and salinity the estuaries of the Danube and Dnieper rivers, Karkinitsky and Sivash gulfs are considered to be unsuitable for mussel mariculture. In these sites water salinity drops sharply in spring till 5-10% or elevates higher to 40% in summer. Water temperature may be below zero (till -5°C). Ice formation was watched at large-scaled shallow areas.

The most suitable area for mussel cultivation are regions of Caucasus, Crimea, north-western and western Black Sea with temperatures from 2-3°C up to 24°C, salinity from 14-15% up to 18.4%. However these regions are affected by stormy winds, that is why storm-resistant constructions, sequently money-expensive, must be established for the cultivation.

Climatic and physico-geographical conditions of some regions form local ecological climates.

To solve mariculture problems we are to have sufficient detailed knowledge regarding seasonal, inter-year and other external factor varieties - the source for great perturbations in thermocline structure of Black Sea waters.

A more important task is to find out the reason-consequence correlation between oceanological factors and biological processes for mussel fodder formation, larval pooling, growth seasonal rates, biodeposit dispersion and dissolution.

In connection with the organization of experimental mussel-culture farming by the Institute of Biology of Southern Seas (Sevastopol) the region Sarych cape - Laspi bay was thoroughly studied.

It is situated in a climatic zone of the Crimea that is the analog to a mediterranean dry subtropical type: hot summers and moderate warm winters (Fig. 1) (VAZHNOV, 1983).

Mountain massif (to 663 m height) protects the aquatorium against western and northern winds. Ilyas-kaya mountain (679 m) and other mountain peaks (to 625 m) prevent from eastern and south-eastern winds. The mean sunlight duration comprises 2400 hours a year. A total bay bottom slope surpasses 2%. This allows to consider the shore as a pre-deep type for which heavy wave loadings are typical for storms induced by S-SE towards W-SW winds. The offshore depths reach 55 m. At Laspi shores the upwelling induced by western winds occurs the same way as in any region of the Crimean South coastline (BOGDANOVA, 1959).

Significant variations within a year in water masses' influence induced by winds define the unsteadiness of water thermochaline structure at Laspi Bay. The fluctuations will impact on the bay hydrobiological regime including phyto- and

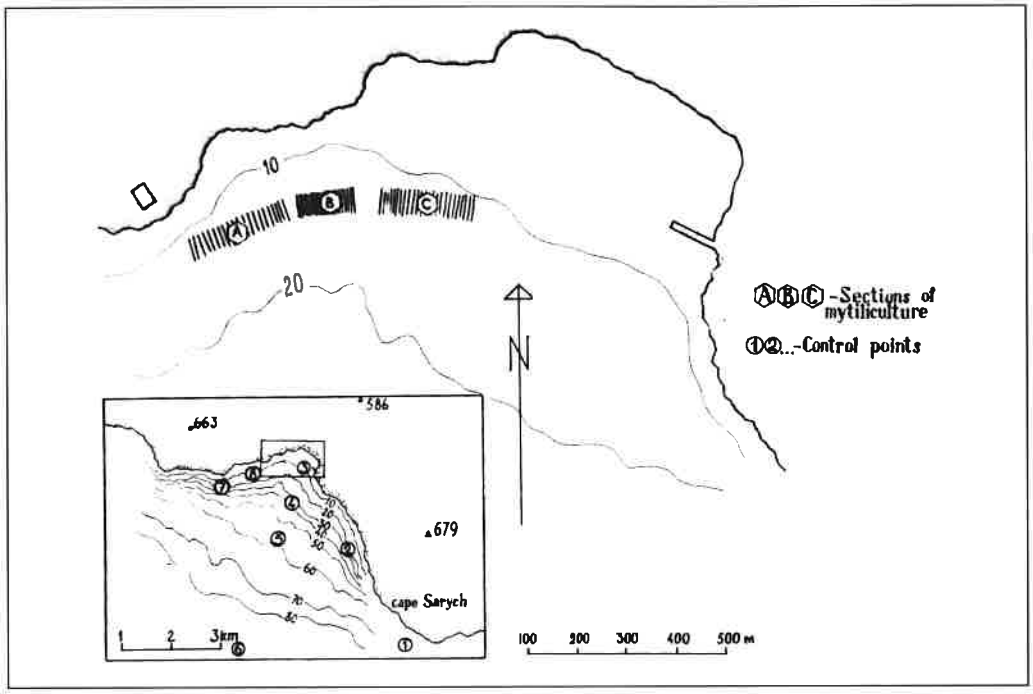

Fig. 1 - Location of experimental mariculture farming of the Institute of Biology of Southern Seas and control watch points.

zooplankton concentration and status of ichthyofauna. For example, high upwelling and subwelling induced by winds incurred complete vanishment or sharp increase of mussel larval number (KAZANKOVA and PIRKOVA, 1987). In September 1985 high up-welling entailed water temperature drop till 16°C and caused fish mass mortalities.

Fig. 2 illustrates the mean reiteration of winds at Sarych cape for many years. It demonstrates insignificant dominance of the eastern wind. Fig. 3 a,b shows the long-term mean

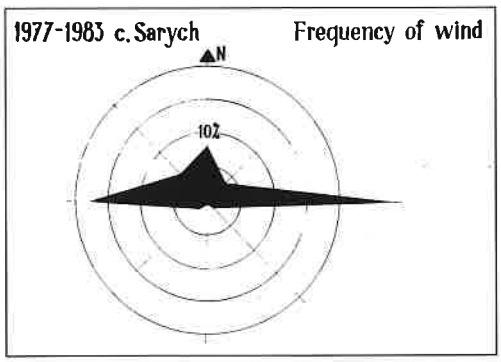

Fig. 2 - Reiteration of winds at Sarich cape.

monthly surface water temperatures and anomalies noted by us in 1985-1989.

In spring-summer period negative anomalies corresponded to W wind prevailance; in autumn-winter - to NE, N winds.

In contrast, in the same period (spring-summer) positive anomalies corresponded to subwelling induced by NE, E and SE winds or related to a small-gradient field of the atmospheric pressure.

In the autumn-winter period positive anomalies in surface temperatures were defined with W wind high repeatedness. Compared with inter-year changes in temperature anomalies corresponding change in salinity is no less complicated. This related to a dominant advective character of salinity pool formation. Synoptical changes in Black Sea water circulation much affected the inter-year changes, and in its turn the ciruclation itself underwent these changes too (BLATOV and BULGAKOV, 1984). Analogically to variations in salinity pool formation it's noteworthy to account variables of passive mixtures during the pool formation. Phytoplankton and zooplankton may be related to mixtures.

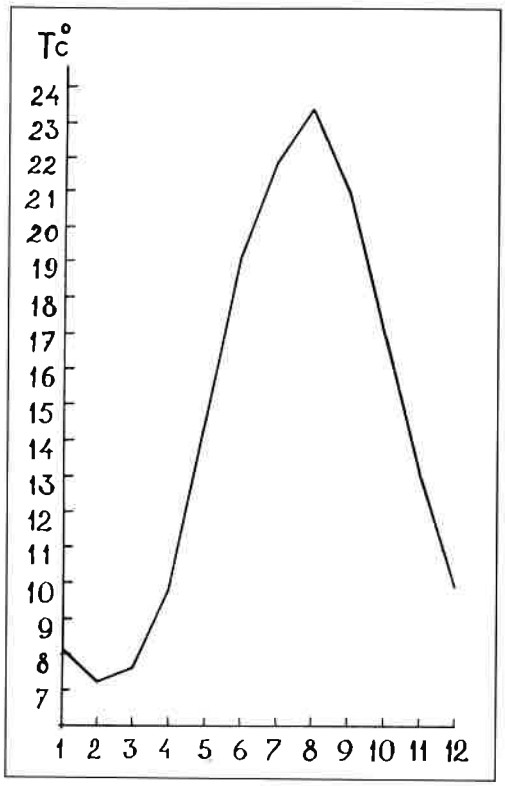

Fig. 3a - Mean many-year-monthly surface sea water temperature in Laspy Bay

Thus it is feasible to predict ecological and productive conditions basing on synoptical prognosis.

In hydrobiological regime of Laspi Bay the role of a breeze effect, more expressed within warm season was very significant. As a result - wind rechanged twice a day that was concomitant with alterations in current and thermochaline structures. The most significant changes were revealed in spring-summer period when the upper boundary of the autumn thermochaline surfaced or submerged 15-20 m in precoastal bay zone.

During the same period coastal currents were registered with speed sometimes higher than 0.5-0.6 m/sec. Those currents were formed during morning or evening changes in wind and current fields.

The most repetitive character for current distribution in upper profiles at daytime is represented in Fig. 4. Night-time current spread is shown in Fig. 5. Current velocities fluctuated from 0.03 to 0.35 m/sec.

Current systems to be formed in the bay and in close distance to the main Black Sea current provided abundant water exchange. This may reason the absence of the accumulated suspensions released by mussels under cultivation technical constructions.

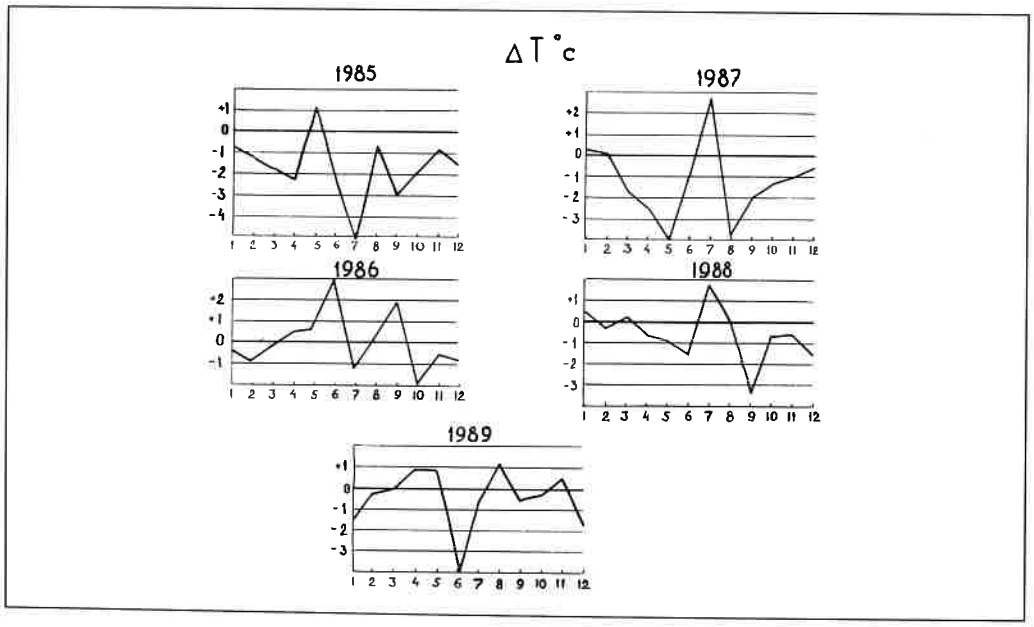

Fig. 3b - Anomalies in mean-monthly surface water temperature in Laspy Bay during 1985-1989.

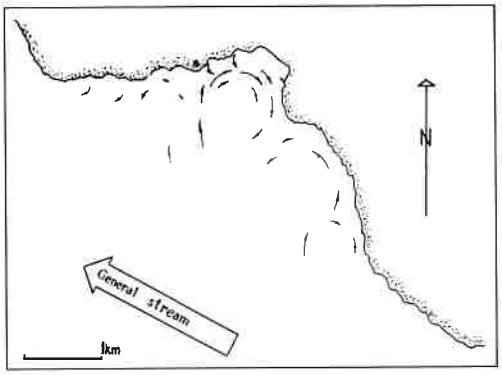

Fig. 4 - Daytime most often reiterated system of currents.

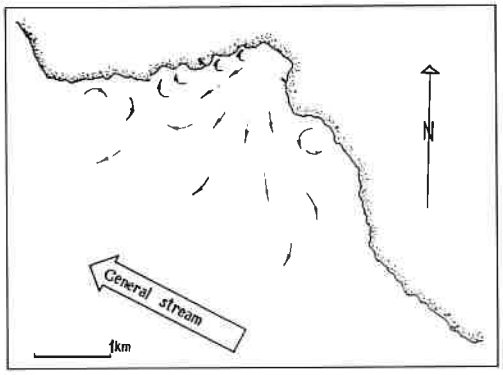

Fig. 5 - Night-time most often reiterated system of currents.

The establishment of experimental mariculture farming (Institute of Biology of Southern Seas, Sevastopol) with the account of potential wind direction and wave loadings allowed to provide satisfactory storm-resistancy for technical equipment able to withstand storms force 5 which occur more than 4 times at Laspi Bay. The wave height of one yearly observed storm within 1985-1989 storms reached 4 m, length - 75 m. Independently cold or warm seasons storms entailed heavy changes in temperature and salinity pool structures along the whole Crimean coast as well as in Laspi Bay. All the foregoing affected mussel growth rates, their spawning and phytoplankton supply at the farming.

Thus, Laspi bay gives large-scaled potentials for experimental researchings in mariculture thanks to great diversities in hydrological parameters which may be met at relatively small aquatorium.

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DYNAMICS OF PHYTOPLANKTON COMMUNITY IN THE REGION WITH MUSSEL MARIFARMING

Abstract

In cold years big diatom and peridinium algae are the basis in phytoplankton biomass in the region with mussel mariculture farming. Mussels consump ultra and nanoplanktonic coccolithophorides, peridinia and small flagellates, mass development of which was watched during warm years. Actively filtrating and transforming into faeces and pseudofaeces a mass of planktonic algae mussels serve as meiorators in the environment.

Mussel great filtration with immobile behaviour allow to satisfy their feeding demands and renovate energy expended for growth and reproduction. It is known that mussels cultivated on ropes are fed more essentially on viable phytoplankton than mussels in natural settlements which consume more detritus (KIYASHKO, 1987). Filtrating huge suspension which contain vast algal diversity, mussels choose only ovate-orbicular and cylindrical-shaped cells in a volume from 14 to 160000 μm^3 not reaching a high number in phytoplankton, except coccolithophorides. Algae with long spicules, *Ceratiums*, long coarse *Chaetoceros* with very long Rhizosolenia, forming long colonia and being rich in plankton (*Sceletonema costatum, Pseudonitzschia delicatissima, Cerataulina bergonii*) are coated with mucus and then they are mass excreted as pellet-like pseudofaeces. Thus not a whole phytoplankton community may be a feeding base that differed greatly within a season. That's why to evaluate fodder capacity in the region with mariculture farming, to place collectors in proper distances and to control the «red tides» possible occurence, one must know seasonal and inter-year dynamics in number, biomass, phytoplankton qualitative and sizeable structure in dependence on climatic conditions, hydrological and hydrochemical parameters of the aquatorium.

Investigations at the experimental mussel mariculture farming established by the Institute of Biology of Southern Seas (Sevastopol) started in June 1983 and are underway nowadays.

Phytoplankton was bathometered one time a season at 8 stations, depth profiles - 0; 1,5; 3; 5; 10; 24; 30; 65; 75; 90 m. All-year-round stationary watchings with 3 monthly samplings were conducted at two stations. The first station - near the farming site, the second - control - 3 miles offshore. Small flagellates and coccolithophorides were counted in an «alive» drop. Other algae - in a sample obtained by method of reversal filtration (31 seawater through 1 μm nuclear filter). Big algae were calculated in the total sediment. The content of guts, faeces and pseudofaeces were luminescently analysed.

The monitoring results showed that at mariculture farming region forms of mineral nitrogen were distributed analogically to their usual disperse in Black Sea coastal waters. Phosphates exceeded the background values by 2-3 times in spring, the beginning of summer and late autumn. In the cold period when a seasonal thermocline was absent it was noted that homogenous distribution of biogenic elements from surface downwards bottom. In the summer period when water is distinct by stratified a low content of biogenic elements in an upper quasi- homogenous layer and their increase under the thermocline (KUFTARKOVA et al., 1990) was marked.

164 algal species were met in bay plankton. They related to 68 genera, 5 branches. Diatoms were represented by 73 species, peridinia - 72, yellow-green - 16, green - 3, others - 2 taxons. The highest species diversities were noticed in

spring, in summer and autumn - 110-114 species, the lowest, in winter, 68.

The main organic substance was accumulated in the first half-year owing to diatom algal mass development that demanded low water temperatures and high number of biogenic elements. Algal quantitative development, species composition and «bloom» start were defined with temperature conditions in February-March when well-expressed temperature minimum coincided on these months. According to this indicator the whole investigated period may be divided into cold and warm years.

In cold years (1985, 1987) surface water temperature decreased to 5- 6°C in February-March. Water intensive intermix enriched the supply in biogenic elements. Based on them diatom algae started to develop from the second mid-March at 7°C: *Rhizosolenia alata, R. fragilissima, Chaetoceros curvisetus, C. affinis, Cerataulina bergonii.* Among peridinea big species of *Ceratium tripos, C. fusus, C. furca, Peridinium pellucidum* prevailed. By the end of May the «bloom» began to lessen. But in June-July after several heavy successive wind-induced-water-motion effects the lower thermocline boundary upwelled water masses with 7-8°C. Upper sea layers were re-enriched in mineral salts and diatom algal «bloom» durated till end of July. Spring species prevailed in plankton, but qualitative composition became more variable as a higher number of warm-loving algae appeared. Diatom algae *Chaetoceros compressus*, smaller peridinium species *Peridinium triquetrum, Exuviaella cordata, Gyrodinium fusiforme, Glenodinium paululum* reached high numbers.

The phytoplankton total number from March to July in a layer of 0-10 m varied in limits 40-430 mln cells/m^3, biomass - 140-1184 mg/m^3. In the same period peridinium algae increased their number from 0.2 to 32 mln cells/m^3, biomass - 9-73 mg/m^3. At the end of July after diatoms died there occurred a short-term flash of small coccolithophorides , *Coccolithus huxleyi* reaching in number 200 mln - 2 mlrd cells/m^3 and 55-620 mg/m^3. Then with water warming and a thermocline deepening weak short-term wind-induced water distrubances did not upwell deep waters and the phytoplankton development decreased sharply. August-November summerized values ranged from 9 to 125 mln cells/m^3; biomass - 48-135 mg/m^3. Peridinia *Exuviaella cordata, Prorocentrum micans, Gryodinium fusiforme, Coccolithus huxleyi* dominated in biomass. Diatom algae *Sceletonema costatum, Pseudonitzschia delicatissima, Thalassionema nitzschioides* showed the highest number in October-November. By the end of December the algal number decreased to 2 mln cells, biomass - to 18 mg/m^3. Dominants were *Coccolithus huxleyi, Exuviaella cordata, Sceletonema costatum.*

In warm years of 1983, 1984, 1986, 1988, 1989 small colonial diatom algae *S. costatum, P. delicatissima, Rhizosolenia fragilissima* began their mass development in the second half of February at water temperature about 7°C and continued till mid-May. The phytoplankton total number increased from 140 mln cells/m^3 to 5 mlrd cells/m^3, biomass - from 154 mg/m^3 to 5.4 g/m^3. And peridinium algae developed more intensively also. In February-May their number increased from 0.8 to 42 mln cells/m^3, biomass - from 12 to 217 mg/m^3. During February-March big algae *Ceratium tripos, Ceratium furca, C. fucus, Peridinium pellucidum* prevailed. In April-May small algae prevailed - *Peridinium trochoideum, P. triquetrum, Prorocentrum micans, Exuviaella cordata, Gyrodinium fusiforme.* In 1989 when the spring was anomally warm and early, March registered a violent flash of *Peridinium trochoideum*, the number of which amounted to 47-112 mln cells/m^3, biomass - 135 mg - 1.4 g/m^3.

During a warm year period the phytoplankton development much depended on upwelling and subwelling processes induced by winds. If in May-June strong wind-induced water movement upwelled water masses with 9-12°C then coccolithophoride *Coccolithus huxleyi* began their mass development. Vegetating by small numbers in plankton all-year-round, this species reached 455-760 mln cells/m^3, 155-177 mg/m^3 in some years (1983, 1988). The unusual violent «blooming» of *C. huxleyi* was noticed in June 1989 when the sea coloured whitish, water transparency lowered to 3 m. Its number composing 99% of summerized phytoplankton amounted to 7.6mlrd cells/m^3, biomass - 2.0 g/m^3 at sea surface. At 1.5-3 m depth its number decreased by 2-3 times and after this depth profile it rather equally distributed till 25 m depth. Flashes of *Coccolithus huxleyi* were noticed earlier at the Black Sea. They are seamingly connected with periodical outcomings of high phosphate-enriched waters at the Shelf. In July-August usually

some weak upwellings induced by winds were noted which did not bring cold waters to the surface. In 0- 10 m layer the phytoplankton number fluctuated 230-960 mln cells/m^3, biomass - 100-430 mg/m^3. *Coccolithus huxleyi* and peridinium algae *Exuviaella cordata, Peridinium triquetrum, Gyrodinium fusiforme* dominated at the surface.

At 5 and 10 m profiles diatom algae *Sceletonema costatum, Pseudonitzschia delicatissima, Chaetoceros affinis, Rhizosolenia alata, R. calcar-avis* composed 42-96% of total phytoplankton.

By the end of August, first to mid-September high wind induced waters upwelled cold masses and incurred the autumn flash of phytoplankton development which durated from September till the end of December. In this period the summerized algal number varied from 158 mln cells to 2.6 mlrd cells/m^3, biomass - 50-940 mg/m^3. When a lower thermocline boundary surfaced at 7- 8°C, then coccolithophorides, diatomea and peridinia developed intensively (1988). Coccolithophorides made up 58% of the total number, diatom *Cerataulina bergonii, P. delicatissima, S. costatum* - 12%, peridinium *Exuviaella cordata, Prorocentrum micans, Exuviaella micans, E. compressa* - 3%. Peridinium algae (26%) and diatoms (47%) dominated in biomass. When the upper thermocline boundary surfaced (15-16°C) then coccolithophorides *C. huxleyi* and small flagellates dominated in phytoplankton during the whole autumn period (1983, 1989).

As it was mentioned above, diatom algae composed the bulk in phytoplankton biomass during a year. But only a small number was utilized by the mussels. A small number of Cyclotella, Thalassiosira, Coscinodiscus, Pleurosigma, cocconeis, Licmophora, Striatella, Navicula, Rhizosolenia were found in mussel guts in volumes 250-160000 μm^3 not exceeding 16 min cells/m^3 in plankton, and only small-sized algae from those gulped were assimilated by mussels, others were excreted. Single cells of Cyclotella, Thalassiosira and Navicula in volumes of no more than 80000 μm^3 were revealed in hepatopancreases wherein main intracellular digestion occurred. Large amounts of colonial and big lonely algae were unacceptable for mussels because of their high concentration or sizes and they were excreted as pseudofaeces.

In late spring, early summer and autumn during intense albumen synthesis connected with mussel growth and reproduction the ultra and nanoplanktonic peridinium algae played a main feeding role. For a year their biomass changed from 9 to 270 mg/m^3. In this aspect of importance were coccolithophorides and small flagellates forming biomass of 0.3-2 g/m^3. Besides mussel guts contained great numbers of *Peridinium trochoideum, P. triquetrum, Prorocentrum micans, Exuviaella cordata, E. compressa, Dinophysis sacculus, Gyrodinium fusiforme, Peridinium pellucidum, Coccolithus huxleyi. Maximal value of the latter coincided with periods of the highest concentrations of carbohydrats and lipids in a mussel body (Goromosova and Shapiro, 1984). Mussels likely gulped more algae than they could assimilate when food was eccessive, that's why a bigger part of viable cells was released with faeces. Algae that passed via mollusc intestine grew significantly faster in nutrient medium than the algae sampled at sea.*

In summer and winter seasons when phytoplankton number was low and feeding behaviour was weak mussels obviously obtained main content of fats and carbohydrates from dissolved organic substance and detritus that composed till 90% of suspension. During this period the algal number was not high in mussel guts.

The most intensive mussel growth was noticed in years with high biomass of peridinium algae (to 1.5 g/m^3), coccolithophorides and small flagellates (to 2.7 g/m^3) (1988, 1989). In contrast, mollusc biomass accretion was minimal in those years when peridinia did not surpass 130 mg/m^3 and coccolithophorides - 26 mg/m^3.

Thus, the feeding base for mussels cultivated in water depths was characterized with not total quantity of phytoplankton biomass of which reached significant values but with of algae cell concentration selectively used by mussels to satisfy their energetic needs. At the same time mussels may carry out the role of meliorators for eutrophic waters by filtering and transforming huge numbers of planktonic algae into faeces and pseudofaeces.

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DYNAMICS OF REPRODUCTIVE CYCLES, SIZE AND MASS CORRELATIONS OF CULTURED MUSSELS (*MYTILUS GALLOPROVINCIALIS* Lam.)

Abstract

Dynamics of reproductive cycles of cultured mussels Mytilus galloprovincialis Lam. in the Southern Crimean region and seasonal evaluations of relative values of soft tissues as a consequence of reproductive activity are described. Some actions of biotic and abiotic factors influencing gametogenesis synchronization and mussel spawning are discussed.

It is usually considered that *Mytilus galloprovincialis* reproduction occurs analogically in different Black Sea regions but with a small shift in time since temperatures that are available for the spawning are spread from south to north and north-west (ZOLOTNITSKY et al., 1984; IVANOV, 1968; IVANOV et al., 1981; KISELEVA, 1972; KONSULOVA, 1988; KUDINSKY et al., 1985). Data on reproductive cycle peculiarities depending on regional ecological conditions are interesting from a viewpoint of biotechnical cultivation process optimization as well as in regard to seasonal changes of mollusc quality as generative production makes up a considerable part of soft tissues' energetic equivalent (ROMANOVA, 1986).

In bivalves reproduction cycles, three periods are marked: gametogenesis, spawning and post-spawning rebuilding (KASJANOV, 1980).

According to qualitative changes in mussel gonads and sexual cells the gametogenesis is conditionally subdivided into 4 stages: each next stage is a continuation of a previous one and thus they are overlapped. The adhearance to this or that stage is defined by predominance of visual and microscopic features in complex.

STAGE OF RELATIVE REST

Gonads of post-spawned mussels are thin and transparent. Acina are empty, thin, filled in undifferentiated sexual cells - gonia or oocytes at stage I in females (GRUZOVA, 1979); spermatogonia and spermatocytes in males (KASJANOV et al., 1980). Adhesive tissues are maximum developed.

GAMETOGENESIS START

A spermatogenic layer of male gonads consists of spermatogonia, spermatocytes and small quantity of spermatids and occupies almost the whole acinus. Female gonads have oocytes at stages I and II passing pachytene and diplotene of the meiosis prophase.

ACTIVE GAMETOGENESIS

A gonad is dense, of middle width, colour is typical for mature gonads. This stage is characterized by presence of sexual cells at all stages of development. Spermatozoids are formed in male gonads. In female gonads - oocytes at stages I, II and stage III passing diplotene and diakinesis of meiosis prophase. Oocytes at stage IY (diakinesis of meiosis prophase) are met in singles.

PRE-SPAWNING STAGE

A gonad is of maximal size, dense; male gonads are white, yellow, orange; female gonads are white, orange and pink. A spermatogenous layer is thin. Sperms fulfilled almost the whole acinus aperture. Female gonads are characterized by presence of oocytes at stages I, II and III, oocytes at stage IY, passing kiakinesis (immature) and a small number of oocytes, stage IY at metaphase I of meiosis (mature oocytes). While stimulating the spawning at this stage there is possible release of sperms and of oocytes at stage IY.

SPAWNING STAGE

Female acina are filled in oocytes of stage IY at mataphase I and a small number of oocytes at stage IY passing diakinesis. Oocytes at stages I and II are met singularly. Acina of males' gonads contain sperms, the spermatogenous layer is thin or is absent completely. Acinus gets empty to different extents. The presence of mature gametes in spermoducts testifies on the mussel portional spawning.

POST-SPAWNING REBUILDING

In gonads there are acinus patches with unspawned mature sexual cells. Resorbing oocytes or sperms and products of their resorbtion are noted in some acina. Main square of a gonad at histological slices resembles the 2d stage of gametogenesis.

To watch dynamics of mussel gonad mass during a reproductive cycle was unfeasible because of their close connection with tissues of the visceral system. However the assessment of soft tissue dry mass taking into account the gonad stage of maturation permits to judge about these changes. As it is known the dependence between a shell length and mass of soft tissues is equated with a gradual function (VINBERG, 1986):

$W = a * L^b$

where: a, b - regression coefficients; W - weight (mass mg);

L - shell length (mm).

In mussels passing a stage of relative rest (stage I in a reproductive cycle) dry mass of soft tissues is significantly lower than that of the equal-sized mussels but at other reproductive stages:

$W1\ st = 0.141 * 10^{-4} * L^{2.508 \pm 0.107}$;

$(20.0 \leq L \leq 62.5)$

$r = 0.914$; r - correlation factor;

Soft tissue dry mass of cultured mussels reaches its maximum before the spawning:

$W4\ st = 0.229 * 10^{-4} * L^{2.567 \pm 0.420}$;

$(25.8 \leq L \leq 75.9)$

$r = 909$

Significant fluctuations in mass of soft tissues are noticed for equal-sized molluscs during the spawning. This is connected with partial or incomplete release of sexual products and reflects the spawning asynchronization:

$W5\ st = 0.328 * 10^{-4} * L^{2.456 \pm 0.430}$;

$(29.8 \leq L \leq 75.9)$

$r = 900$

Values of mollusc dry mass when they pass the post-spawning rebuilding coinside with those of mussels passing the stage of start gametogenesis (2d stage in a reproductive cycle):

$W6\ st = 0.116 * 10^{-4} * L^{2.044 \pm 0.132}$;

$(33.0 \leq L \leq 61.0)$

$r = 0.812$

$W2\ st = 0.398 * 10^{-4} * L^{2.306 \pm 0.085}$;

$(20.4 \leq L \leq 73.7)$

$r = 0.934$

The comparison of mean values of soft tissue dry mass in equal-sized mussels passing 1st and 4th stages within a season showed the increase of soft tissue mass during the gametogenesis mainly due to generative growth. The loss of soft tissue mass during the spawning is expressed by the difference between soft tissue mass of equal-sized mussels at a pre-spawning stage and mussels passing a post-spawning rebuilding. One must mind that mussel linear growth during the spawning is retarded (IVANOV et al., 1989). The values are 0.0340 g for a 30 mm mussel and 0.3600 g for a 60 mm mussel; or 19% and 41% respectively, of the mollusc mass before the spawning.

In the Southern Crimean coastline continuous wave-like gametogenesis processes were noticed in mussel population. In its dynamics the gametogenesis is alternative to the spawning period, i.e. the percentage of mussels passing different stages of gametogenesis is proportional to a share of the spawning specimens (Fig. 1). The mollusc number ratio at an early gametogenesis stage (stage I) shows that the maturation period occurs sinchronously for males and females undepending on seasons (Table 1). Being not high during a year, the share of molluscs passing a stage of relative rest increases after the end of mass spawning. For example, in 1989 these data was maximal in February-March, May and November, i.e. after winter, spring and autumn spawnings. Gametogenesis synchronization is interrupted in a maturation period (3-4 stages) that is explained by oogenesis and spermatogenesis peculiarities during different seasons. In the winter-spring period the number of females passing a stage of active gametogenesis exceeds the male number at a very stage. Consequently, vitello genesis intensity decreases at relatively low water temperature (7-10°C). On the contrary, such water temperature does not affect the spermatogenesis. The maximum number of mussels passing late gametogenesis stages is marked be-

TABLE I
% OF MUSSEL OCCURRENCE PASSING DIFFERENT STAGES OF A REPRODUCTIVE CYCLE IN 1989

Reproductive cycle	GAMETOGENESIS												SPAWNING			Postspawning rebuilding			Sample volume, specimens
Gonad maturation stage	1			2			3			4			5			6			
Sex data	♀	♂	undefined sex	♀	♂	⚥	♀	♂	⚥	♀	♂	⚥	♀	♂	⚥	♀	♂	⚥	
16.01	0	0	4.2	2.1	0	0	18.8	4.2	0	17.7	15.6	1	5.2	25	1	1	4.2	0	96
26.01	2.4	2.4	0	7.2	4	0	18.4	16	0	9.6	12	0	4.8	20	0	1.6	1.6	0	125
02.02	1.9	4.3	2.8	13	2.9	0	21.7	11.6	1.4	7.2	5.8	0	2.9	20.3	1.4	1.4	1.4	0	69
15.03	3.7	3.7	0	2.8	4.0	0	18.5	4.6	0	14.8	8.3	0	6.5	25	0.9	2.8	4.4	0	109
20.04	0	0	2	2	5.1	0	11.1	6.1	0	21.2	17.2	0	12	19.2	1	2	1.2	0	99
11.05	2.3	3.6	1.9	11.3	5.0	0	28.1	18.7	0	4.1	21.3	1.3	0	3.2	0	0	0	0	225
07.06	1.8	0	4.5	7.2	6.3	00	18	10.8	0	7.2	22.5	0	6.3	10.8	0.9	3.6	0	0	111
14.06	0	0	0	9.8	11.8	0	19.6	15.9	2	5.9	19.6	0	3.9	11.8	0	0	0	0	126
19.07	0	2.5	3.4	12.7	13.6	0	18.6	16.1	0.8	10.2	11.9	0	0	8.5	0	0	1.7	0	118
26.07	0	1.8	3.5	17.5	19.3	0	24.6	22.8	0	3.5	7	0	0	0	0	0	0	0	175
09.08	0.7	0.7	2.1	7.6	19.4	0	15.3	29.9	0.7	3.5	16.7	0	0.7	2.8	0	0	0	0	144
17.08	1.6	6.6	1.6	9.8	11.5	0	24.6	14.8	1.6	4.9	14.8	1.6	0	6.6	0	0	0	0	61
23.08	3.2	3.2	0	4.3	5.3	0	16.8	26.3	0	8.4	30.5	1.1	0	1.1	0	0	0	0	95
07.09	0.9	2.9	2.9	6.9	7.8	0	18.6	25.7	0	7.9	7.9	0	4.9	11.8	0.9	0	0.9	0	102
27.09	2.8	0.7	2.1	5	8.5	0	7.1	18.4	0.7	7.8	14.9	0	7.8	17.0	0	2.1	5	0	141
05.10	1.3	4.9	3.2	3.3	9	0	3	5.8	0.6	11	14	0.7	15.8	20.2	1.3	1.8	4.1	0	123
25.10	10.6	15.0	7.1	0.9	8.8	0	3.5	8.8	0	4.6	6.2	0.9	10.6	15.9	1.8	1.8	3.5	0	113
14.11	0	2	5	3	0	0	8	3	0	12	16	0	13	32	1	2	3	0	100
13.12	6.2	0	0	7.9	0	0	19.8	2.8	0.6	11.3	12.9	0	0.6	20.9	1.1	5.6	10.2	0	177
26.12	4.6	4.6	0.9	24.1	3.7	0	13.0	17.6	0.9	0	8.3	0.9	0.9	10.2	0	1.9	8.3	0	108

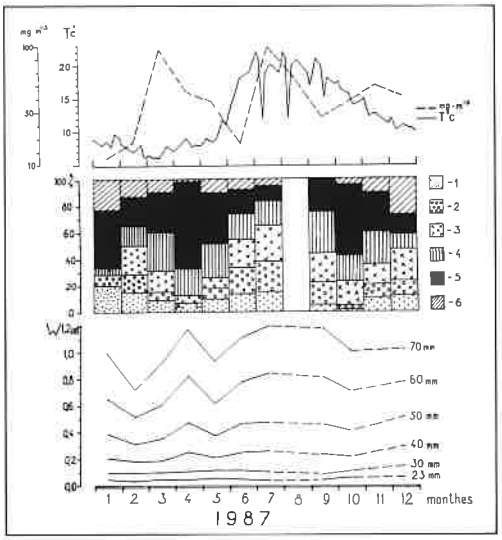

Fig. 1 - Annual surface water temperature changes in the region with experimental mariculture farming (SHALYAPIN, pr. publ.); food phytoplankton biomass changes (SENICHEVA, pr. publ.); dynamics in a reproductive cycle and soft tissue dry mass of cultured mussels during 1987 (1-6 stages of a reproductive cycle).

fore the spring and autumn mass spawning occur. Also the maximum number is noted in the summer period.

For example, in June 1989 their share was 58%. During July-August mollusc numbers at these stages stayed at one level practically, i.e. the gametogenesis retarded that occurred due to relative stable and high water temperature (22-26°C. Other authors note this penomenon not only for *Mytilus galloprovincialis* but for *M. edulis* also (LUBET et al., 1986).

A minimal number of molluscs passing late gametogenesis stages was marked in January 1987 and February 1988 during the winter mass spawning.

Two periods of mass reproduction of the cultured mussels are characteristic for all black-sea mussels: spring and autumn. But the mass spawning is possible in the winter season if the water temperature is optimal for the spawning. This winter spawning we consider to be a continuation of the autumn one. The time mass spawning started was different in various years. There was marked regularity connecting the start of the spawning period with the temperature. So, the spring mass spawning started at 7-8°C, the autumn mass spawning - when the temperature lowered to 17°C. Intensity of the spring mass spawning was defined by the extent of gametogenesis synchronization during the winter-spring period. At 5- 6°C the gametogenesis lessened and hence its synchronization was set. In these years mussel spawning behaviour was intensive in the population. In April 1987 the spawning specimens numbered at about 63% (Fig. 1). In winter 1988-1989 at 7-8°C water temperature, which was optimal for the gametogenesis and spawning, a small intensive asynchronous and prolonged winter-spring spawning was noticed. A maximum number of spawning molluscs did not exceed 40%.

The sea region with the experimental mariculture farming is exposed to winds entailing upwelling and subwelling phenomena, which are concomitant with sharp fluctuations of water temperature, hydrochemical parameters (SHALAPIN, pr.publ.), phytoplankton increase (SENICHEVA, pr. publ.). Such compilation of abiotic and biotic factors is a natural stimulator for mussel spawning. Spawning summer flash of the cultured mussels was observed at the end of June 1988 (30%) and at the beginning of June 1989 (20% of the spawning molluscs). During the second mid-summer the mussel spawning rate was minimal at stable high water temperature (22-26°C). Autumn mass spawning began after a sharp decrease of water temperature caused by upwelling induced by winds with further temperature increase to 17°C. Thus, in September 1987 and 1989 after single and short-term wind-induced upwelling there was noted the beginning of autumn mass spawning with its peak in the beginning of October. During this period water temperature was relatively stable (15-17°C). In December the mussel spawning reduced to 10%. In 1988 the autumn mass spawning began already at the end of August after the wind-induced upwelling and lasted till mid- September. In September wind-induced upwelling and subwelling reiterated several times and once they were in October, they caused the prolonged stable water temperature decrease to 10°C with the following increase to 18- 20°C. Such temperature varieties were the reason of synchronous and short spawning. At the end of September the mussel spawning decreased to 7%. At mid- October the number of spawning mussels increased to 20%, thanks mainly to the spawning males. We noted that the number of spawning males reliably ex-

ceeded that of females (Fig. 2) though the ratio of both sexes was equal on collectors. Hence, the male readiness for spawning comes earlier and the spawning process is more prolonged in time than that of females. Spawning synchronisation in females and males occurs during the spawning peak in spring and autumn reproductive processes.

Seasonal changes in mussel soft tissues (relative values) as a sequence of reproductive activity are different in various years. For example, in 1987 mollusc accretion in mass was at maximum level in April, September and December. Minimal dry mass was obtained in February, May and the end of October-November (Fig. 1). The latter was resulted by increase in gonad mass in the pre-spawning period and in the start period of mass spawning. Decrease of dry mass occurs after the spawning end. Increase of soft tissues (dry mass) - in the beginning of June - is explained by high intensity of gametogenesis and, likely, by intensive somatic growth during summer maximum in quantity of feeding phytoplankton. It is evident that population characteristics for mussel spawning activity on collectors in different years ought to be considered while designing cultivation biotechnics and defining harvest time of commercial production.

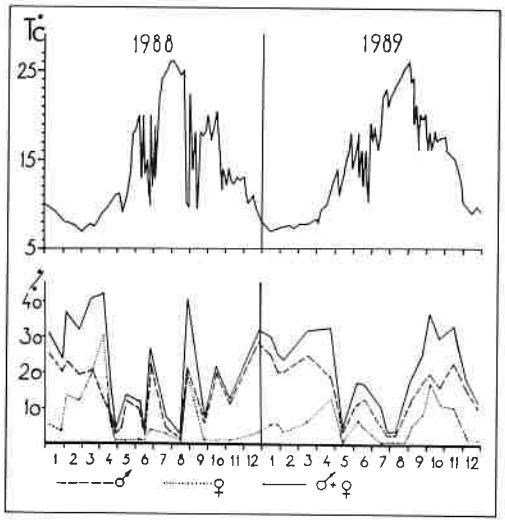

Fig. 2 - Surface water temperature changes in the region with experimental mariculture farming (SHALYAPIN, pr.publ.) and spawning dynamics of cultured mussels during 1988-1989.

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REGULARITIES IN MUSSEL SETTLEMENT FORMATION ON ARTIFICIAL SUBSTRATES

Abstract

The paper deals with study results regarding structure formation of mussel settlements at mariculture farm collectors: larval settlings, dynamics in size, genetic and sexual structure of settlements, mollusc growth and its dependence on environmental conditions.

Mollusc settlements are formed on collectors in process of mussel larvae primary and successive settlings, their metamorphosis and growth, mortality and storm-caused partial drop.

Size, weight, age, sex and gene parameters are settlement features defining volume and harvest quality. Complex analysis of these parameters enables the development recommendations on culturing optimization.

The experimental mussel mariculture farm organized by the Institute of Biology of Southern Seas consists of three charts with storm-resistant carriers a, b and c (Shalyapin, pr.publ.). A chart has 20 carriers, long lines 50 m length, perpendicular to a shore and 300-500 m apart it. 125 collectors per 8 m length are fastened to a carrier. collectors are made of capronic rope with foamed plastic insertions. The carriers are 14-20 m submerged.

Investigations were performed through standard hydrobiological procedures in 1983-1988. Mollusc age was defined using shell slices (Zolotarev, 1989). Mussel larval settlings on foamed plastic collectors were regularly watched during 1987- 1988 (Table 1). The data showed continuous larval settlings during the watch period. However, the settling rate in intensive and weak periods differed by 20 times. Their start time and duration depended on seasonal peculiarities within a year.

Our own and the published data permit us to distinguish main factors characterizing larval settling rates on a substrate: larval concentration at a stage of veliconcha with an eye; sea water temperature; substrate quality; substrate fouling by macrophytes; substrate depth; substrate age, i.e. a bacterial film presence on it; water turbulence; illumination and its direction; salinity (Ivanov et al., 1989).

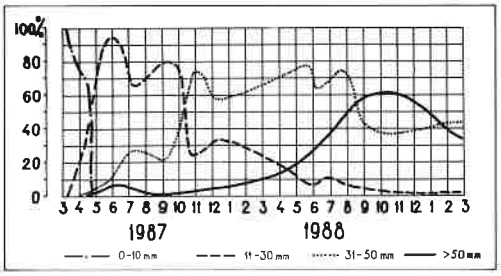

Fig. 1 - Size structure dynamics of mussel settlements on collectors in 1987- 1988:
1 - length 0-10 mm;
2 - 11-30 mm;
3 - 31-50 mm;
4 - > 50 mm.

The dependence of a larval settling rate on the depth the substrate submerged is of peculiar interest. In autumn 1984 in the mussel marifarm region the settling rate was 5-8 times higher in the upper collector part (1-3 m depth) than that of the 6-9 m depth. In spring 1985 the settling rate was at maximum level in a 5-6 m depth and surpassed the data obtained for 1-2 m depth by 2.5 times. In spring 1987 the rate was 20 times higher (11 and 220 specimens per slide).

The examined collectors revealed that in spring beginning from depth profiles of 3-4 m

TABLE I
SEASONAL DYNAMICS OF SPAT SETTLINGS ON FOAMEDPLASTIC SLIDES*

Watch time	1987				1988			
	IX	X	XI	XII	I	II	III	IY-Y
Larval mean concentration, specimens per m^3	30	25	35	38	66	149	52	70
Settling rate specimens per m per month	3000	1200	3000	1300	19000	28000	14000	19280

* - mean monthly data were obtained from weekly samples

foamed plastic slides were fouled by green filamentous algae onto which mussel larvae readily settled. This fact explained a settling rate increase at profiles deeper than 3-4 m (Table 2). Data were statistically treated and they showed the reiteration (according to Kohren criterium) of algal fouling effect on the spat settling rate.

The settled juveniles (0.3-0.5 mm) may detach and crawl along a substrate or float. With respect to the latter, juvenile number decrease on artificial substrates may be misinterpreted as the increased mussel mortalities at early stages of ontogenesis though juvenile, fallings to the bottom also may take place.

SIZE STRUCTURE DYNAMICS OF SETTLEMENTS

Molluscs were sampled and sized per groups: 0-5; 6-10; 11-20; 21-30; 31-40; 41- 40; 51-60; 61-70 mm. Number change in these groups was watched at 1-9 m depth during 1985-1988. Fig. 1 represents the summarized dynamics for the last two years. Settlement density, its size structure and mussel biomass depended on the depth of a substrate submerged (Fig. 2).

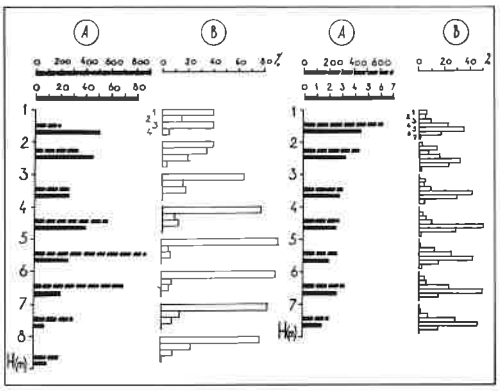

Fig. 2 - Changes along the collector length:
A - changes in number (broad rectangles) and in biomass (narrow rectangles);
B - changes in size structure of settlements:
1: 0-5 mm; 2: 6-10 mm; 3: 11-20 mm; 4: 21-30 mm; 5: 31-40 mm; 6: 41-50 mm; 7: 51-60 mm.
Watch time: 1 - June 1985; 2 - September 1986.

TABLE 2
MUSSEL SPAT NUMBER ON COLLECTOR SLIDES (4 x 10 cm) PLACED AT DIFFER DEPTH PROFILES

Depth, substrate, m	Spat number at a slide				Mean	Dispersion
1-2	0	4	3	3	2.5	2.99
2-3	31	33	29	35	32.0	6.66
3-4*	98	114	64	73	87.3	524.87
4-5	120	121	130	125	124.0	20.70
5-6	160	177	180	171	172.0	77.97

* - filamentous algae appearance at 3 m depth; deeper-complete algal covering

In June 1985 (watch start) molluscs were concentrated at maximum at 5-6 m depth and reached in number 900 specimens per m. Maximum biomass was at the very top of a collector (50 g/m) where the majority of the autumn-generated molluscs concentrated. The size structure of a settlement was formed by specimens from two generations unevenly distributed along a collector. The autumn-generated mussels housed predominantly the upper part of a collector, the spring-generated - the lower part.

As the correlation in mussel number from different generations was changed along the collector length so did the size structure of a settlement with the depth. Fifteen months later (September 1986) these differences levelled significantly. The number and biomass decreased with a depth especially in the upper 3-metered section of a collector. The same tendency preserved in 1987 as well. Mussel settlement was so dense at 1-2 m depth that practically 2-3 layers of molluscs placing at the top of each other formed the zone. This redistribution is still not explained.

Of practical interest is a mussel secondary settling and its contribution into the size structure formation. During spring more mass settlings took place (April 1987), the settled juveniles numbered 14-20%, in autumn 1986 - only 0.2-1.6%. Bearing this in mind, one shouldn't take special measures to prevent the secondary settling.

MUSSEL GROWTH ON COLLECTORS AND PHENETIC STRUCTURE OF A SETTLEMENT

Mollusc linear growth was studied using two methods: direct measurements of mussel monthly accretions sampled in sediments and indirect - via analysis of dynamics in settlement size structure.

Two mollusc groups of 20 and 35 mm at two depth profiles 1 m and 15 m proved different mussel growth rates at various depths:

$Y = 2.208 - 0.043\ X_1 - 0.0043\ X_2$ (I-II)

$Y = 3.815 - 0.055\ X_1 - 0.032\ X_2$ (II-III)

$Y = 5.558 - 0.084\ X_1 - 0.185\ X_2 + 0.0055\ X_1 * X_2$ (IY)

$Y = 9.943 - 0.160\ X_1 - 0.143\ X_2$ (Y)

$Y = 6.643 - 0.1026\ X_1 - 0.1401\ X_2$ (YI)

$Y = 7.060 - 0.1160\ X_1$ (YII-YIII)

where: Y - mollusc accretion length, mm per month

X_1 - mollusc length, mm ($20 < X_1 < 35$)

X_2 - depth, m ($I < X_2 < 15$)

Minus before a coefficient reflects growth inhibition for bigger individuals dwelling in relatively deeper layers.

The analysis of changes in settlement size structure enabled to state signficant variabilities for the settled juvenile growth that transformed the size structure of a settlement. Mean growth rate in 50% of juveniles for 63 days (June 3 - July 25, 1985) was in limits 0.33-0.40 mm/d., mussel length increased from 3 up to 25-30 mm. During the same time period 45% of mussels of total settlement grew slower, mean rate of 0.174-0.236 mm/d. The summer growth rate for 95% of mussels settled in spring reached 0.29 mm/d. Within the same season fastgrowing mussels with 0.48 mm/d mean rate did not succeed 1% in number in biomass - 1% of corresponding values for the total settlement.

In 1985 summer-autumn growth rates of cultured mussels ranged 0.108-0.476 mm/d. From the second half of October till November 1985 mollusc growth was not notably different. In the beginning of winter (December 1985-January 1986) the linear mollusc growth did not depend on their sizes. Mean growth rates varied in narrow limits 0.20-0.23 mm/d. Very low temperatures in mussel somatic growth were registered at the end of winter, spring, summer and the beginning of autumn 1986. This was associated with anomally low concentrations of trophic valuable algae, lower water temperature and gonad maturation. Further mussel growth proceeded in September-October 1986 when the feeding base had been improved.

Blackviolet specimens (homozygotes) usually surpass the striped specimens (heterozygotes) in growth rates. In their turn the striped surpass the brown specimens (homozygotes). However, these differences tended to decrease with age. Mussels with a blackviolet phene contained relatively more meat which came to a maximum level in August of 53.4%.

In rocky settlements, as well as in the roped cultures, the blackviolet specimens survived easier. In silty settlements - the striped and brown specimens. Therefore, with mollusc growth on collectors the phene ration was changed in favour of the blackviolet specimens approaching the phenetic composition of specimens from rocky settlements (Table 3).

TABLE 3
PHENE RATIO (%) IN DIFFER-AGED MUSSELS OF SPRING AND AUTUMN SETTLINGS IN 1983-1984

Phenotype	Age, months					
	1	9	12	15	17	20
Spring settling						
Blackviolet	40.31	50.96	46.85	58.56	58.88	–
Striped	38.77	45.16	51.51	39.47	36.45	–
Brown	20.92	3.88	1.64	1.97	4.57	–
Autumn settling						
Blackviolet	–	36.18	55.29	–	–	69.32
Striped	–	61.79	42.28	–	–	28.57
Brown	–	2.03	2.43	–	–	1.97

SEXUAL STRUCTURE OF A MUSSEL SETTLEMENT

We revealed that 33.5% of the total settled mussels in April-May spawned in November, i.e. after 7-8 months. Males matured earlier than females. Male- female ratio of different-aged settlements was I:I. For example, the number of females and males did not vary statistically in settlements aged 0.5-2.5 years old. Hermaphrodites composed 3.13%. Among molluscs aged 4 years and more, the female number was somewhat higher. Fig. 3 shows common regularities in distribution of sexes in different-aged mussel groups. Fig. 4 depicts sexual structure of settlements cultivated in 1987-1988. It confirms the approximately equal number of females and males.

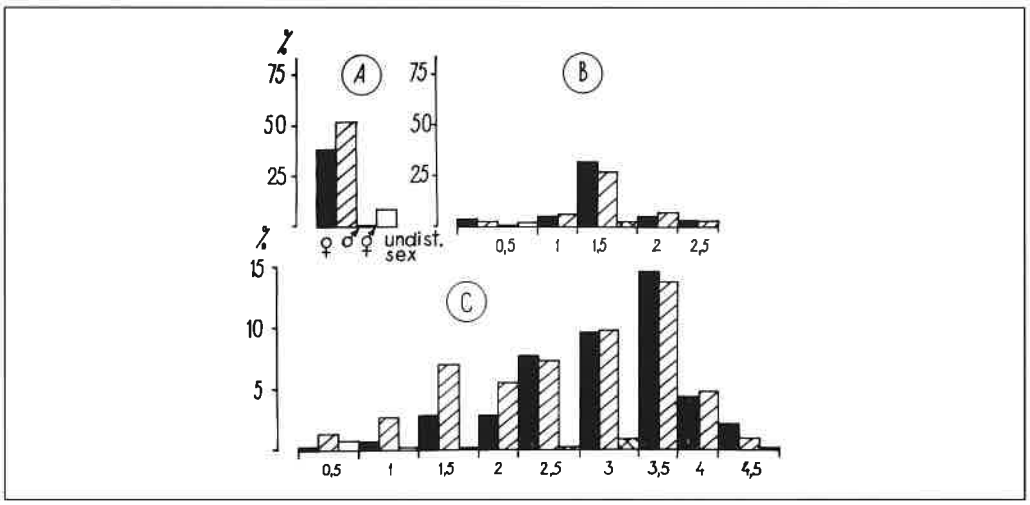

Fig. 3 - Aging-sexual structure of cultivated mussel settlements:
A - 7-8 month-aged molluscs;
B - 2.5 year-aged settlement, molluscs - 0.5-2.5 years;
C - 4.5 year-aged settlement, molluscs - 0.5-4.5 years.

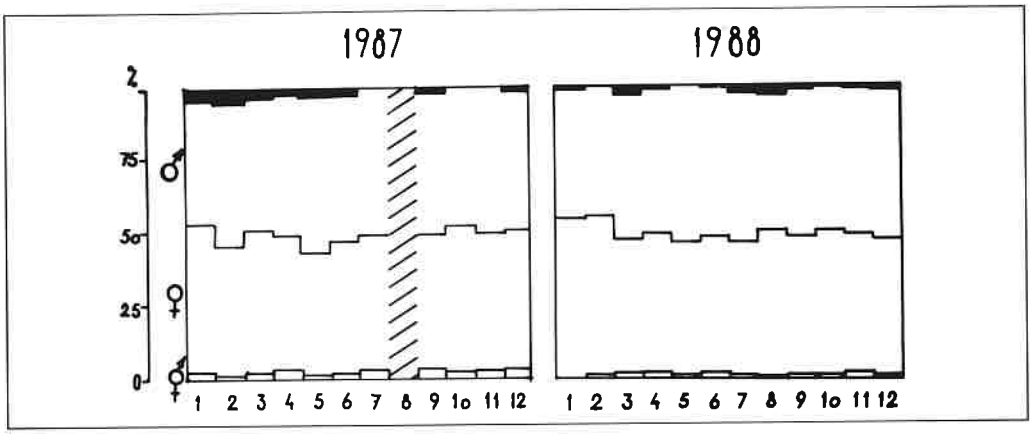

Fig. 4 - Sexual structure of settlements in 1987-1988 (n.d. - sex was not defined).

CONCLUSION

At present the Black Sea mariculture is based on a natural mussel reproductive potential. That is why the regularities in mussel settlement formation on collectors are also defined by natural processes: settling, age, elimination (selection) at mussel mariculture farming. Quantitative and qualitative features of mussel biocenosis - farming production - we suppose that they are much defined by functional feasibilities of a community on collectors and of the ecosystem including the mariculture farming.

The study of various direct and inverse liaisons of this system in complex with biotechnical measures designing represents great reserve for higher efficiency in culturing processes.

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PROGNOSIS FOR MUSSEL FARMING INFLUENCE ON THE ENVIRONMENT BASING ON THE MUSSEL ENERGY BUDGET

Abstract

Functional characteristics of experimental mussel farming are evaluated based on qualitative data for mussel energetic balance. Rates of excretion and substance consumption by mussels during their cultivation are defined. Peculiarities of marifarm impacts on the environment are discussed.

INTRODUCTION

Due to mussel mariculture farming organization at the Black Sea the task to prognose mussel mariculture influence on coastal ecosystem became actual.

Mussel impact on the environment is mainly caused by the consumption and release processes of suspended and dissolved organic matter. To quantify them is possible while studying energetic budget of individual mussels and of all mussels at the whole mariculture farming.

MATERIAL and METHODS

Researching was performed during 1983-1988 at the experimental mussel mariculture farm organized by the Institute of Biology of Southern Seas and located 40 km off Sevastopol. Technical characteristics for the farming is given in the present publication.

The growth and reproduction of mussels were studied by scientists of the foregoing Institute. The following parameters were used: linear accretion, analysis of gonad state and seasonal dynamics in the mussel's soft tissues (IVANOV et al., 1989). Oxygen consumption was assessed through equations suggested by V.D. BRAIKO and S.S. DERECHKEWICH (1978). Organic matter content in a shell was defined by A.F. KOZINTSEV (1989).

Ration value was calculated as energy needed to rehabilitate all losses for body building, synthesis of shell organic substance, reproduction and respiration. Assimilation efficiency was taken as 75% (IVANOV et al., 1989).

In the given paper rough excretion rates of dissolved organic substances were used. They were determined by scientists experimenting with *Mytilus edulis* (BAYNE et al., 1976; GOLOVKIN et al., 1979; KAUTSKY and WALLENTINUS, 1980).

RESULTS and DISCUSSION

Periods of mussel culturing to commercial size (more than 49 mm) durated 18 months at the experimental mussel marifarm. Data on mussel growth, consumption and excretion are represented in Table 1. All values are given per one specimen. Mussel growth on collectors depended on many factors (IVANOV et al., 1989): seawater temperature, weight and age of a mollusc, genotype, feeding quantiative and qualitative content, mollusc physiology - a stage in reproductive cycle, dissolved oxygen concentration, mollusc place in a cluster, etc. Conditions for *Mytilus galloprovincialis* maximum growth (to 0.48 mm a day) are the following: water temperature 15-16°C; food concentration to 4-6 mg/l; juveniles - from spring generation; species phenetype - blackviolet specimens; water salinity 15-20%; oxygen saturation not less than 80%; mollusc gonads in state of rest.

Organic substance high content in shells is an essential argument to shell using as food supplements.

TABLE 1
GROWTH, CONSUMPTION AND SUBSTANCE EXCRETION BY MUSSELS CULTURING AT EXPERIMENTAL MARIFARMING

	1987									1988									
Watch period / months	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VII	IX	X
Length, mm	I	5	9.5	15	20	24	27.5	29.5	31.5	32.5	34	35.5	37	39.5	43	46	48	49	50
Wet weight, g	–	0.028	0.146	0.480	1.014	1.629	2.320	2.785	3.303	3.582	4.028	4.507	5.019	5.948	7.418	8.839	9.874	10.418	10.979
Body dry weight, g	–	0.00008	0.00040	0.01256	0.0258	0.0408	0.0574	0.0685	0.0807	0.0873	0.0978	0.1089	0.1209	0.1424	0.1762	0.2086	0.2322	0.2445	0.2572
Accretion, cal/d	–	0.0133	0.0533	2.0266	2.2117	2.4967	2.7683	1.8383	2.0450	1.0967	1.7432	1.8633	1.9867	3.5883	5.6316	5.4033	3.9333	2.0499	2.1133
Shell mass, g	–	0.0094	0.0498	0.1633	0.3452	0.5545	0.7900	0.9481	1.1245	1.2196	1.3715	1.5344	1.7087	2.0253	2.5255	3.0096	3.3617	3.5469	3.7382
Shell organic substance accretion, cal/d	–	0.0467	0.2033	0.5667	0.9167	1.0333	1.1833	0.7833	0.8883	0.4778	0.7500	0.8167	0.8833	1.5833	2.5000	2.3670	1.8000	0.9333	0.9500
Summerized accretion, cal/d	–	0.060	0.2566	2.5933	3.1284	3.5300	3.9520	2.6230	2.9333	1.5745	2.4933	2.8700	2.8700	5.1716	8.1160	7.7703	5.7330	2.9830	3.0633
Respiration, cal/d	–	0.322	1.201	3.311	5.237	7.006	7.461	8.593	9.811	10.449	11.444	17.948	19.539	22.343	18.321	19.774	21.169	21.875	24.907
Ration. cal/d	–	0.639	2.439	10.000	14.229	17.977	19.572	19.328	21.967	20.813	27.077	35.307	38.358	47.013	45.435	47.483	46.558	43.225	45.256
Faeces, cal/d	–	0.192	0.732	3.000	4.269	5.393	5.872	5.798	6.590	6.244	8.123	10.592	11.507	14.104	13.631	14.245	13.967	12.968	13.577
Ration, mg/d	–	0.133	0.508	2.083	2.964	3.745	4.078	4.027	4.576	4.336	5.641	7.356	7.991	9.794	9.466	9.892	9.700	9.005	9.428
Excretion NH_4 - N, mg/d	–	0.257	0.960	16.037	28.903	42.000	55.500	64.080	73.320	78.171	85.742	93.684	101.971	116.582	138.744	159.27	173.84	181.33	189.00
Dissolved organic substance excretion, mg/d	–	0.011	0.042	0.172	0.245	0.310	0.337	0.333	0.379	0.359	0.467	0.609	0.661	0.811	0.783	0.818	0.802	0.745	0.780
Excretion N_{org}, mg/d	–	0.00017	0.00063	0.0026	0.0037	0.0047	0.0051	0.0051	0.0057	0.0054	0.007	0.0092	0.0099	0.012	0.012	0.012	0.012	0.011	0.012
Excretion P_{org}, mg/d	–	0.00002	0.000084	0.00034	0.00049	0.00062	0.00067	0.00067	0.00076	0.00072	0.00093	0.0012	0.0013	0.0016	0.0016	0.0016	0.0016	0.0015	0.0016
Excretioni Si, mg/d	–	0.018	0.0067	0.028	0.039	0.050	0.054	0.053	0.061	0.057	0.075	0.097	0.106	0.130	0.125	0.131	0.128	0.119	0.125
Excretion PO_4-P, mg/d	–	0.0096	0.192	6.632	16.738	18.609	11.025	8.214	6.856	5.238	2.346	3.922	7.252	17.087	84.566	110.140	150.472	111.493	49.382

Mussel respiration rate also depended on its physiological state which was in association with year season. The highest level for blacksea mussel metabolism was revealed in spring at relatively high temperatures. That was linked with gametogenesis (Braiko and Derechkewich, 1978). The summer temperature increase was not followed with energy exchange enhancement. In contrast, the latter lessening was watched.

From ecological and geochemical viewpoints one of the most significant factors- indicators of mussel settlement functioning was water filtration and consumption of suspended organic substances. During the cultivation period mussel filtration rate increased from shares of a liter to 25 liters a day (Table 2).

Known that in the region where molluscs were cultivated, especially with their high density for example, to 270 kg oysters per sq.m (Mariojouls, 1987), and with limited water exchange (Sornin, 1981, 1986) there was high water enrichment in suspended and dissolved organic substances noted. The suspended substance sedimented forming biodeposition. This modified sediment properties and benthos content (Kraeuter, 1976; Tenore et al., 1982).

The aquatoria with experimental farm had intensive water exchange and rare mytiliculture due to which biodeposit accumulation was not noticed. Phytoplankton consumption rates by mussels were defined basing on the existing data showing phytoplankton concentration at an aquafarm and water filtration rates. The obtained values were compared with mollusc nutrient demands, that allowed to evaluate a phytoplankton role in mussel feeding (Table 2). The phytoplankton share in food made from 1.2 up to 96%. Consumption rate of organic substances by different-aged mussels changed from 4 to 300 mg/mo within different seasons, its excretion with faeces was 1.2-90 mg/mo (Table 2). For 18 months one cultured mussel consumed 3.19 g of dry organic substance and excreted 0.96 g.

Based on mussel energy budget date (Table 1) it was calculated that the farming of 100 t mussel capacity would consume 29 t of dry suspended organic substance and release with faeces 8.7 t during the cultivation process. At the end of the latter the consumption rate would reach 88.4 kg/d, excretions 26.5 kg/d. The given marifarm housed 1 ha so maximum density of sedimented faeces would be 2.6 g/m2/d of dry substance. At the end of the cultivation consumption rates of food with main chemical elements would average 35.3 kg C/d; 5.3 kg N/d; 0.33 kg P/d.

In the process of metabolism mussels released dissolved nitrogen and phosphor- containing organic and mineral compounds. Approximate number for dissolved substance release was: Norg till 0.109 kg/d; Porg - 0.015; Si - 1.193; NH4 - N - 1.72. If to calculate per volume of the filtered water by mussels the data will be: 0.522 mg Norg/l; 0.070 Porg/l; 5.695 Si/l; 8.21 mg NH4 - N/l.

The former experience regarding mussel mariculture farming showed the notable influence of mariculture on plankton and bottom biocenosis (Kraueter, 1926; Galkina, 1975, 1985; Golikov and Skarlato, 1979; Kautsky et al., 1980; Tenore et al., 1982; Kulakovsky et al., 1983; Sornin, 1986). More than 70% of dissolved organic substance excreted by mussels were compounds which molecular weights did not exceed 700 (Galkina, 1985) and therefore were relatively easy included into metabolism of planktonic community. Besides organic substances mussels released biogenic salts stimulating phytoplankton growth. Concentration and primary production of phytoplankton were one order higher in region with mariculture farming (Kulakovsky et al., 1983).

Biodeposit affected bottom habitats depended on substance sedimentation and mineralization rates. Benthos number increase was marked with moderate sedimentation. However known, that intensive sedimentation entailed anoxic conditions and sharp decrease in bottom population (Sornin, 1981, 1986). In aquatoria with limited water exchange and dense culture the water quality and mollusc growth rates decreased significantly even till mariculture ceased (Uyeno et al., 1980; Mariojoules et al., 1987).

Evidently, critical density of molluscs-filtrators in mariculture goals is expressed by the accumulation/loss balance of organic substance at the bottom, depending on local hydrological conditions. Therefore, density for mussel displacement is to be ascertained for each aquatorium.

The above mentioned value and feeding supply extent defines the potential of the chosen region to be the mariculture farm.

The foregoing testifies that complex of scientific research must be conducted prior to

TABLE 2
PHYTOPLANKTON ROLE IN FEEDING OF MUSSELS CULTIVATED AT EXPERIMENTAL MARIFARMING.
MOLLUSC SUMMERIZED CONSUMPTION AND EXCRETION OF FORMED ORGANIC SUBSTANCE, dry mass

	1987									1988									
Watch period	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VII	IX	X
Phytoplankton concentration, mg/l	0.110	0.140	0.040	0.030	0.015	0.014	0.020	0.020	0.004	0.006	0.030	0.080	0.150	0.014	0.020	0.030	0.013	0.020	0.188
Water filtration, l/d/egz	–	0.910	1.790	7.610	10.304	6.119	7.258	14.370	15.531	8.310	8.770	9.241	17.780	21.106	23.080	24.730	19.500	14.980	15.360
Needed feeding concentration, mg/l	–	0.146	0.284	0.274	0.288	0.612	0.562	0.280	0.295	0.522	0.643	0.796	0.449	0.464	0.410	0.400	0.497	0.601	0.614
Phytoplankton, % feeding	–	96	14.1	10.9	5.2	2.3	3.6	7.1	1.4	1.2	4.7	10.1	33.4	3.0	4.9	7.5	2.6	3.3	30.6
Consumped feeding, mg/mo	–	4.05	15.45	63.36	90.15	113.91	124.04	122.49	139.19	131.89	171.58	223.74	243.06	297.90	287.92	300.88	295.04	273.90	286.77
Organic substance in faeces, mg/mo	–	1.20	4.64	19.20	27.06	34.20	37.22	36.73	41.82	39.63	51.55	67.12	72.93	89.44	86.46	90.29	88.51	82.27	86.04

mussel marifarming organization to evaluate the potency of the chosen region and outline recommendations on how to optimize the cultivation process during exploitation of the farming place.

An ideal situation is based on the balance equations for water exchange and organic substance consumption-excretion ratio which would be to create a mariculture farm that will produce food and decrease eutrophying loadings to the sea.

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POPULATION-GENETIC INVESTIGATIONS OF BLACK SEA *MYTILUS GALLOPROVINCIALIS* Lam.

Abstract

The population structure of Black Sea Mytilus galloprovincialis Lam. is analysed using karyotype date (n=28), phenetic polymorphism of mussels sampled from different biotopes. The selection was in favour of blackviolet specimens from collectors and rocky settlements, of striped and brown specimens from silty settlements. Cultivation of mussels with blackviolet shell colour is more profitable for marifarms.

Data on genetic varieties in natural population species as mariculture objects are necessary for sire selection, potential assessment for genetic-selective study, choice of optimal conditions for rearing. *Bivalvia larvae* as plankton components are far distributed by currents that stipulates a constant gene flux among separate groups. Regarding this fact, genetic distinctions among geographically related groups are more often revealed in population dwellings in ecologically different conditions (GARTNER-KEPKAY et al., 1983; GOSLING, 1977; GOSLING and WILKINS, 1977; KOEHN and LIEFENALLER, 1981).

In the Black Sea mussels *Mytilus galloprovincialis* are distributed from the interface downwards 80 m depth forming the most numerous settlements on coastal hard substrates - rocks, stones, artificial constructions (0-10 m depth) as well as on deep-watered silts (30-60 m depth). Single juveniles are found at the depths more than 60 m and in the coastal sands. A mussel role in silts and rocky foulings is so significant that some authors isolate regional biocoenosis of «mussel silt» and biocoenosis of a «rocky mussel» (ZERNOV, 1913; BACESCU et al., 1971; KISELEVA, 1981).

Mussel habitat conditions are not equal for different Black Sea regions (SHALYAPIN, pr. publ.). They are appreciably unlike in different biotopes of mussel silt and rocks. In silt-mussels live by singles or small clusters. At rocks they live like a dense carpet or stigilis. Rocky sublittoral mussels are exposed to fluctuations in salinity and temperature, but well-oxygenated, their main food - algae and detritus.

Silt mussels are at relatively constant temperature and salinity but less- oxygenated, main food - detritus. Distinctions in mollusc habitat conditions may promote genetic differentiation for separate mollusc groupings.

Based on morphological peculiarities of shells sampled from different- conditioned regions a number of varieties were distinguished earlier. (MILASHEVICH, 1916). Mussels from silt biotopes were identified as a separate species *Mytilus frequens* (VINOGRODOVA, 1958; SALSKIY, 1958). However, further on, scientists refused to subdivide Black Sea mussels for forms and varieties.

In population investigations of organisms, molluscs in their number, the structure of chromosome sets, albumen and ferment biochemical markers, as well as, phenes - discrete morphological features having, as a rule, a mere genetic interpretation - are taken as population-genetic markers.

Black Sea mussels have a diploid chromosome number of 28 (2n=28); 6 metacentric pairs; 6 submetacentric pairs and 2 subtelocentric pairs (Fig. 1) (BULATOV and IVANOV, 1981). Chromosome sizes are decreased monotonously that impedes the speciation for separate pairs. The first pair of metacentric chromosomes as well as the 7th pair of submetacentrics are the most distinguished from the others due to their morphology and sizes. Chromosome number may variate in groups that is likely stipulated by pericentric inversions or translocations. No differences were

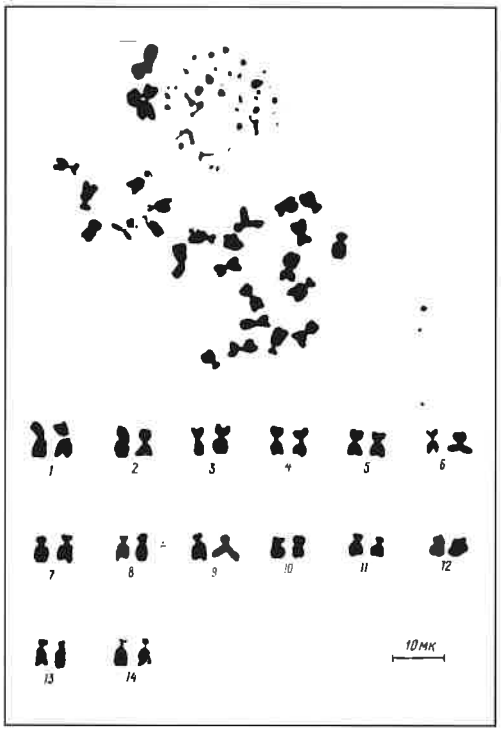

Fig. 1 - Chromosome set of *Mytilus galloprovincialis* Lam.

revealed between chromosome sets of rocky and silty mussels. But rocky mussels showed less cells with chromosome number differring from the model one than those in silty mussels.

Karyotype for Black Sea mussels *M. galloprovincialis* is the same as for the mediterranean *M. galloprovincialis*, atlantic *M. edulis* (France and USA shores) as well as kergelen *Mytilus desolationis* (Ahmad and Sparks, 1970; Thiriot-Quievreaux, 1983; Dixon and Travell, 1986). There are differences in chromosome morphology, which likely are sufficient for speciation process, however they do not prevent from interspecific hybridization between the two types *M. edulis* and *M. galloprovincialis* in artificial and natural conditions.

Results on age and seasonal changes of mussels from various biotopes regarding biochemico-genetic markers are contradictive. From one side, this evidences the considerable panmixia among Black Sea mussels. From the other - possible informative deficit for procedures directed to Black Sea *M. galloprovincialis* population structure research (Shevchenko et al., 1988; Zhukovskaya et al., 1988).

Many authors noted the shell colour polymorphism in Black Sea mussels (Milashevich, 1916; Lebedev, 1959; Dragoli, 1966). Known that shell colour of many mollusc species is ancestral and variations are used as markers in population genetics (Lamotte, 1960; Innes and Halley, 1977; Newkurk, 1980; Mitton, 1977).

The colour analysis of mussels taken from different biotopes and Black Sea regions allowed to pool three main colour types: blackviolet, brown and striped. Mussel shell colour consists of the own external shell layer colour and the colour of periostracum (Bulatov, 1984). The latter ranges from yellow till almost black. Therefore the shell colour is more precise by identified after the periostracum removal. Then blackviolet shells become blue, brown shells - whitebrown. The 3rd type, striped shells have longitudinal blue stripes against whitebrown background and beginning from the anterior. The number and width of the stripes vary greatly. They may be spread symmetrically and asymmetrically, diffusively or grouped. Watchings after shell growth did not show the colour inversion in mussels.

The presence of two alternative types (blackviolet and brown) and the third intermediate (striped) type preposes the heredity of shell colour on one-locus- two-allele system without domination. The panmixia permits to check up this thought by comparison of the watched and expected phene type distribution using the Castle-Hardy-Weinberg law (Lee, 1980).

Let's take a blackviolet allele as A_1, brown allele - A_2. Blackviolet and brown species as homozygotes A_1A_1 and A_2A_2.

Striped specimens as heterozygotes A_1A_2 with observed frequencies 'a', 'b', 'c', respectively. Genotype frequencies 'A_1 - P' and 'A_2 - Q' are assessed from following equations:

$$p = \frac{2a + b}{2N}; \qquad Q = \frac{2c + b}{2N}$$

where N - a sampling volume.

According to the obtained frequencies we may find the expected frequencies for various genotypes:

$a = P^2 * 100\%$

$b = 2P * Q * 100\%$

$c = Q^2 * 100\%$

Correspondence of the observed to the expected genotype frequencies in mussel samples confirm the supposition on genetic nature of shell colour in the test mussels and on character of colour heredity (Table 1). Wide variety in number and width of shell stripes are most sure reasoned by existance of gene-modificators which impact in dependence on external conditions.

In the study process we analysed a mass of mussel samples taken from rocky and silty settlements inhabiteding different blacksea regions. Blackviolet specimens prevailed at small depths in rocky settlements; striped and brown - in silty (Table 2). Distinctions on phenetype distribution were relatible. They appeared due to dominating survival of blackviolet molluscs in rocky mussel settlements; striped and brown specimens - in silty settlements (Table 3).

The most appropriate of mechanism for brown and striped mollusc elimination from rocky biotopes was their selective detachment off a substrate because of differences in their attachments. It was noted that blackviolet mussels attached by stronger and more numerous byssuses than those of the striped and brown molluscs (BULATOV and ZVEZDINA, 1987).

TABLE 1
THE OBSERVED AND THEORETICALLY EXPECTED DISTRIBUTION OF VARIOUS GENOTYPES IN MUSSEL SPAT FROM DIFFER BLACKSEA REGIONS: A ROCKY BIOTOPE

Distribution region	Genotypes, %			P ± ΔS	Q	Sample volume	x^2	Significance level
	A_1A_1	A_1A_2	A_2A_2					
SUDAK								
observed	64.90	29.39	5.71	0.79 ± 0.0257	0.204	490	0.78	0.50
expected	63.35	32.49	4.16					
BATILIMAN								
observed	50.45	40.65	8.90	0.701 ± 0.0003	0.299	337	0.074	0.90
expected	49.14	41.92	8.94					
SEVASTOPOL								
observed	67.13	28.99	3.88	0.816 ± 0.0001	0.184	721	0.106	0.75
expected	66.59	30.03	3.38					

TABLE 2
GENOTYPE DISTRIBUTION IN MUSSEL SETTLEMENTS FORM DIFFER REGIONS OF THE BLACK SEA

Sampling region	Depht, m	Genotypes, %			P ± ΔS	Q	Sam-pling volume
		A_1A_1	A_1A_2	A_2A_2			
1. Caucasus	40	13.24	64.70	22.06	0.456 0.0009	0.544	136
2. Sudak	I	78.50	20.20	1.30	0.886 0.0001	0.114	303
Sudak	40	29.70	49.60	20.70	0.545 0.0004	0.455	345
3. Batiliman bay	I	54.26	45.11	0.63	0.768 0.0001	0.232	798
Batiliman	40	27.03	55.58	17.39	0.548 0.0002	0.452	529
4. Sevastopol	I	75.86	22.47	1.67	0.871 0.0001	0.129	728
Sevastopol	40	15.00	42.50	42.50	0.372 0.0002	0.628	473
5. Karkinitsky gulf	I	74.91	22.55	2.54	0.862 0.0001	0.138	590
Karkinitsky gulf	40	21.89	66.42	11.69	0.551 0.0003	0.449	402
6. Constantsa	I	56.27	37.60	6.13	0.751 0.0002	0.249	375
Constantsa	40	11.84	58.77	29.39	0.368 0.0005	0.632	228
7. Varna	I	52.63	34.10	13.27	0.696 0.0003	0.304	375
Varna	40	15.74	47.94	36.32	0.397 0.0003	0.603	413
8. Saloniki (Aegean sea)	I	97.52	2.48	0.00	0.988 0.00003	0.012	202

TABLE 3
GENOTYPE DISTRIBUTION ACCORDING TO AGE GROUPS IN SAMPLES TAKEN FROM SILT AND ROCKS

Age	Depth m	Genotypes, %			Sample volume
		A_1A_1	A_1A_2	A_2A_2	
-1.1	40	28.00	23.00	49.00	100
2		20.95	47.77	31.28	110
3		20.00	60.00	20.00	5
4		0.00	100.00	0.00	14
-1	1	54.55	37.01	8.44	154
1		68.24	28.35	3.41	233
2		86.76	11.28	1.96	204
3		97.65	2.35	0	85
4		98.01	1.99	0	56
5		100.00	0.00	0.00	18

Comparing data on Black Sea mussels multiplication, their larvae distribution and survival of individual specimens under different ecological conditions we may infer the following: Black Sea mussel settlements are recreated from larval genetic mixed pool and this process, levels the differences among mollusc separate groups. Later on, under the influence of the selection process, there occurs differentiation of features due to various survival of specimen-carriers of different phenes.

While cultivating mussels on the submerged collectors the organisms were stocked in conditions closer to rocky biotopes than to silty. This was reflected in the phenetic character of mussel settlements cultivated on collectors. Bearing in mind the fact that the spawning of silty and rocky mussel settlements differed in time (KISELEVA G., 1972), it is better to set collectors for spat oriented at larval settlings spawned by rocky mussel settlements.

In future the data from population-genetic researchings with Black Sea mussels *Mytilus galloprovincialis* will be the basis for selection works.

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MEROPLANKTON OF THE BLACK SEA AND SEASONAL DYNAMICS OF MUSSEL LARVAE AT EXPERIMENTAL MARIFARM REGION

Abstract

The distribution of meroplankton at the Black Sea is described. Seasonal dynamics of larval number and juvenile settlings in the region with experimental mussel farming are discussed.

The formation processes of benthos settlements on natural and artificial substrates are much defined by number, distribution and ecology in meroplankton, i.e. by a community of pelagic larvae of bottom invertebrates. Bivalvia larvae dominate in the Black Sea meroplankton.

The most intensive meroplankton investigations were developed at one of the oldest biological stations, Biostation in Sevastopol founded in 1871. In the 50-70th years there were studies the pelagic larvae of all the big taxons from multicellular invertebrates: bivalves and gastropoda (Zahvatkina, 1959, 1963; Kiseleva G., 1965; Chuhchin, 1960), polychaeta (Kiseleva G., 1967; Kiseleva M., 1957, 1958), decapoda (Dolgopolskaya, 1948, 1954).

In the last few years new publications appeared relating to meroplankton at the Black sea. In their number are papers on mussel *Mytilus galloprovincialis* larval distribution, the main object for mariculture (Alexandrov, 1987; Ivanov, 1965, 1978; Kiseleva G., 1972; Konsulova, 1984, 1988; Konsulov and Konsulova, 1982; Murina, 1987, 1989; Murina and Kazankova, 1987; Chuhchin, 1984; Petran, 1977).

More detailed knowledge on meroplankton distribution at the Black sea was obtained during scientific cruise «Akademik Kovalevsky» (Autumn 1984). 269 samples were taken at 57 stations. Fig. 1 shows the larval distribution of bottom invertebrates in the richest layer at 0-10 m depth.

In the eastern region, transect Tuapse-Sarich cape, maximal larval number was found at the station located 1.7 miles off the shore over 40 m depth. With distance growing apart from the Caucasus coastline the larvae density decreased and over 2100 m depth, 44 miles offshore, there was only 47 specimens per m^3. Taxonomic content exhibited distinct domination of Bibalvia larvae, veligers and veliconchi of which in some samples reached 99.6% of the total meroplankton number. Larvae of Gastropoda, Bryozoa, Decapoda, Cirripedia and Polychaeta were met in small quantities. Figure 2 illustrates mussel larval number in the eastern sea region.

Six stations were made in the region of Sarich cape at depth profiles from 30 to 2100 m. Apart from the Crimean coastline towards the sea centre the larval density was gradually reduced from 4215 to 52 specimens per m^3. Though domination of bivalvia larvae in meroplankton was evident (mean 85%) the mussel number was not high. It ranged from 1 to 30 specimens per m^3 increasing at precoastal stations.

The north-western stations, transect Sarich cape - Constantsa, were located mainly over high depths. Therefore the larval density was not numerous (13-55 specimens per m^3), except some stations (station 35 gave 172 specimens per m^3).

In October the well-expressed autumn peak for bivalvia number was observed at the Zernov's phyllophora field and Carcinitsky gulf region. Bivalvia comprised 92 and 93% of total meroplankton (781 and 3639 specimens per m^3, respectively). In August 1957 bivalvia concentration numbered 1100 specimens per m^3 in

plankton sampled at Tarhankut cape vicinity (KISELEVA G., 1965). The highest number 51 533 specimens per m^3 was registered in September 1967 at Romanian shores (PETRAN, 1977).

The south-western Black Sea region was studied especially in details. 21 stations were made here, half of them - over 45-300 m depth, and half - 500-2100 m depth. Of interest is to compare the mean larval number per 1 sq.m of water column in shallow and deep-sea regions. The shallow region showed 16 811, the latter - 2487 specimens per m^3, i.e. seven times less. This evidences the further the distance from parent population dwellings the littoral, the less larval concentration is, which decreased gradually due to disperse, predation, settlings to bottom and natural death. Larvae of neretic species of bottom invertebrates which were brought to chalistic regions at late developmental stages of metamorphosis sank to depths deeper than 200 m into anoxic H_2S zone seeking for a substrate to settle where they perished.

The south-western region is characterized with high numbers of meroplankton (Fig. 1). The main part of meroplankton consisted of bivalvia. Their maximal concentration 1222 specimens per m^3 was noticed at Caliacre cape. In August 1957 pelagic larvae of bottom invertebrates equalled 8000 specimens per m^3 at Bulgarian shores (KISELEVA, 1965).

KONSULOVA (1985) gave interesting data referring bivalvia larval number at Caliacre cape in 1981-1983. In April at 9.15°C veligers numbered 40 specimens per m^3. In May at 14.7°C it increased to 1918 specimens per m^3 and gradually decreased to 148 specimens per m^3 in August. The second peak for veligers in plankton 4085 specimens per m^3 KONSULOVA marked at 21.7°C in September. Regretful species composition for bivalvia larvae was not defined though it may be proposed that in this region where mussel plantation was placed, larvae of *Mytilus galloprovincialis* prevailed (Caliacre cape).

We determined mussel larval concentration as 50 specimens per m^3 in the south-western region. Mussel veliconchi were found at all depth profiles from 1-10 m to 200-250 m. In deeper layers larvae were of big sizes (veliconchi with eye). This testified their durated presence in the pelagial.

Meroplankton taxonomic content in the south-western region did not differ from other

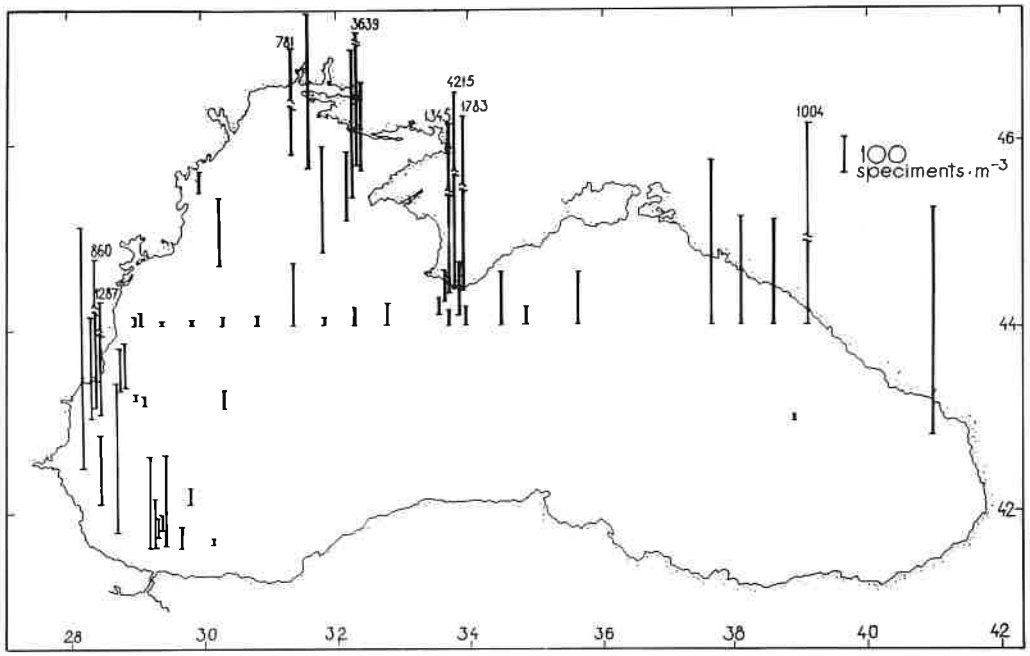

Fig. 1 - Meroplankton distribution in 10-0 m layer at the Black Sea in Autumn 1984.

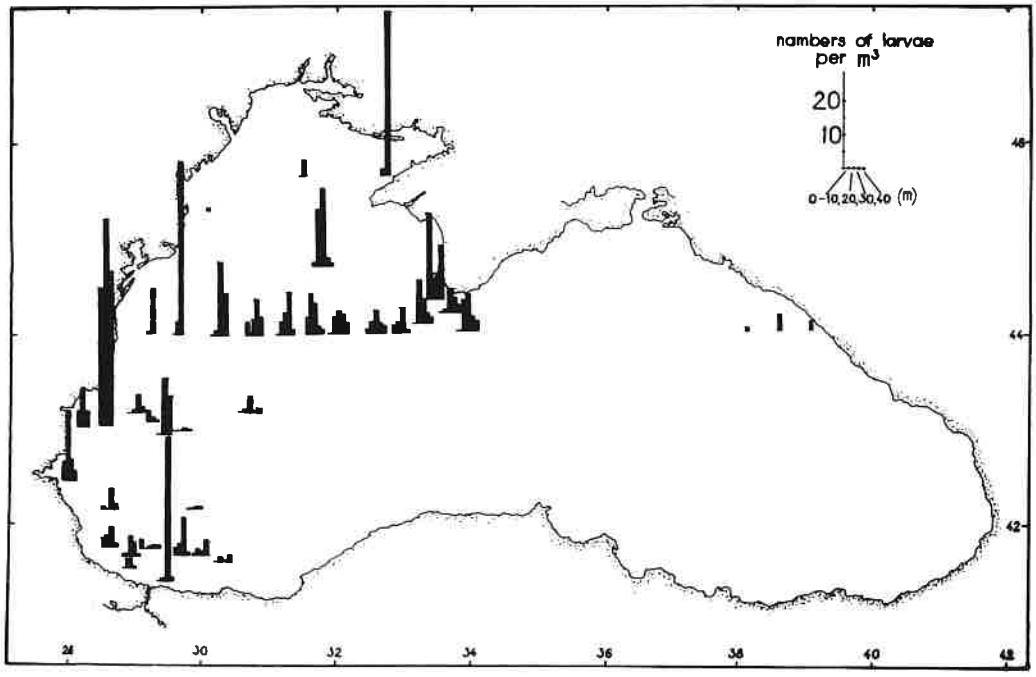

Fig. 2 - Mussel larval distribution at a stage of veliconcha with eye in 10-0 m layer at the Black Sea in autumn 1984.

regions - bivalvia larvae dominated distinctly in zooplankton. So, 20 out of 21 stations resulted 77.4-98.6% of all veligers and veliconchi. Other groups of bottom invertebrates were represented by Gastropoda veligers, Polychaeta nectochaetsa and trochophores, mainly *Polydora ciliata* and *Prionospio sp.* as well as Decapoda rare zoeae, Nemertini pelidiums and *Phoronis* actinotrochas.

Larval vertical distribution in plankton illustrated vividly the preponderance of main larval number to the upper 10-metered layer for all regions. Having the prolonged pelagic developmental stage - till one month - mussel larvae were transported far offshore. They were revealed in samples taken 90 miles off. These passive migrations are of interest in view of gene exchange among separate mollusc beds (IVANOV and BULATOV, pr. publ.).

In 1983 the experimental mussel mariculture farming was founded in Laspy bay (the South Crimea, Sarich cape vicinity). Its goal is to study regularities for mussel larval distribution in plankton and mussel settlements developing on collectors. Researches were conducted monthly in 1984-1985 and 1988-1989. More than 400 zooplankton samples were treated collected with Judday net, gas N 49 & 61, at all standard profiles using 3 control stations located at different depths: Batiliman bay, Laspy bay near the farm and Ajya cape (SHALYAPIN, pr. publ.).

Formation of mussel larval pool in the researched region had three main sources: maternal settlements on littoral rocks; mussel clusters on collectors and larvae brought by currents. Sharp fluctuations in mussel larval concentrations were exhibited in dependence on the season.

At the mariculture farming region mussels started their mass spawning in spring at 7-8°C; the autumn spawning - when water temperature lowered to 17- 18°C. If temperature was optimal for the spawning then there occurred winter and autumn flashes in number of spawning molluscs (PIRKOVA, pr. publ.). At low 3-6°C temperature the spawning impeded. So, in 1985 the peak in spring spawning appeared in April as water was cool and the reproductive period durated till mid-June (Fig. 3). Respectively the number peak for mussel veligers was in April. In 1985 it came up to May.

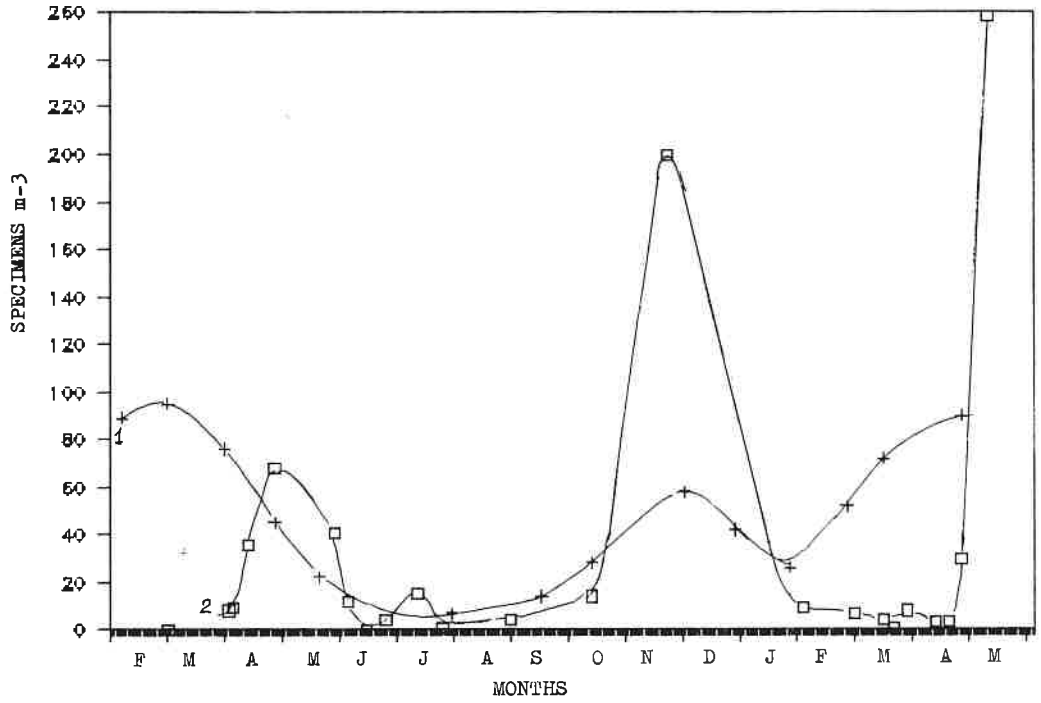

Fig. 3 - Rocky mussel spawning and veliger concentration in plankton sampled in 10-0 m layer at the marifarm region in 1984-1985:
1 - percentage of spawning molluscs of the total sampling number, 100 specimens;
2 - veliger concentration, specimens per m^3.

In plankton from the Crimean coast mussel larvae were met all-year-round. But the ratio for different-aged larvae (developmental stages) was unlike in various seasons. During spring mollusc reproduction the larvae in samples were mainly represented by veligers. Their number reached 68 specimens per m^3, in some samples - 110 specimens per m^3. In April 1984 and in May 1985 - 258 specimens per m^3.

What period is the best for establishment of collectors it ought to be studied the mussel larvae ratio in plankton at two late stages of metamorphosis: veliconchi with eye and veliconchi without it. The former - are the larvae which prepared to settle on a substrate. They were absent in spring 1984 and appeared only in July when their concentration averaged 39 specimens per m^3 (Fig. 4). The second type of veliconchi had 2 peaks in number- April and July. They disappeared completely in end-August and appeared only in May 1985 reaching 52 specimens per m^3.

Another picture was shown in 1989: only one spring peak was marked at a late stage. It was in May and resulted 160 specimens per m^3. Uneyed veliconchi had 2 peaks: April and June - 570 and 540 specimens per m^3, respectively; for cold period - a small increase in December - 60 specimens per m^3 (Fig. 5).

If in 1984-1985 veliconchi of both stages showed an equal low concentration unexceeding 40-60 specimens per m^3, then in 1989 the maximal number of the «eyed» veliconchi surpassed that of the «uneyed» ones by 3 times. The given data is evidenced exclusive seasonal and interyear changes for mussel larvae pooling. This must be taken into account while planning biotechnical works.

Mussel larval vertical distribution at a stage of settling was different for various aquatorium sections. Near the shore (deeper 30 m) veliconchi of a total mussel larval number (veliconchi + veligers) in zooplankton composed approximately equal shares at all depth profiles. In offshore

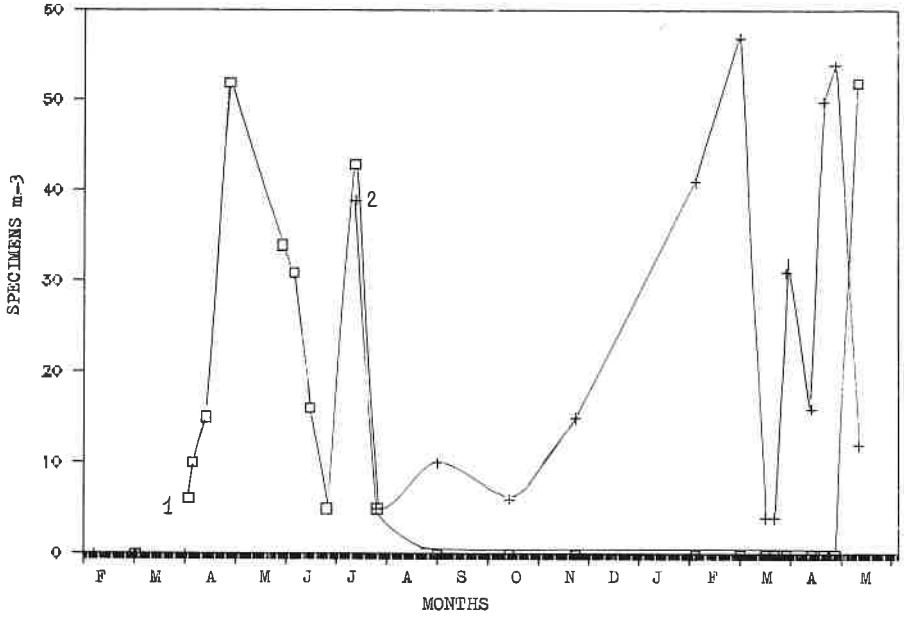

Fig. 4 - Mussel larval concentration at late developmental stages in plankton sampled in 10-0 m layer at the marifarm region in 1984-1985:
1 - veliconchi without eye, specimens per m^3;
2 - veliconchi with eye, specimens per m^3.

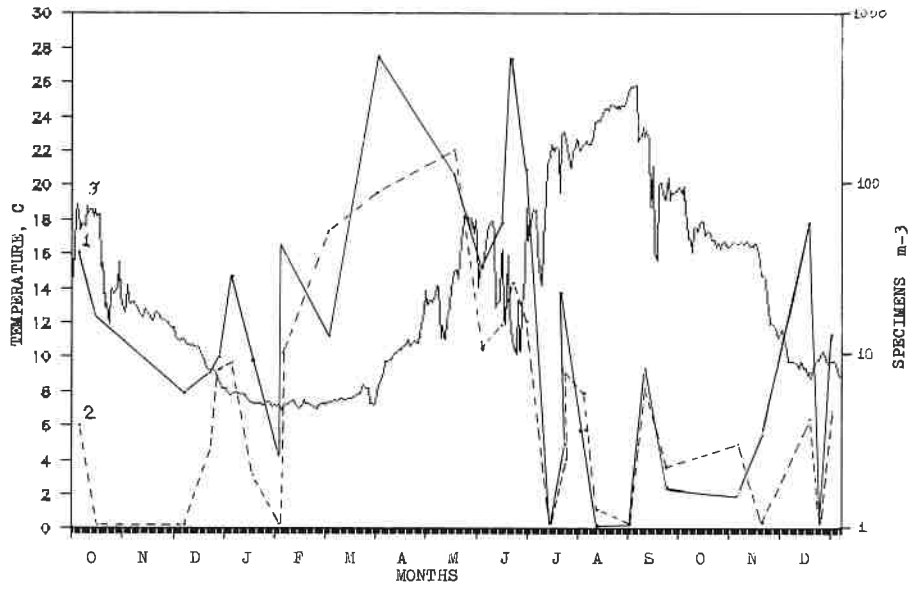

Fig. 5 - Mussel larval concentration at late developmental stages in plankton sampled in 10-0 m layer at the marifarm region in 1988-1989:
1 - veliconchi without eye; 2 - veliconchi with eye (expressed in logarithm scale); 3 - temperature.

site (depth 40-60 m) this share was higher. The latter may be explained by larval floatation decline at later developmental stages.

While studying settlings of mussel juveniles on experimental collectors (dim glass slides were placed at depth from 1 m till 10 m) no confident distinctions were noted in settling intensity with depth dependence of the submerged slides. Possible that equal distribution of veliconchi in this layer was the reason for that. Study of larval settlings onto slides with accumulated mussel aggregations showed that more intensive settlings occurred at lower depths beginning from 12-15 m. The slides were placed at depth profiles from 3 to 19 m.

Thus, bivalvia larval pooling, mussels first, represents a rather dynamic system fulfilling from different sources and depending on many ecological factors. The revealed common regularities in larval distribution and local peculiarities defining larval settlings and mussel settlement formation on mariculture collectors permit to predict many circumstances while establishing mussel mariculture.

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