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Challenges and their solutions in mariculture

Abstract

The paper presents the results of long-term observations on the process of cultivation of some commercial invertebrates and algae. The results obtained allow optimizing the process of their cultivation and achieving its profitability. However, unfortunately, these results are not familiar to the staff of the VNIRO Branch - writers of technologies, and this affects the state of mariculture in the Krai.

Keywords: *Mizuhopecten yessoensis*, *Mytilus trossulus*, *Crassostrea gigas*, kelp, *Saccharina japonica* and *Saccharina cichorioides,* mariculture

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Introduction

The technology of *M. yessoensis* cultivation borrowed from Japan has a costly operation - transplantation of the spats from collectors into cages. An average of 30% of spat is lost during the transfer.[1] As a consequence; the cultivation of *M. yessoensis* in Primorsky Krai is usually unprofitable[2] and is compensated by fishing and breeding of the valuable holothuria *Apostichopus japonicus*. These losses are rather caused by the fact that they contain a lot of manual labour,[3] and still do not have the mechanization that the Japanese, the creators of this technology, have. In Japan, the lifting of collectors and cages is carried out by a crane, the sorting, drilling and hanging of *M. yessoensis* by the ear is mechanized, and the grown crop is conveyed by a conveyor belt. The cleaning of flat cages from fouling is also mechanized. However, the lack of these devices can be compensated for by another collector design that allows the shellfish to be grown without transfer to cages. Bag collectors are an ecological trap for the associated *M. yessoensis* valuable species. Transplanting *M. yessoensis* into cages results in the mortality of these valuable species. When transplants are avoided, the holothuria *Apostichopus japonicus*, the crab *Paralithodes camtschaticus* and the sea urchin *Strongylocentrotus intermedius* reach a viable size, and the short life span of other fouling species means that they are not controlled as they die the following year. A 38-year study of the population dynamics of the seaside scallop has found it to have a quasi-biennial dynamic (Figure 1), meaning that there is a constant occurrence of average and poor harvest years.

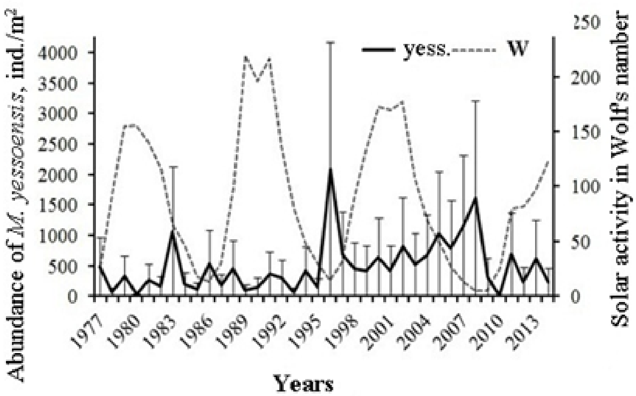

Figure 1 38 -year old dynamics of juvenile *Mizuhopecten yessoensis* abundance on collectors in Minonosok Inlet, Posyeta Bay, and solar activity in Wolf numbers.

Material and methods

To stabilise the collection of juveniles, we reared *M. yessoensis* larvae in kapron sieve cages placed in the sea. The larvae were fed from the sea through holes in the sieve and inhabited the cage. Early larvae of *M. yessoensis* were obtained in 200 litre tanks standing on the shore of Minonosok Bay, Posieta Bay and in 1 m^3 kapron sieve cages. For spawning, 5-7 year old producers caught in the shallow waters of Minonosok Bay were used. They were kept in the air for one hour, where they were washed from silt and fouling and during this time they opened their shells, allowing the sex to be determined. The females were then placed in a large tank and the males in a ten litre vessel. Being in the air, as well as ultraviolet radiation stimulated spawning and males almost immediately began spawning. To stimulate females, water with males was added to them at the rate of 5 spermatozoa per egg.[4] During larval rearing in tanks[5] it was found that veligers flow to surface in the evening and in cloudy weather, but in bright light they lie down and fall asleep. This allowed the top layer of water to be changed without fear of losing larvae in bright light, as there was no fine sieve to hold the early veligers. Once the larvae reached the veliger stage (120 µm shell length) they were transferred to a cage. In 1977, *M. yessoensis* producers were captured from deeper water off Furugelm Island and the reared larvae were also transferred to a cage.

To facilitate bottom cultivation of *M. yessoensis*, artificial reefs - "bottom collectors" made of waste net materials, whose vertical position was created by weight on the bottom and buoyancy at the top, were submerged on the bottom. In Posieta Bay in 1977-1980 about 1500 reefs were placed at 14 stations, including 30 reefs in Minonosok Bay. At the same time with the reefs, at these stations, 10-30 bag collectors of Japanese design were attached to the kapron rope instead of net materials, depending on the depth. After *M. yessoensis* larvae reached 10-15 mm in shell height, all bag collectors were raised to the surface where all bivalves were counted and measured. The obtained results were compared with climatic factors provided by the Hydrometeorological Station of Posyet village, and solar activity of Wolf numbers was taken from ftp://ftp.ngdc.noaa.gov. Statistical processing of the material was carried out using STATISTICA 6 (StatSoft Inc.,Tulsa, Oklahoma, USA).

Results and discussion

The shorter duration of the pelagic stage in M. yessoensis larvae (20-25 days) compared to 40 days[6] - is due to the fact that the author made observations at 8-10 °C, while in our case - at 12-17 °C.[5] The mesh size in the cage in 1977 was ~120 µm and most of the veligers escaped outside. As a result, the spat size was smaller in the plantation close to the cage than in collectors located in a distant plantation.[7] Our experiments using white growers found ~15% of reared larvae to be retained in the plantation.

After several years of reefs in Minonosok Bay, a high density of *M. yessoensis* was found on the bottom. Long-term observations of reefs made of waste net materials allow us to conclude that their functioning depends on the amount of buoyancy. In the first year underwater, their entire surface was involved in larval collection and rearing. The sea stars could not climb up the kapron rope Ø 3-6 mm connecting the weight and substrate. The following year, due to the growing mussel *M. trossulus*, the substrate started to touch the bottom and the stars creeped on it. After the second spawning, the surviving *M. trossulus* died, the substrate was detached from the bottom and at the expense of fouling - hydroids and brown algae fully functioned as a collector. However, in autumn the substrate was coloured emerald due to the mussel *Crenomytilus grayanus*, whose larvae had settled on the bissus of *M. trossulus* two years ago, and the substrate partially lost its collecting properties. Over time, under the weight of long-lived *C. grayanus* and other long-lived fouling organisms, including *Chlamys farreri*, *Mytilus galloprovincialis*, *Mytilus coruscus* and *Balanus rostratus*, the substrate was slowly sinking to the bottom, but even after 13 years the part of the substrate protruding above the bottom continued to receive and nurture larvae.

Observations of juvenile abundance on collectors have shown that *M. yessoensis* larvae settle more at head lands open to the southeasterly winds prevailing in June. These head lands slack currents caused by southeasterly winds, making it easier for larvae to attach to the substrate. The vertical arrangement of the bags allowed us to establish that each species has its own horizon where the abundance of their juveniles is maximized. Taking into account the nature of vertical distribution on collectors of juvenile starfish *Asterias amurensis* on the one hand, and spat of commercial bivalves on the other hand, we can recommend a horizon of 9-16 m for the collection of *M. yessoensis* larvae, 0-4 m for *M. trossulus*, 5-6 m for *Chlamys farreri*, and 8.5 - 16.5 m for *Swiftopecten swiftii*.[8] Even on collector-cage cones, differences between species were observed in the choice of settling sites. *M. trossulus* was selected on the outer side of the coats. *M. yessoensis*, *Ch. farreri*, *Pododesmus macrochisma* and *Septifer keene* settled on the outer side of the cones, while juveniles of *S. swiftii* and *Cr. grayana* were more often found inside the cones. In tiered settlements, substrate and food for numerous fouling organisms are more fully utilised, thus achieving less strain on community relations.[9]

The incorrect choice of depth for scallop plantations in Alekseev Bay and Slavyanskiy Bay in 1978 (10 metres) resulted in scallop collectors and cages being covered with *M. trossulus*. This is the main competitor for *M. yessoensis* and the high labour costs in controlling *M. trossulus* led to a great loss of mariculture farms and after 10 years they were closed down. However, farmers still use these depths for cultivation of *M. yessoensis*.[10] Due to the location of marine plantations near the surface, juveniles of *M. yessoensis* shake off to the bottom of the bags during storms, creating overcrowding and leading to death or growth arrest of the molluscs.[11] Even greater escape is observed in *M. trossulus*, whose larvae settle on substrates without coats near the surface because they cannot withstand rocking and temperature increases up to 28°C.[12] Favourable conditions for harvesting *M. trossulus* were formed if collectors were flooded for winter immediately after larval settlement.

Comparison of the material obtained in Posyet Bay with other water areas of Primorsky Krai allows us to conclude that the reproductive conditions of *M. yessoensis* in Peter the Great Bay and northwards to Cape Olyarovsky coincide. However, to the north (Kit Bay), asynchrony with the southern water areas is observed.[13] This is probably due to the fact that near Kit Bay there is a chain of mountains with the highest mountain in Primorsky Krai, Mount Oblachnaya (1854m), which locally transforms the climate.[14] Farther north (Vladimir Bay), according to our two-year observations and those of G.G. Shumik, the reproduction level begins to coincide with the southern water areas due to the bay entering the rain shadow area.[15] If we compare solar activity in Wolf numbers with the total abundance of juvenile *M. yessoensis* in Primorye, we find a high correlation coefficient, allowing us to speak of solar activity as determining the harvest of the year, while specific results in the water area depend on its regional characteristics.[16] This asynchrony in the reproduction of *M. yessoensis* between Posieta Bay and Sokolovsky Bay is already used in the exchange of juveniles.

In Posieta Bay, scallop collectors placed in the sea in mid-May had 4 times more king crab larvae *P. camtchaticus* than collectors submerged in mid-June, and the most optimal depth for their collection was 13.5 m.[17] Crab juveniles on scallop collectors are able to escape through the Ø 5 mm mesh during moulting, as all two-year-old individuals were found on top of the bags. In the summer, they actively resisted and died in water reaching 24°C when brought to the surface. Most likely, juveniles of *P. camtchaticus* have aggregations (podding), as fishermen reported that seiners near Slavyanka settlement sometimes lift trawls full of juveniles. We first found juvenile *P. camtchaticus* in 1980 on artificial reefs exposed in 1978 near Furugelma Island. The reefs were overgrown with the hydroid *Obelia longissima*, a food for *P. camtchaticus* and autumn homothermy allowed us to find them sitting on *O. longissima* as the reef rose to the surface. In my opinion, the creation of such reefs near Kamchatka Peninsula, where there are a lot of larvae, is more expedient for restoration of stocks of valuable crustacean than rearing of juveniles in aquariums of Primorsky Krai with subsequent transfer to artificial reefs.

When growing kelp seedlings (*Saccharina japonica*) in the pools of the Experimental Mariculture Base of Glazkovka village, it turned out that half of them died under the influence of Gram negative bacteria, and the remaining half was eaten by phytophagous crustaceans during the “adaptation” of the seedlings in Kit Bay. This resulted in six hectares of marine plantations without seedlings in 1985. However, increase of pool illumination up to 9 thousand lux, daily turning of frames with seedlings and cancellation of “adaptation” allowed to keep 100% of seedlings and three seaweed areas of Primorsky Krai in the late 80s in total collected 5 thousand tons of raw material. However, our experience of growing *S. japonica* seedlings was not useful for the new scientists and in 2021 there were again no sporophytes on the plantation from Popov Island.

In the rhizoids of *S. japonica* kelp, juvenile of *M. trossulus* becomes a “nitrogen fixer”, as its metabolites are assimilated by the rhizoids whose growth zone is adjacent. After harvesting, the rhizoids of *S. japonica* remain intact for another year and *M. trossulus* reaches commercial size on them. It reaches the same size together with *M. yessoensis* in collector-cages if their cover has a mesh size of 15-20 mm.

Suspended cultivation of the valuable alga *Saccharina cichorioides* has shown that in the Stark Strait of Popov Island its thallomes are heavily covered with *M. trossulus* due to indentations and if *M. trossulus* is not cleaned, the thallomes become a mussel collector, where the optimum abundance of *M. trossulus* is 70 specimens.

Once settled on shell collectors, the oyster *Crassostrea gigas* attaches itself so strongly to the shell of *M. yessoensis* and its neighbours that the grown crop has to be removed with a screwdriver, injuring hands and the oyster. Even on plastic collectors *C. gigas* interfere with each other's growth. In this case, the most optimal substrate for *C. gigas* would be pyramids of rods with a cross diameter of 8-10 mm, absorbed on the bottom and forcing *C. gigas* to grow upwards, weakening competition and also making it easier to harvest the grown crop.

Acknowledgments

None.

Conflicts of interest

The author declares that there are no conflicts of interest.

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