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About through-cultivation of two commercial bivalve molluscs

Abstract

The technology of collection of *Patinopecten yessoensis* larvae on mesh collectors, designed in Japan, requires transplantation of juveniles into cages. However, this transplantation is labor-intensive and dangerous to the species being cultivated. In cultivation ofthe oyster *Crassostrea gigas*, a lot of time is spent to increase the distance between scallop valves after larval settlement on them and to remove excess juveniles from them. at the same time, the use of the realized niche, instead of the fundamental one, in selecting the area and the depth to install the collectors and improving their design, provides an opportunity to grow these bivalves without transplanting them to other constructions. This not only facilitates the cultivation process, but also increases the growth rate and the survival rate of the species cultivated, because being exposed to air and various technological operations pose a strong stress to it.

Keywords: Transplantation of juveniles, Cultivation, *Patinopecten (=Mizuhopecten) yessoensis*, *Crassostrea gigas*

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Introduction

The technology for cultivation of the scallop *Patinopecten yessoensis*, originally borrowed from Japan, has a labor-intensive operation: replanting of the youngs from collectors to cages in autumn.[1] In cultivation of the Pacific oyster *Crassostrea gigas*, a labor-intensive operation is distance increase between shells after settlement of larvae and scraping off excess juveniles from a shell collector.[2] Depending on productivity of year, from 30 to 50% of juvenile scallops are lost during replanting of the youngs,[3,4] as many scallops experience stress that results in a slowdown of their growth and formation of "rings of interference" on the shell caused by the air exposure. The labor intensiveness of these technologies makes them unprofitable in Russia,[5] in many countries of Europe, cultivation of scallop is considered unlucrative too.[6] The studies aimed at finding the ways to optimize the growing process[7-14] and reduce operations of scallop transplantation[15] have been conducted for a long time.

Scallops that have reached one year of age in collectors or cages are often reseeded to the bottom, where they become exposed to many negative factors contributing to their low survival. Our experiments for the study of realized niche in scallop and the tests of the new design of the collectors set up on the bottom allow us to improve the borrowed technologies and avoid transplantations. The goal of this publication is to elucidate the results of cultivation two species of commercial bivalves to commercial size without transplantation by creation of optimum number of young's on collectors.

Materials and methods

To achieve this goal, I determined first the time for immersing in the sea the collectors in order to create the optimum number of young scallops. The determination began with the study of dynamics of the gonadal index in spawners. Every ten days, starting from the middle of May to late June, 1977-1990, a total of 25-30 scallops were collected by divers in Posyet Bay (42°30'N, 130°55'E) (Figure 1). Total weight, weight of soft tissues, muscle, and gonads of the scallops were measured with an accuracy of ± 0.02 g. A similar work was carried out in 1985-1987 in Kit Bay (43°3'39''N, 134°12'12''E). The gonadal index of scallops was estimated by the method of Ito and co-authors.[16] The time of the onset of spawning in bivalves was determined as an abrupt decrease, by 9-12%, in the gonadal index. A week after spawning in 1977-1999,, plankton samples were collected with an Apstein net every two to three days from the horizon 0-10 m at one or three stations in Minonosok Bay (42°36'32''N, 130°51'48''E), during four years at five stations in Kit Bay, and during two years at four stations in Vladimir Bay (43°54'N, 135°30'E). In 1985, in Kit Bay, at the deepest station, plankton samples were taken from 20 and 10 m. The mesh size of the mill screen was 100 μm. Plankton samples were fixed with 4% formaldehyde. Larvae were counted and measured in Bogorov's chamber under a MBS-10 microscope; number of larvae was expressed per 1m^3.

After the scallop larvae reached 250 μm, the collector-cages, designed by Gabaev DD,[17] were placed in Minonosok bay, in road Pallada bay (42°35 ' 55 "N, 130°50 ' 45" E), in Kit bay and in Vladimir Bay. For comparison in Minonosok bay, in Northern bay (42°56 ' 37 "N, 131°23 ' 11" E) and in Alekseeva bay (42°59 ' 6 "N, 131°43 ' 26" E) in the sea were placed collectors of the Japanese design.[18] Besides, in 1989 in Vladimir Bay, and in 1990 in road Pallada bay were placed the thinned collector-cages at which the distance between conus has been increased twice. To determine the optimum horizon for positioning the collectors and the dynamics of larvae settlement on the substrate, collectors of the Japanese design were placed on the bottom at 16 stations within the horizon 0-19 m, at different times, starting from the autumn of the previous year, in 1977-1982. The method of obtaining materials to determine the required mesh size of shell, the optimum angle of the collector wall relative to the water flow direction, as well as forecasting and increase in the number of larvae in case of a lean year was described earlier.[19] Four months later and in the spring of the following year, the collectors were lifted to the surface, cleaned of fouling organisms, live and dead bivalves were counted, and the abundance of the main predator, the sea star *Asterias amurensis*, was determined. In 1980-1987, we carried out a mass counting of juvenile *P. yessoensis*, which settled on the Japanese collectors deployed at different times in a commercial farm in Minonosok Bay. For the study, we took into account the contents of three collector bags taken from three places of every fifth of the one-hundred-meter lines.

Figure 1 Index map of the water area used for experimental cultivation of *Patinopecten yessoensis* or *Crassostrea gigas*. 1: Minonosok Bay, 2: Posyet Bay, 3: Novgorodskaya Bay, 4: Northern bay, 5: Alekseeva bay, 6: Kit Bay, 7: Vladimir Bay.

Juvenile scallops, removed from the collectors, were reseeded into cages and onto the bottom. Yearling scallops were transplanted from the collector cages onto the bottom also. A part of the collector cages were left underwater for the second and third years. To determine the rate of scallops' survival on the bottom, live and dead individuals were caught using diving equipment or a dredge coupled with an aquaplane. At least 100 specimens of each species were measured with a Vernier caliper to an accuracy of ± 0.1 mm; in 25-30 specimens, the weight increment was analyzed by means of electronic scales VLTK-500. The final production was determined as the total biomass of the species on the facility. A major part of the works on scallop cultivation was conducted in Posyet Bay in 1977-1996, in Kit Bay in 1985-1988, and in Vladimir Bay in 1988-1989 and 1999.

In 1977 and 1982, a total of 118 pyramids made of stainless rods with a cross section of 8 mm were installed on the bottom of Minonosok Bay before settling of oyster *C. gigas* larvae. Grown up oysters were measured with Vernier calipers and weighed. All oysters that settled in four pyramids in 1977 were subjected to a complete biological analysis. Their number ranged from 11 to 253. In the summer of 1979, six bunch of oyster collectors, the main substratum of which were polyethylene rings with a furrow on their flat part,[20] were suspended on a raft in Novgorodskaya Bay (42°38'37''N, 130°52'17''E) (Figure 1). The rings had different colors, were fixed at different distances from one another, as well as had or lacked the overall netted cover. For the control, a garland of oyster collectors from shell of *P. yessoensis* was also placed there. In August 1982, all the collectors were hauled to the surface and processed according to the standard procedure. The obtained data were analyzed statistically using a program STATISTICA 6.0[21] and tested at the level α=0.05.

Results and discussion

A collector - cage, designed in 1981 for collecting and breed the scallop *Patinopecten yessoensis*, has the interior partitioned into cones with planes (Figure 2) that protect bivalves from falling down and creating a high density there.[17] This reduces the competition between bivalves and increases their survival and growth rate in comparison with those in collectors of the Japanese design (Table 1). In case an cover with a mesh size of 10 mm is used, the collector - cages can be left in the sea for a year without any damage to scallop and accompanying species (Figure 3). Providing these collector - cages with an cover with a mesh size of 15 mm allows growing scallop in them to a marketable size without transplantations (Table 2).

Figure 2 Conus from collector-cage with juvenile of molluscs.

Figure 3 *C. gigas* has grown without intervention on metal rods to commercial size.

Even more promising is cultivation of *P. yessoensis* in collector - cages enveloped with an overall cover. The presence of an overall cover on the construction installed on the bottom stimulates use a machine that hauls it from the water, removes all fouling organisms, puts on a new cover, and immerses it again into the sea.[22] Mechanization of the entire cultivation process will significantly reduce the cost of the output product and make it profitable in many countries.

Associated species and predators have a significant impact on the cultivated object and on the sea farms.[23-25] However, our technology is facilitated by the fact that the animals and plants inside the collector - cages create a polycultural community: bivalves, algae, shrimp, and sea urchins produce DOM (dissolved organic matter) that serves as food for bacteria[26] and for phytoplankton,[27,28] on which bivalves actively feed.[29,30] Cultivated bivalves are often resistant to fouling,[31] they use various protective mechanisms against predators,[32] including some fouling organisms on shell that help in this.[33]

Some of predators can have an adverse effect both on scallop's competitors[34-36] and on other predators.[37] In addition, larvae of main scallop's competitors Pacific mussel *Mytilus trossulus* and Japanese scallop *Chlamys nipponensis*as, as well as the predatory seastar *Asterias amurensis* settle in an upper horizon,[38] on conus larvae occupy of different sites[4] and the highly productive years for *M. trossulus* and *Ch. nipponensis* basically do not coincide with those for *P. yessoensis*.[39] Competitors settle at a different time, which can also be used to optimize the contents of the collectors.[11] The connection with the bottom only via a weight (anchor), as well as the use of an cover of the collector, prevents colonization of bivalve shells by the shell-boring polychaete *Polydora* and barnacles, which reduce the rate of bivalves' growth at the bottom.[40,11,41] Anchoring of collectors, in contrast to a suspension culture, reduces the stress on the cultivated species and increases the growth and survival rate in bivalves.[42] By the second and third year, much fewer larvae of invertebrates settle on collectors.[19] Many invertebrates, including main scallop's competitor *M. trossulus* cannot not live longer than two years in Posyet Bay[43] and closing the inner part of collector with cones prevents movements of predators in it.

Table 1 The production parameters of *Patinopecten yessoensis* on three collectors design, exposed in Primorsky Krai in miscellaneous time

Age and Date of Birth	abundance of Scallop and Mussel d/m² *	Scallop share	Scallop survival, %	scallop Shell Height, mm	Depth of Arrangement Collector, m	Collector Site	Area and Collectors Design
4 month 1990	125.5 587.7	0.21	13.8	21.5±2.1	8	depth	Minonosok Bay Japanese
4 month 1981	1389.0 283.0	4.91	100.0	10.9±0.2	8	depth	North Bay Japanese
4 month 1981	744.4 448.0	1.66	82.3	11.7±0.7	8	depth	Alekseeva Bay Japanese
4 month 1990	1962.5 227.8	8.62	59.3	25.4±4.3	8	depth	Minonosok Bay collector-cages
4 month 1990	1115.5 241.3	4.62	97.9	21.6±4.6	20	bottom	road Pallada bay thinned of collector-cages
1year 1990	989.0 781.5	1.26	62.2	38.2±1.2	20	bottom	road Pallada bay thinned of collector-cages
1 year 1990	197.0 72.5	2.71	95.4	55.4±2.1	20	bottom	road Pallada bay collector-cages
1 year 1985	52.5 59.8	0.87	37.8	39.8±0.7	8	depth	Minonosok Bay collector-cages
1 year 1985	28.5 44.9	0.63	96.1	21.5±0.4	8	depth	Kit Bay collector-cages
4 month 1989	44.5 12.5	3.56	100.0	13.0±3.1	8	depth	Vladimir Bay collector-cages
4 month 1989	85.5 100.0	0.86	100.0	9.3±2.1	8	depth	Vladimir Bay thinned of collector-cages
1 year 1988	171.5 333.3	0.51	100.0	34.3±4.3	8	depth	Vladimir Bay collector-cages

*Note: in a numerator - number of scallop, in a denominator - number of mussel.

Table 2 The results cultivation of *P. yessoensis* in Primorsky Krai during three years on three technological schemes

variants*	scallop Shell Height, mm	Survival, %	The General Weight with Shell, g	Weight the Soft Tissue, g	Weight Muscle, g	production, g/m2
1	82.3±1.8	75.0	58.1±4.2	21.7±1.8	9.5±0.8	14728.0
2	75.1±6.5	55.2	48.6±4.3	18.2±1.7	7.6±1.8	4050.0
3	88.9±1.5	30.0	79.3±4.1	39.8±1.8	15.1±0.7	397.0
4	84.4±8.6	56.0	79.5±8.1	31.8±9.5	13.5±1.5	7950.0
5	84.1±1.7	30.3	76.7±3.9	23.7±3.2	6.0±0.8	11045.0

* 1- on collector - cages in Kit Bay without transplantation, 2 - in cages in Kit Bay after transplantation from collectors, 3 - at the bottom in Posyet Bay after planting of youngs. 4 - in cages in Posyet Bay after transplantation from collectors. 5 - on collector – cages in Posyet Bay without transplantations.

Thus, the "transplantation-free" method of scallop cultivation is as follows: to obtain a constant and optimum number of larvae, which allows improving the conditions for their cultivation, the forecast of their harvest is made based on the number of days with sea ice in shallow bays. For this purpose the graph showing interrelation of the sum of ice days and abundance of young on collectors I divide into three equal parts. Years with the number of sea ice days smaller than or equal to 103 are classified as lean; from 103 to 108, medium-productive; and more than 108, productive. In the case of a lean year, the collector walls are set up at a horizon of 14-16 m and at an angle of 90-120° relative to the shore on day 25-32 after the beginning of scallop spawning in shallow bays. In the case of a medium-productive year, the wall is set up at a horizon 12-14 m at an angle of 120-150° to the shore on day 15 to 20 after the beginning of scallop spawning; in the case of a productive year they are installed at a horizon of 10-12 m and at an angle of 150-180° relative to the shore since the autumn of the previous year. In case of a lean year, the walls set up in the sea have the cover with a mesh size of 5-8 mm; in the case of a medium-productive, with a mesh size of 8-11 mm; and in case of a productive year, with a mesh size of 11-15 mm.[22] In the near-shore waters of Posyet Bay, hydrological facilities are characterized by quasi-two-year oscillations.[44] Harvests of young scallop also show quasi-two-year fluctuations.[3] A lean year is, as a rule, followed by a productive year. Therefore, setting up the walls in the autumn of a lean year reduces the number of larvae settling in the productive year. This provides an opportunity to stabilize and optimize the cultivation process.

If the forecast predicted a harvest below the optimum one, it can be increased by artificial spawning of producers and by releasing 2-4 day old trochophores and veligers at a distance of 2-3 km from the farm.[22] To stimulate the scallop spawning and optimize its reproduction, it is necessary to launch artificial upwelling during two days each year.[45]

The technology of the Pacific oyster (*Crassostrea gigas*) cultivation involves several labor intensive operations. To collect larvae from plankton in the sea, *P. yessoensis* shell are stringed on a wire and immersed into the sea. After settling of oyster larvae, special partition plates are placed between the neighboring shell in autumn, excessive juveniles are removed from each valve.[2] Juvenile oyster, settling on the valves, attaches to the substrate with the entire surface of its lower shell, and removing it during harvesting poses a significant danger both to the oyster and to worker's hands. Our collector for collecting and growing-out oyster larvae up to a marketable size consists of a bunch with plastic rings, the flat part of which has a deepening stimulating the larval settlement.[20] After the settlement is complete, the distance between the rings is easily increased by untying one knot. The narrow size of the rings does not allow the bivalve to attach with its entire lower shell surface, and the influence of the neighboring molluscs makes them all grow upward (Figure 4). This arrangement of oysters on the substrate reduces competition between molluscs and facilitates harvesting of the grown animals. The obtained results of oyster cultivation without thinning on various substrates in two Bays allow us to draw a conclusion about practicability of the simplified technology of growing of this bivalve (Table 3 & 4). The weight of meat of molluscs grown by us almost does not differ from the values for oyster grown by the traditional technology in the same bay, and presented by V.A. Rakov.[2]

Table 3 Results cultivation of *Crassostrea gigas* on wattling pyramids in Minonosok bay

No pyramid data	1	2	3	4
Quantity of living oysters, ind	173	94	253	11
Survival, %	72.8	39.3	52.2	100.0
Age of oysters, years	5	5	5	5
Meat weight, g	24.0±1.6	11.5±1.0	11.9±0.8	28.2±1.7

Table 4 Results cultivation of *C. gigas* on raft in Novgorodskaya Bay

Collector design*	1	2	3	4	5	6
Age, year	**3**	**3**	**3**	**3**	**3**	**3**
shell height, mm	101,9±15,4	99,9±15,4	108,5±16,2	99,5±18,7	93,3±15,9	109,7±13,3
The general weight with shell, g	76,1±31,9	83,8±28,2	90,9±34,7	65,2±32,3	55,3±26,4	90,2±24,2
Meat weight, g	9,9±4,6	11,2±3,5	11,4±3,6	9,2±4,0	6,9±3,5	9,3±2,6

*1 - Rings black and divided, 2 – Rings black and divided, 3 – Scallop shell, 4 – Rings white and not divided, 5 – Rings black and not divided, 6 – Rings black and divided with netted cover.

Figure 4 Conus from collector-cage with juvenile of *P. yessoensis*.

These materials allow us to conclude that bivalve aquaculture provides an opportunity to harvest without damage to valuable accompanying species and that grown up bivalves will have a higher taste quality and other useful properties, as they are cultivated in their natural habitat.

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Conflicts of interest

None.

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