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Inter-annual differences in spatial distribution of some marine bivalve Molluscs' juveniles

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Abstract

Operating in Russia technologies of bivalve mollusk's cultivation are based on the larvae collection for artificial substrates. However, besides those ones cultivated, the competing larvae and predatory species also settle on these substrates. The competing species have similar nutritional needs with cultivated ones, but the predators eat them. In order to reduce negative influence of companion species, the long-term spatial distribution of the sea-scallop collectors' main inhabitants is being researched which allows to find the most optimal water area for the cultivated *Patinopecten yessoensis*. The comparison of the long-term spatial distribution dynamics with climatic factors defines the most influential ones on horizontal and vertical distribution of the researched species. Using the ability to predict the climatic factors, for instance, the solar activity it helps to apply the forecast for the optimizing conditions of the cultivated species existing.

Keywords: larvae and spats of *P. yessoensis; M. trossulus; Ch. Farreri; S. swiftii;* Variability of spacial distribution

1. Introduction

The alternative to the fishery industry is aquaculture - the most prospective and the fast developing field of the fishery industry. In terms of catches in four advanced marine culture countries it exceeded 50% of the total seafood volume production [1]. However, the increased scales of cultivation have led to the negative consequences in biodiversity, ecology and cultivated objects productivity [2; 3; 4; 5], often called by the algae covering reduction [6], reacting negatively for Global Warming [7]. Moreover the ecological situation is exacerbated oftenly by the alien species' settlement into the water area [8]. The high densities of the cultivated objects call the water area eutrophication which leads to the changes of phytobenthos species composition and phytoplankton, containing either inedible either toxic seaweed species [9; 10]. Global Warming often has a negative influence on cold-loving species and a positive one for the thermophilic ones. [11; 12]. They move to the North [13; 14], replacing negative species [11], and Global Warming increases their survival capacities and the chances to settle in new water areas [15], where the community dynamics correlate to the seasonal and spatial changes in the environmental conditions [16].

Some aquaculture sources - the soil, the fresh water, the feeding and the energy are connected to the significant influence on the environment and if the aquaculture doesn't find the way to produce more products, minimizing the dependence on these resources, its growth will be difficult [4]. As a consequence the leading China has reduced its share in the fishery field to 57,9% by 2018 and the further decline is expected in coming years [1]. In order to bridge the gap between today's world animal protein consumption and the demand in it in 2050, the aquaculture production should be increased more than twice [4]. However, the extensive technologies for bivalve molluscs breeding containing several transfers need to have semi closed bays for the water surface operations. The weak water exchange in such water areas

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exacerbated by the plantation's presence leads to negative consequences for the inhabitants [3]. The feces and pseudo feces exerted by cultivated molluscs can lead to the phytoplankton flourishing including poisoned species and their destruction can decrease significantly the oxygen level [17] and the biodiversity of benthic animals [18].

As a sequence it is urgently required the search of activities to improve aquaculture productivity without declining its negative impact. One of the means for cultivation process optimization can become the search of water areas and depths mostly suitable for valuable objects with low competitors' presence. The spatial and temporal heterogeneity of the habitat makes influence on the speed, direction and effectiveness of adaptive evolution [19; 20], and the underestimation of habitat spatial structure was the disadvantage of ecology communities in 1970 years [21]. The species interactions can be destroyed by accompanying action of temperature connected changes and local anthropogenic stress. Its effects together with global climate changes become more severe [22]. The resettlement is a key process in dynamic metacommunities allowing to keep the diversity of complex community network [23], and the spotting distribution of the researched species is the ecological feedback or the damage result reducing the diversity of the macrofauna community [24]. Oceanological processes and climate gradients make significant influences on the variability in community structure [25], and the stream called by the wind in coastal upwelling regions strongly affects on settling [26]. The relationship of the coastal topography and the streams are the primary determinants of the density and reproduction [27; 28], as the water whirlpools have very important meaning for the larvae settling [26].

In Coastal waters where the recruits are being collected the character of larvae distribution is more influenced by the winds and swimming behavior than in open waters [29]. These factors get the decisive meaning for the hydrobionts' living activity with the figures close to the extremal ones [30]. Biotic and abiotic factors make the strongest influence on bottom population of the cultivated species [31] and the norm of balanus larvae settling on the vacant subtract was different between the places almost twice [32]. Moreover, in spite of the interannual distribution changing the spatial specialities of water area and the autocorrelation amplitude stay similar [33].

The spawning peaks partly reflect the population refilling dynamic that tells about relative independence of spawning intensity and about the success of further population refill [34]. However, the changing in reproduction period allows larvae to realize themselves in summer in order to escape upwelling negative effects and make the local holding easier this way [35]. The small part of the larvae pool is being brought from parental individuals into the open sea and the main mass stays near the parental population in the shallow water [36; 37; 38; 39]. That's why the biggest part of plankton larvae are the descendents of local molluscs [16], although it is visible an import by the habitat edge [40].

The juveniles actively settle near by adults and those which were settled far are the subjects to the high mortality due to predation, physiological stress or due to other factors [41]. The larvae abundance depends on the producer's quantity [42], but it is not possible to underestimate the climate conditions of one year [43]. And the borders of larvae mussel vertical distribution in plankton at the areas of the Black Sea shallow waters also corresponds to the depths of molluscs' settlement formation [44].

However, the highly negative correlation between juvenile density and adult scallops meets sometimes [45] and with high biomass of adults their filtration activity can significantly decrease the larvae quantity and become a limiting factor [46; 47]. There are quite good reasons to consider that in high density settlement the adult molluscs suppress the larvae settling as a result the mussels can be represented by one or several close in age categories [48].

The trials to collect biological information on reproduction with the help of planktonic or benthic samples are laborious and unreliable as the diffusion of marine larvae depends on advection and turbulence and also it depends on active larvae behavior [49; 50]. The researches of the benthos are also less useful for the water areas determination, favorable for invertebrate larvae collection as at the bottom they are exposed to the predators' influence, storms and downfalls. The lack of information about long-term reproductivity changes of macro fauna of the sand coastal area are caused by many difficulties in material collecting [51].

These negative factors can be escaped in case of using artificial substrates for the quantity dynamics research and spatial recruits distribution. And in order to obtain reliable information it is necessary to use scallop collectors [52], which allow to estimate not only horizontal but also vertical juvenile distribution. For developing better representativity of marine diversity, distribution and testing of macro ecological generalizations it is necessary 3D approaches [53]. In mangrove habitats the density and the presence of cypris balanus on different distances from the edge of the sea and their vertical distribution create a good predictor of settling models [54]. The settling plates are also being widely used for the ecological research during the reproduction determination and the growth of sessile benthic communities [55]. But the settling plate covers absence can distort the larvae supply due to their intensive eating by the fishes [56]. The use for the research of the invertebrate scallop reproduction collectors of Japanese construction has the wide range of advantages compared to the open subtracts as their cover protects molluscs from fishes and holds the invertebrates inside during the storms.

In the countries with market economy the intensive technologies often are being used as necessary means directed on producers refilling. After the natural production revival the marine farmers came to the larvae collecting in the sea [57; 58], as the spat collecting method in the ocean is more effective and profitable [59; 60]. But the accompanying larvae and predator species settle on collectors [61], and if not to choose the correct time of exposition, the horizon and the water area of settling then the competitors can become more than cultivated species [62; 63]. These competition species can lead to the delay of cultivated species growth and even to its massive death [3]. The Japanese technology of the sea scallop cultivating contains multiple molluscs transplanting from collectors into cages and again in cages [64]. Besides the high laboriousness, this technology leads to the molluscs' loss during transplantations and stress when staying in air which can be visible on the interference ring of the shell [65]. Even the fastening of the individuals by the ear requires the scallops growing up to one year old, but in Mutsu Bay this technology is not being used due to the frequent storms leading to breaking of the shell’s ear and molluscs’ loss [66].

In relation to Global Warming [67;68] the vertical molluscs’ distribution can be changed too as it is known that during the subtracts searching the larvae choose for settling optimal temperature for living [69; 27; 70]. As a result of this it is necessary to search for a favorable water area for cultivation in modern climatic conditions [71]. In Korean waters the wild distribution of cold-loving scallop *Patinopecten yessoensis*, because of water temperature increase is limited by the moving to the North of the southern meeting border [72]. The modern warming cases impose on smooth warming trends increasing the opportunity of sharp changes in structure and ecosystem functioning [73]. The organisms distribution is one of the main ecology issues and the setting of scallop collectors in the horizon of *Mytilus trossulus* mussel maximum quantity leads to the complete mortality of *P. yessoensis* [62]. As a consequence the knowledge of spatial distribution specialities and the variability among competitor species is actual.

The research district was the Posyet Bay (42˚30’N,130°55’E) situated in the north-west part of the Japanese Sea at the edge of three countries - Russia, China and Korea and it runs into the shore up to 17 miles. This bay is considered as the cleanest one due to the absence of large production companies in the Peter the Great Bay and little population [74]. The streams are being formed in the research district under the influence of the whole circulation of the Japanese Sea waters, monsoon winds and tides. From the north the Primorskoe stream makes it cold and from the south the East-Korean stream makes it warm (the branch of the warm Tsushima Current) [75]. The tides in the bay are not significant, wrong, with semi-diurnal nature, that’s why the main influence for water mass transportation is the wind [76]. This district is getting warmer in summer and the average monthly water temperature here is several degrees higher than in Vladivostok city district [77]. The researched four species of bivalve molluscs (*P.* yessoensis, *M. trossulus*, *Chlamys farreri и Swiftopecten swiftii*) have different origin, distribution and ecology]78], what makes them different in juveniles spatial distribution on artificial substrates. The different species of one community have a discrepancy on different area horizons [36]. However, there is a little information about the distribution of the researched species and its interannual variability [79]. It was created the first marine culture plant in Russia in 1971 in s’ Bay of the Peter the Great Bay. During the plantations expanding in the bay up to 16% from total surface area and mutual cultivation of the scallop and the mussels the problems with benthic biodiversity [80] and trade production receiving have started [81; 3]. This research serves to search for interspecies differences of spatial distribution of four massive artificial substrate foulers, the relationship of long-term distribution changing with the climatic factors and the opportunity to use the forecasting climate for the cultivated *P. yessoensis* refilling production optimization.

2. Material and methods

2.1 The determination of collectors’ time setting

In order to obtain this target the Japanese construction equipment of the scallop collectors consisted of 10 to 30 net bags depending on the depths they were set on the bottom in the north-west part of the Posyet Bay. The optimal time for collectors setting was determined from the spawning moment of the cultivated *P. yessoensis.* The dynamic of their gonadal index was studied for that purpose. Every ten days from the middle of May until the end of June 1977-1990 in the Posyet Bay (Figure. 1, st.1) with the help of diving equipment 25 to 30 samples of the scallops were caught and weighted of their total weight, the weight their soft tissues, muscles and gonads with the accuracy of the ±0,02 g.

The gonadal index was calculated by the method of Ito and his coauthors [82]. The time of spawning began was determined according to the reduction of the gonadal index at 9-12% among the females. One week after the spawning once in two-three days the plankton probes were taken by the Epstein net in the horizon of 0-10 m. The size of the mill sieve cell was 100 μm. In 1979 and 1989 in the Bay of Reid Pallada the probes were taken at 14 stations (Table 1) and in 1977-1990 and in 1995 and 1996 at 1-3 stations at s' Bay (annually 8-11 probes). The plankton probes were fixated by 4% formaldehyde. The calculation and measuring of the four. types of bivalve larvae were made in the Bogorov camera under the microscope MBC-9 and their quantity was recalculated for 1 m^3. Together with the plankton probes taking the water temperature was measured, moreover in 1987-1990 it was measured on three horizons (0,5 and 10 m).

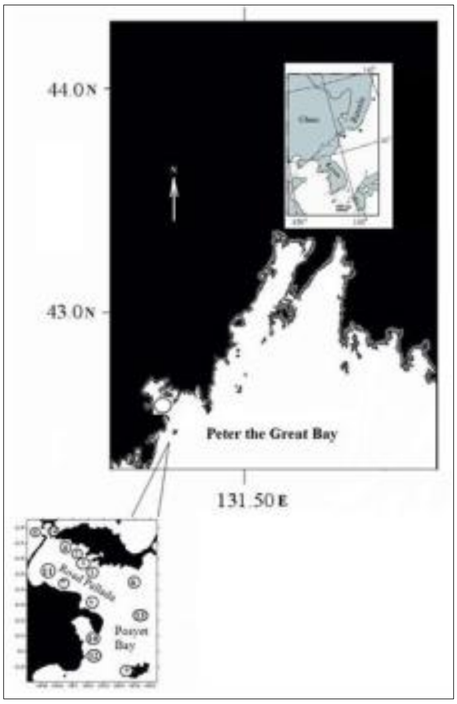


Figure 1 Study area: Posyet Bay with Road Pallada Bay and stations of capture of a planktonic tests and immersing of collectors

Table 1 Information of sampling planktonic sample and exposure scallop collectors

Stations, №	Areals	Removal, km	Depths, m	Latitude °	Longitude °
1	I. Minonosok	7	16	42.61	130.86
2	I. Klykova	5	15	42.62	130.84
3	c. Nizmeny	9	14	42.59	130.87
4	i. Astafjego	3	15	42.63	130.82
5	I. Pemzovaja	11	13.5	42.55	130.85
6	c. Deger	12	15	42.59	130.92
7	c. Ostreno	8	12	42.58	130.82
8	c. Schelex	1	14.5	42.64	130.79
9	i. Furugelm	22	19.5	42.47	130.91
10	I. Kalevala	15	11	42.52	130.85
11	c. Mramorny	6	11	42.59	130.80
12	c. Deda	16	15.5	42.50	130.85
13	s. Klykova	15	26	42.57	130.90
14	i. Tcherkavskogo	1	5	42.64	130.81

2.2 The research of artificial substrates

After appearing in the plankton the scallop larvae with the shell length of 250 µm (stage of settling) at 14 stations in North-West part of the Posyet Bay in 1978-1982, 1985, 1989 and 1990 and in 1977-2014 in s' Bay (st. 1) the Japanese construction equipment of net collectors were set. In total the collectors covered the horizon from 0 to 26 m. In 1988-1990 on the probes taking day the pairs of garlands collectors at 60 m far one from another were set at the plantation in s' Bay. After the *P. yessoensis* juveniles grew up to 8-10 mm at shell's height the part of collectors were taken up on the surface. Four mass species of the bivalve molluscs: *P. yessoensis*, *M. trossulus*, *Ch. farreri* и *S. swiftii* were taken out from substrates, measured and counted living and dead individuals. The reproduction level of these molluscs was defined by the way of addition of living and dead individuals.

2.3 The climate observations

In order to research the influence level of climatic factors on reproduction ability of these species the daily temperature, water saltiness, sea level, rainfall level, wind speed and direction for 1977-2014, collected in Posyet Bay (42°33'N, 130°48'E) by Hydrometer Station (HMS) measurements were used. The spawning and the pelagic period of *P. yessoensis* and *M. trossulus* mainly passes in June, due to this reason the HMS data for the researches of climatic factors influence level on the most responsible for reproduction period was taken for June. The value of solar activity expressed in Vulf's numbers was taken at the web site of USA National Administration for Atmosphere and Ocean ftp://ftp.ngdc.noaa.gov. The water surface average temperature error in June of each year was calculated. The length of the ice period was observed only in Expedition Bay (Figure. 1, st. 8). Due to this the average meaning and the average error were not defined.

2.4 The statistical material processing

The influence level on spatial distribution and reproduction of the researched molluscs were defined by the way of statistical comparisons of the climatic parameters dynamic with spatial distribution and their abundance dynamic. The correlation Person analysis was used for the interconnection estimation between the depth and vertical distribution of juveniles on collectors and also between water average temperature in June and maximal plantation removal from the warm st. 14. The standard error (SE) was estimated for all the average values. The depth of maximal juveniles quantity, the ice period duration, average water surface temperature in June, standard error of average water surface temperature in June, the average sea level in June, the average rainfall value in June, the average wind speed in June, the average wind direction in June, the average water saltiness level in June, the average solar activity during the year in Vulf's numbers, the average *P. yessoensis* shell height by the 23rd of September of each year were estimated by non metric multidimensional scaling (nMDS). The relationship of climatic factors and the abundance dynamic of cold-loving *P. yessoensis*, *M. trossulus*, *S. swiftii* and warm-loving *Ch. farreri* (1977-2014) was estimated by the same analysis. The statistical material processing was held with the assistance of STASISTICA 6 (StatSoft Inc., Tulsa, Oklahoma, USA) [83]. The meanings of regressive analysis were tested at the level of $\alpha=0.05$.

3. Results

3.1 The planktons probes research

The larvae observations in plankton showed that the two species have the differences in special distribution. The biggest abundance of the *P. yessoensis* larvae observed in the bays: (st. 2; 1; 5 and 10). At the same time the *M. trossulus* larvae distributed more evenly with little increase at stations 1 and 10. The warm-loving larvae *Ch. farreri* met more often along the Krabbe peninsula washed by the Reid Pallada Bay from the south (st. 1, 2, 3 and 6) and the larvae of cold-loving scallop *S. swiftii* - at the opposite side of the Reid Pallada Bay - (st. 5, 7 and 10) (Figure. 2).

Four year researches of plankton in Minonosok Bay (1987-1990) showed that only in 1988 the larvae *P. yessoensis* abundance was positive and reliably connected to the water temperature at three horizons (0,5 and 10 m) and *M. trossulus* only at ten meters. However, in 1989 the reliable relationship between the larvae *P. yessoensis* abundance and the temperature was only at one horizon (5 m), and moreover it was negative. (Table 2).

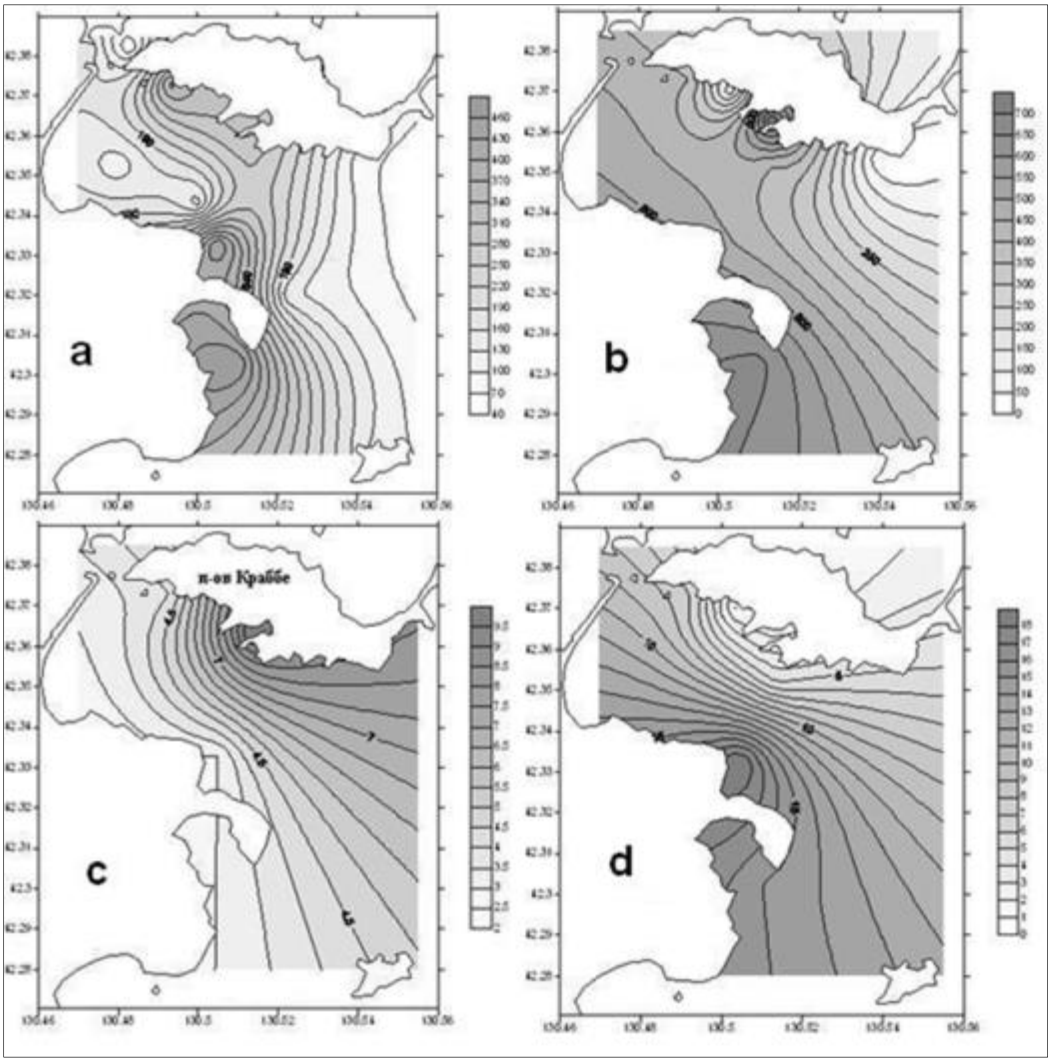


Figure 2 Results of processing of a planktonic tests. a - distribution of the larvae *P. yessoensis* in June 1979, b - distribution of the larvae *M. trossulus* in June 1979, c-distribution of the larvae *Ch. farreri* in June 1989, d - distribution of the larvae *S. swiftii* in June 1979.

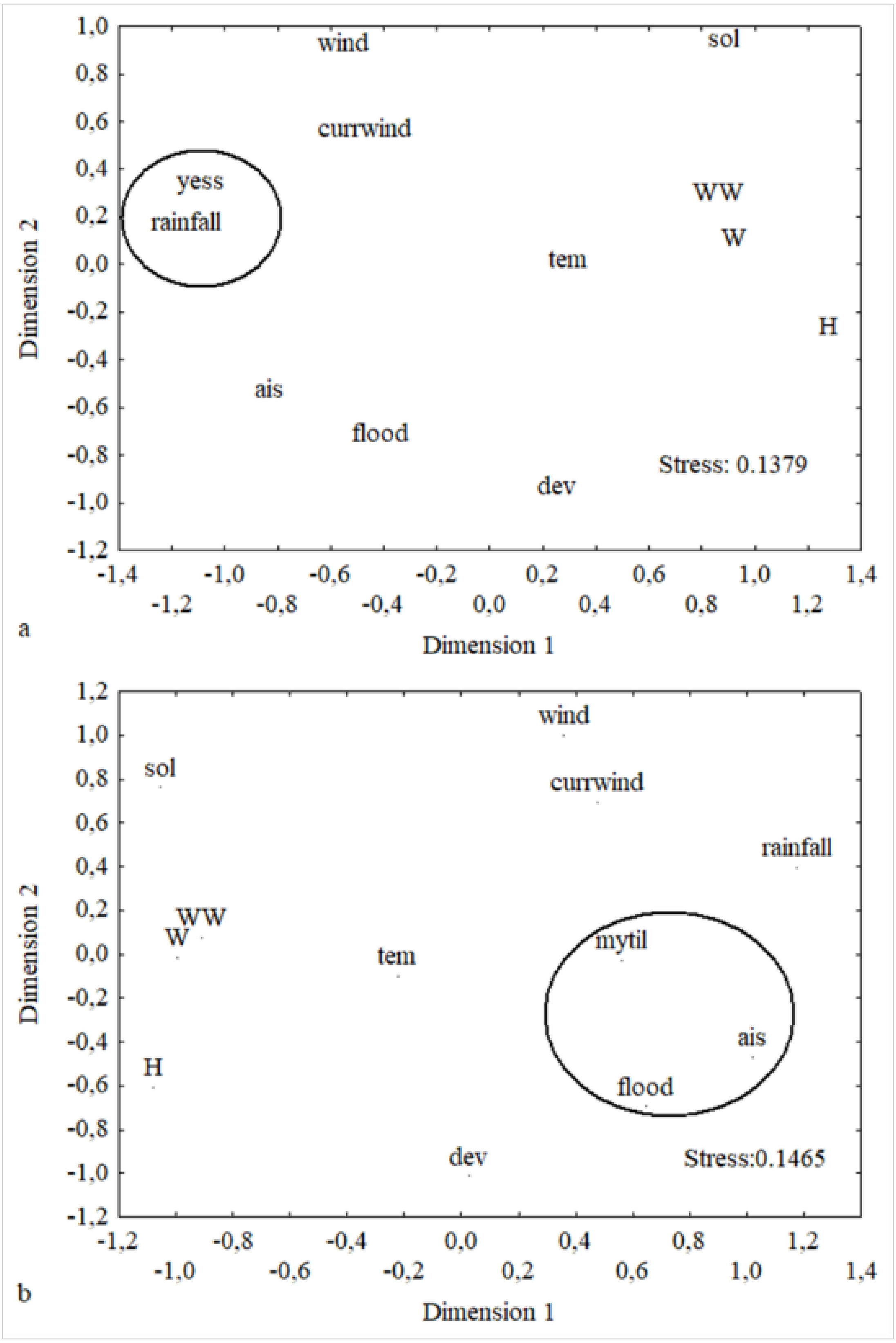
Table 2 Pearson correlation coefficient between abundance larvae of Japanese scallop, Pacific mussel and water temperature on three horizons in Minonosok Bay. The bold print emphasise significant correlation parameter

Water temp. °C	**1987**		**1988**		**1989**		**1990**	
	scallop	**mussel**	**scallop**	**mussel**	**scallop**	**mussel**	**scallop**	**mussel**
0 м	-0.17	0.45	**0.71***	0.62	-0.81	0.44	-0.49	-0.17
5 м	0.02	0.06	**0.75***	0.71	**-0.90***	0.22	0.02	0.41
10 м	0.15	0.17	**0.76****	**0.81****	-0.58	-0.60	0.29	0.49

. * - $p \leq 0.05$; ** - $p < 0.03$

3.2 The population dynamic and climatic factors

The comparison between the juvenile *P. yessoensis* population dynamic and the climatic factors showed that the most important factor of its successful production was the rainfall abundance in June (Figure 3a).


a
Dimension 1
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WW
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Stress: 0.1379
b
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rainfall
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Stress:0.1465

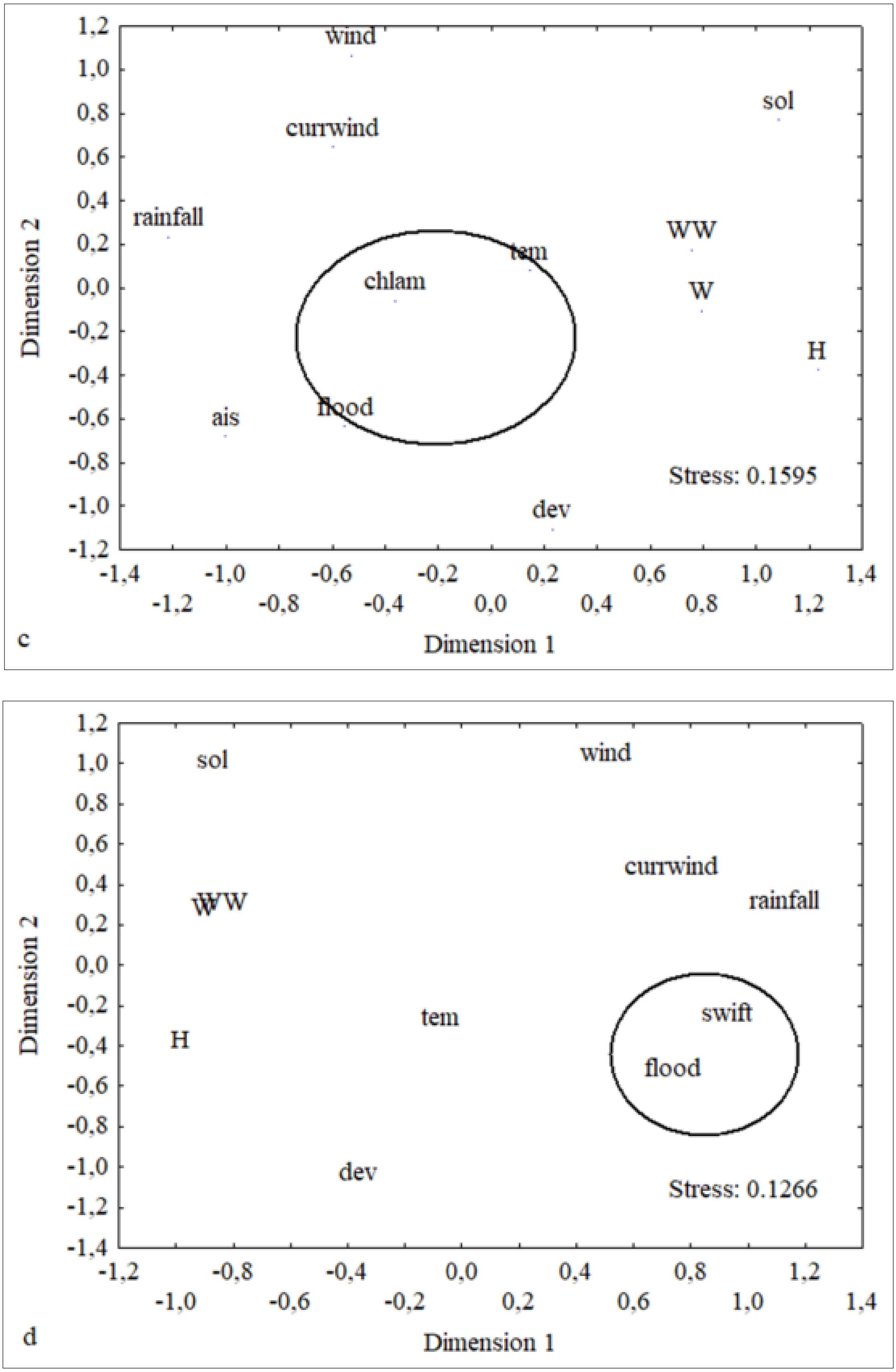


Figure 3 None-metric multidimensional scalling (nMDS) relationships dynamics number of molluscs with climatic factors. a – P. yessoensis, b – M. yessoensis, c – Ch. farreri, d – S. swiftii

But at *M. trossulus* it was the high tide in June and the duration of ice in previous year (Figure 3b), at *Ch. farreri* it was the high tide at the water temperature in June (Figure 3c), and at *S. swiftii* it was the high tide in June (Figure 3d). Probably the different tolerance of the larvae to the climatic factors leads to the differences in spatial distribution of these species, but all of them more or less were the subjects of solar activity (Figure 4).

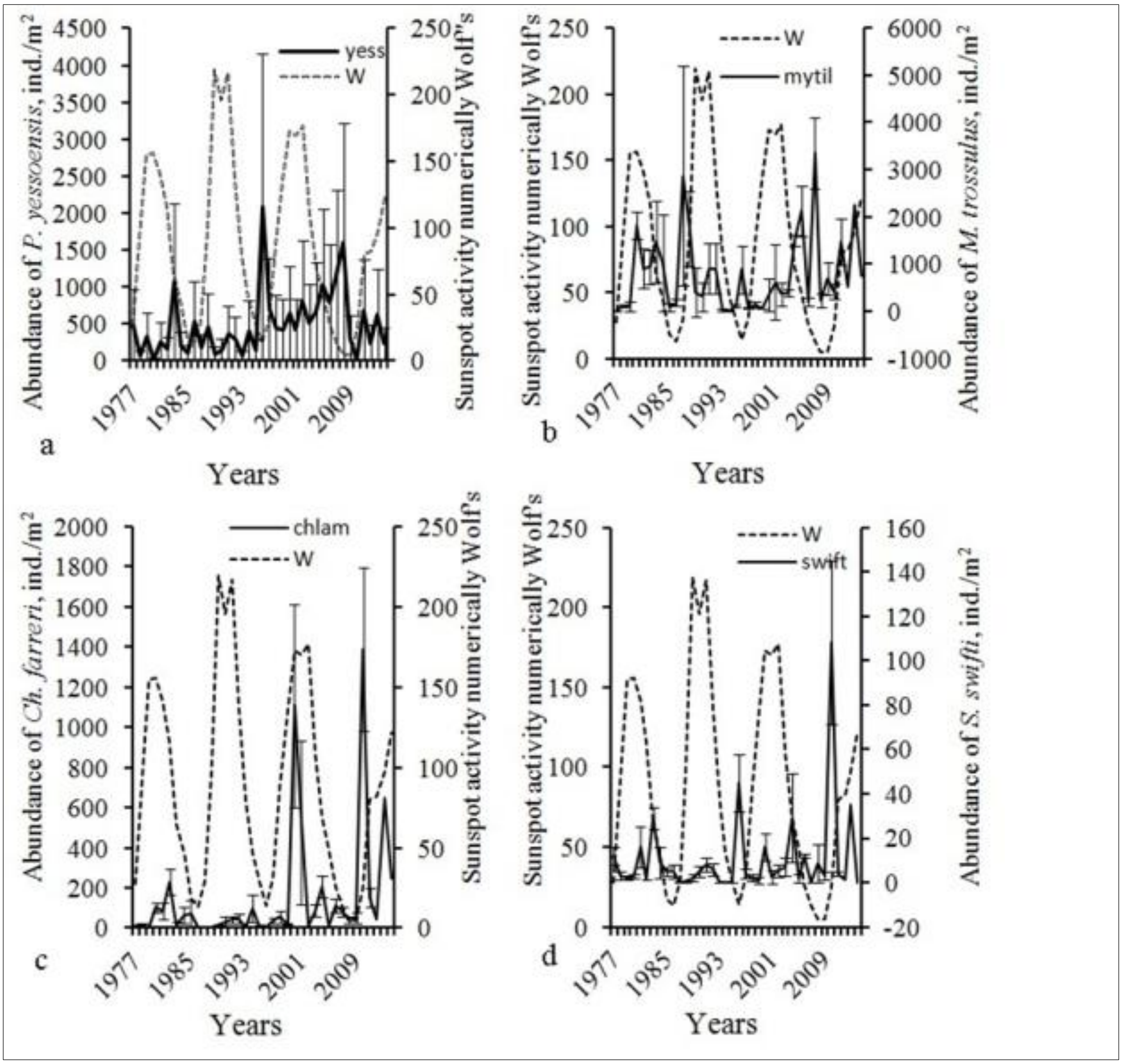


Figure 4 Dependence dynamics of number of the molluscs with dynamics of solar activity in Volf's numbers. a – *P. yessoensis*, b – *M. yessoensis*, c – *Ch. farreri*, d – *S. swiftii*.

negative influence on temperature and it variability (Figure 5).

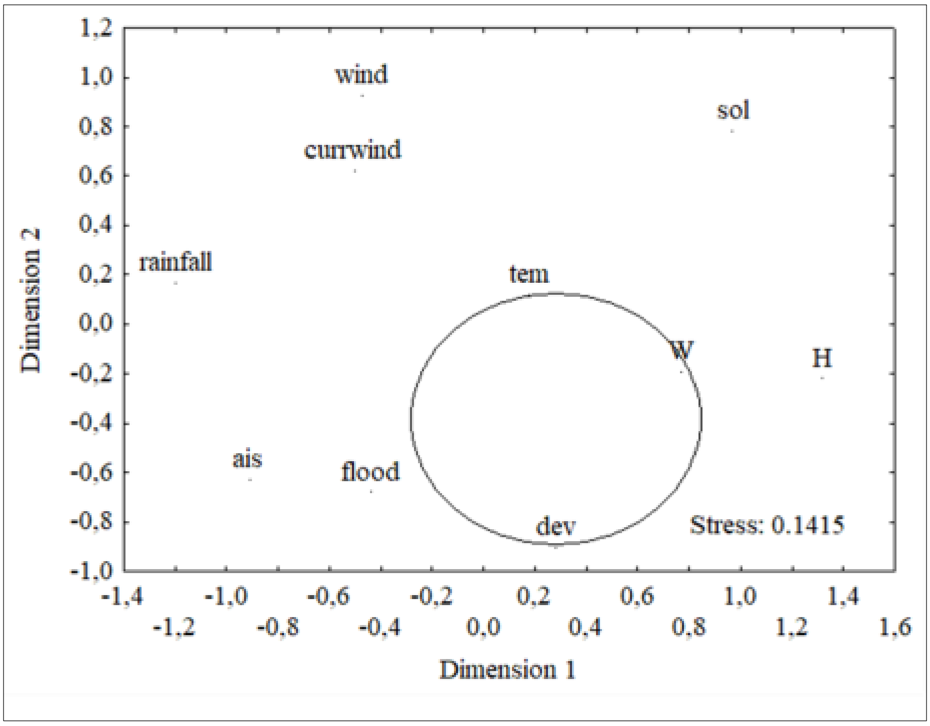


Figure 5 Dependence of climatic factors with dynamics of solar activity in Volf's numbers

3.3 Horizontal distribution

3.3.1 The distribution of P. yessoensis

In 1978 the most favorable conditions for the *P. yessoensis* reproduction were developed in the Northern part of Reid Pallada Bay (st. 4 and 6) (359,2 and 139,6 ind./m^2 respectively), and in 1979 the leader was the more cold water area (st. 10; 3 and 5) (356,7; 321,1 and 319,8 ind./m^2 respectively). In 1980 the st. 10 was in the leader position and the st. 11 joined to it (196,5 and 77,7 ind./m^2 respectively), and in 1981 the favorable conditions for the reproduction again have happened in Northern part of Reid Pallada Bay (st. 3 and 1)(184,7 and 179,9 ind./m^2 respectively). Unusual climatic factors of 1982 were led to the big juveniles appeared in warm water area (st. 1 and 8)(158,5 and 124,4 ind./m^2 respectively), and in 1985 in s Bay (st. 1)(76,2 ind./m^2). The juvenile abundance increase in collectors was noticed at the open sea water area in 1988-1990. The maximum abundance was in semi open bay in 1988 (st. 2) and at st. 8 (954,5 and 698,3 ind./m^2 respectively), in 1989 the northern and western parts of Reid Pallada Bay were the leaders in this species reproduction (st. 2, 11 and 4)(481,3; 400,0 and 397,4 ind./m^2 respectively), and in 1990 the maximum abundance appeared at the st.3 (285, 5 ind./m^2) (Figure 6a).

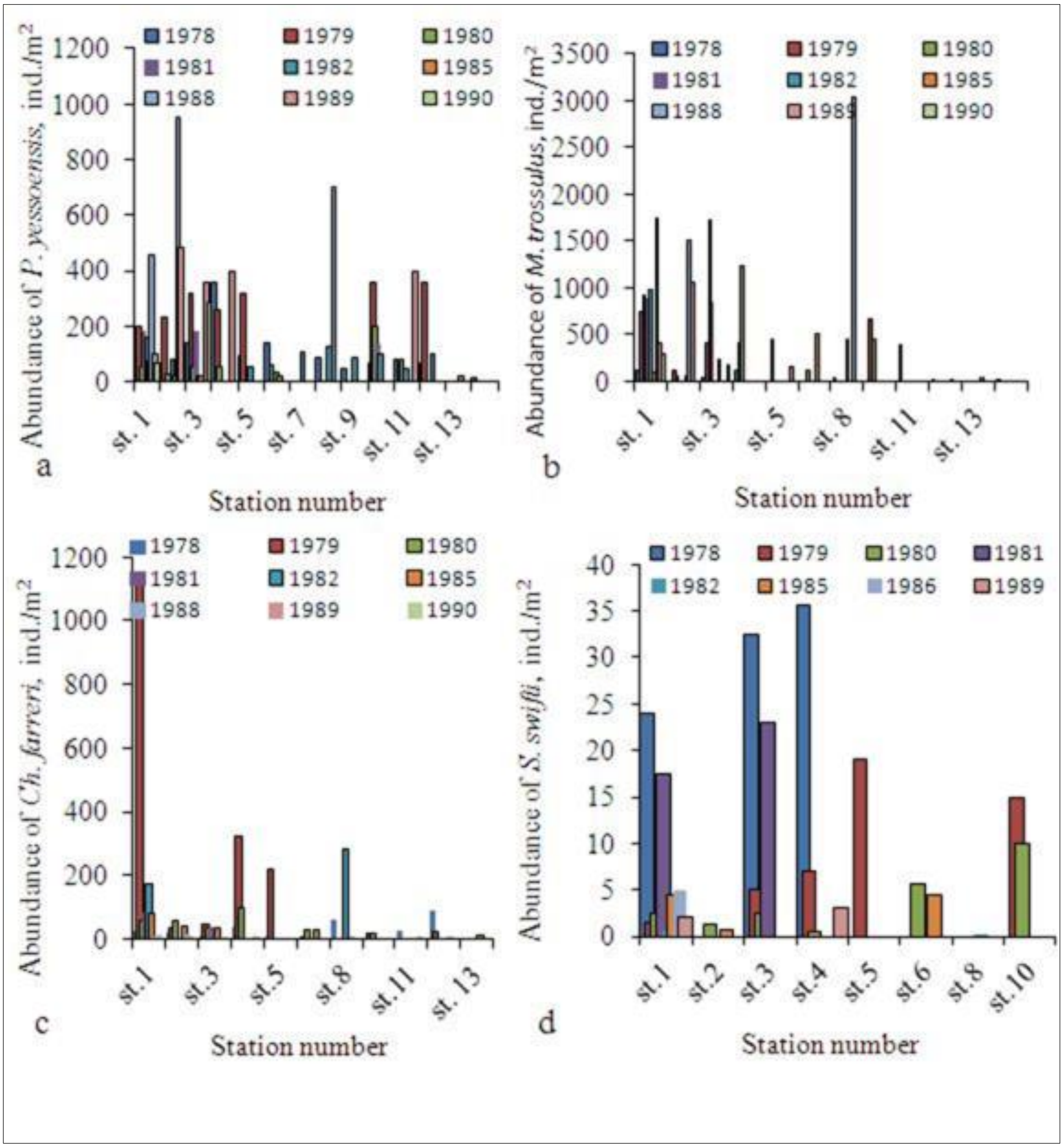
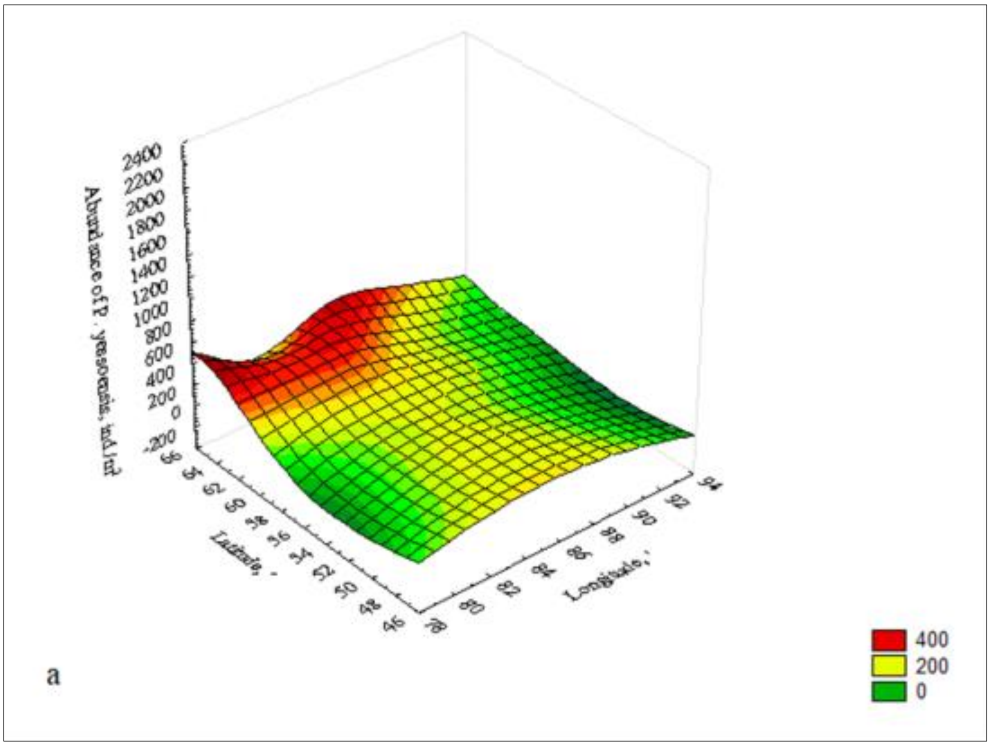
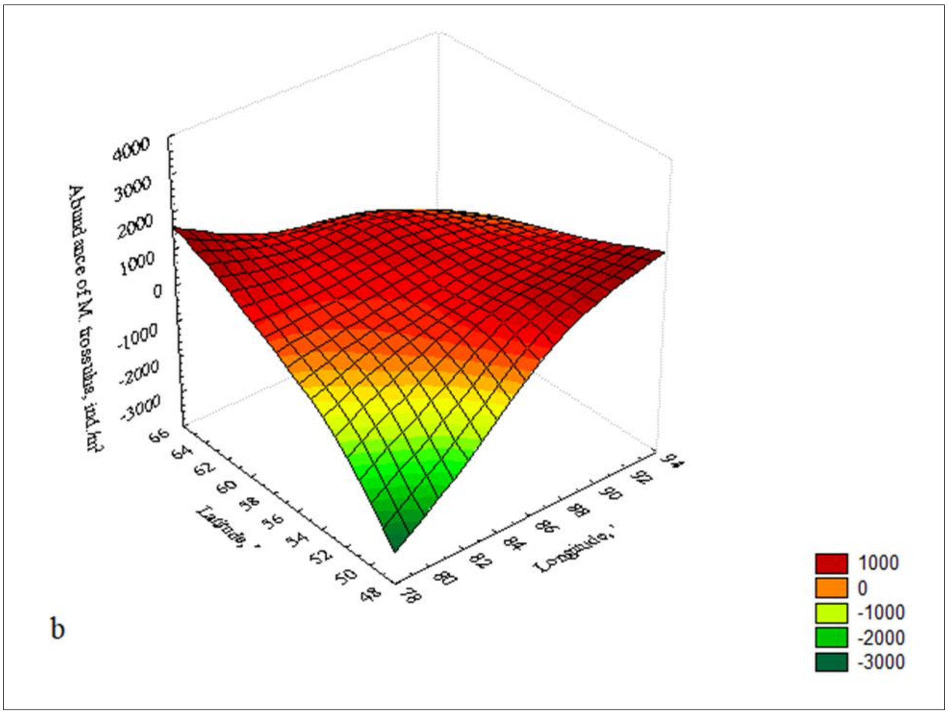
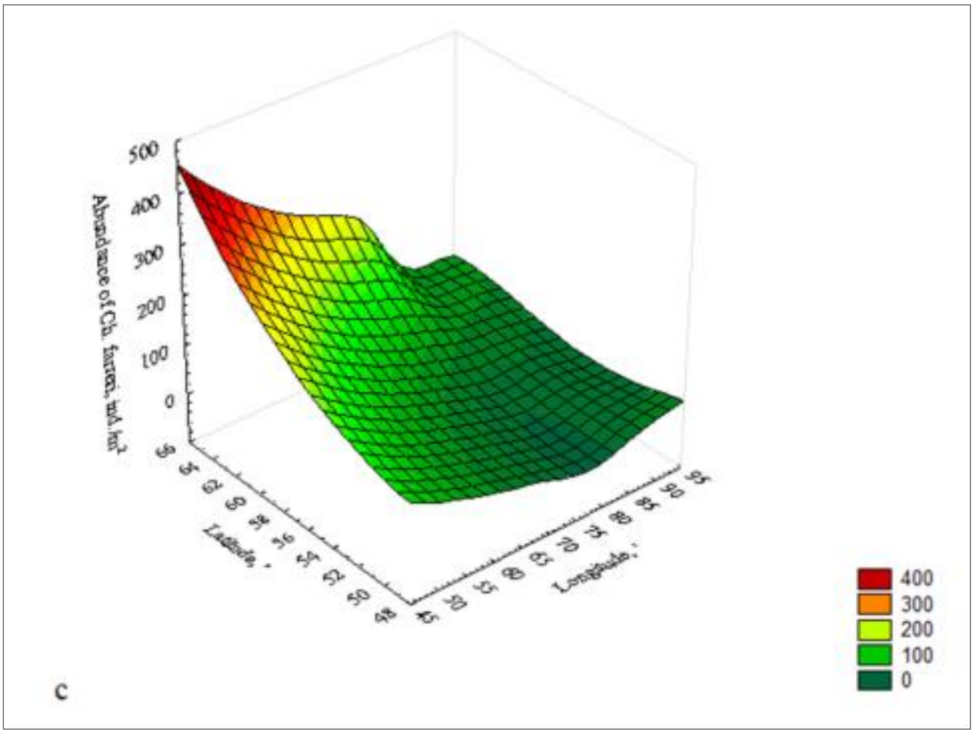


Figure 6 Distribution of molluscs at the stations. a – a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

In general, the available materials allow us to make the conclusion that the most favorable conditions for the reproduction of *P. yessoensis* happen at the Bay's north near the capes opened to the prevailing south-eastern wind (Figure 1, Figure 7a), and general pattern of the horizontal.


Abundance of P. yessoensis, ind./m²
Latitude, °
Longitude, °
400
200
0
a


Abundance of M. trossulus, ind./m²
Latitude, °
Longitude, °
1000
0
-1000
-2000
-3000
b



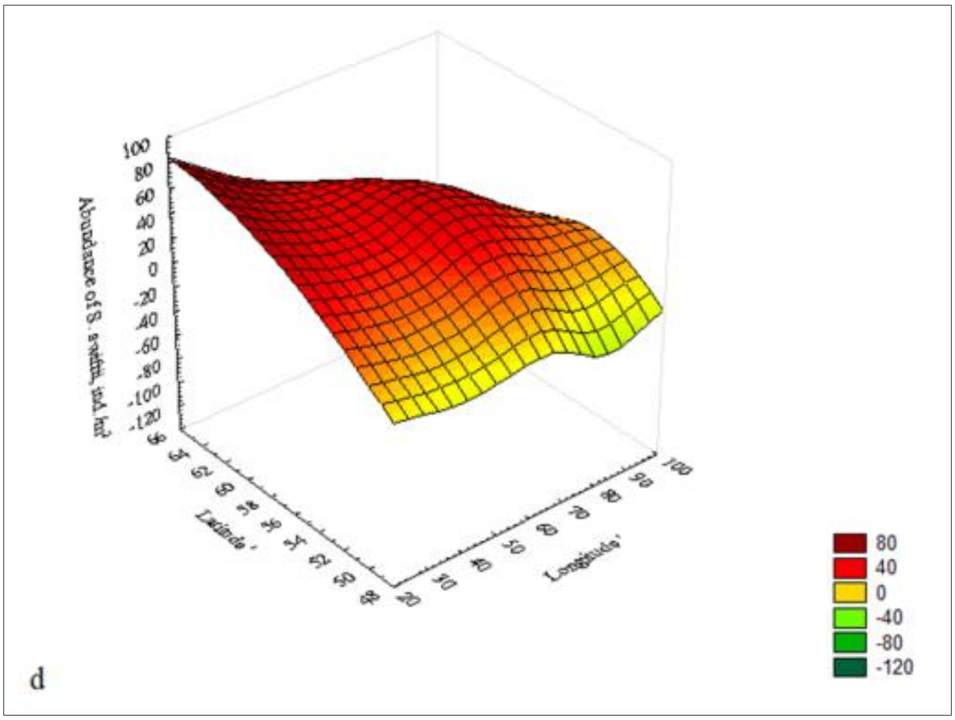


Figure 7 Dependence of spatial distribution of investigated juveniles from the longitude and latitude of stations. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

distribution turned out the reproduction conditions synchronicity at all the researched stations (Figure 8a).

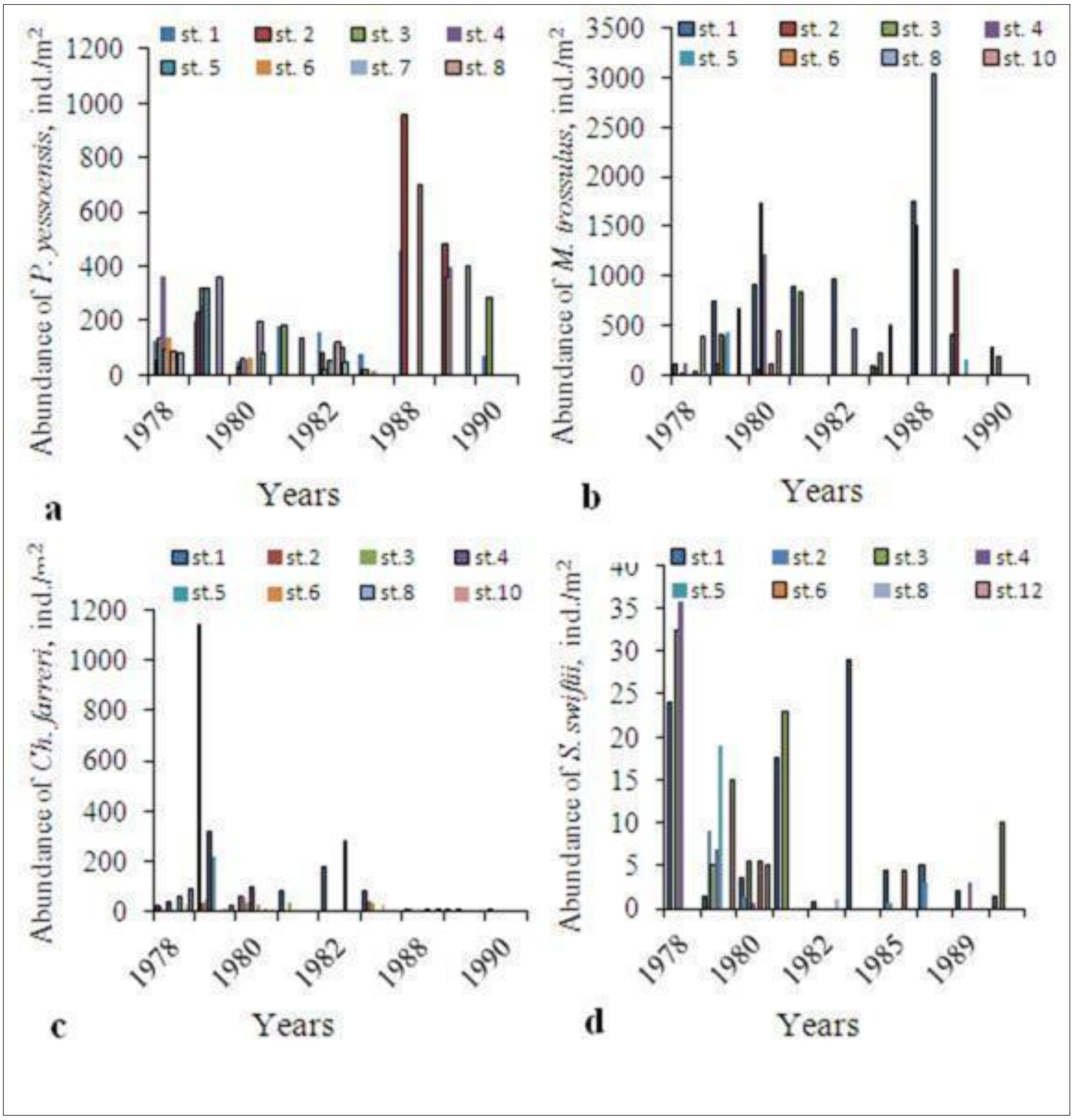


Figure 8 Abundance juveniles of the molluscs in years of the supervisions. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

3.3.2 The distribution of M. trossulus

In 1978 the biggest abundance of juvenile *M. trossulus* was found at the collectors exposed at st. 11 (390,0 ind./m^2). Next year the most fruitful water areas were semi closed bays (st. 1 and 10) (750,1 and 665,7 ind./m^2 respectively), and in 1980 at the capes opened to the prevailing winds (st. 3 and 4) (1729,1 and 1226,5 ind./m^2 respectively). But in 1981 and 1982 there was a recovery of the most favorable conditions for its production in semi-closed bay (st. 1) (891,8 and 968,3 ind./m^2 respectively), and the station 3 in 1981 has confirmed its value – 840,1 ind./m^2. In 1985 the most favorable conditions for the reproduction of *M. trossulus* were in adjacent open water area bays (st. 6 and 3)(510,1 and 229,3 ind./m^2 respectively). In 1988 the biggest abundance was in bays (st. 8; 1 and 2)(3031,2; 1743,4 and 1500,6 ind./m^2 respectively), and next year the obvious leader was st. 2 – 1062,1 ind./m^2. In non harvest 1990 the maximum abundance of *M. trossulus* was at st. 1 – 287,0 ind./m^2 (Figure 6b). Unlike *P. yessoensis* the favorable conditions for reproduction at *M. trossulus* happens at wide water areas with north-west and south-east stations prevailing and local abundance decrease was noticed at stations situated in the south-west (Figure 7b). These two species in 1988 were very fruitful for juvenile and also as at *P. yessoensis* it was visible the synchronization of reproduction conditions at this water area (Figure 8b).

3.3.3 The distribution of Ch. farreri

In 1978 the most favorable water area for the *Ch. farreri* reproduction was the most southern cape (st. 12) and warm water st. 8 – 86,0 and 57,8 ind./m^2 respectively. In fruitful 1979 the maximum abundance was noticed at st. 1 and 4 - (1142,8 and 320,4 ind./m^2 respectively). In 1980 the production conditions were favorable at st. 2 and 4 (59,3 and 94,8 ind./m^2 relatively), in 1981 the leader became st. 1 (84,0 ind./m^2), and in 1982 – st. 8 (283,2 ind./m^2). In 1985 the leader again became the st. 1 (81,7 ind./m^2), in 1988 the neighboring st. 2 (13,1 ind./m^2) became a leader, and in 1989 and 1990 the st. 1 (10,0 and 11,0 ind./m^2) restored leading positions (Figure 6c). In general, the most favorable area of *Ch. farreri* reproduction was found at warm water north-west of the researched water area (Figure 7c). The biggest abundance observed in 1979 and as in the previous two species general pattern of the horizontal distribution turned out the reproduction conditions synchronicity at all the researched stations in Bay. (Figure 8c).

3.3.4 The distribution of S. swiftii

In 1978 the biggest juvenile abundance at *S. swiftii* was at st. 4 and st. 3 (35,7 and 32,1 ind./m^2 respectively). As it was at *P. yessoensis* the maximum abundance in 1979 appeared at st. 5 and 10 (19,1 and 15,3 ind./m^2 respectively), and in 1980 – at st. 10, but in comparison with *P. yessoensis* and at st. 6 (10,0 and 5,6 ind./m^2 respectively). In 1981 the st. 3 was reproduction leader (22,9 ind./m^2), and in 1982, 1985 and 1988 the st. 1 became the most fruitful (0,7; 4,5 and 5,0 ind./m^2 respectively). In 1989 the biggest abundance of these molluscs was at st. 4-3 ind./m^2 and in 1990 at st.3 – 10 ind./m^2 (Figure 6d). The horizontal distribution at *S. swiftii* is rather similar to *Ch. farreri*, however the favorable reproduction conditions at *S. swiftii* were indicated at wider water area, moreover the obvious reproduction superiority was found at the north of Posyet Bay (Figure 7d). By the experiment termination in the open water area it turned out that the first research year (1978) was the best for its reproduction capacity and as at previous three species general pattern of the horizontal distribution turned out the reproduction conditions synchronicity at all the researched stations in Bay (Figure 8d).

3.4 The vertical distribution

3.4.1 Different time of collectors setting

P. yessoensis

In 1988 at three horizons (7,5; 9,8 and 12 m) the biggest juvenile *P. yessoensis* abundance was on the collectors set in the sea 12th of June with the water surface temperature of 13.5° C (Figure 9a).

But in 1989 on the collectors set on 12th of June the maximal juvenile population was only on upper collector (15,2°C), at a depth of 9,8 m the maximum abundance noted on the collector set on the 23rd of June and at a depth of 12 m set on the 16th of June (Figure 9c). In 1990 the biggest abundance of *P. yessoensis* at the depth of 7,5 m was observed in case of collectors set on 19th of June (14,0°C), and at the depth of 9,8 and 12 m set on the 14th of June 14 (12,4°C) (Figure 9e). In 1995 the biggest abundance of plankton *P. yessoensis* larvae observed on the 13th of June (400,2 ind./m^3)(15,1 ºC), but the maximal juvenile abundance met on the collectors set on the 15th of June with the water surface temperature of 15,6°C.

M. trossulus

In 1988 the maximum *M. trossulus* juvenile abundance at three horizons (7,5; 9,8 and 12m) was observed at the collectors set in the sea by the 1st of June with the water surface temperature of 11,3ºC (Figure 9b). In 1990 the maximum abundance at the upper horizon (7,5 m) was observed on the collectors exposed on the 14th of June (12,4°C). At the average horizon (9,8 m) set on the 13th of June (17,7°C) and at the lower ones (12 m) set on the 2nd of June (18,6°C) (Figure 9f).

Ch. farreri

The most favorable time for juvenile *Ch. farreri* scallop harvesting in 1989 was the 9th of June. Its maximum abundance was at three horizons (Figure 9d). The water surface temperature was 15,3° C. But in 1990 the biggest quantity of juvenile was at the collectors exposed on the 19th of June (Figure 9g). The water surface temperature was 14,0° C.

S. swiftii

In 1988 the *S. swiftii* juvenile was met only at the upper collectors (7,5 m) and the most optimal time for their dive was the 12th of June with the water surface temperature of 13,5°C. In 1989 at the collectors a small amount of *S. swiftii* juvenile was observed. Hardly visible increase there was at the collectors exposed on the 26th of June (19,1 º C).

However, in 1990 in spite of low abundance of this species it was possible to find out that the optimal time for the collectors' exposition moved for earlier periods for the 19th of June and the horizon of the maximum abundance turned out at the depth of 10 m (Figure 9h). The water surface temperature was 14,0°C.

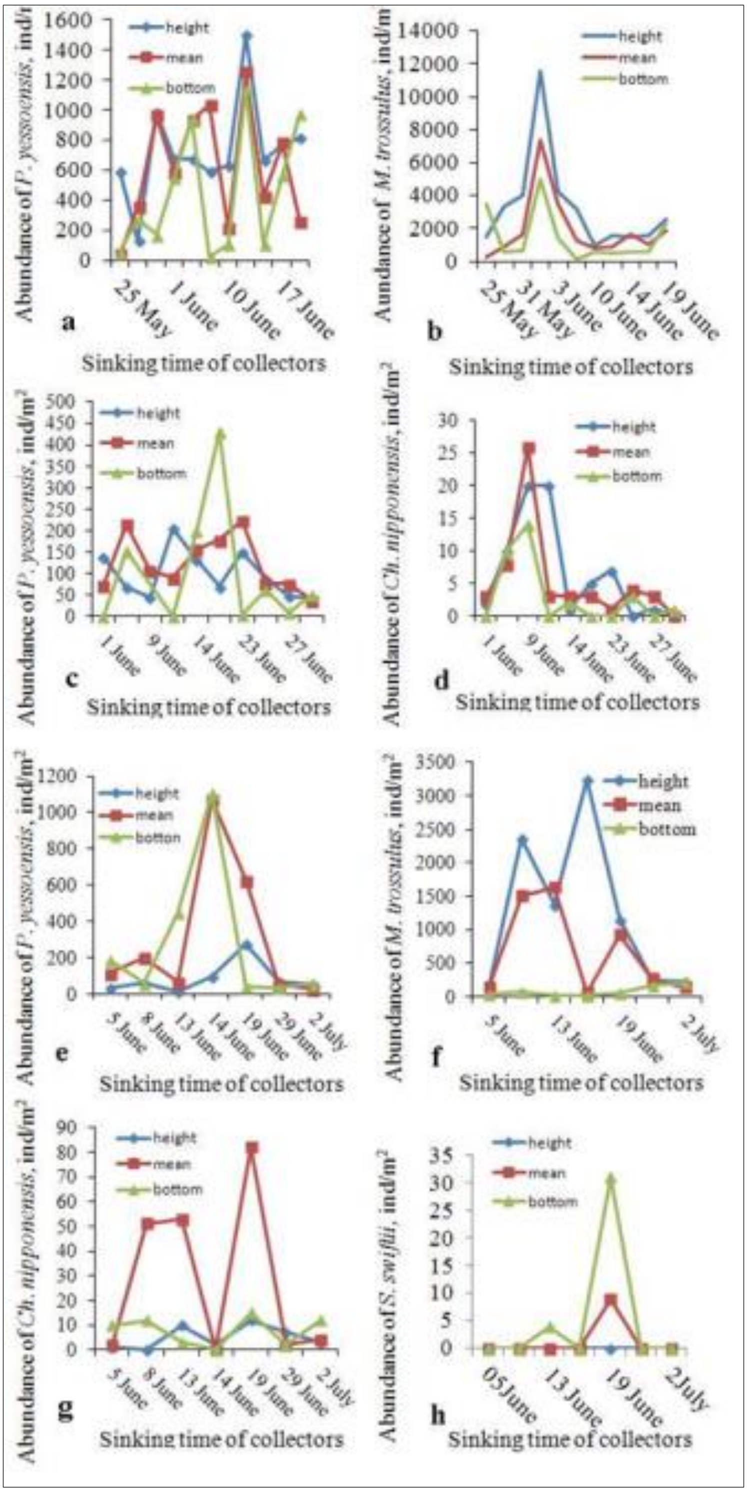


Figure 9 Abundance juveniles of the molluscs on the collectors exposed at various times. a – *P. yessoensis* in 1988, b - *M. trossulus* in 1988, c - *P. yessoensis* in 1989, d - *Ch. farreri* in 1989, e - *P. yessoensis* in 1990, f - *M. trossulus* in 1990, g - *Ch. farreri* in 1990, h - *S. swiftii* in 1990

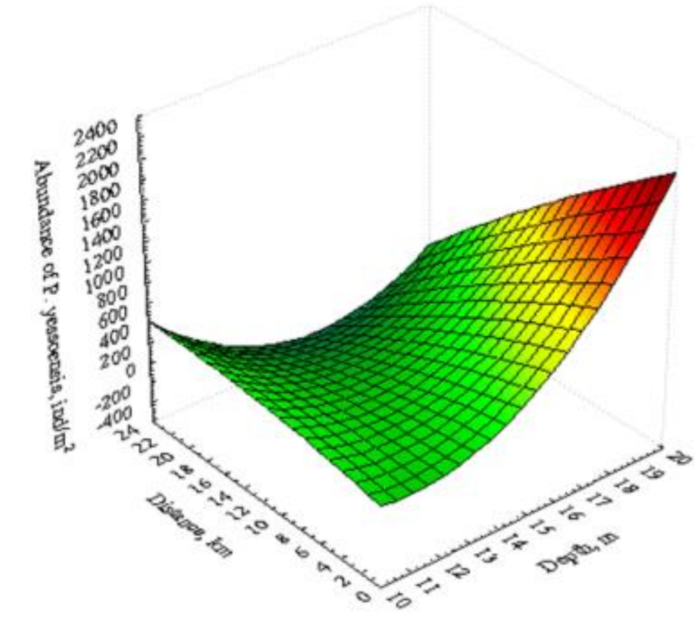
3.4.2 The depth

P. yessoensis

Table 3 Characteristics stations with maximum abundance of investigate species

Species	Years	Station, №	Distance, km	Depth, m	Abundance, ind/m²
P. yessoensis	1978	4	3	11.5	857.1
	1979	5	11	6	815.3
	--«»--	12	17	14	808.0
	1980	3	8,3	11.5	212.4
	1982	7	8,4	12	444.7
	--«»--	12	17	10.5	419.4
	1985	1	7	9.8	116.4
	1990	1	7	9.8	312.5
M. trossulus	1978	11	7,4	3	442.3
	1979	1	7	7.5	5764.2
	--«»--	3	8,3	3	2170.5
	1980	3	8,3	6	3611.0
	1981	1	7	7.5	2083.2
	1982	8	1	6	1458.7
	1983	1	7	7.5	3562.0
	1985	3	8.3	7	759.3
Ch. farreri	1978	8	1	6.5	178.0
	1979	1	7	7.5	2532.4
	--«»--	4	3,2	6.5	11252.2
	1980	4	3,2	9.0	208.6
	--«»--	1	7	7.5	127.1
	1981	1	7	12	180.6
	1982	8	1	8.5	625.0
	1983	1	7	7.5	32.1
	1984	1	7	9.8	182.7
	1985	1	7	9.8	180.1
S. swiftii	1978	3	8,3	12.5	53.1
	--«»--	4	3,2	10.5	35.7
	1979	5	11,9	6.5	46.1
	--«»--	12	17	14.5	46.1
	1980	3	8,3	11.5	18.1
	--«»--	6	12	10.0	17.0
	1981	1	7	9.8	36.0

	1983	1	7	12	58.5
	1985	13	13	22.5	55.6
	1988	1	7	7.5	5.0
	1989	4	3	12	8.3



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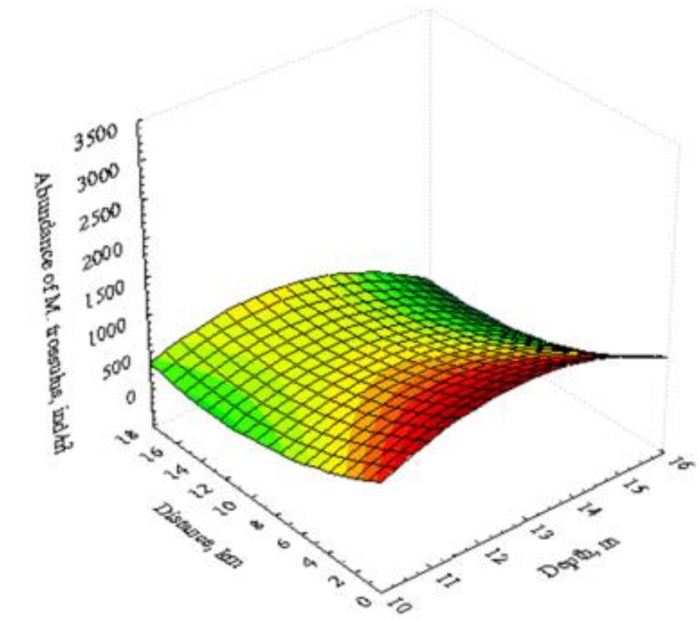

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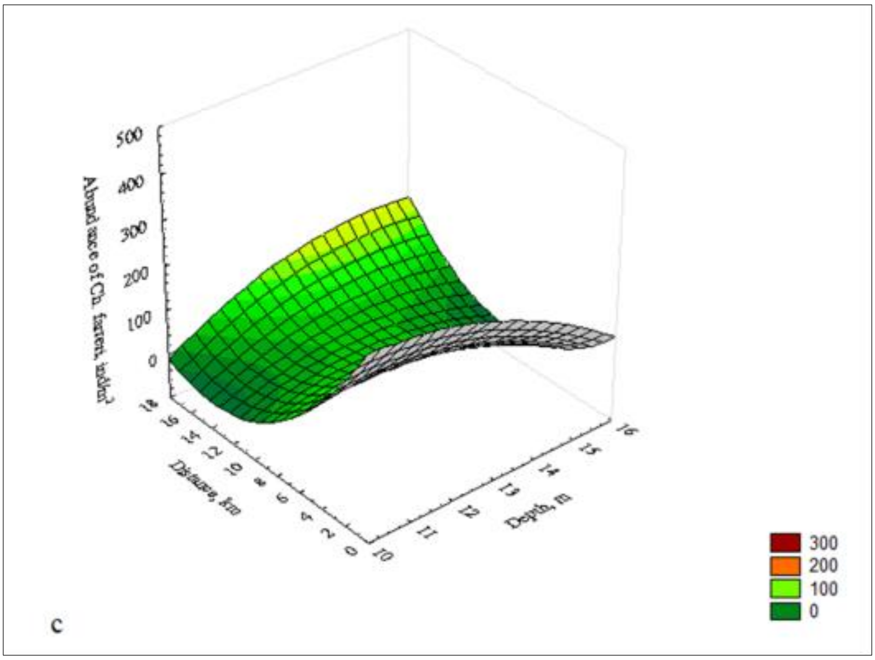


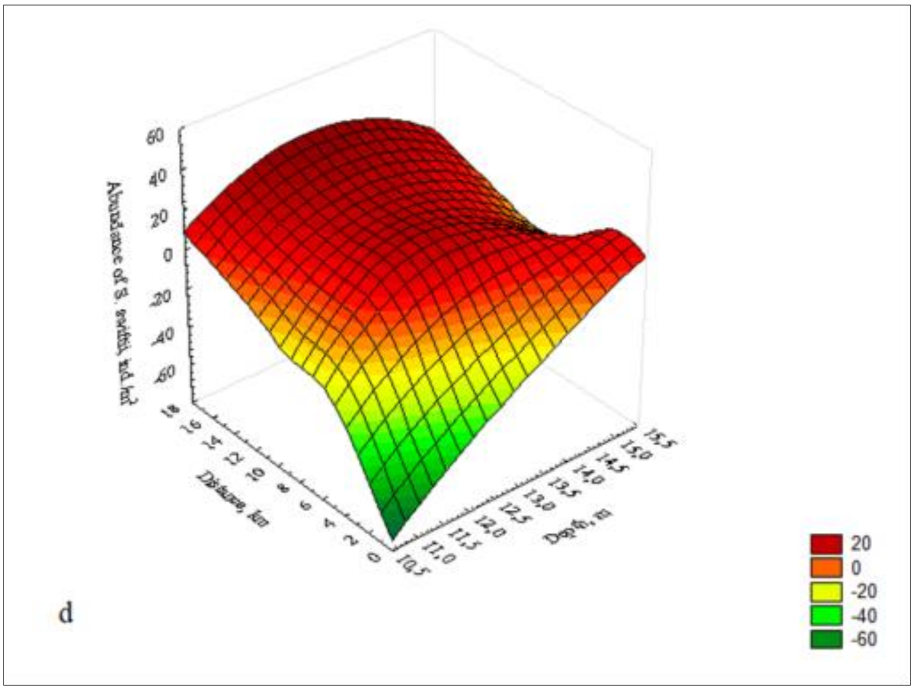


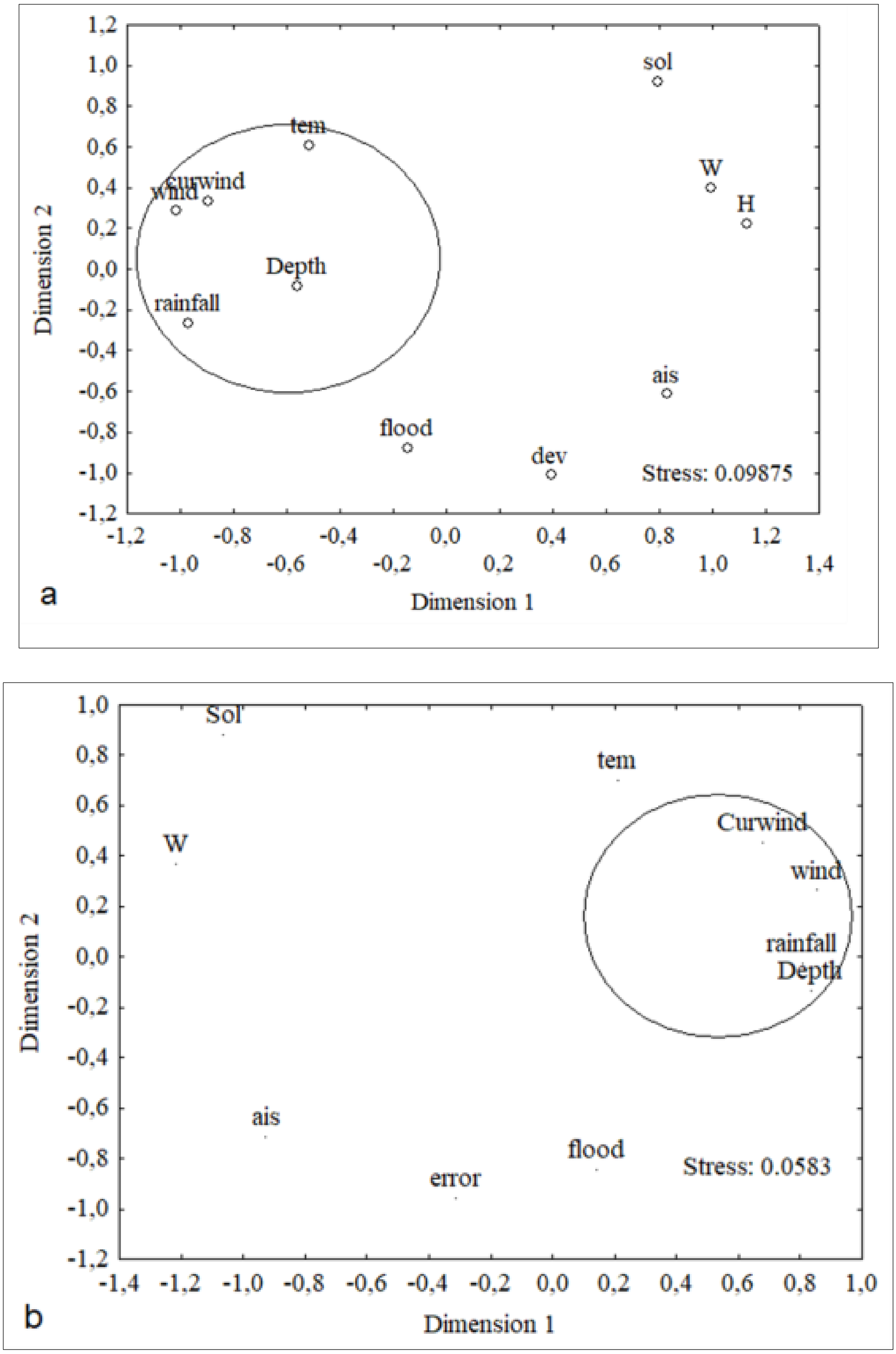
Figure 10 Dependence of spatial distribution of investigated juveniles from depth of water area and removal from warm-water station 14. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

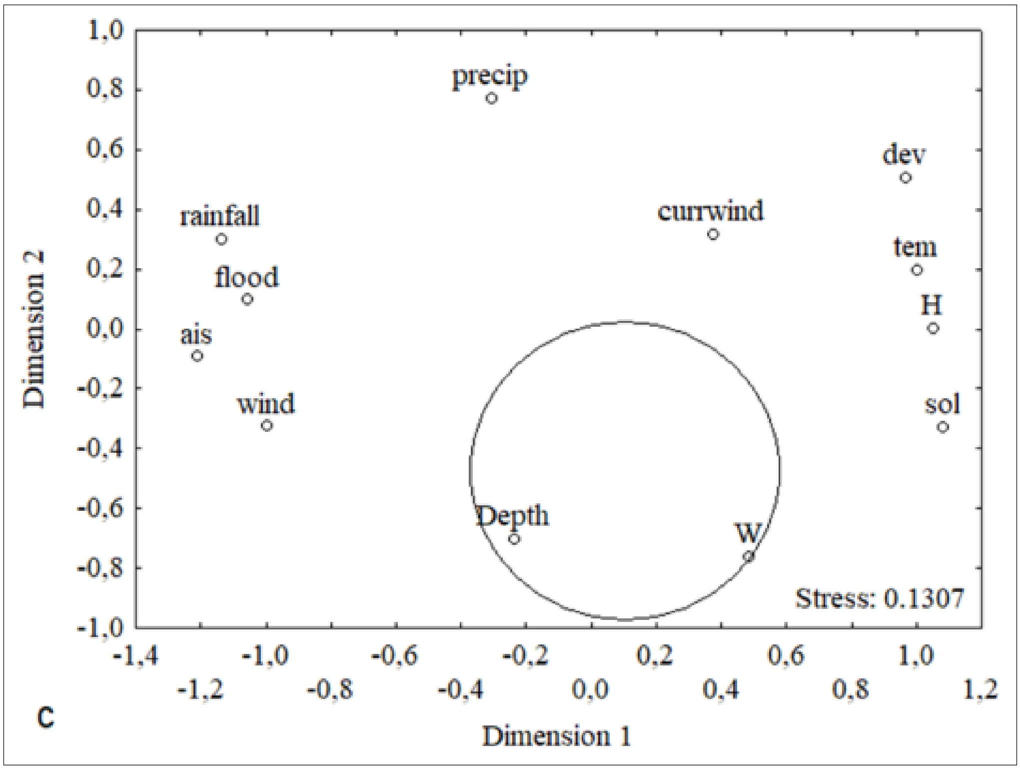
In 1978 the biggest abundance of *P. yessoensis* juveniles was observed at st. 4 at the depth of 11,5 m and distant from the warm water st. 14 at 3 km (857,1 ind./m^2). In 1979 the biggest abundance of this mollusc was observed at st. 5 at the depth of 6 m and at the distance of 11 km from the st. 14 (815,3 ind./m^2) and less abundance (808,0 ind./m^2) turned out at the st. 12 at the depth of 14 m, which is distant from the 14th station at 17 km. In 1980 the biggest abundance of *P. yessoensis* juvenile was found at st. 3 at the depth of 11,5 m, distant at 8,3 km from warm water st. 14 (212,4 ind./m^2). In 1982 the most abundant became the 7th station at the depth of 12 m, which was distant from 14th station at 8,4 km (444,7 ind./m^2) and a bit less abundance was observed at the same coast of Reid Pallada Bay at the 12th station at the depth of 10,5 m and distant from 14th station at 17 km (419,3 ind./m^2). In 1985 and 1990 the most favorable station for the *P. yessoensis* reproduction was st. 1 at the depth of 9,8 m and distant from st. 14 at 7 km (116,4 and 312,5 ind./m^2

respectively) (Table 3). When summarizing this material it turned out that in spatial distribution the *P. yessoensis* one abundance maximum - at the southern stations with great depths (Figure 10a).

The Person's correlation coefficient has shown little relationship between the water surface temperature and favorable for reproduction water area moving at distance from shallow water st. 14 (r = 0,392; p = 0, 296).

The depth of maximum abundance of *P. yessoensis* juveniles mainly depends on water surface temperature, wind speed and its direction and also rainfall volume in June (Figure 11a).





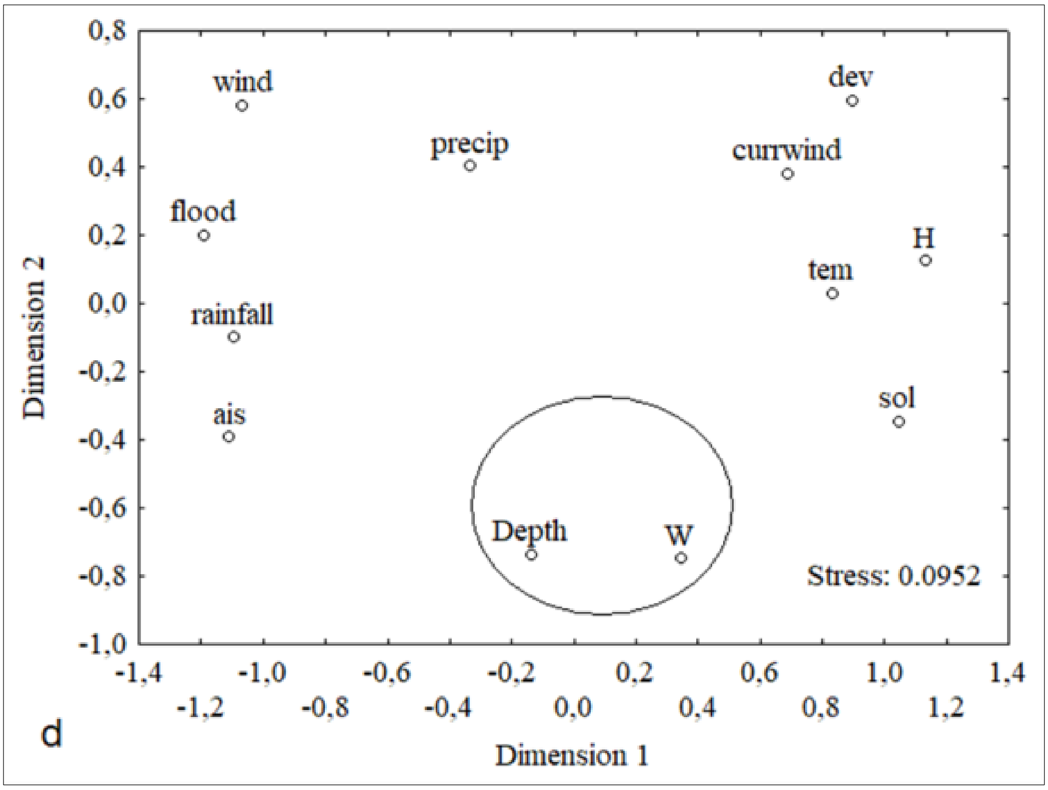
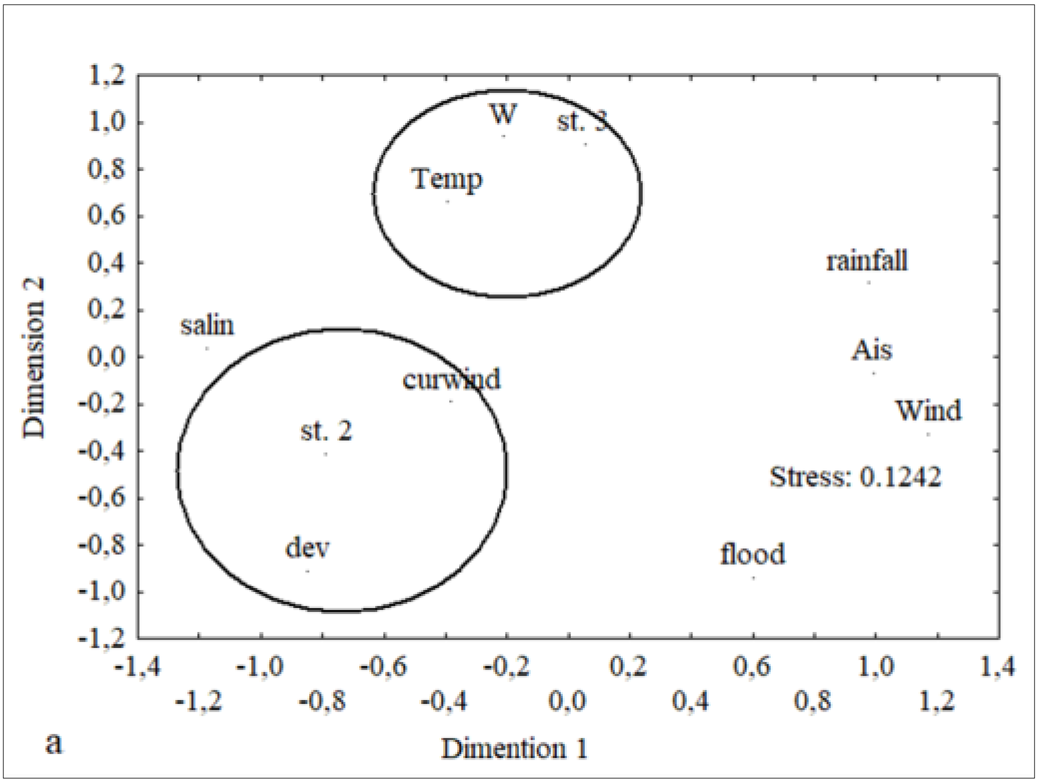
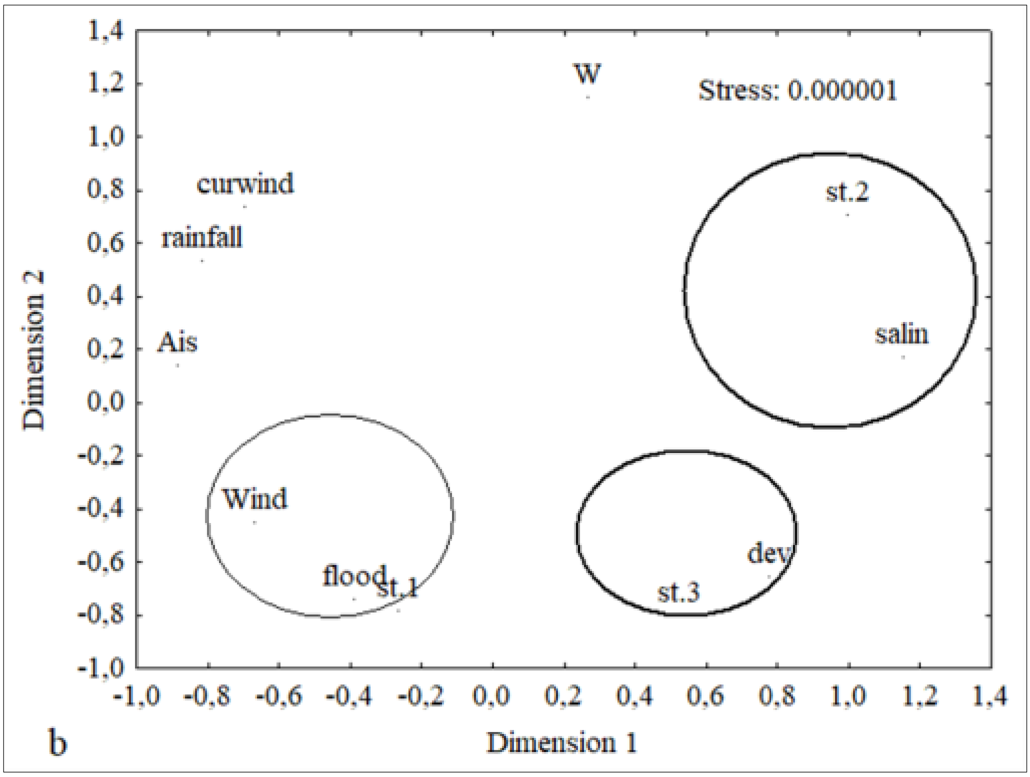
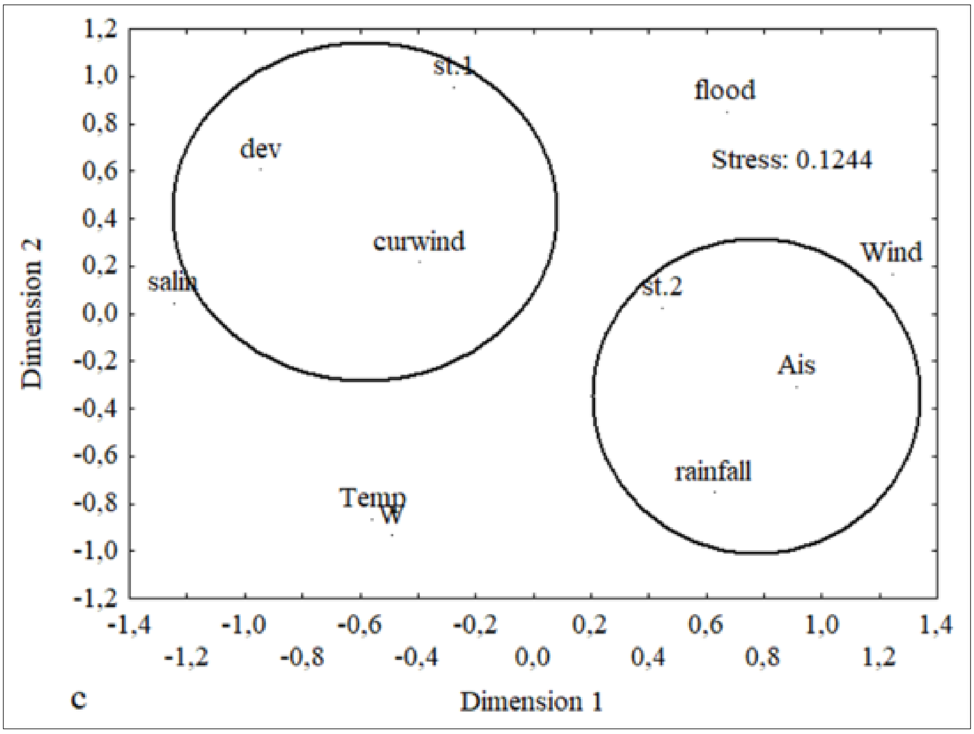


Figure 11 None-metric multidimensional scalling (nMDS) analysis interrelations of depth of the maximum abundance of the molluscs and climatic factors. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

However, there are regional differences between the stations. At the st.2 the depth of maximum abundance mainly depends on seawater surface temperature variability level and the wind direction in June, and at the st. 3 the biggest influence on larvae settling on artificial substrates besides the water surface temperature in June also made a solar activity expressed in Vulf's numbers (Figure 12a).







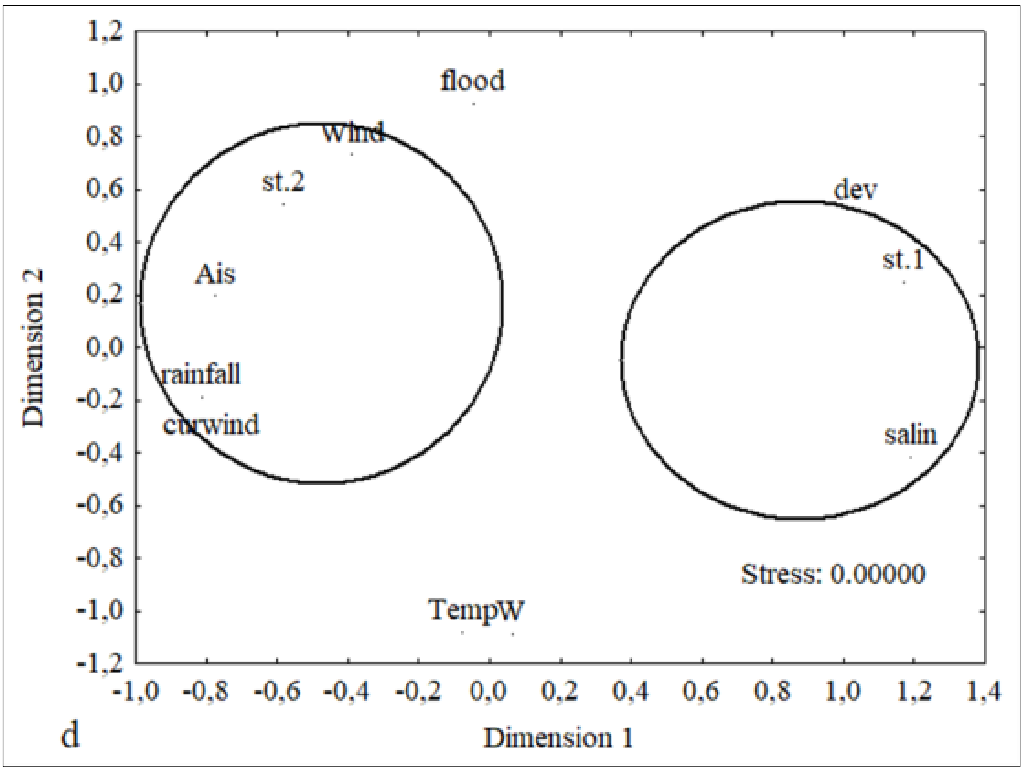


Figure 12 None-metric multidimensional scalling (nMDS) analysis interrelations of depth of the maximum abundance of the molluscs and climatic factors at the stations. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

In long-term vertical distribution of *P. yessoensis* juvenile the population peak was significantly visible at a depth of 11.0 m (579.7 ind./m^2 respectively) (Figure 13a),

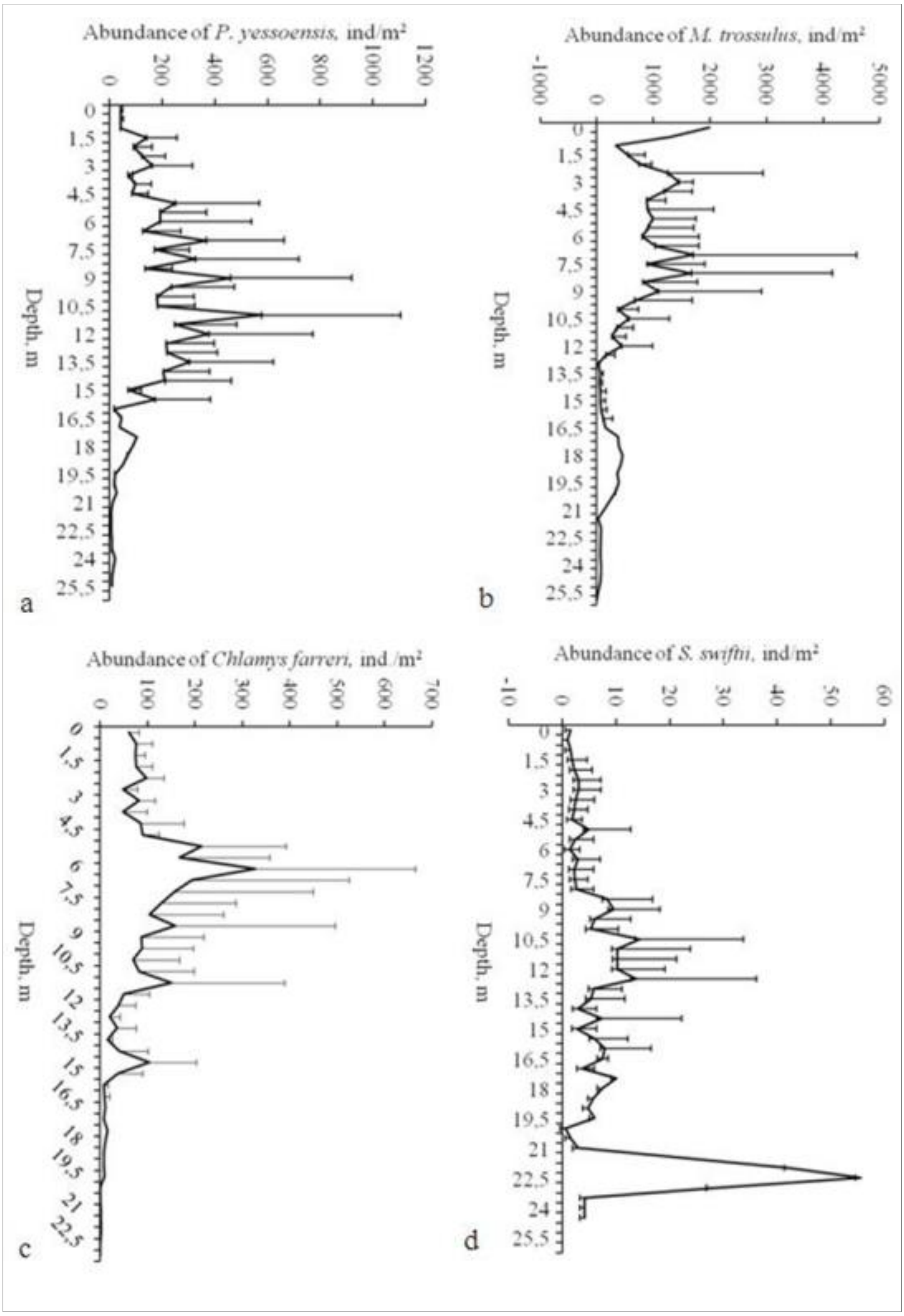


Figure 13 Plurannual vertical distribution of juveniles on the collectors. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

and the most changeable horizon was the depth of 15.5 m (Figure 14a).

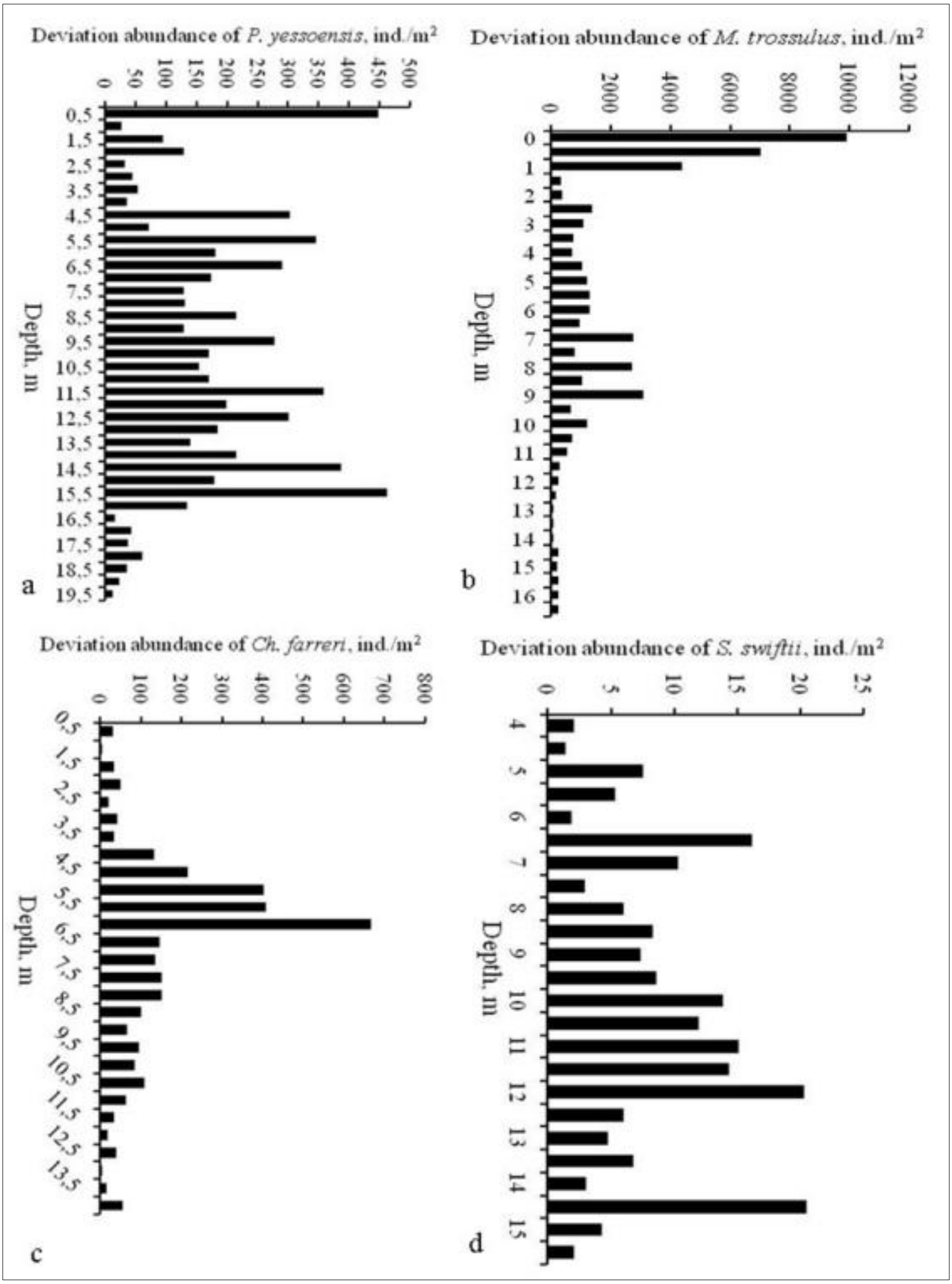


Figure 14 Variability vertical distribution of juveniles on collectors. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

In 44.7% cases from 38 observations there was noticed a positive relation between vertical distribution of *P. yessoensis* juvenile and the depth (Figure 15a).

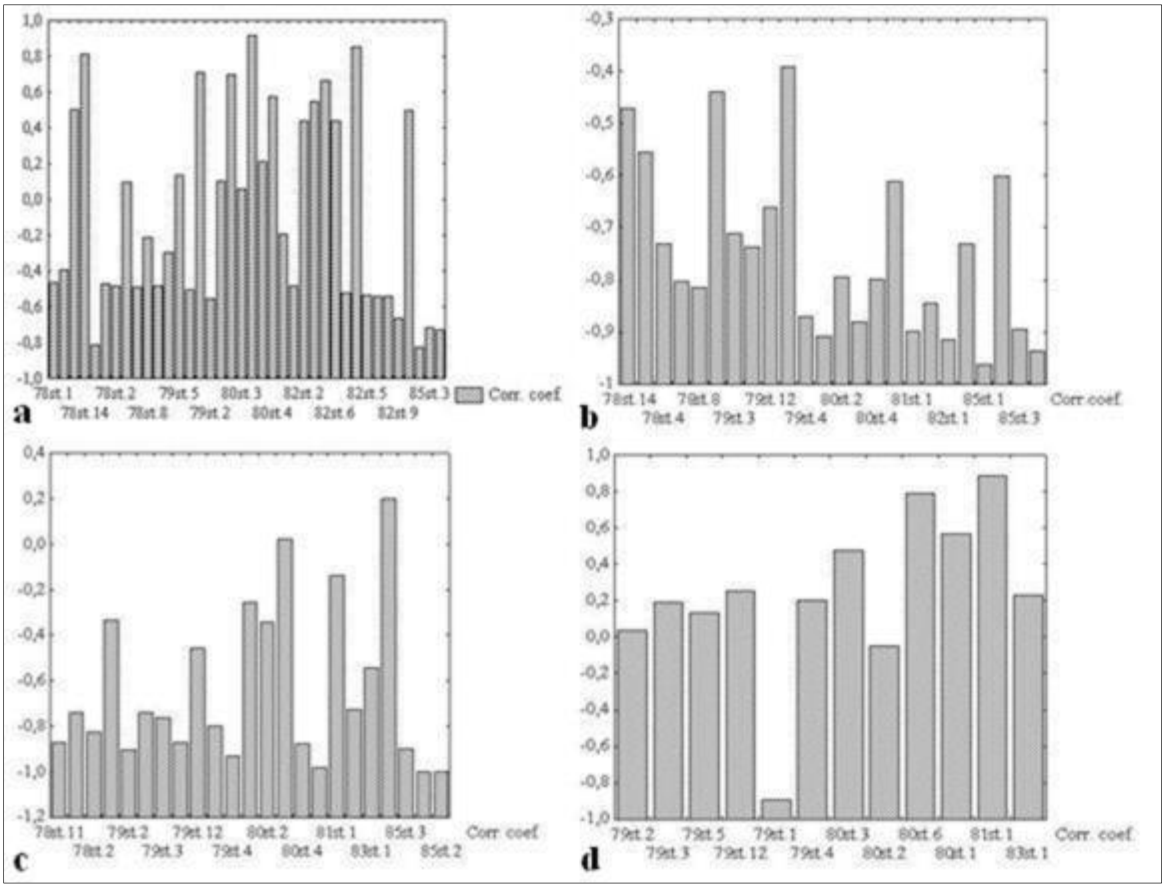
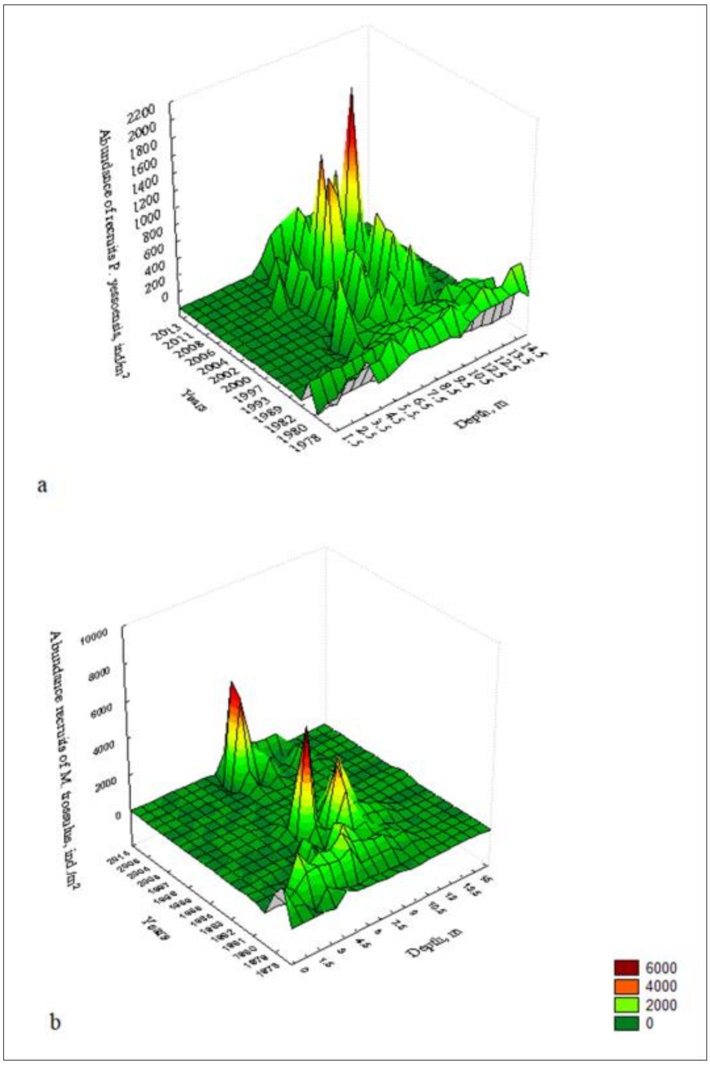


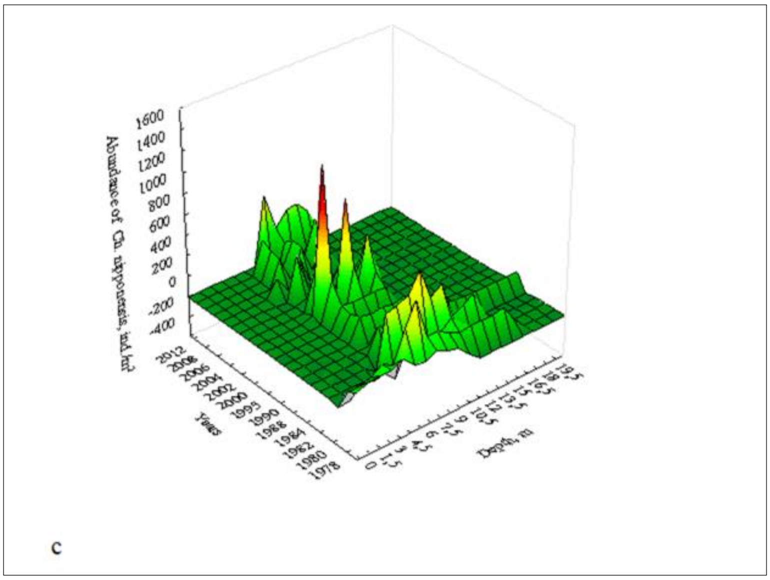
Figure 15 Coefficients correlation between depth and vertical distribution of juveniles on collectors. X-direction - year investigation and stations. Y-direction - Pearson correlation coefficients. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

Table 4 Interrelation of vertical distribution animals and deep in Posyet Bay. Bold print separate authentic interrelation

Species of mollusk	Years attendance	R	p
Patinopecten yessoensis	1978	**0.430**	**0.022**
--«--	1979	**0.657**	**0.000**
--«--	1980	0.201	0.326
	1981	-0.605	0.586
--«--	1982	-0.201	0.226
	1983	-0.517	0.654
--«--	1984	0.200	0.704
	1985	-0.620	0.574
Mytilus trossulus	1978	**-0.778**	**0.000**
--«--	1979	**-0.899**	**0.000**
--«--	1980	**-0.825**	**0.000**
--«--	1981	**-0.806**	**0.005**
--«--	1982	**-0.783**	**0.000**

--«--	1983	**-0.855**	**0.002**
--«--	1984	-0.486	0.329
Chlamys farreri	1978	**-0.680**	**0.001**
--«--	1979	**-0.615**	**0.000**
--«--	1980	**-0.324**	**0.092**
--«--	1981	**0.103**	**0.776**
--«--	1982	**-0.629**	**0.003**
Swiftopecten swiftii	1979	**0.527**	**0.001**
--«--	1980	**0.525**	**0.004**
--«--	1981	**0.888**	**0.001**
--«--	1982	0.339	0.133
--«--	1984	**0.867**	**0.012**
--«--	1985	0.163	0.315





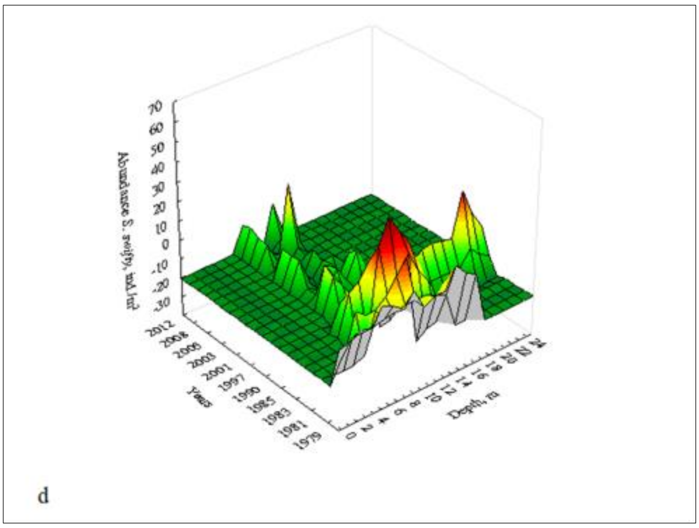


Figure 16 Dependence of vertical distribution of investigated juveniles from climatic factors of the years. a - *P. yessoensis*, b – *M. trossulus*, c – *Ch. farreri*, d – *S. swiftii*

The summing of long-term observations has shown that from eight researched years the four years were with positive correlation between the depth and vertical juvenile distribution, in addition two years the correlation was reliable (Table. 4). Generally the interannual changing of juvenile vertical distribution is being observed and maximum abundance notices on the lower horizon and in this anniversary the obvious one becomes its deepening (Figure 16a).

M. trossulus

In 1978 the biggest abundance of *M. trossulus* juveniles on scallop collectors were observed at st. 11 immersed in the depth of 3 m and stayed far from warm water st. 14 at 7,4 km (442,3 ind./m^2). In 1979 the biggest abundance was at st. 1 at the depth of 7,5 m and stayed far from st. 14 at 7 km (5764,2 ind./m^2), and also at st. 3 at the deep of 3 m and stayed far from st. 14 at 8,3 km (2170,5 ind./m^2). In fruitful for *M. trossulus* 1980 year at st. 3 again the maximum abundance was appeared - 3611,0 ind./m^2 (the depth 6 m), in 1981 the superiority in reproduction turned to the st. 1 - 2083,2 ind./m^2 (the depth 7,5 m), and in 1982 the leader became the st. 8 at the depth of 6 m and stayed far from st. 14 at 1 km (1458,7 ind./m^2). In 1983 the maximum abundance of *M. trossulus* at st. 1 was observed at the depth of 7,5 m – 3562,0 ind./m^2, and in 1985 at st. 3 at the depth of 7 m – 759,3 ind./m^2 (Table 3). Generally the biggest abundance of mussels was observed at average depths with minimal distance from warm water st. 14 (Figure 10 b).

The depth of maximum abundance of *M. trossulus* mainly depends on rainfall abundance, speed and direction of the wind in June (Figure 11 b). However, on three researched stations the regional differences were observed. Thus, at st. 1

the most important factor was the wind speed and sea level in June, at st. 2 - the water saltiness, and at st. 3 - the deviation of average temperature on the water surface in June (Figure 12 b).

The generalization showed the biggest *M. trossulus* juvenile abundance was observed at the surface and at the depth of 8 m (1997,0 and 1672,3 ind./m^2 respectively) (Figure 13b) and also the same depths were the most changeable for the juvenile collection (Figure 14b). This mollusc didn't have any positive correlation between the depth and vertical juvenile distribution

(Figure 15b) and the negative correlation was reliable as a rule (Table 4). In the long-term plan it was visible some deepening of the horizon of the maximum abundance and its increasing in recent years (Figure 16b).

Ch. farreri

In 1978 the most optimal water area for the juvenile collecting of warm-loving scallop *Ch. farreri* was st. 8, the depth 6,5 m, set far from st. 14 at 1 1 km (178,0 ind./m^2). In 1979 the best conditions for the reproduction of *Ch. farreri* were at st. 1 at the depth of 7,5 m and set far from st. 14 at 7 km and also at st. 4 at the depth of 6,5 m and set far from st. 14 at 3,2 km (2532,4 and 1122,2 ind./m^2 respectively). In 1980 again the leading one was st. 4 - the depth 9 m and st. 1 - the depth 7,5 m (208,6 and 127,1 ind./m^2 respectively). In 1981 the most optimal horizon for *Ch. farreri* collecting at st. 1 was the depth of 9,8 m (180,6 ind./m^2), in 1982 at st. 8 at the depth of 8,5 m (625,0 ind./m^2), in 1983 at st. 1 at the depth of 7,5 m (32,1 ind./m^2), in 1984 at st. 1 at the depth of 7,5 m (182,7 ind./m^2), and in 1985; 1989 and 1990 the st. 1 traditionally became the most favorable for the reproduction of this species – (180,1; 22,9 and 45,1 ind./m^2 respectively) – the depth of 9,8 m (Table 3). After the material generalization it turned out that the most optimal water area for larvae collection of this type was nearby the warm water st. 14 at the average depths and great depth, maximally distant from that station (Figure 10c).

The most important factor influenced on the depth of maximal quantity of *Ch. farreri* turned out the solar activity expressed in Vulf's numbers (Figure 11c). However at st. 1 this indicator was greatly influenced by the wind direction and water average temperature deviation in June and at st. 2 the rainfall abundance in June and the duration of ice period at st. 8 (Figure 12c). The total vertical distribution showed the most optimal horizon for juveniles collecting which was set at the depth of 5 and 6 m (213,6 and 327,9 ind./m^2 respectively) (Figure 13c), moreover the most changeable was the depth of 6 m (Figure 14c).

In 91,6% of cases from 23 observations at *Ch. farreri* was negative correlation between the vertical juvenile distribution and the depth (Figure 15c). The generalization of five year observations showed that those years the correlation was reliable and moreover only in 1981 it was positive and other years it was negative (Table 4). The long-term observation processing showed interannual changing of reproduction conditions of *Ch. farreri*, and the most optimal conditions for juvenile collection were in the beginning of 2000 at a horizon of 6,5 - 11 m (Figure 16 c).

S. swiftii

In 1978 the biggest abundance of the cold-loving *S. swiftii* juvenile appeared in the northern part of the Reid Pallada Bay. At the st. 3 which was distant from warm water st. 14 at 8,3 km at the depth of 12,5 m its abundance amounted 53, 1 ind./m^2, and at st. 4 at the depth of 10,5 m and distant from st. 14 at 3,2 km - 35,7 ind./m^2. In 1979 the biggest abundance of *S. swiftii* juvenile appeared in south-western part of the Reid Pallada Bay - at st. 5, at the depth of 6,5 m, and it was distant from st. 14 at 11,9 km (46,1 ind./m^2) and the same result the st.12 demonstrated at the depth of 14,5 m, and it was distant from st. 14 at 17 km. In harvestless 1980 the biggest abundance was noticed at st. 3, which was distant from st. 14 at 8,3 km at the depth of 11,5 m (18,1 ind./m^2) and nearby the st. 6, which was distant from st. 14 at 12 km at the depth of 10 m (17,0 ind./m^2). In 1981 the biggest abundance was at st. 1 at the depth of 9,8 m - 36,0 ind./m^2, and in 1983 at the depth of 12 m (58,5 ind./m^2). In 1985 the maximal abundance was found at the st. 13, distanced from the st. 14 at 13 km at the depth of 22,5 m (55,6 ind./m^2), and in 1988 at the st. 1 at the depth of 7,5 m (5,0 ind./m^2). In 1989 the terms of reproduction turned out favorable at the st. 4 distance from the st. 14 at 3 km at the depth of 12 m (8,3 ind./m^2), and in 1990 – at the st. 3, distanced from the st. 14 at 8,3 km at the depth of 19 m (10 ind./m^2) and at the st. 1, distanced from the st. 14 at 7 km at the depth of 9,8 m (5,5 ind./m^2) (Table 3). After the generalization of this material it turned out that the most favorable water area for its reproduction is situated in maximal depths among the researched ones and at the maximal distance from warm water st. 14 (Figure 10 d).

The depth of maximal population of this type mainly depends on the solar activity, calculated in Vulf's numbers (Figure 11d). However, at st. 1 the most influential factor was water saltiness on the surface in June and at st. 2 - the ice period terms in previous winter, wind speed and direction and the rainfall abundance in June (Figure 12d). As a difference of previous two species the *S. swiftii* juvenile increases and its maximum observed at the depth of 22,5 m (55,6 ind./m^2) (Figure 13d), and the most changeable horizon became the depths of 12 and 14,5 m (Figure 14d).

In 10 of 12 cases (83,3%) the positive correlation between the depth and vertical distribution of this molluscs was observed (Figure 15d). The generalization of annual observations showed this correlation was reliable in four from six years (Table 4). The past researches showed that maximal abundance of *S. swiftii* was observed at the average and lower horizons, moreover the most fruitful years were in the beginning of 90s of last century (Figure 16d).

4. Discussion

The researched species of bivalve molluscs have different temperature preferences, leading to different periods of spawning beginning and its duration [84], and as a consequence to the different time of attaching to the substrate. The positive phototaxis was noticed at *M. trossulus* larvae [85], that's why it's juvenile met oftenly at the water surface [61]. When settling of the collectors cones the larvae took different positions [86]. But if they appear at the surface then the juvenile abundance of *P. yessoensis* calls a lot of dead cases [62]. In order to reduce competition it is necessary to take into consideration the vertical preferences of both species. Somewhat their vertical distribution can be judged according to the vertical larvae distribution. They have daily vertical migrations [87; 44], which become more complicated due to different phototaxis in the ontogenesis process. In Saroma Lake (Hokkaido, Japan) *P. yessoensis* larvae were concentrated in upper horizons during high tide and in lower horizons during low tide, in the day time the larvae were situated at the depth of 6-12 m, before sunrise they raised in the lay of 0-3 m and night time they stay at the surface [88]. Early larvae had positive phototaxis and the late ones the negative one [89; 90]. The shell weight also influences the larvae moving. The larvae less than 120 μm don't get down less than the thermocline and the larvae larger than 170 μm are not the subject of thermocline [91] and close results were obtained by [92]. The turbulent mixing influences on the larvae distribution in plankton. It happens under the influence of dynamic factors and more often due to wind and tides factors [93]. In mixing water areas the larvae distribute equally over the water thickness of 40-50 m and in stratified waters they inhabit upper than thermocline. [94].

However in spite of food abundance in the upper 10 m, the larvae are concentrated deeper [95]. In plankton the larvae behave as active individuals. They meet quite oftenly lower than thermocline and stay at the place in spite of the stream initiated by upwelling and down welling [96]. Though the larvae behavior is specific according to its species [97], many of them enter the hyponeuston and having the pollution there the threat to the existence of bottom biocenosis happens [98].

In the water thickness the intensity of the food consumed by the molluscs increases [99], which increases the negative influence of the competitors. That's why the collectors and the cages are put into the horizon where the competitors number is less. In many countries of the world during the scallop breeding the collectors and the cages are put deep at 12 m [100;101], at 15 m [102; 103], at 18 m [104] and even at 20 m [105]. The total biomass of the fouling competitors depends on plantation location and always decreases with the depth increasing [103] and putting them at distance from shallow areas [106].

As water turbulence as food supply can make an influence on vertical larvae distribution and in case of food low concentration the turbulence increases the contact probability between the larvae and food cells [107]. For *P. yessoensis* it is necessary suspension concentration at 11.0 mg.l^{-1}, and for *M. trossulus* – 2.5 mg.l^{-1} and such seston bio masses are characteristic for the bays of Japanese Sea [108], moreover, in subsurface layer they change from 2.4 to 5.0 mg.l^{-1}, and at the bottom reaches 10.0 mg.l^{-1}. Probably, that's why, the subsidence and the best growth of *M. trossulus* happens in the layer of 0-5 m, and the scallop at the bottom [109]. At shallow water stations the food concentration is maximal at the depth of 9-10 m [110]. However the biggest quantity of juvenile P. *yessoensis* meets at the horizon from 9-16 m where their main competitors – *M. trossulus, Ch. farreri* and predator – *Asterias amurensis* are less [61]. The juvenile number increasing with the depth at the stations with hard bottom can be connected with the stream speed decreasing at the rough ground and with the illumination increasing [65]. At the Posyet Bay in 1978-1979 the biggest number of *M. trossulus* juvenile was at shallow water stations 1 and 11, and besides in vertical distribution there were visible two peaks of population - at the depth of 0 and 3,5 m [61]. Possibly, due to Global Warming at the depth of 8 m the third peak of its population was found out later (Figure 13b). Probably the trigger of larvae settling was the favorable for living temperature finding out that's why depending on hydrological specialities of the year the optimal horizon for the larvae settling could move at 1-2 m [111]. In warm years the optimal for living temperature becomes deeper and the larvae *P. yessoensis* which find it turned out at the great depth creating positive correlation between the depth and the vertical juvenile distribution (Table 4). That's why the appearance of negative correlation between the water temperature at the water surface and the vertical juvenile distribution of *P. yessoensis* can be explained by a temporary cold in the beginning of 1980s (Figure 17).

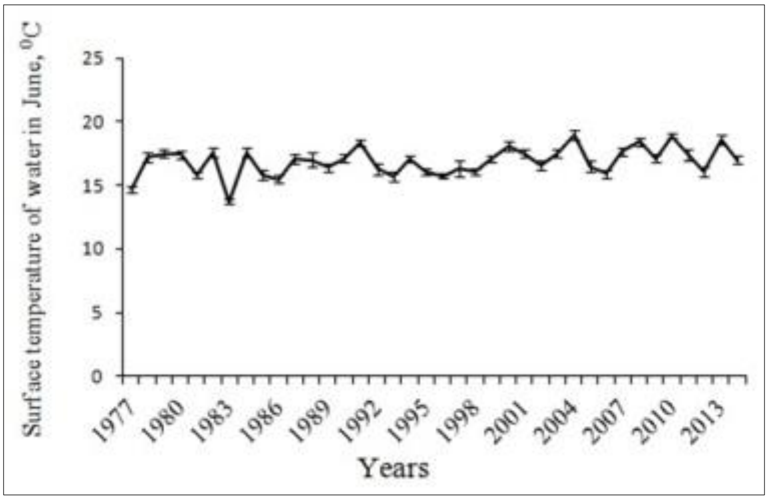


Figure 17 Long-term variability of surface temperature of water in June in Posyet Bay

Two population dynamics comparison of *M. trossulus* at mussel collectors set in 1977-1989 at horizon of 0-4 m [3] and at the scallop collectors, set at the same years at the horizon of 7,5-12 m [112] showed, that there is a negative correlation at mussel collectors: r = -0.231, p = 0.448 between the surface water temperature and the population number of *M. trossulus*, and at the scallop collectors the correlation is positive: r = 0,199; p = 0.514. In case of high temperatures the *M. trossulus* larvae willingly settle on the non-mussel collectors, but on the scallop ones. Last century *P. yessoensis* was found at the depth from 0.5 to 80.0 m, but the biggest gatherings were at the depth from 6-30 m [113; 114]. Within that the clear dependance on favorable for life grounds and scallop mass settling was noticed. In protected bays and on the edges of deep protruding bays the main grounds were liquid or clay silts, but the suitable for *P. yessoensis* grounds such as silty sand, sand and pebble were common only for coastal area and in such district the biggest gathering of *P. yessoensis* was at 6-18 m [113]. Probably, the optimal horizon for larvae settling is that horizon where the parental individuals are available. After the experiment done in 1982 with white producers the biggest population of albino individuals was in s Bay at the scallop collectors situated at horizon of 7,5-12,0 m, and at the same depth the producers for the experiment were caught at the same depths [86]. Natural scallop populations inhabit different horizons, apparently having specific genotypes. On the east coast of Korea the *P. yessoensis* larvae distributed five miles away from the coast in horizon of 10-30 meters and its location depends on temperature, stream and wind factors, however the density depends on taking probes place and when high tides it increases significantly [69]. According to the concentration districts larvae location can judge about settling of adult animals and also about population status of bottom grouping [42]. Minonosok Bay (st. 1) often demonstrates a high juvenile population thanks to having plantations there which help to the producers' abundance. The increased quantity of sea farms in the Primorsky region let us confirm the boundaries of synchronic reproduction of *P. yessoensis*. This century's not fruitful years were at the water area much wider than of the Posyet Bay [76]. On the coast of Primorsky region the northern boundary of habitat of *P. yessoensis* was the Bay Rudnaya and the Chikhachev Bay (51° 28´ N), and also western Sakhalin; in Okhotsk Sea - Aniva Bay, lagoon Busse and the district to the south of Bay of Patience [78]. But the modern researches of *P. yessoensis* revealed the northern boundary of habitat raised at metric up to the Tabo Bay (51º37'N), and the depth of habitat reached to 138 m [115]. Global Warming calls physical distress of animal reproduction of temperate waters [72] and the southern boundary of habitat of *P. yessoensis* for twenty years moved in Korea almost 1° to the north of 36°04'N in the 1980s to 37°13'N in the 2000s (116; 117). Connected with the solar activity the ultraviolet radiation (UVR) influences negatively on gametogenesis of *P. yessoensis* [118] and food for larvae [119; 120]. However, as per long term forecast the solar activity [121] influences positively on the Earth temperature [122] (Figure 5). That's why Global Warming will stimulate the deepening and moving to the north of the cultivated *P. yessoensis*.

5. Conclusion

The mollusk species under study have different thermopathy, so they show different reproductive responses to climatic conditions and different spatial distribution.

Compliance with ethical standards

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