THE PRIMORSKAYA PINK SALMON DYNAMICS AND ATMOSPHERIC MACRO PROCESSES CHANGES IN THE MIDDLE TROPOSPHERE OVER THE SEA OF JAPAN AND THE ADJACENT AREAS

Goryainov A.A., Shatilina T.A.

Pacific Research Fisheries Centre (TINRO-Centre), Vladivostok, Russia

Introduction

Climate identifies conditions of reproduction and feeding up of salmon in every riverine and marine stage of life cycle. A plenty of published matter concerned the investigation of interconnection between global climatic changes and abundance dynamics of the Pacific Salmon (Birman, 1969; Davydov, 1986; Beamish & Bouillon, 1993; Radchenko & Rassadnikov, 1997; *et al.*). However, data on the interconnection between the climatic factors and the salmon abundance dynamics are scarce. This leads to wrong estimation of the dynamics tendency. For complete and adequate consideration of climate forcing to the salmon abundance dynamics it is necessary to analyze information about climatic changes of regional pattern. It is widely known that global geophysical processes influence salmon habitats conditions in different ways not only within sea areas, but even locally at their reproduction and feeding up areas. At the presented report the dynamics of Primorskaya pink salmon catches is analyzed in association with climatic changes within its areal and adjacent regions.

The main areas of Primorskaya pink salmon reproduction are situated within the watershed of rivers that flow into the Sea of Japan in the north of Primorye. The Primorskaya pink salmon is feeding up and wintering in the south of the Sea of Japan. As the indicator of climatic alteration there are used the geopotential data H_{500} (height of the 500 hPa isobaric surface at the altitude of 5 km above the sea level) being the integral indicator of alteration of atmospheric macroprocesses in middle troposphere. Multi-year changes peculiarities of different parameters of large-scale circulation in middle troposphere regarding their representativeness to monitoring of climate were considered in details in L.K. Kleshchenko's work (1982). The processes to occur in the near-land field are not regarded here, because it was found that the atmospheric processes anomalies are reflected more clearly in middle troposphere (Razoreneva & Zveryayev, 1996).

Material and Methods

Amurrybvod's and TINRO-center's fishery statistics data on Primorskaya pink salmon catches were used. The geopotential H_{500} data were collected at 19 aerological stations being located along the perimeter that comprised aquatic area of the Sea of Japan and a part of the Okhotsk Sea with adjacent land territory. The data collected since 1950 to 1998 were analyzed. The information used was presented by Primorsky Hydrometeo service Board.

Upon regarding connections between the catch volumes and H_{500} anomalies these connections were supposed to be weak at the coefficient of correlation from 0.1 to 0.3. At the volume of 0.3 and higher the interconnection was supposed significant. The coefficients from 0.7 to 1.0 show close functional connection, however, for this report they were not reached. The correlation coefficients of $p<0.05$ level were admitted as statistically reliable ones. To describe graphically trends and to smooth away occasional extremes in the dynamics of Primorskaya pink salmon catches and in the anomalies of H_{500} geopotential the curves produced by temporal periods averaging were used. The method of polynomial smoothing away was applied. The temporal periods of spectrum smoothing away was fulfilled with Parsen filter application.

The Results of Achievement

<u>Pink salmon catch dynamics.</u> Fig. 1 shows the dynamics of Primorskaya pink salmon catches during the period that comprised more than 70 years since 1926 to 1999. Sharp short-term fluctuations of abundance in odd and even years are characteristic for pink salmon so, that in consideration of it here and further, these odd and even years are discussed separately.

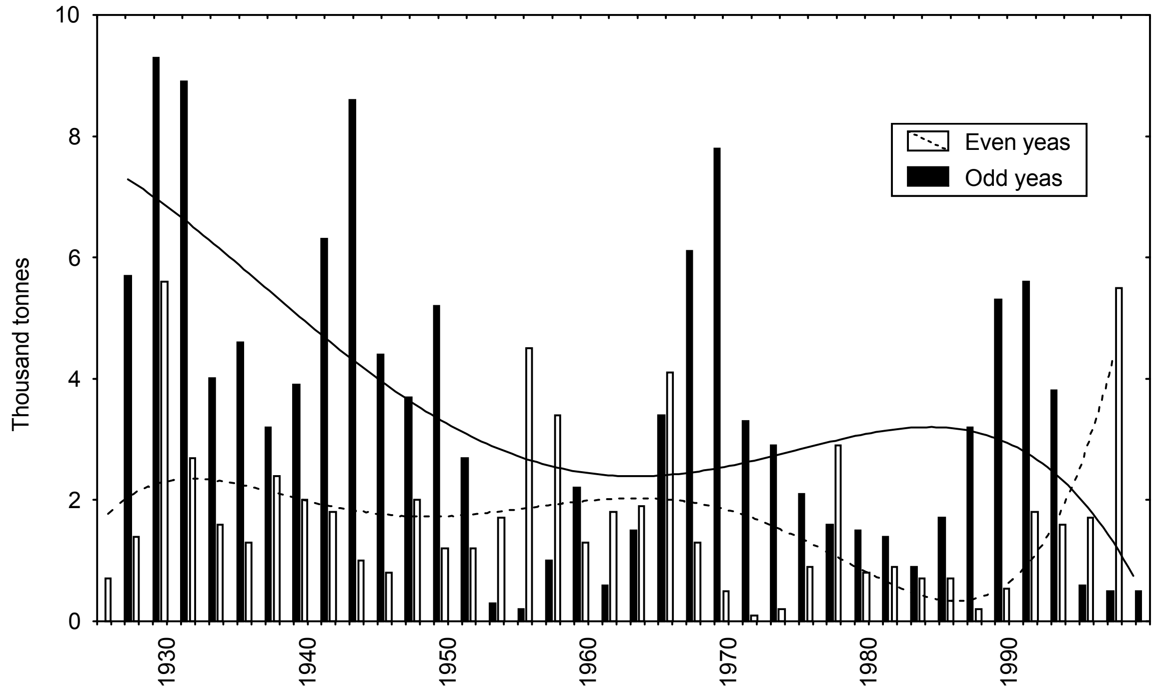


Fig. 1. Commercial catch of pink salmon in the major rivers of Primorye

Odd years. Average multi-year values of pink salmon catches in odd years are equal to 3.7 thousand tons. The highest catches, when their average multi-year values increased to as much as 50% and more were observed from the 20ˢ end to the 40ˢ end and also in the 60ˢ end and in the 90ˢ beginning. The spectrum analysis results show presence of fluctuation with periodicity of 9, 12 and 36 years. Among them 9 year cycle is dominant.

Even years. In even years the average multi-year value of pink salmon catches is two times less than in odd years. Meanwhile there should be noticed the predominance in abundance of the even years generations during short periods of the 50ˢ end, the 60ˢ beginning, the 70ˢ end and the 90ˢ. At the same time it is evident, that periods of odd years generations dominance in odd years were reported in the 30ˢ, the 40ˢ and the 90ˢ. In even years, likewise in odd ones, the spectrum analysis performs fluctuations with the periodicity of 12 and 24 years.

Dynamics of H_{500} anomalies. In the present work we analyze the dynamics of H_{500} anomalies (deviations from average multi-year value) in January and May. These months were chosen by us basing on the following facts. January is one of the “critical” months for reproduction of Primorskaya pink salmon. Incubation period finishes during this month but natural conditions of the month are characterized as especially severe having low air temperature, maximum low level of water in spawning river grounds, thickening of ice cover. January is the period of wintering in the sea for elder generations. This month the cold currents forcing is intensified in southern part of the Sea of Japan where Primorskaya pink salmon is wintering. In May the great part of the Primorskaya pink salmon alevins is migrating from spawning habitats into river’s estuary and to seacoast. The whole period of dwelling in the seacoast habitats for the salmon alevins is accompanied by high level of mortality. The elder generation of pink salmon undertakes anadromous migrations.

We presented in the chronological Table 1 data on the most significant H_{500} anomalies according to all classes of stations. Following the table data, four large-scale anomalies in H_{500} field appeared in January across the area under consideration. The anomalies were observed in 1963, 1974, 1979 and 1991 years. In May the large-scale anomalies of the area were marked off in 1954, 1955, 1967, 1968 and 1969 years. Dominant period is two-year one for the whole number of years. In winter 5, 8-9- year cycles were singled out most often, but in May 12, 16, 24-year cycles were marked off. In even years there are 3, 5-6, 12, 24-year cycles in winter and 8, 12, 24- year cycles in May. In odd years there are 3, 4, 5, 6-year cycles in winter, but 2, 6, 8, 12, 24-year cycles in May.

Table 1

Chronology data on the most significant H500 anomalies and cycles, 1950-98

Stations (points)	Years of positive(+) and negative(-) anomalies	Cycles		
		All years	Even yeas	Uneven yeas
January				
Harbin	92(+) 63(-)	2[2], 5, 8	3[2], 5	6, 8[2], 12, 24
Petropavlovsk-Kamchatsky	74(+) 67, 79(-)	2[2], 3, 5, 9	3[2], 6, 8, 12	3, 4[2], 5, 6, 8, 12, 24
Tokyo	63(-)	2-3, 6-7, 12, 16[2]	2, 3, 4[2], 5, 6, 8	3[2], 8
Yuzhno-Sakhalinsk	89(+)	2, 8, 9[2], 24	3, 4, 5[2], 6, 12, 24	4[2], 5, 24
Nickolaevsk-na-Amure	74, 91[1] 97(+) 59, 78(-)	2, 8, 9[2]	3, 5, 6, 12, 24[2]	5[2], 4, 6
Yakutsk	91(+) 52[1], 79, 94(-)	2, 3, 7, 9[2]	3, 12, 24[2]	3, 4, 5[2]
May				
Harbin	64(+) 72[1], 62, 76(-)	2, 4, 12, 16[2]	3, 6, 8[2], 12	2[2], 4, 6, 8
Vladivostok	69(-)	2[2], 7, 12 16, 24	3[2], 18, 12	2, 5, 6, 8, 12[2], 24
Aikawa		2, 4[2], 24	2[2], 12, 24	2, 8, 12[2], 24
Yuzhno-Sakhalinsk	69(-)	2-3[2]	2, 5, 8[2], 12	2, 3[2], 5, 12, 24
Petropavlovsk-Kamchatsky	55, 67, 68[1], 70(+) 54, 69, 80, 97[1](-)	2-3[2], 4, 16, 24	3, 6, 8, 12[2], 24	2[2], 3, 4, 6
Magadan	55, 68, 84, 67[1](+) 54, 63[1], 69, 80(-)	2[2], 6	4, 8, 12[2], 24	3[2], 6, 8, 12
Nickolaevsk-na-Amure	55, 68[1], 84, 90, 96(+) 54, 63, 69[1], 65, 80(-)	2-3[2]	4[2], 5, 8, 12, 24	2, 6, 8, 12[2], 24

Note: 1 – extreme years; 2 – dominant cycles

Dynamics of pink salmon catch in odd years and H_{500} geopotential anomalies H_{500} in January of odd years (Fig. 2a). Pink salmon generations of odd years spend January of odd years in wintering period in sea. The considerable positive correlation between catches values and H_{500} anomalies is traced at Aikawa, Tokyo and Aburatsu stations, of which Aikawa is singled out ($r = 0.3$). It should be noted that Aikawa station on Sado Island in south-eastern part of the Sea of Japan, namely in the wintering site. At the same time there was observed negative correlation of above-listed Figures at Ust-Kamchatsk station. In January of odd years rather feeble and statistically doubtful correlation was observed for other station.

H_{500} in January of even years (Fig. 2b). Pink salmon generations of odd years stay on embryo-larvae stage during January of even years. Considerable number of pink salmon embryos are perishing from freeze of spawning grounds during winter decrease in water level in the coastal part of rivers of fish spawning. The greatest correlation positive of pink salmon catch volumes of odd years generations and H_{500} anomalies in even years is observed in Blagoveshchensk, Okhotsk and Yuzhno-Sakhalinsk stations. Fluctuations of catch values occurred simultaneously with H_{500} anomalies at the first three stations of mentioned observations.

H_{500} in May of odd years (Fig. 2c). Pink salmon from odd years generations are traveling in anadromous migrations in May of odd years. The most and statistically reliable correlation is marked for stations of Okhotsk ($r = -0.48$, $p = 0.02$), Khabarovsk ($r = -0.42$, $p = 0.05$) and Vladivostok ($r = -0.54$, $p = 0.01$). It is evident that the fluctuations of catch volumes and H_{500} anomalies during all temporal period under consideration are going on anti-phase. It is remarkable that maximum decrease in catches that took place in the middle of the 50[s] occurred the most H_{500} anomaly from average multi-year one.

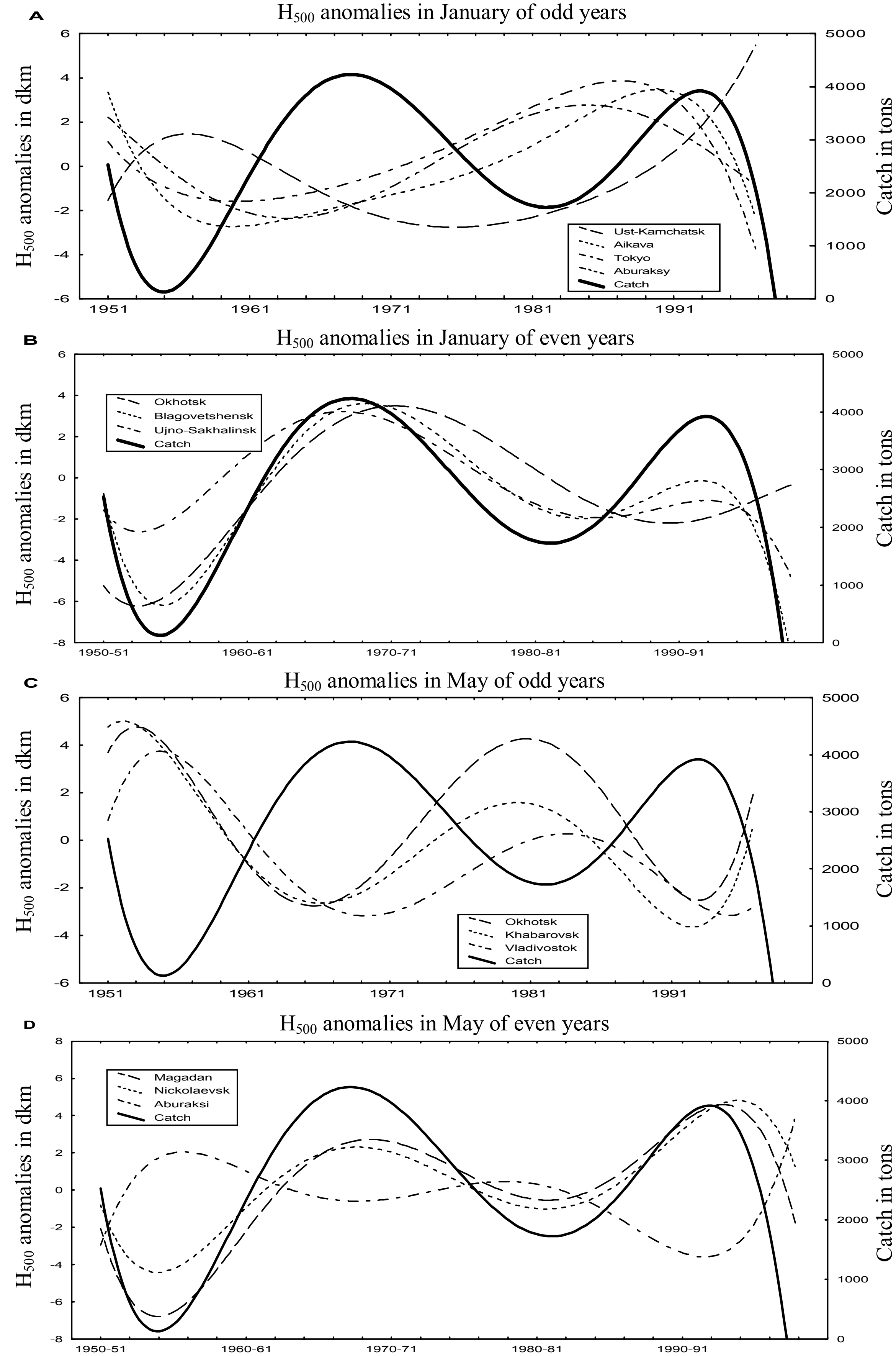


Fig. 2. Catch of pink salmon in odd years and H_{500} anomalies (polynomial smoothing)

H_{500} in May of even years (Fig. 2d). Pink salmon generations of odd years are travelling in catadromous migrations in May living in estuary-coastal zone. Relatively high and statistically reliable positive correlation was observed between catch values and H_{500} anomalies for the next stations: Magadan ($r = 054$, $p = 0.01$), Ust-Kamchatsk ($r = 0.50$, $p = 0.02$), Nickolaevsk-na-Amure ($r = 0.56$, $p = 0.01$). Fluctuations of catches and H_{500} anomalies at above-mentioned stations are simultaneous and coinciding during all temporal periods. At the same time the feeble and statistically doubtful negative correlation was observed at island stations, for example, at Aburaksy. In latter case the processes run in anti-phase.

Catch dynamics of pink salmon of even years and H_{500} geopotential anomalies H_{500} in January of odd years (Fig. 3a). Even years generations stay on embryo-larvae stage of development in riverine period during January of odd years. Here we note positive feeble and statistically doubtful correlation at Magadan, Ust-Kamchatsk, Okhotsk, Petropavlovsk-Kamchatsky stations (correlation coefficient is from 0.22 till 0.31 respectively). At Vasilyev stations there was marked positive significant and reliable correlation ($r = 0.43$, $p = 0.04$) between value of catches and geopotential deviation. It is interesting that at such stations as Harbin, Pusan, Tokyo and Aburaksy very feeble negative correlation of these volumes is registered.

H_{500} in January of even years (Fig. 3b). Even years generations were wintering in sea during January of even years. In this case the significant and statistically reliable negative correlation between catch values and H_{500} anomalies was registered at the land stations, such as Yakutsk ($r = -0.46$, $p = 0.02$), Blagoveshchensk ($r = -0.50$, $p = 0.01$), Nickolaevsk-na-Amure ($r = -0.50$, $p = 0.01$), Alexandrovsk-Sakhalinsky ($r = -0.53$, $p = 0.01$), Khabarovsk ($r = -0.45$, $p = 0.03$). Increase in catches in even years of the 50^s took place on the background of negative H_{500} deviations at the above-mentioned stations, but from the 60^s beginning on the contrary, decrease in catch values took place on the background of increase in deviations to positive direction.

H_{500} in May of odd years (Fig. 3c). Even years generations of pink salmon travel in catadromous migration and its alevins are dwelling in the estuaries and coastal marine areas during May of odd years. During this period the feeble and statistically questionable positive correlation between catches and geopotential anomalies is registered at every station. Among them Vasilyev, Abasiri and Aburaksy stations should be marked off where feeble and statistically questionable negative correlation is observed.

H_{500} in May of even years (Fig. 3d). Even years generations of pink salmon travel in anadromous migrations in May of even years. During this period two groups of stations are distinguished according to correlation figure between H_{500} geopotential anomaly and pink salmon catches. Yakutsk, Magadan, Taiganos, Ust-Kamchatsk, Blagoveshchensk, Nickolaevsk-na-Amure and Alexandrovsk-Sakhalinsky belong to the first group. Aikawa, Tokyo, Aburaksy stations belong to the second group. At above-mentioned stations groups the feeble connection is traced. Any connection for the rest station is absent.

So, the greatest number of reliable correlation cases ($p < 0.05$) is observed on catches of pink salmon of odd years generations and H_{500} anomalies in May of even years. Maximum of values and significant coefficients are registered on the stations of Nickolaevsk-na-Amure (0.56), Alexandrovsk-Sakhalinsky (0.55), Magadan (0.54), Ust-Kamchatsk and Petropavlovsk-Kamchatsky (0.50). It is known that odd years generations pink salmon spend May of even years in final stage of riverine and beginning stage of estuarine and coastal period.

Discussion on Results

Similarity in pink salmon catch dynamics and atmospheric processes periodicity is found. Beyond two-year cycle, 12-year cycle trends in abundance fluctuations are posed most distinctly in Primorskaya pink salmon catch dynamics. Excepting 2-year and 12-year cycle trends, the fluctuations with 9-year and 36-year periodicity for odd years generations and 24-year cycle for even years are discovered. Resemblance in cycles appeared also in H_{500} anomalies dynamics above aquatic areas of the Okhotsk Sea and the Sea of Japan as well as above adjacent areas. Moreover, it is disclosed difference in the atmospheric processes run for odd and even years, when analyzing climatic alterations.

The highest correlation between catches and H_{500} anomalies is observed generally at the life cycle periods related to dwelling in sea, namely during marine coast period and in wintering time. To demonstrate clearly we offer the spatial distribution of correlation coefficients of Primorskaya pink salmon catches and H_{500} anomalies at the above-mentioned stations of study (Fig. 4, 5).

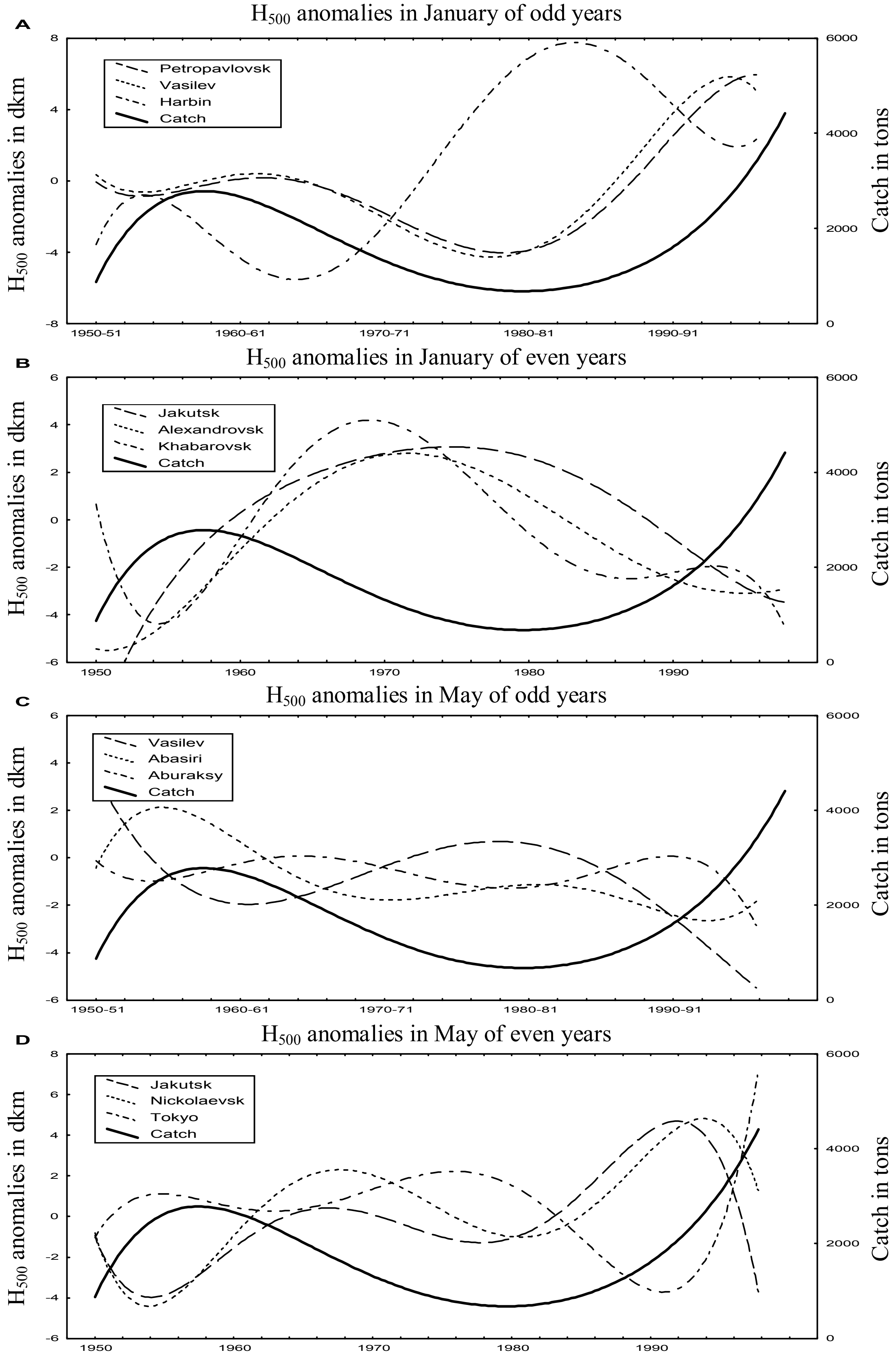


Fig. 3. Catch of pink salmon in even years and H_{500} anomalies (polynomial smoothing)

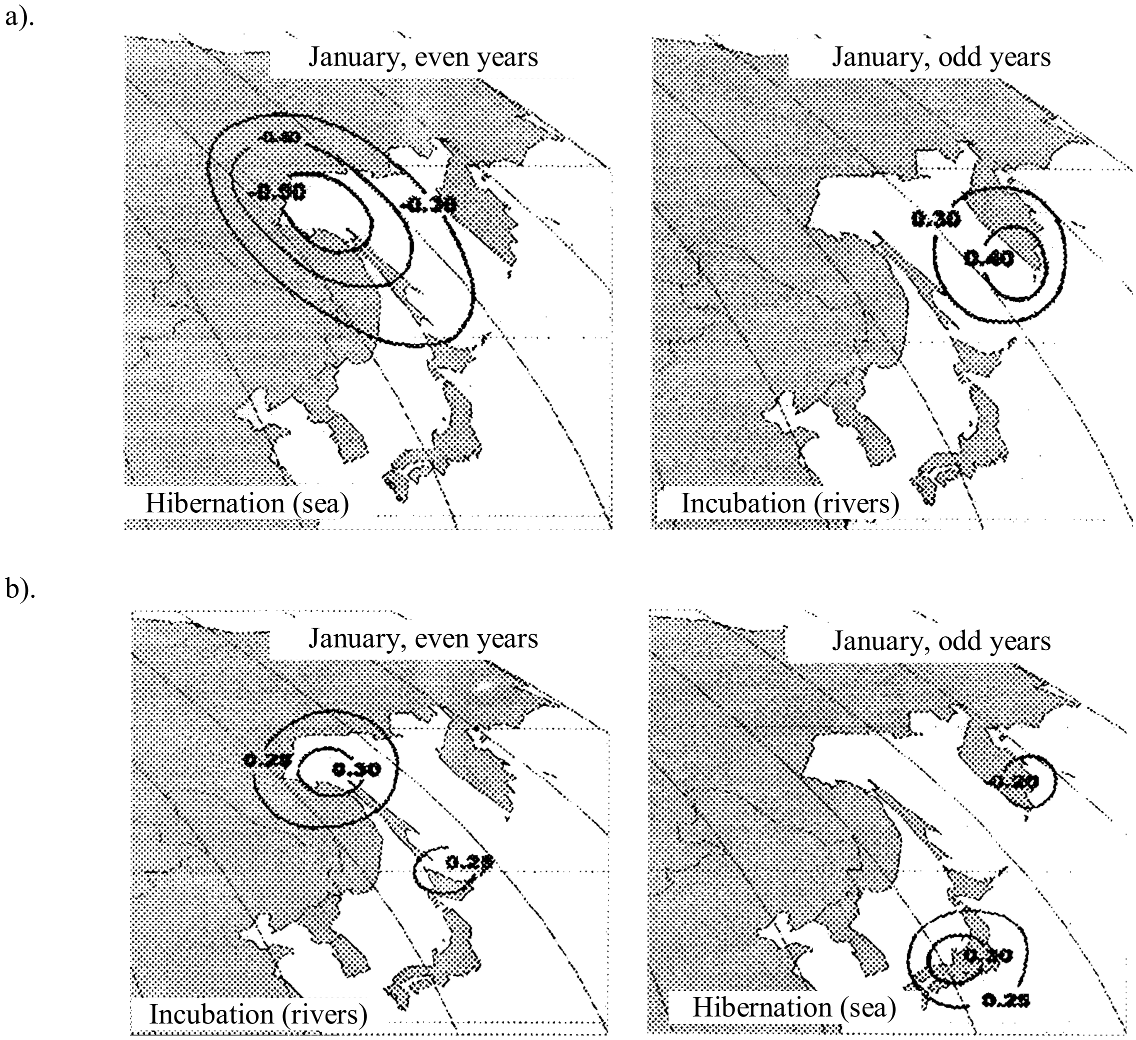


Fig. 4. Spatial distribution of the correlations of Primorskaya pink salmon catch and H_{500} anomalies in January. Generation of even (a) and odd (b) years

The atmospheric processes taking place above northern aquatic area of the Sea of Japan and areas adjacent to its north-western coast produce in January of even years most intensive forcing to conditions for feeding up and wintering of pink salmon generation of even years. This region is situated in the sphere of Okhotsk minimum (climatic center of action in middle troposphere). At the same time in odd years the display of higher relations between catch values and H_{500} anomalies in January is discovered at the stations being situated along aquatic areas adjacent to southern part of the Sea of Japan. The relations are feeble at other stations during the mentioned years. Let's consider the abundance correlation of Primorskaya pink salmon and H_{500} anomalies in January. Even years generations demonstrate the most significant correlation at the stations located in Kamchatka (sphere of Pacific ridge influence). Odd years generations manifest the most significant correlation at the stations of the northwestern coast of the Okhotsk Sea and Sakhalin (sphere of Okhotsk minimum) (Fig. 4).

Taking into consideration isocorrelates, the "nucleus" of greatest for abundance of Primorskaya pink salmon generations of odd years, when fish stays at the coastal period of life cycle, is spread above the Okhotsk Sea where in spring Okhotsk anticyclone is formed. Meantime, it should be noticed that the highest correlation between catches of pink salmon and H_{500} anomalies was registered on the stations situated in the northern part of the Tatar Strait. Rather a high level of relation between catches and H_{500} anomalies in May of odd years was not registered. Two zones with low coefficients of correlation are spread over oceanic areas. In May of even years two zones with relatively high correlation could be marked off above the Okhotsk Sea and northern part of the Tatar Strait as well as above southern part of the Sea of Japan. In May of odd years the highest coefficients of correlation between catches and H_{500} anomalies were discovered at the stations located above continental regions (Fig. 5).

a).

b).

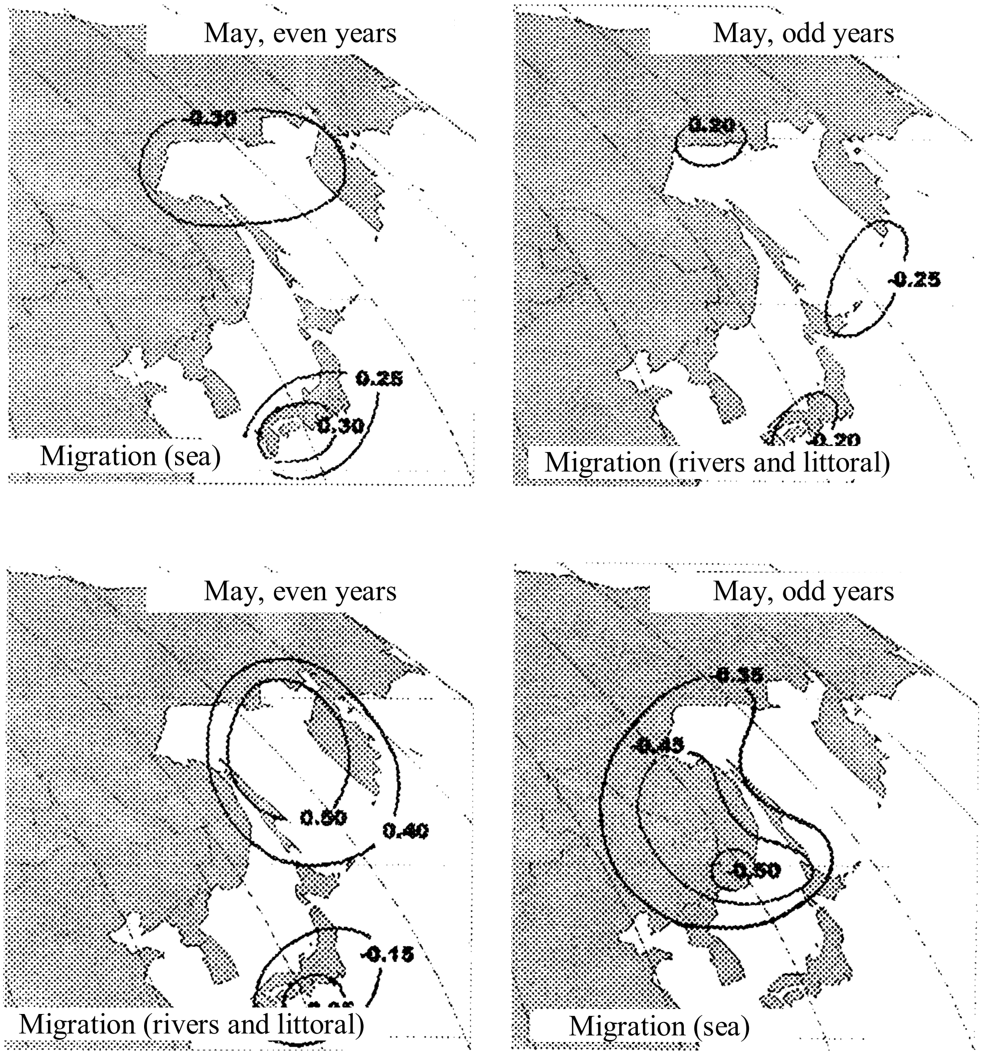


Fig. 5. Spatial distribution of the correlations of Primorskaya pink salmon catch and H_{500} anomalies in May. Generation of even (a) and odd (b) years

Thus, basing on above-mentioned data concerning spatial distribution of correlation and H_{500} anomalies in January and May it might be summarized that the higher influence on pink salmon abundance has the forcing of climatic alterations happening above aquatic areas of the Okhotsk Sea and northern part of the Sea of Japan (generally above the Tatar Strait) and over adjacent continental territory.

In Fig. 6 real situation of macroprocesses development in May during period of catadromous migration and dwelling in marine coastal habitat of favorable (1968) and unfavorable (1952) years. Rather significant difference in atmospheric processes is clear. In 1968 the higher field of pressure and warm “nucleus” were observed above the Okhotsk Sea. Such processes assisted the earlier warming of water in the Tatar Strait. In 1952 the large cold depression capable to inspire cold “nucleus” rise spread over the Okhotsk Sea.

Basing on climatic situation analysis and taking into consideration the character and coupled trends of catch fluctuations and H_{500} anomalies there were compiled the hypothetical schemes of favorable and unfavorable climatic conditions for pink salmon (Fig. 7). The unfavorable conditions to winter in sea are supposed to be those of intensive strengthening of the Okhotsk Sea minimum and related to it cold climatic hollow above the Sea of Japan. Under this type of atmospheric circulation the forcing of cold water to southern part of the Sea of Japan, namely to pink salmon wintering habitats is increased. Favorable conditions of wintering are supposed to be those of Okhotsk minimum shifted to continent. As a result of a such shift the forcing of cold to central and southern parts of the Sea of Japan is weakened.

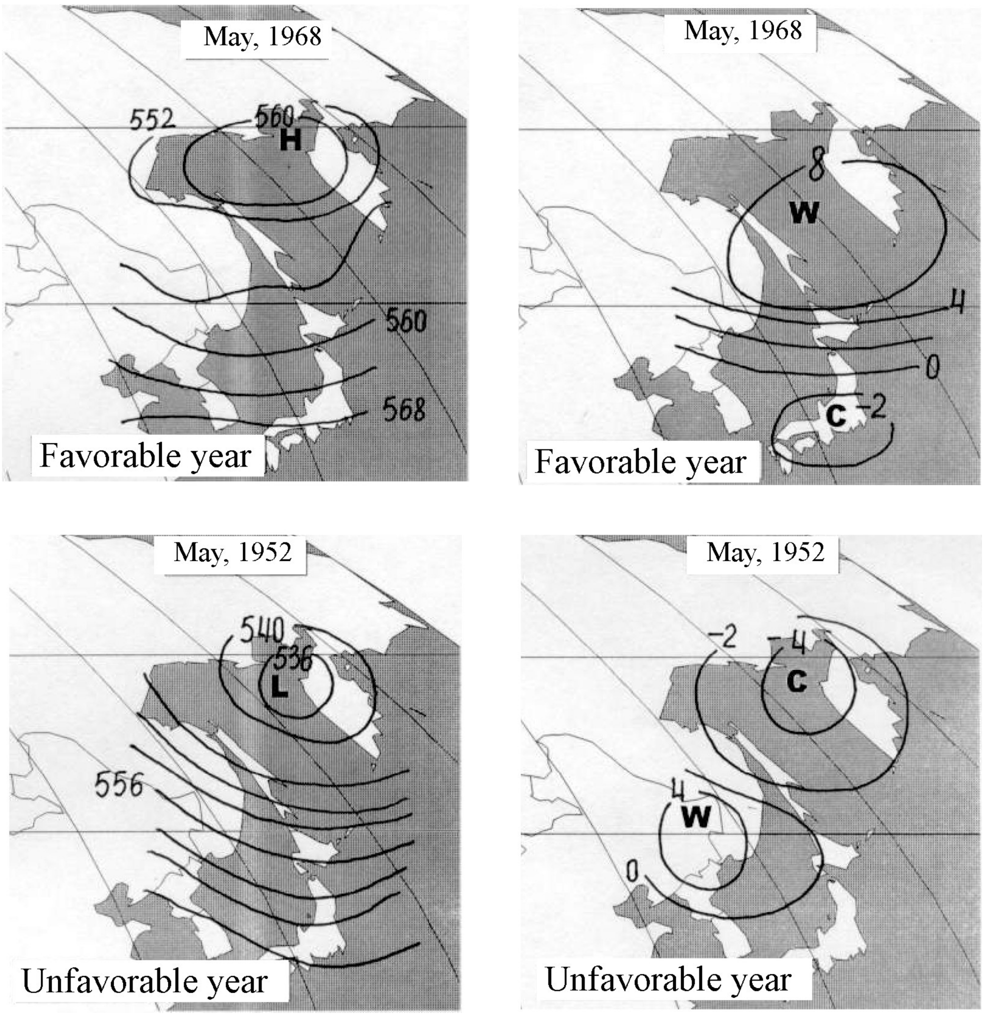


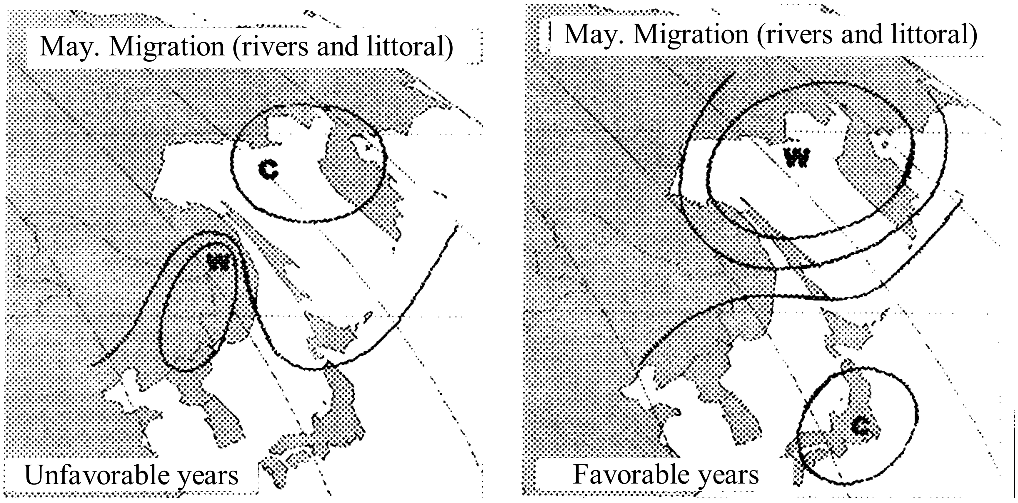
Fig. 6. A real situation of macroprocesses development in May during period of catadromous migration and dwelling in marine coastal habitat of favorable (1968) and unfavorable (1952) years. C – cold, W – warm

During catadromous migration of alevins and their dwelling in coastal habitats the unfavorable climatic conditions are supposed probably to be those, when warm ridge is spread over continental regions and above the Okhotsk Sea the cold "nucleus" which is prolonged as cold hollow above the Tatar Strait and northern part of the Sea of Japan are spread. At such synoptic situation earlier warming of continental waters happens and catadromous migrations take place earlier, although coastal marine areas adjacent to the spawning months hasn't got warm yet.

Conclusions

- Besides 2-year cycles, 12-year cycles of abundance fluctuations are exhibited most distinctly in catch dynamics of Primorskaya pink salmon. Beyond 2 and 12-year cycles there were observed fluctuation of 9 and 36-year periodicity for odd years generations and 24-year ones for even years. The same cycles including others are exhibited in H_{500} anomalies dynamics above aquatic areas of the Sea of Japan and the Okhotsk Sea with adjacent areas.
- The greatest forcing to abundance of Primorskaya pink salmon generations of odd years is produced by the atmospheric processes running above aquatic areas of the Okhotsk Sea and the Sea of Japan with adjacent areas during estuarine-coastal and marine periods. Meantime the nucleus of atmospheric processes forcing is spread above northern part of the Tatar Strait.
- Winter monsoon forcing to environmental conditions of Primorskaya pink salmon dwelling in wintering habitats is different. It is strengthened in even years and weakened in odd years. It may be explained by presence of 2-year cycle in alterations of Asiatic anticyclone intensity.

a).



b).

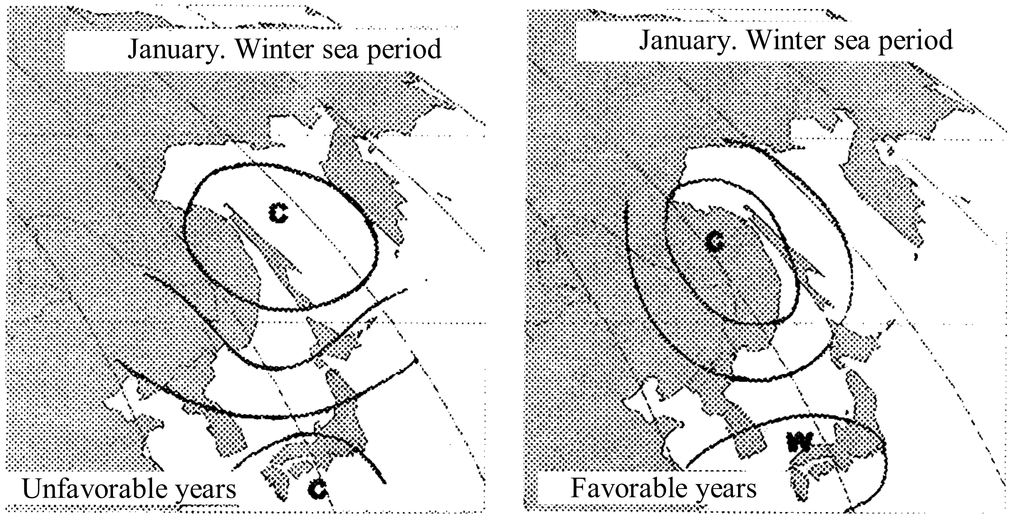


Fig. 7. Hypothetical schemes of favorable and unfavorable climatic conditions for Primorskaya pink salmon at January and May. C – cold, W – warm

References

1. Beamish R.J. & Bouillon D.R. 1993. Pacific salmon production trends in relation to climate // Canadian J. Fish and Aquatic Scien. Vol. 50. N 5. P. 1002-1016.
2. Birman I.B. 1969. Periodic changes of salmon abundance and sun activity // Izv. VNIRO. Vol. 67. P. 171-189.
3. Davydov I.V. 1986. To the nature of long changes of fish abundance and possibilities of their foreseeing / TINRO. Vladivostok. P. 5-16.
4. Kleshchenko L.K. 1982. Some assessments of climatic alterations of large-scale circulation features in the middle troposphere // All-Russian Hydrometeorological Research Institute of Word Hydrometeorological Data Center. Vol. 97. P. 85-97.
5. Radchenko V.I. & Rassadnikov O.A. 1997. Long-term dynamics trends of Asian stocks of Pacific salmon and factors determining it // Izv. TINRO. Vol. 122. P.72-94.
6. Razoreneva O.A. & Zveryayev I.I. 1996. The features of low frequency in middle troposphere of northern hemisphere during winter time // J. Meteorology and hydrology. N 5. P. 83-96.