# Influence of external environmental factors on the dynamics of the number of Pacific cod and saffron cod of the Eastern part of the sea of Okhotsk


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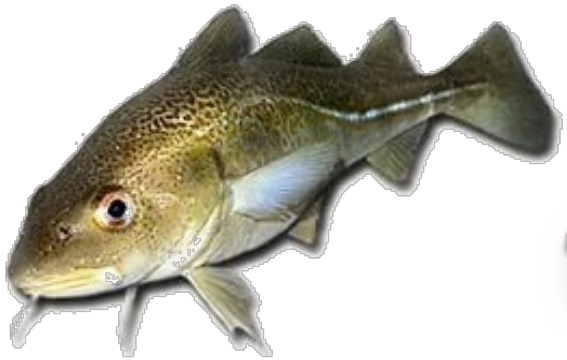

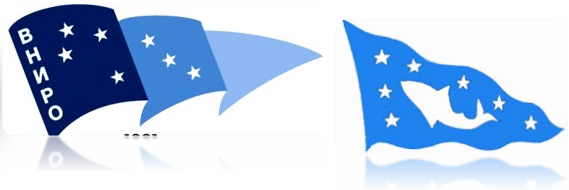

# Objective:

**Aseeva N. L.** 2012. Restructuring of the structure of the bottom ichthyocene of the Western Kamchatka shelf due to changes in water temperature / / Questions of commercial Oceanology. Vol. 9 No. 1. Pp. 77-88.
**Bondarenko M. V., Borisov V. M., Krovnin A. S., Klovach N. V., Mudriy G. P.** 2001. Large-scale fluctuations of stocks of marine commercial organisms / / world ocean: Use of biological resources. Information and analytical collection. M: Vol. 2. Pp. 87-94.
**Bugaev A.V., Tepnin O. B., Radchenko V. I. 2018.** Climatic variability and productivity of Pacific salmon of the Russian Far East / / Research. aq. Biol. resources of Kamchatka and Northwest parts of the Pacific: Cl of pr. Kamchat. SRI fisheries and Oceanography. Vol. 49. Pp. 5-50.
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**Zuenko Yu. I., Chernoivanova L. A., Vdovin A. N. Ustinova E. I.** 2010. Influence of climate change on reproduction of navaga Eleginus gracilis in Peter the Great Bay (sea of Japan) // Questions of commercial Oceanology. Vol. 7 No. 1. Pp. 132-144.
**Kotenev B. N., Krovnin A. S., Klovach N. V., Mordasova N. V., Muriy G. P.** 2015. Influence of climatic and Oceanological factors on the state of the main stocks of pink salmon in 1950-2015. / / Works of VNIRO. Vol. 158. Pp. 143-161.
**Kulik V. V.** 2009. Dynamics of fish and invertebrate abundance in the pelagial of the sea of Okhotsk due to Heliophysical and climatic-Oceanological factors// abstract of dissert. of biol. sciences'. Vladivostok. 24 PP.
**Novikova O. V. 2004.** Population dynamics of the West Kamchatka navaga and its natural causes / / Economic, social, legal and environmental problems of the sea of Okhotsk and ways to solve them. Materials of the regional scientific-practical conference November 23-25, 2004 Petropavlovsk-Kamchatsky. Pp. 93-96.
**Terentyev D. A., Tepnin O. B., Chetvergov A.V.** 2002. Influence of abiotic factors on the dynamics of the West Kamchatka navaga stock Eleginus gracilis Tilesius (Gadidae) // Studies of aquatic biological resources of Kamchatka and the northwestern Pacific ocean. Vol. 6. Pp. 116-119.
**Feldman M. G., Shevlyakov E. A.** 2015. Survival of Kamchatka pink salmon as a result of the combined effect of density regulation and external environmental factors. News of TINRO. Vol. 182. Pp. 88-114.

**And many others.**

# Objective:

## GOAL:

Assessment for the complex effects of the climatic factors on the stock abundance of Pacific cod and saffron cod in the eastern part of the Sea of Okhotsk.

## TASKS:

- to evaluate correlations of the population dynamics of the studied fish species;
- to analyze the direct and complex influence of climatic factors on the fish population at different stages of ontogenesis;
- to select the most significant climatic factors affecting the population dynamics of the studied species.

# Data and methods

**Biomass of *Gaddidae*, *Pleuronectidae* and *Cottidae* (1971-2018)**

**Abundance of Saffron cod (1987-2018)**

**Abundance of Pacific cod (1971-2018)**

**Data of summer trawl surveys GIS «CartMaster» (Bizikov et al., 2007)**

**Obtained with the method of the cohort model «Sintez» (Ilyin et al., 2014)**

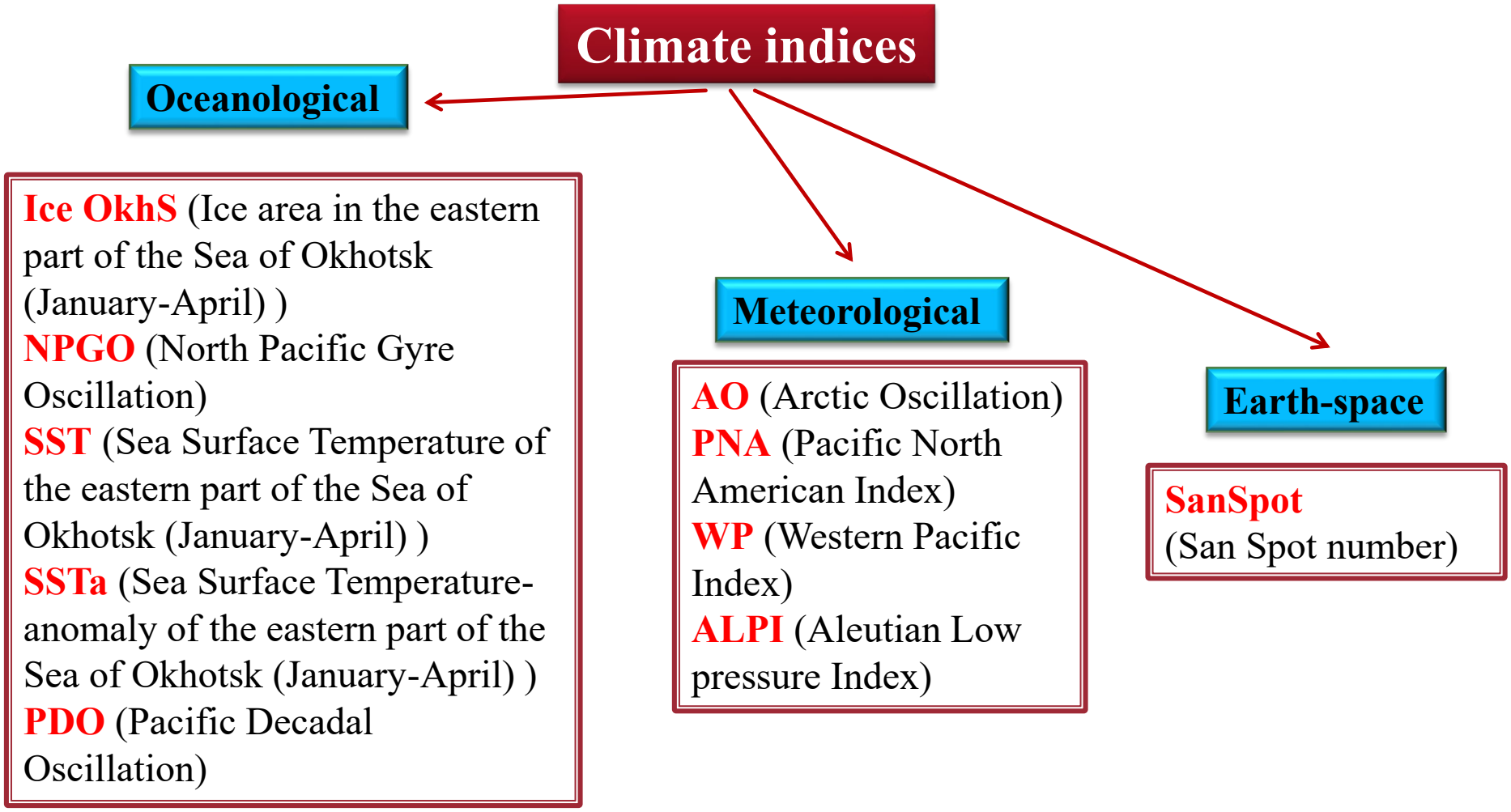
**For evaluation of simple (one-dimensional) relations between the variables («fish stock–fish stock» or «index–fish stock»)**

Pearson correlation coefficient (*r*) (“STATISTICA”)

**To identify the degree of influence of the complex of climatic factors on the number of fish**

Stepwise multidimensional regressive analysis (“STATISTICA” )

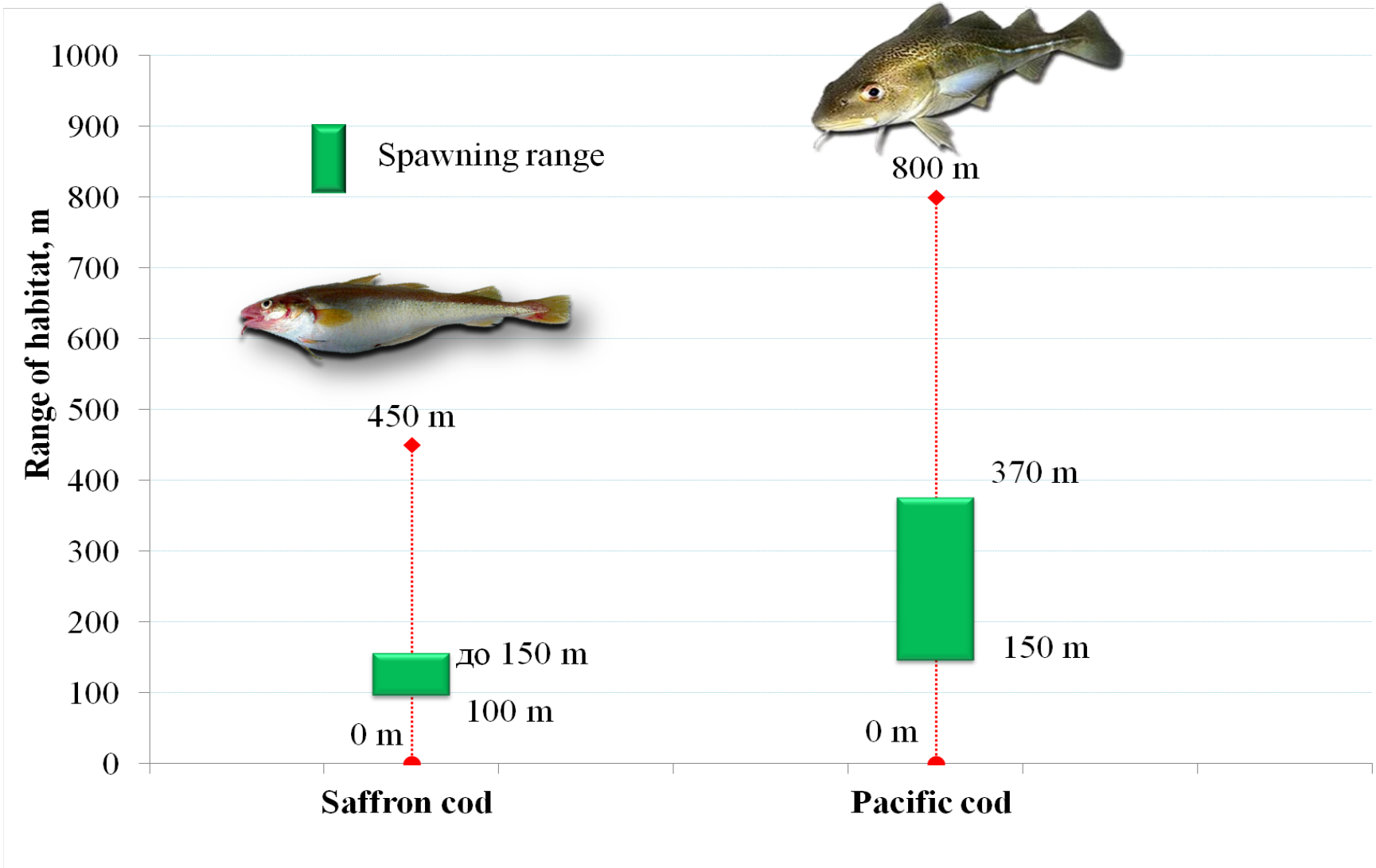
# Data and methods




https: www.esrl.noaa.gov/psd/data/climateindices/list/
http://www.pac.dfo-mpo.gc.ca и
http://www.03d.org/npgo/npgo.php.

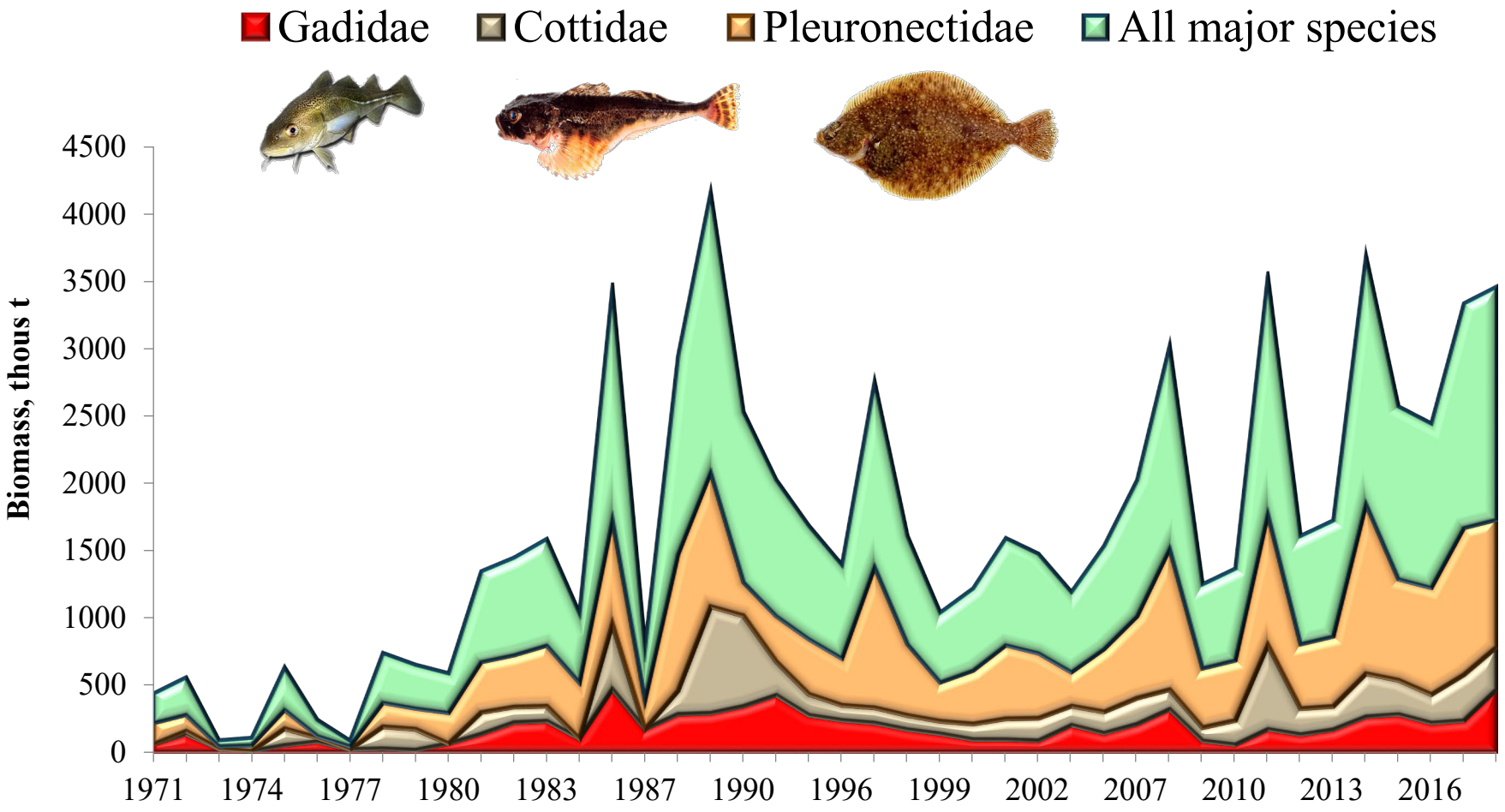
# Introduction

Depth range of the habitats and spawning grounds of saffron cod and Pacific cod (eastern part of the Sea of Okhotsk)



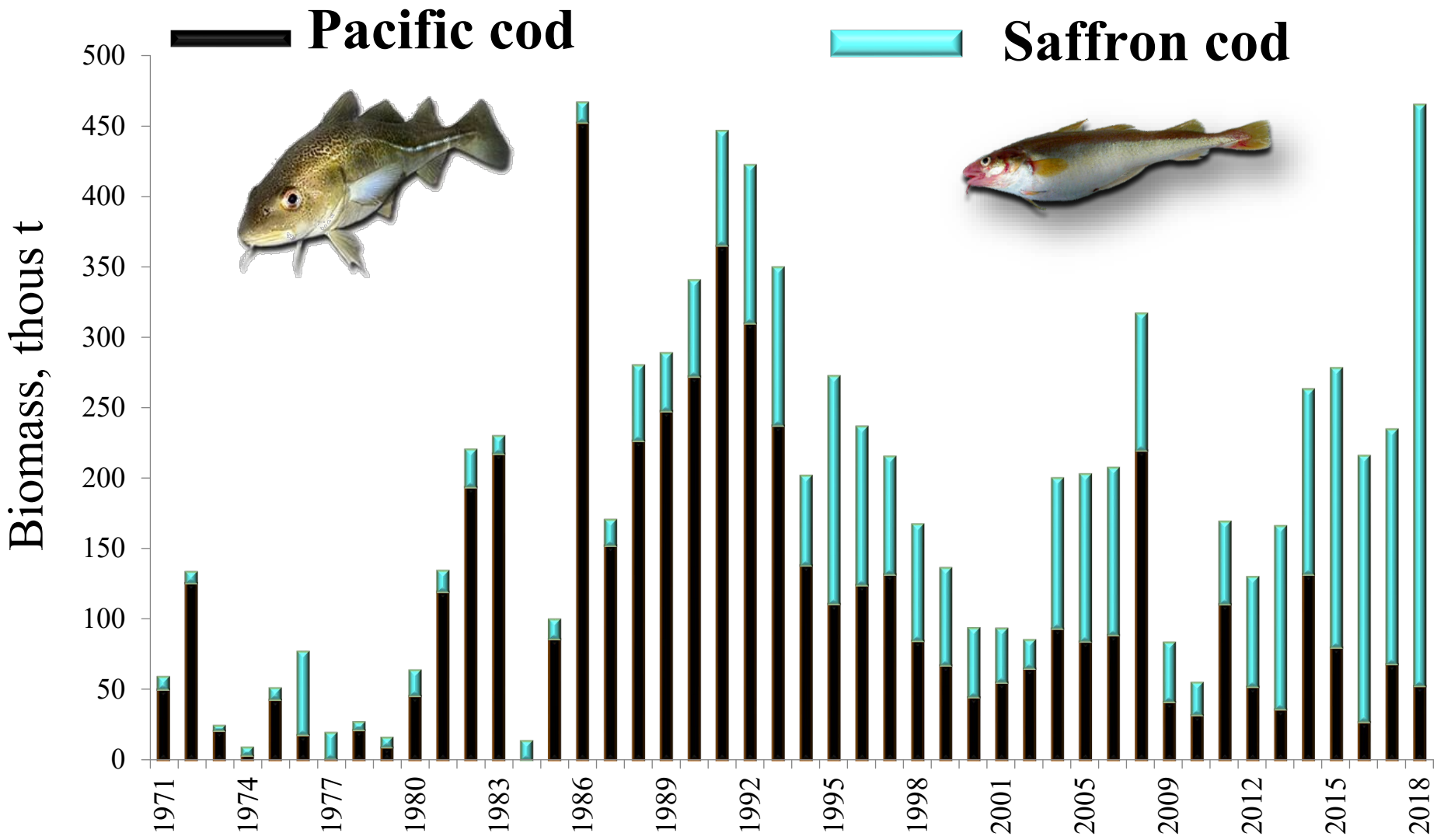
# Introduction

The total biomass of demersal fish (cod and saffron cod) decreased significantly from the last half of the 1990s due to decrease of the cod stock



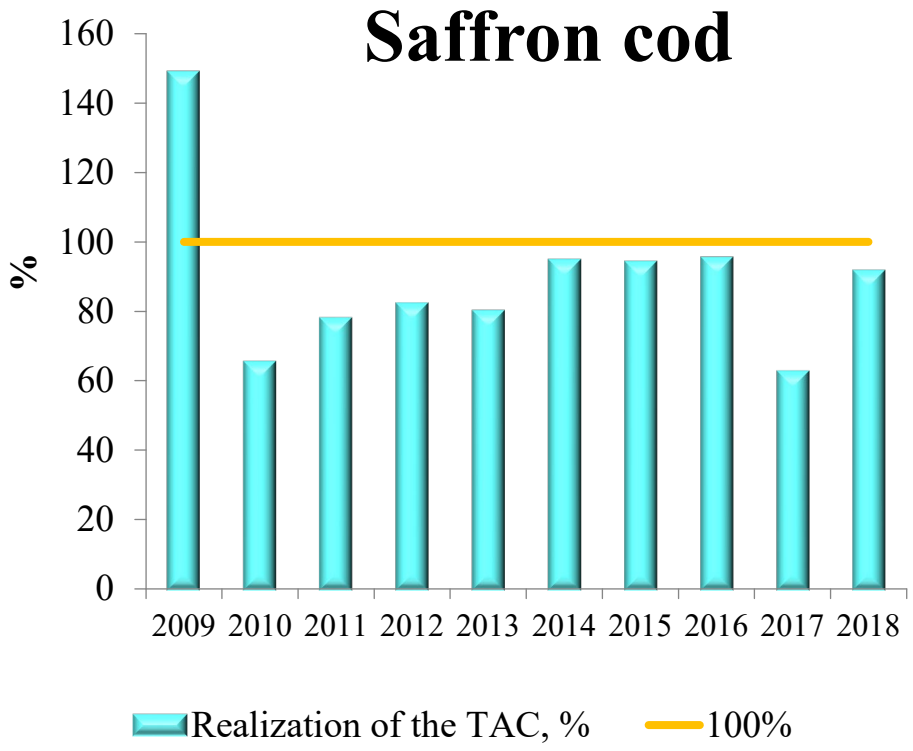
# Introduction

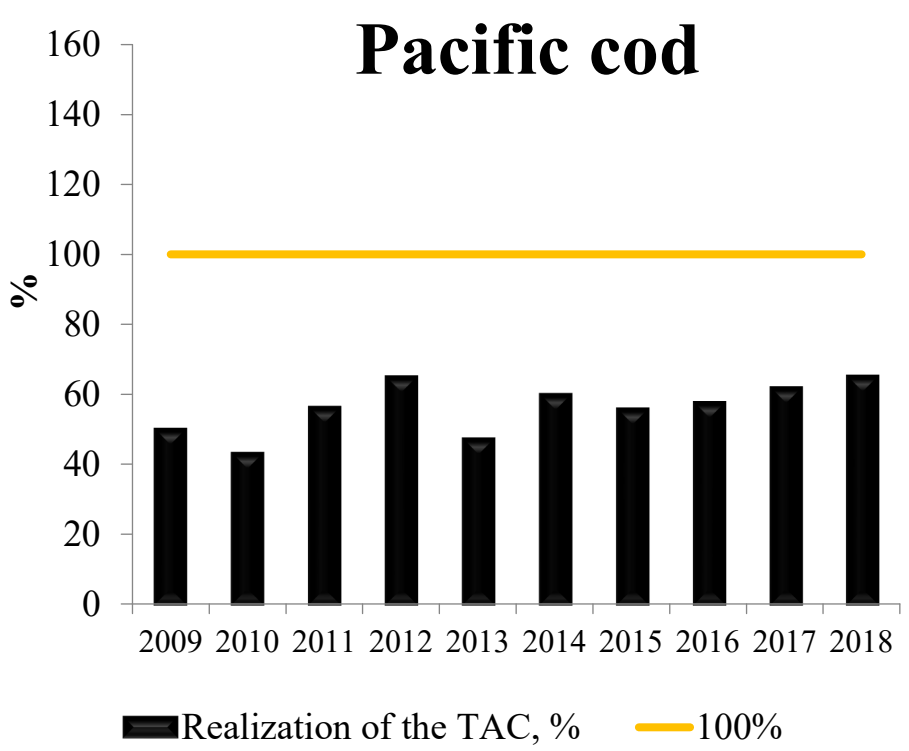
Consequent decrease of the Pacific cod stock abundance to a low level and a quick increase of the biomass of saffron cod



# Introduction

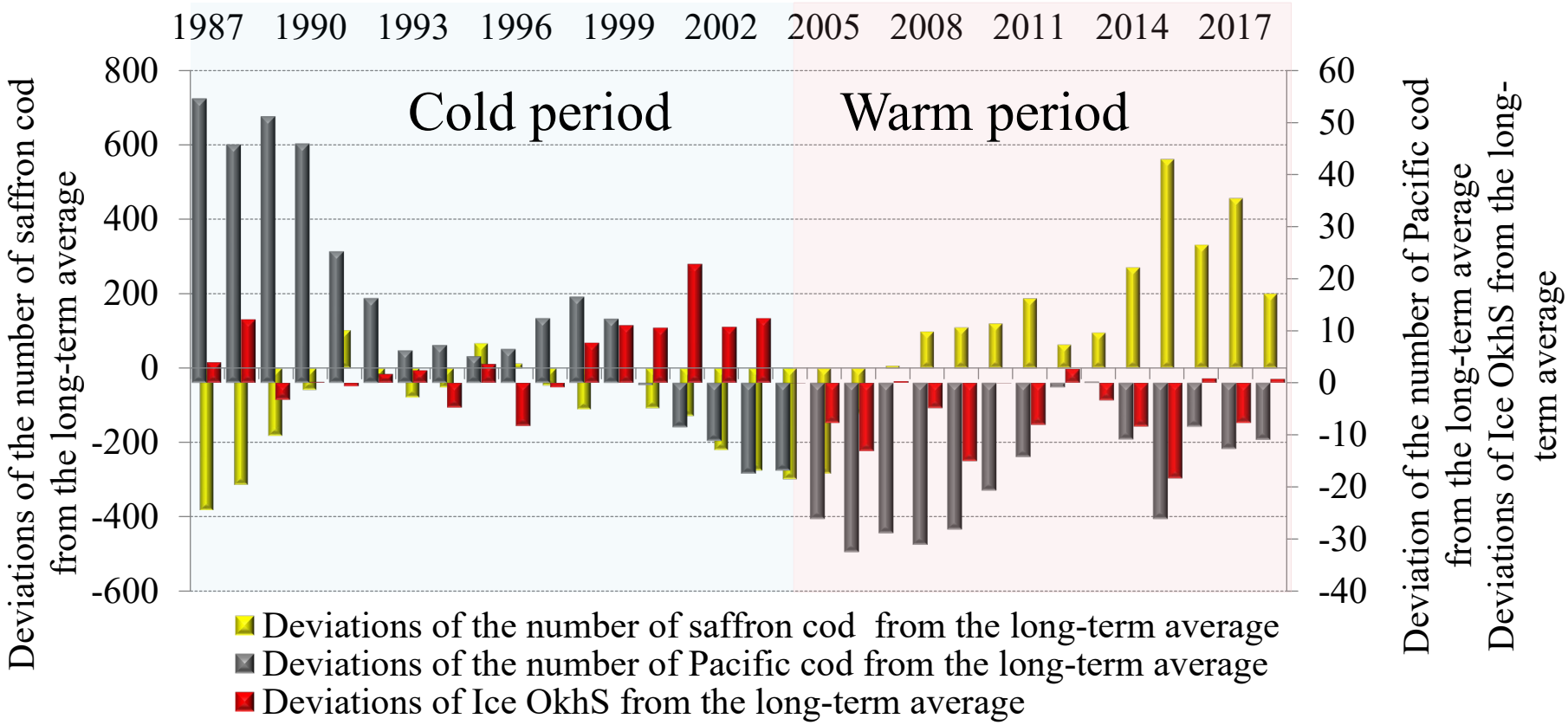
The ratio between the stock biomasses was observed at the background of underexploiting the resources of cod and almost 100% realization of the TAC for saffron cod



# Results

## Correlation coefficients between saffron cod and Pacific cod stock abundance (eastern part of Okhotsk sea, 1987–2018)




The stock abundance of Pacific cod and saffron cod demonstrate changing in antiphase: ***R = - 0.3811, p = 0.031***

# Results

The values of the Pearson correlation coefficients ($r$) and the confidence probability ($p$), characterizing the correlation between the stock abundance **of saffron cod** and the climatic indices on the data for 1987–2018 (**the lag of 1 year**)

| Climatic indices | Ice OkhS | NPGO | SST | SSTa | San Spot | PDO | AO | PNA | ALPI | WP |
|---|---|---|---|---|---|---|---|---|---|---|
| Stock abundance | -,0365 | -,1719 | ,0297 | **,5977** | ,2388 | ,1324 | ,0280 | -,2715 | -,3515 | -,1144 |
| | p=,897 | p=,540 | p=,916 | **p=,022** | p=,391 | p=,638 | p=,921 | p=,328 | p=,199 | p=,685 |

*Saffron cod had highly abundant generations in case of increasing surface temperature of the Sea of Okhotsk near the coast of Kamchatka (SSTa) (r = 0,59).*

# Results

The values of the Pearson correlation coefficients (*r*) and the confidence probability (*p*), characterizing the correlation between the stock abundance of **saffron cod** and the climatic indices on the data for 1987–2018 (**the lag of 3 years**)

| Climatic indices | Ice OkhS | NPGO | SST | SSTa | San Spot | PDO | AO | PNA | ALPI | WP |
|---|---|---|---|---|---|---|---|---|---|---|
| Stock abundance | **-,6651** | ,1586 | -,4370 | ,0880 | -,2489 | ,4478 | ,0782 | -,5027 | ,1354 | -,3351 |
| | **p=,024** | p=,684 | p=,239 | p=,822 | p=,518 | p=,227 | p=,842 | p=,168 | p=,728 | p=,378 |

*Highly authentic negative correlation was obtained between the abundance of generation reached mass maturation and ice condition of the sea (Ice OkhS) (r = -0.6651) .*

# Results

The values of the Pearson correlation coefficients (*r*) and the confidence probability (*p*), characterizing the correlation between the stock abundance of **Pacific cod** and the climatic indices on the data for 1971–2018 (**the lag of 1 year**)

| Climatic indices | Ice OkhS | NPGO | SST | SSTa | San Spot | PDO | AO | PNA | ALPI | WP |
|---|---|---|---|---|---|---|---|---|---|---|
| Stock abundance | **0,841** | ,1562 | -,1879 | ,2102 | -,0829 | ,3247 | ,1897 | -,3334 | ,1289 | -,5048 |
| | **p=,000** | p=,578 | p=,502 | p=,452 | p=,769 | p=,238 | p=,498 | p=,225 | p=,647 | p=,055 |

*With the lag of 1 year Pacific cod demonstrated highly authentic correlation to the ice condition of the sea (Ice OkhS)(r = 0,84).*

# Results

The values of the Pearson correlation coefficients ($r$) and the confidence probability ($p$), characterizing the correlation between the stock abundance **Pacific cod** and the climatic indices on the data for 1971–2018 (**the lag of 4 years**)

| Climatic indices | Ice OkhS | NPGO | SST | SSTa | San Spot | PDO | AO | PNA | ALPI | WP |
|---|---|---|---|---|---|---|---|---|---|---|
| Stock abundance | ,0192 | -,0937 | -,5825 | -,1034 | -,3573 | **,6955** | ,3394 | ,3353 | ,1617 | ,4986 |
| | p=,961 | p=,810 | p=,100 | p=,791 | p=,345 | **p=,038** | p=,372 | p=,378 | p=,678 | p=,172 |

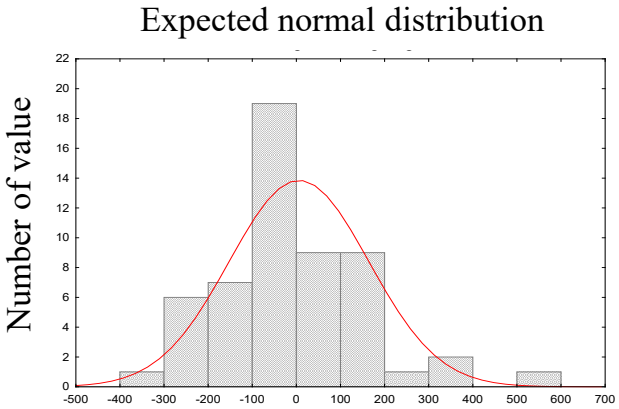
*With the lag of many years (4 years) the most strong correlation was obtained in case of the change of the Pacific Decade Oscillation (PDO) phase (r = 0,69), calculated on the ocean water surface temperature anomalies.*

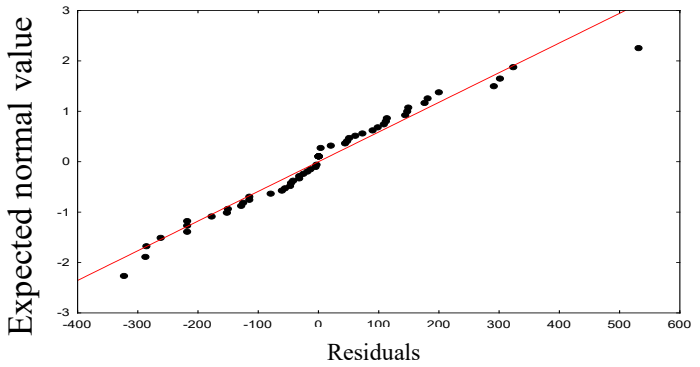
# Results

The results of the multidimensional regression modeling the correlations between the **saffron cod** stock abundance (mln.) and the climatic indices on the data for 1987–2018

**With the lag of 1 year**

| The results of the regression | | | | | | General parameters of dependent variables | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | $R^2$ | SE | F | df | p | Predictor | Beta | SE (Beta) | B | SE (B) | t | p |
| 0,48 | 0,23 | 207,1 | 1,2 | 4,24 | 0,15 | $b_1$ (ALPI) | -0,27 | 0,18 | -24,5 | 16,4 | -1,49 | 0,14 |
| | | | | | | $b_2$ (WP) | -0,20 | 0,18 | -116,0 | 104,2 | -1,11 | 0,27 |
| | | | | | | $b_3$ (PNA) | -0,26 | 0,18 | -11,7 | 8,3 | -1,39 | 0,17 |
| | | | | | | $b_4$(PDO) | 0,23 | 0,18 | 55,9 | 44,2 | 1,26 | 0,21 |



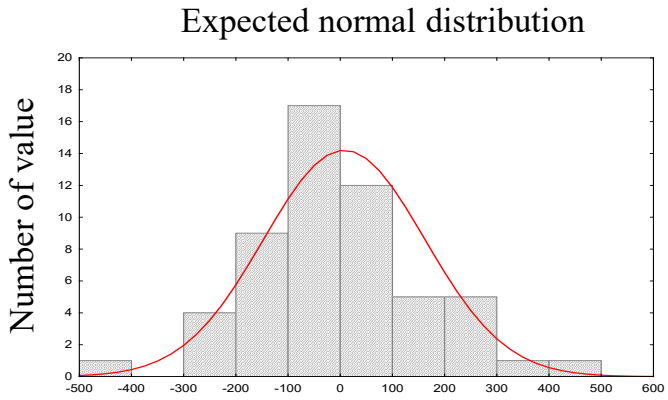

*The level of the correlation was R = 0,48 with the lag of 1 year. In this case all indices, determining the conjugacy of the multidimensional interaction, were unreliable.*

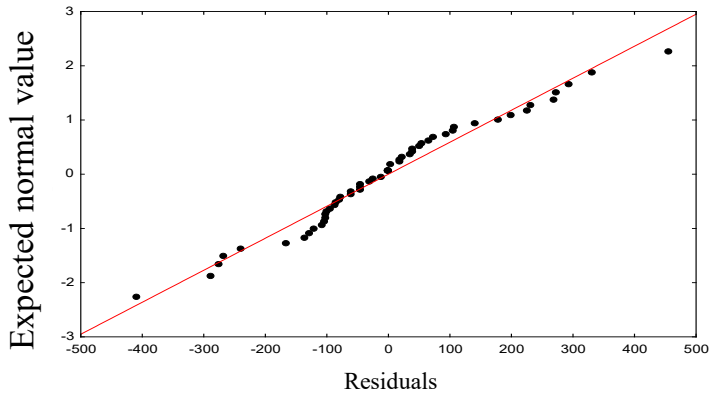
# Results

The results of the multidimensional regression modeling the correlations between the **saffron cod** stock abundance (mln.) and the climatic indices on the data for 1987–2018

**With the lag of 3 years**

| The results of the regression | | | | | | General parameters of dependent variables | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | $R^2$ | SE | F | df | p | Predictor | Beta | SE (Beta) | B | SE (B) | t | p |
| 0,58 | 0,34 | 194,2 | 2,7 | 4,22 | <0,05 | **$b_1$ (PNA)** | **-0,52** | **0,18** | **-23,6** | **8,4** | **-2,79** | **<0,05** |
| | | | | | | $b_2$ (WP) | -0,25 | 0,17 | -146,2 | 99,5 | -1,46 | 0,15 |
| | | | | | | $b_3$ (PDO) | 0,37 | 0,21 | 87,9 | 49,1 | 1,79 | 0,08 |
| | | | | | | $b_4$(NPGO) | 0,24 | 0,20 | 52,3 | 43,4 | 1,20 | 0,24 |



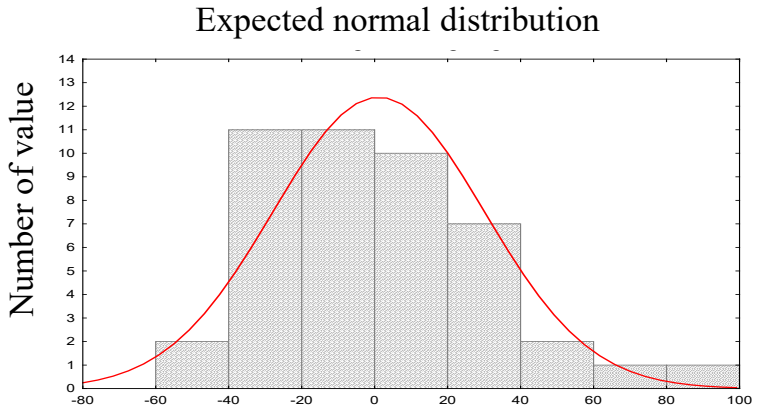

*The level was higher R = 0,58 with the lag of many years (3 years). Nevertheless, the results of the multidimensional modeling demonstrated only one reliable index –* ***$b_1$ (PNA) = -0,52.***

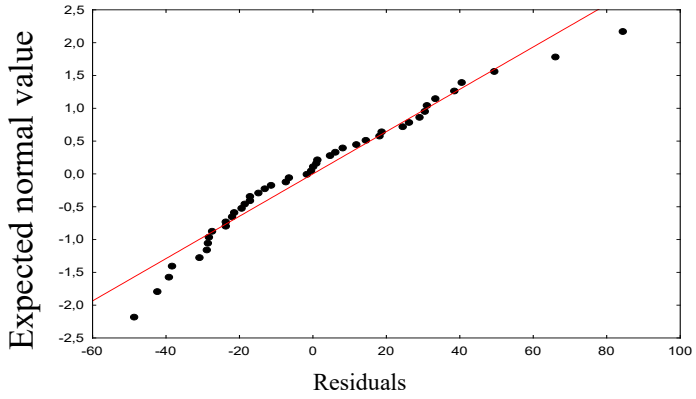
# Results

The results of the multidimensional regression modeling the correlations between the **Pacific cod** stock abundance (mln.) and the climatic indices on the data for 1971–2018

**With the lag of 1 year**

| The results of the regression | | | | | | General parameters of dependent variables | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | $R^2$ | SE | F | df | p | Predictor | Beta | SE (Beta) | B | SE (B) | t | p |
| 0,58 | 0,34 | 31,4 | 5,4 | 4,0 | <0,01 | **$b_1$ (PDO)** | **0,42** | **0,13** | **17,0** | **5,3** | **3,18** | **<0,01** |
| | | | | | | $b_2$ (SanSpot) | 0,20 | 0,13 | 0,11 | 0,1 | 1,52 | 0,13 |
| | | | | | | $b_3$ (ALPI) | 0,26 | 0,13 | 3,9 | 2,0 | 1,98 | 0,05 |
| | | | | | | $b_4$(AO) | 0,17 | 0,13 | 15,8 | 12,3 | 1,28 | 0,21 |
| | | | | | | $b_5$(WP) | -0,16 | 0,13 | -15,2 | 12,6 | -1,20 | 0,24 |



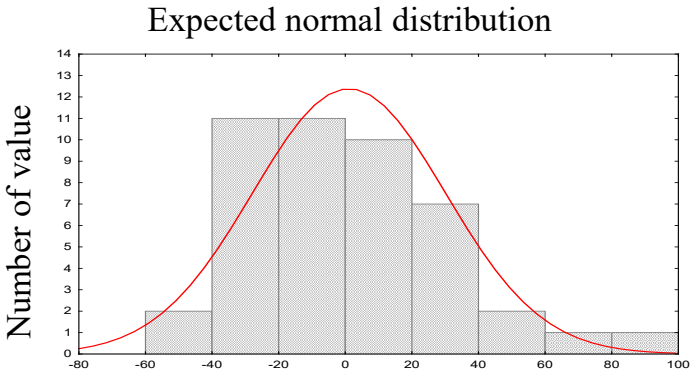

*In case of Pacific cod the most strong index was* ***$b_1$ (PDO) = 0,42*** *with the lag of 1 year. Multidimensional modeling provided the multiple regression coefficient R = 0,58.*

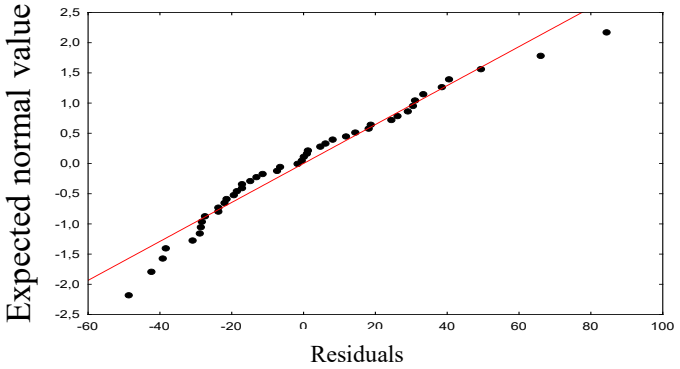
# Results

The results of the multidimensional regression modeling the correlations between the **Pacific cod** stock abundance (mln.) and the climatic indices on the data for 1971–2018

**With the lag of 4 years**

| The results of the regression | | | | | | General parameters of dependent variables | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R | $R^2$ | SE | F | df | p | Predictor | Beta | SE (Beta) | B | SE (B) | t | p |
| 0,70 | 0,49 | 27,0 | 3,9 | 6,25 | <0,01 | $b_1$ (SanSpot) | 0,28 | 0,18 | 0,1 | 0,1 | 1,55 | 0,13 |
| | | | | | | **$b_2$ (PDO)** | **0,40** | **0,15** | **15,0** | **5,5** | **2,73** | **<0,05** |
| | | | | | | $b_3$ (WP) | 0,13 | 0,17 | 11,9 | 15,7 | 0,76 | 0,45 |
| | | | | | | $b_4$(PNA) | -0,17 | 0,15 | -1,3 | 1,2 | -1,11 | 0,27 |
| | | | | | | $b_5$(SST) | -0,27 | 0,18 | -20,9 | 14,1 | -1,48 | 0,15 |
| | | | | | | $b_6$(AO) | 0,22 | 0,19 | 17,3 | 14,9 | 1,16 | 0,25 |



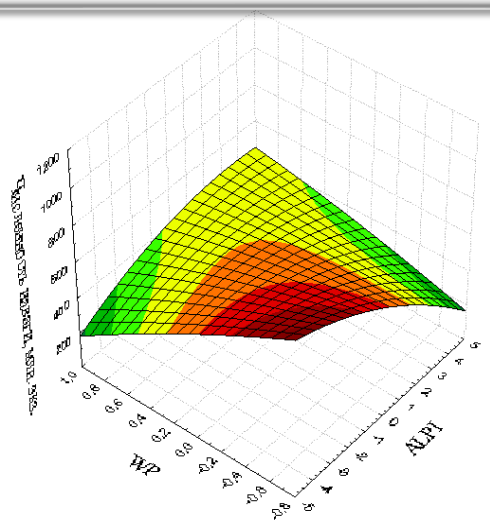

*The level of the correlation between the climatic indices and generation stock abundance, when more than 50% of individuals being mature (the lag of 4 years), was higher R = 0,70. The index* ***$b_2$ (PDO) = 0,40*** *was also statistically significant.*

# Results

The correlation between the **saffron cod** stock abundance (mln.) and the most strong climatic indices on the data for 1987–2018

## With the lag of 1 year

**Stock abundance saffron cod**
=548,524-(27,6877*ALPI)-(109,4662*WP)-(3,8562*ALPI*ALPI)+(54,5675*ALPI*WP)-(28,3991*WP*WP)

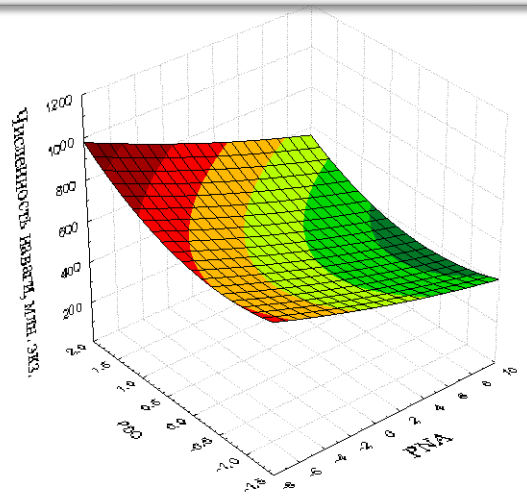


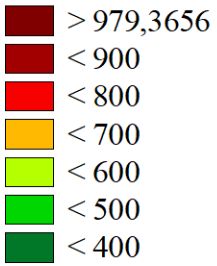


| R | $R^2$ | p | Indices |
|---|---|---|---|
| 0,38 | 0,14 | 0,13 | ALPI, WP |

## With the lag of 3 years

**Stock abundance saffron cod**
=531,8941-(20,5329*PNA)+(36,553*PDO)+(0,2793*PNA*PNA)-(1,6664* PNA*PDO)+(41,3915*PDO*PDO)



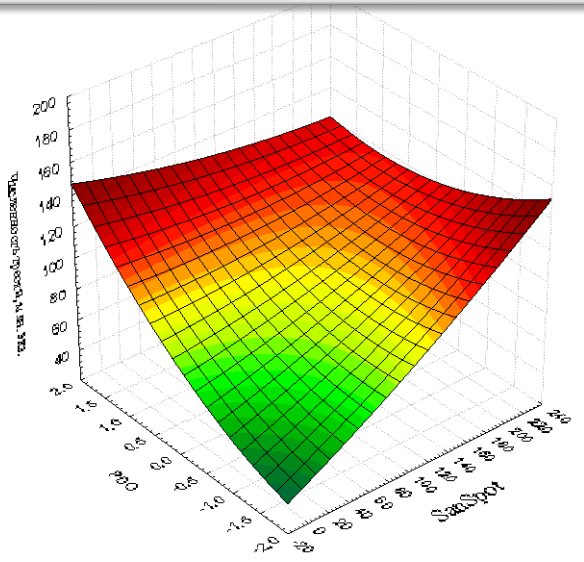

| R | $R^2$ | p | Indices |
|---|---|---|---|
| 0,49 | 0,24 | <0,05 | PNA, PDO |

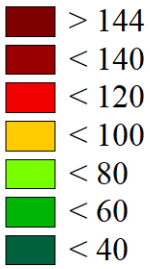
# Results

The correlation between the **Pacific cod** stock abundance (mln.) and the most strong climatic indices on the data for 1971–2018

## With the lag of 1 year

**Stock abundance Pacific cod**
=78,3453+(0,0981*SanSpot)+(24,2011*PDO)+(0,0003*SanSpot *SanSpot)-(0,1324*SanSpot*PDO)+(4,1401*PDO*PDO)

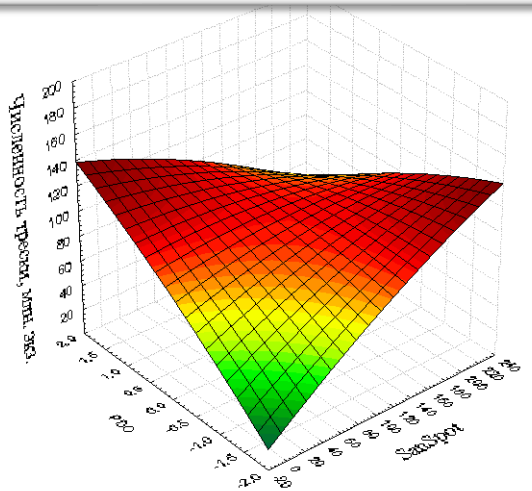


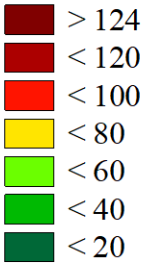




| R | $R^2$ | p | Indices |
|---|---|---|---|
| 0,31 | 0,15 | <0,05 | SanSpot, PDO |

## With the lag of 4 years

**Stock abundance Pacific cod**
=87,9104+(0,1659*SanSpot)+(26,3234*PDO)-(0,0005*SanSpot*SanSpot)-(0,2058*SanSpot*PDO)-(1,7074*PDO*PDO)




| R | $R^2$ | p | Indices |
|---|---|---|---|
| 0,50 | 0,24 | <0,01 | SanSpot, PDO |

# Conclusion

- In **direct correlative** analysis the prolific generations of **saffron cod** appeared with increasing temperature anomalies of the surface of sea of Okhotsk near the Western coast of Kamchatka (SSTa) (r = 0,58). Highly reliable negative correlation was obtained between the number of fish generation reached mass puberty and the ice coverage of the Okhotsk sea (Ice OkhS) (r = -0.66).

- With a lag of 1 year **Pacific cod** was noted high reliable correlation with Ice OkhS (r =0.84). With a long-term lag (4 years), the strongest dependence was obtained with phase change Pacific decadal oscillation (PDO) (r = 0.69).

# Conclusion

- **Stepwise multivariate regression analysis** has showed the greatest impact the indices **PNA** on **saffron cod**, and the indices PDO on **Pacific cod**. All the obtained results showed the presence of true relationships with the number of generations of fish in the second year of life and with the number of generations of fish that have reached more than 50% of maturation.

- On the basis of the obtained equations of multiple regression of the relationship between the numbers of fish with the selected most active climatic indices, three-dimensional regression models were constructed, satisfactorily describing the dynamics of the initial numbers of fish.


Thank you
for your
attention!