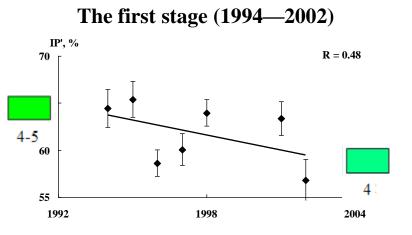**EFFECT OF EUTROPHICATION, TOXIC POLLUTION AND DREDGING ON BIODIVERSITY OF BENTIC ANIMALS, AND WATER QUALITY OF THE NEVA ESTUARY.**
Evgenia Balushkina, Sergey Golubkov
Zoological Institute of the Russian Academy of Sciences

The Neva estuary condition has been studied by the scientists of Zoological Institute of the Russian Academy of Sciences since 1982. 188 taxa of benthic animals were recorded in the Neva Estuary in 1982–2017. The long-term studies carried out by Zoological Institute of RAS have shown that the state of the bottom biological communities in the eastern Gulf of Finland are directly related to the quality of water and bottom sediments reflecting such anthropogenic impacts as eutrophication of open and coastal waters of the Gulf of Finland and their contamination by toxic substances. During the study period (1982–2017) the number of species, species diversity, abundance, biomass and production of benthic animals in the Neva Bay and in the eastern part of the Gulf of Finland were largely determined by toxic pollution and by the rate of primary production of the ecosystem. Indicator species of α-meso and polysaprotoxobic waters became predominant among the widespread oligochaetes and chironomid larvae.

Classes of water quality and a state of ecosystems according to zoobenthos indices St, No/Nc, Kch, 1/BI and Integrated Index IP′
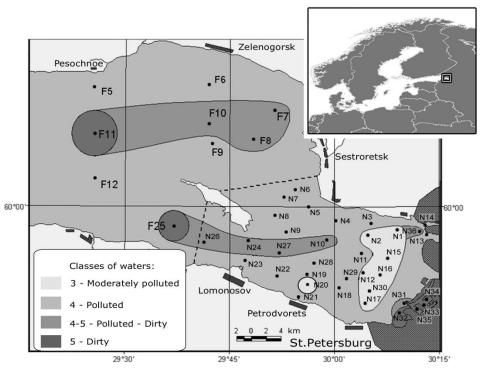
№	Classes of waters	State of the ecosystem	St	No/Nc	Kch	1/BI	IP′
			%				
1	Very clean		<25	25	<1.22	<10	<9.05
2	Clean	Relatively satisfactory	25 - 37.5	0 - 50	1.22- 9.4	10 - 20	9.05 - 29.2
3	Moderately polluted	Tense	37.5 - 62.5	50 - 60	9.4- 56.5	20- 33	29.2- 53
4	Polluted	Critical	62.5 - 80.2	60 - 77.6	56.5- 74.2	33 - 33	53- 66.2
4-5	Polluted--dirty	Crisis	80.2 - 87.5	77.6- 80	74.2- 78.26	33- 50	66.2- 73.9
5	Dirty	Catastro-phic	87.5 - 100	80 - 100	78.26 - 100	50- 100	73.9- 100

Different dimensionality of the indices hampers comparison of their absolute values. Therefore, we expressed parameters St, Kch and 1/BI as percentage from their maximum values. The scale of the new integrated index (IP′) is calculated as an average value of the sum of four or three of these indices.
Since 1994 the Integrated index IP′ has been widely used for the assessment of water quality in Leningrad Region and many other regions in Russia.
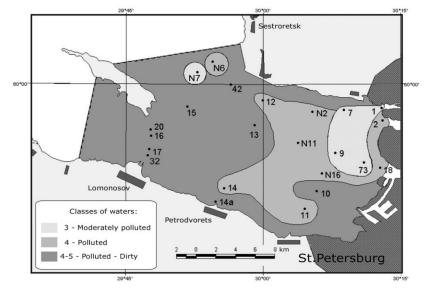
We used for the development of new Integrated index IP′for the assessment of water quality the following indices : 1) Trent Biotic Index BI (Woodiwiss 1964), 2) Index Kch (Balushkina 1987), 3) Index No/Nc (Goodnight, Whitley 1961) 4) Saprotoxobic index St (Jakovlev, 1988) based upon the indicator value of separate species in relation to toxic and organic pollution.

The first stage (1994—2002)

IP', %

R = 0.48

4-5

4

Assessment of the ecosystems state and quality of waters in the Neva Bay and in the Resort District of the eastern Gulf of Finland by Integrated index IP' in 1997.

Classes of waters:

3 - Moderately polluted

4 - Polluted

4-5 - Polluted - Dirty

5 - Dirty

Four stages were noted in the study period 1994-2015. During the first one (1994—2002), processes of restoring of the ecosystem in the Neva Bay, related to the decline of industry in St. Petersburg were observed. In 1994–1997, due to this decline and a decrease in anthropogenic impact on the ecosystem of the Neva Bay, the species diversity of benthic animals increased. Freshwater species of chironomids from subfamilies Diamesinae and Orthocladiinae – clean water indicator s appeared. *IP'* consistently reduced from 58.8 to 48.5%. As a result water quality and state of ecosystem improved by one class. Waters assessed in 1994 – 1995 as "polluted", in 1996 -1997 were assessed as "moderately polluted" the "critical" state of the ecosystems changed for the "tense" state.

Results of statistical analysis showed that in 1994—1997 the number of species in the Neva Bay was determined largely by toxic pollution (heavy metals, oil products and mercury in the water and bottom sediments) and to a lesser extent by primary production values of the ecosystem.

Assessment of the quality of waters and ecosystems state of the Neva Bay by Integrated index IP' in 2001.
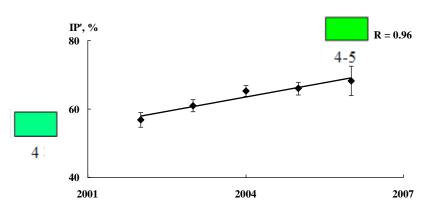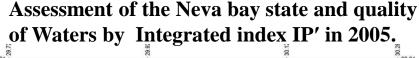

Parameters of equation of relationship between integrated index (IP', %) and depth (h, m), primary production (A, gC·m⁻²·day⁻¹), decomposition of OM (D, gC·m⁻²·day⁻¹), phosphorus concentrations (Ptot, mcgP/l) in the Neva Bay.

Parameters of equation of relationship between integrated index (IP', %) and depth (h, m), primary production (A, $gC \cdot m^{-2} \cdot day^{-1}$), decomposition of OM ($D$, $gC \cdot m^{-2} \cdot day^{-1}$), phosphorus concentrations (P_{tot}, mcgP/l) in the Neva Bay.
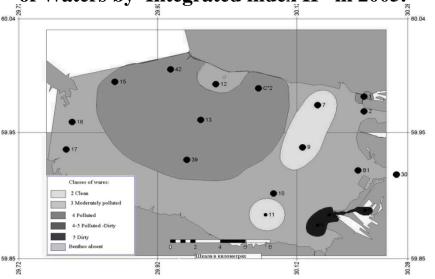
	B′	Std.Err.	t(4)	p-level	R
Intercept	31,93	5,28	6,05	0,10	
A	26,28	5,25	5,01	0,13	
h	5,92	1,51	3,92	0,16	**0.99**
D	-8,75	2,96	-2,96	0,21	
P$_{tot}$	0,05	0,03	1,39	0,40	

In 1998 the area of «moderately polluted» waters in the Neva Bay decreased, and adjoining areas were assessed as «polluted—dirty» and the ecosystem state as "crisis". In 2001, the state of this region slightly improved, but most of the waters in the Neva Bay were assessed by *IP'* as «polluted» and «polluted—dirty», the state as "critical" and "crisis".

Results of statistical analysis show that in 1994-1997 the number of species of bottom animals in the Neva Bay is determined largely by toxic pollution (heavy metals, oil products and mercury in water and bottom sediments) and to a lesser extent by primary production values of the ecosystem.

Analysis of the impact of biotic and abiotic factors on the *IP'* in the Neva Bay in 2001 showed high significance of primary production, depth, and lower significance of destruction of organic matter and total phosphorus concentrations.

The second stage: 2003—2006

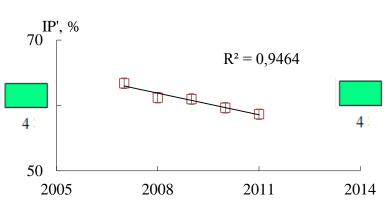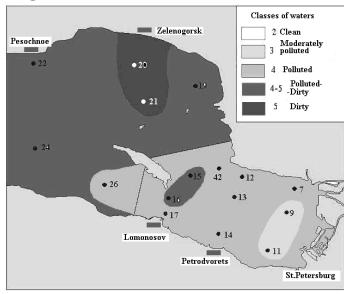**Assessment of the Neva bay state and quality of Waters by Integrated index IP′ in 2005.**

The period 2002—2006 was accompanied by revival of industry, construction of ports, active navigation, development of sea façade and completion of the construction of the St. Petersburg Flood Prevention Facility Complex. A large amount of suspended matter was produced due to dredging, this matter was carried over considerable distances, substantially worsening the conditions of existence of both benthos and phytoplankton.

As a result, the number of species of benthic animals in the second period declined from 23±2 to 15±2 species at one station, and index of species diversity declined from 3±0.2 to 2.6±0.2 bit/ind.

In 2005 waters of class 3 were recorded only at 3 stations of the Neva Bay in the regions of maximum flow velocity.

Average for the Neva Bay values of *IP′* increased during this period from 56.8% in 2002 to 68.2% in 2006. The state of the ecosystem of the Neva Bay in 2006 was the worst during the period of observations and was assessed as "crisis", waters, as "polluted-dirty" (4-5th class).

The third: 2007—2011 гг.

IP', %

70

R² = 0,9464

4:

4:

50

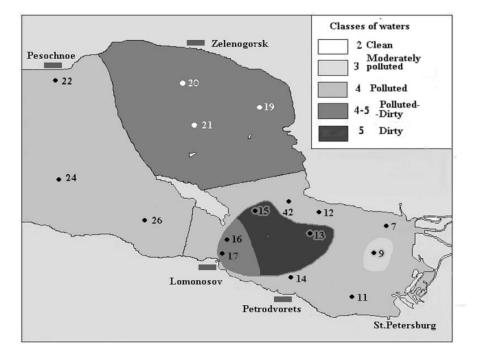2005   2008   2011   2014

Assessment of the state and quality of waters of the Neva Bay and Resort District of the eastern Gulf of Finland by integrated index IP′ in 2010.
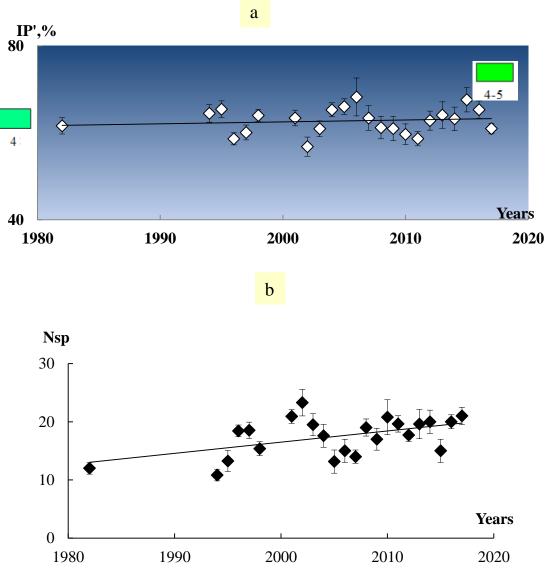

In the subsequent years (the third stage, 2007—2011) the improvement of state of the Neva Bay was related to cessation of large-scale dredging that accompanied the construction of St. Petersburg sea façade. In this period the average for the Neva Bay values of *IP′* declined with certain fluctuations from 63.4% in 2007 to 58.7% in 2011. The state of the ecosystem was assessed as "critical" and water quality improved to class 4 ("polluted"). The average number of species of benthic animals at one station increased from 14±1 to 20±1 species per station and average value of the Shannon species diversity index also increased from 2.4±0.2 to 3.1±0.2 bit/spec.

In 2005–2009 a study was conducted on the influence of hydrophysical and hydrochemical parameters of the Neva Estuary on zoobenthos structural characteristics and on the values of calculated indices. Statistical analysis showed that with growing concentrations of oil products, lead, zinc, caesium (Cs 137), and chromium in near bottom waters and bottom deposits of the Neva Bay a decline of species richness and species diversity of benthic animal was observed.

Assessment of the Neva Bay and Resort District of the eastern Gulf of Finland state and quality of waters by integrated index IP′ in 2013.
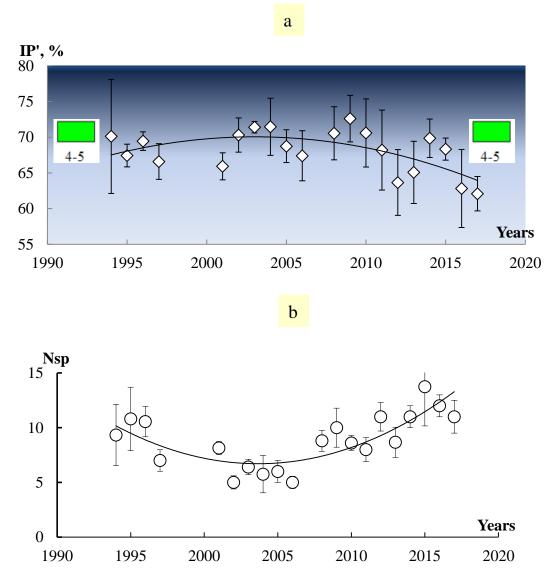

The period 2012-2017, accompanied by a large-scale hydrotechnical works: building of a Marine Multifunctional Reloading Complex (MMRC) "Bronka" and approach fairway to it. In 2013 waters 4-5 transition class notes near Lomonosov district (st. No 17, IP'=67.3) and in the station area No 16 (IP'= 71.8). The worst water quality «dirty» (5th class) in 2013 year was registered near stations 13 ($IP' = 74.1$) and 15 ($IP' = 80.9$ %) .

Average for the Neva Bay values of IP' increased during the fourth stage from 62.8 ±2 in 2012 to 67,6 ± 3% в 2015 г. State of the Neva Bay in 2015 was almost the same as in 2006 and was assessed as "crisis", and water assessed as "polluted-dirty" (4-5 class). The average number of benthic species at one station in this period regularly declined from 18±1 to 15±2 species per one station in 2015 , and average for Neva Bay value of index of species diversity almost did not change: from 2.8±0.2 to 2.7±0.2 bit/ind.

Water quality assessment (a) and number of species at one station (b) in the Neva Bay according to *IP'* in 1982 and 1994-2017. Calculated from the data of 334 research stations.
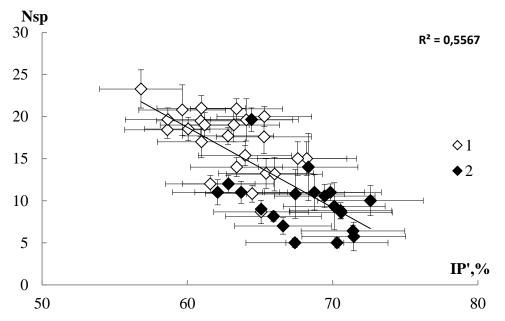

On average the water quality in the Neva Bay according to *IP'* values was relatively stable during 1982-2017 period. It was assessed as «polluted» (4-th class) with exception for abnormality in 2006 and 2015 (4-5-th class) caused by large-scale dredging works.

The average number of species of zoobenthos (at one station) in the Neva Bay increased in the period 1982 -2017 almost 2 times: from 11±1 to 21±2 species per station. Average values of the biodiversity indices of benthic animals in the Neva Bay increased from 2±0.1 to 2.8±0.2 bit/ind.

Water quality assessment (a) and number of species at one station (b) in the Resort District of the eastern Gulf of Finland according to *IP′* in 1994-2015. Calculated with the data from 131 research stations.

a

b

Average values of *IP′* varied in 1994–2017 from 65.9±1.9 to 72.6±3.3%, (except 2012–2013 and 2016–2017) characterizing on the average the state of the Resort District of the eastern Gulf of Finland as "crisis", and waters as "polluted-dirty" (4–5th class of waters), one class lower than the waters of the Neva Bay. In the Resort District of the eastern Gulf of Finland mean values of the IP′ changed during the period 2012–2013 from 63.7±5 to 65.1±4 % and during the period 2016–2017 from 62.1±2 to 62.8±5 %, characterizing the state of the ecosystem as "critical" and water quality as "polluted", as well as the water of the Neva Bay. In 2014–2015 the state of this part of the estuary significantly worsened and assessed as "crisis", and the water as "polluted-dirty."

Relationship between the average number of species at one station (*Nsp*) and Integated index (*IP′*) in the Neva Bay (1) and the Resort District of the eastern Gulf of Finland (2) in 1994-2017 for 450 examined stations.

In the Resort District of the eastern Gulf of Finland eurybiont species of freshwater animals were noted: oligochaetes, chironomid larvae. At present, relict crustaceans *Mysis relicta* Loven, *Saduria entomon* (L), and *Monoporeia affinis* Lindstr in that zone are represented by only rare specimens. As a consequence of pollution species diversity and number of species of benthic animals (*Nsp*) at one station in the Resort District of the eastern part of the Gulf of Finland was significantnly lower than in the Neva Bay. As a result of more intensive pollution (*IP′*) species composition and abundance of macrozoobenthos in the eastern part of the Gulf of Finland were determined by a combination of natural and anthropogenic factors that were unfavorable for their development

Conclusion

Conducted studies have shown a high extent of dependency of structural characteristics of benthic animals on hydrophysical and hydrochemical characteristics of water and bottom sediments. Average structural characteristics of benthic animal communities - species number and species diversity index showed a high value of dependency on eutrophication, toxic pollution, and dredging in the Neva Bay and in the Resort District of the eastern Gulf of Finland. Assessment of water quality of Neva Bay in 1994—2017 by Integrated Index *IP'* remained relatively stable, waters (except in 2006 and 2015) were assessed as "polluted" (4th class), and state of the ecosystem as "critical". As compared to the Neva Bay habitat conditions of animals in the eastern Gulf of Finland were worsened and determined by a combination of natural factors unfavorable for development of benthic animals and anthropogenic impact. Therefore species diversity of benthic animals in the Resort District of the eastern part of the Gulf of Finland is notably lower than in the Neva Bay.

THANK YOU FOR YOUR ATTENTION !