ZOOLOGICAL INSTITUTE OF RUSSIAN ACADEMY OF SCIENCES
St. Petersburg

Anthropogenic carbon as a basal resource in the benthic food webs in the Neva Estuary (eastern Gulf of Finland)

Sergei Golubkov[1], Mikhail Golubkov[1], Alexey Tiunov[2], Anna Demchuk[1]

[1]Zoological Institute of RAS, St. Petersburg, Russia;

[2]Institute of Ecology and Evolution of RAS, Moscow, Russia

Introduction

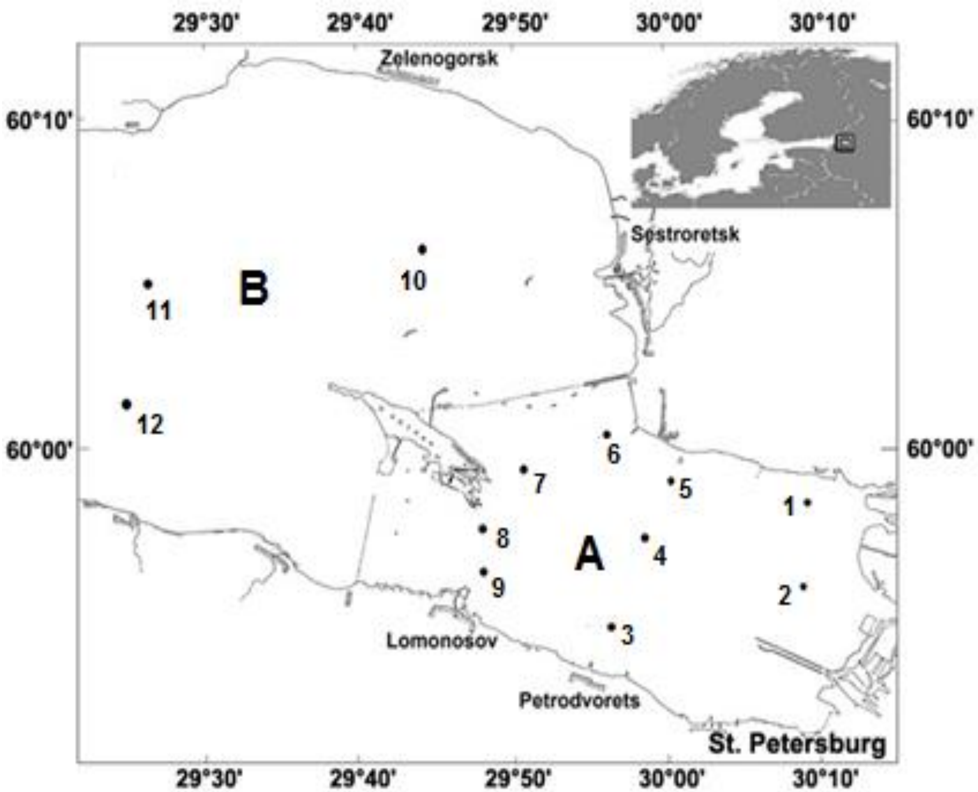
Organic pollution is a serious environmental problem for the coastal zones of the Baltic Sea (HELCOM, 2015). Species composition of zoobenthos shows high organic pollution both in the upper and middle parts of the Neva Estuary. **Domestic wastewaters** are enriched by labile organic compounds and can be an important source of carbon for aquatic invertebrates. Alternative food sources for benthic consumers in the estuary are **autochthonous organic matter produced by phytoplankton** and **allochthonous carbon predominately of natural origin** coming from the Neva River.

Therefore, detail investigations of different forms of OM coming from the watershed and creating in the system are required to realize their role in ecosystem function and to develop effective remedial measures.

The aim of the study was to evaluate the importance of **allochthonous carbon of anthropogenic origin** coming from St. Petersburg City for benthic food webs of the estuary.

Study sites and methods

Sampling stations in the Neva Bay (A) and Inner estuary (B)



Stable isotope analysis (SIA) of carbon and nitrogen of seston (suspended organic matter) (1) of allochthonous predominately natural origin coming from the Neva River, (2) seston enriched with waste waters, and (3) seston from pelagic zone of the estuary mostly consisting of phytoplankton and the tissues of macroinvertebrates and fish were analyzed to quantify basal resources of carbon for consumers. We applied **Bayesian mixing model** running on R Software **SIAR** to depict the contribution of different sources in the diet of a consumer. We also determine the concentrations of chlorophyll *a* and seston in the water and abundance of zoobenthos

Mean biomass (g ww m^{-2}, ±SE) of zoobenthos in the Neva Bay and in the Inner estuary in 2013–2015.

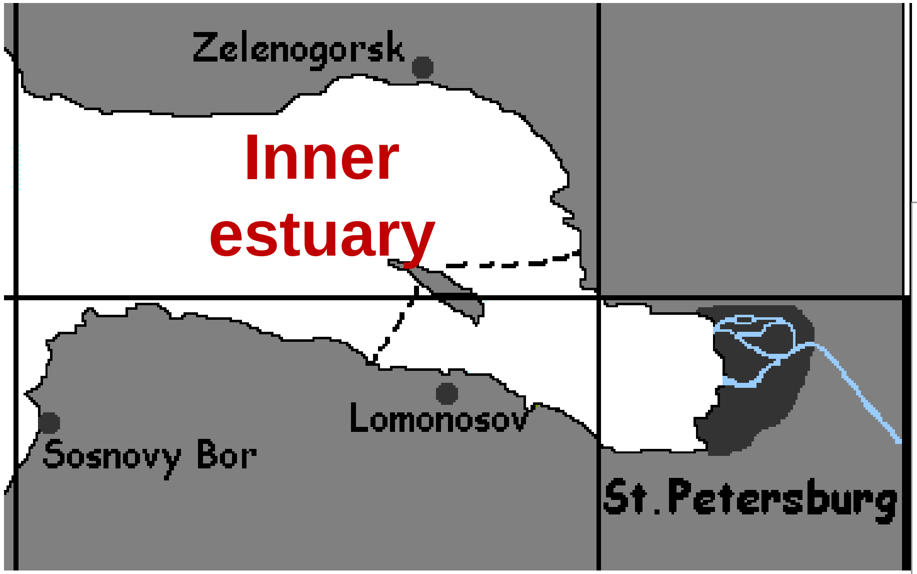
Group, species	Neva Bay	Inner Estuary
Oligochaeta	3.45 ± 0.24	1.38 ± 0.31
Marenzelleria arctia	–	9.14 ± 1.36
Mollusks (Unionidae)	20.44 ± 4.09	–
Chironomidae	0.19 ± 0.03	0.45 ± 0.08
Other	1.49 ± 0.32	0.20 ± 0.05

Polysaprobic species typical for highly polluted environments, oligochaetes ***Limnodrilus hoffmeisteri***, ***Potamothrix hammoniensis*** and chironomid ***Chironomus plumosus***, were among the dominants in both parts of the estuary.

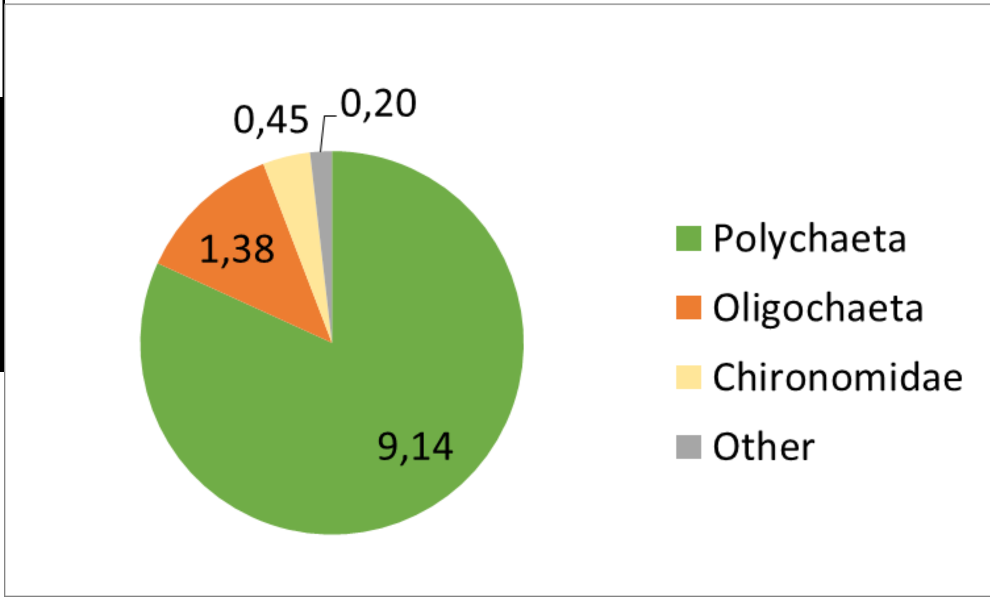
Limnodrilus hoffmeisteri

Chironomus plumosus

Zoobenthos in the Inner estuary



Mean biomass (g WW/m^2) of the dominant groups of zoobenthos in the Inner estuary in 2013–2015



Alien *Marenzelleria arctia* (Polychaeta) sharply dominates in the Inner estuary nowadays

Percentage of chlorophyll *a* in seston and its isotopic signature ($\delta^{13}C$ and $\delta^{15}N$) in different parts of the Neva Estuary, in the Neva River and in waste waters (±SE)

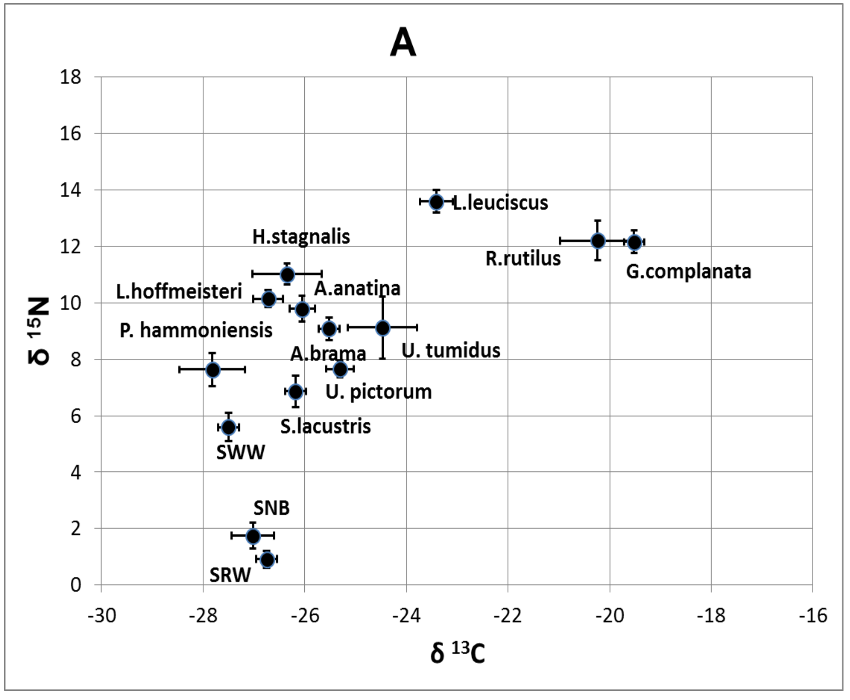
Waters	Chlorophyll *a* in seston, %	$\delta^{15}N$, ‰	$\delta^{13}C$
River waters	0.07 ± 0.01	0.9± 0.1	–26.8 ± 0.1
Waste waters	0.07 ± 0.06	5.6± 0.5	–27.5 ± 0.1
Neva Bay waters	0.13 ± 0.09	1.8± 0.5	–27.0± 0.4
Inner Estuary waters	0.89 ± 0.22	5.0± 0.2	–23.2± 0.6

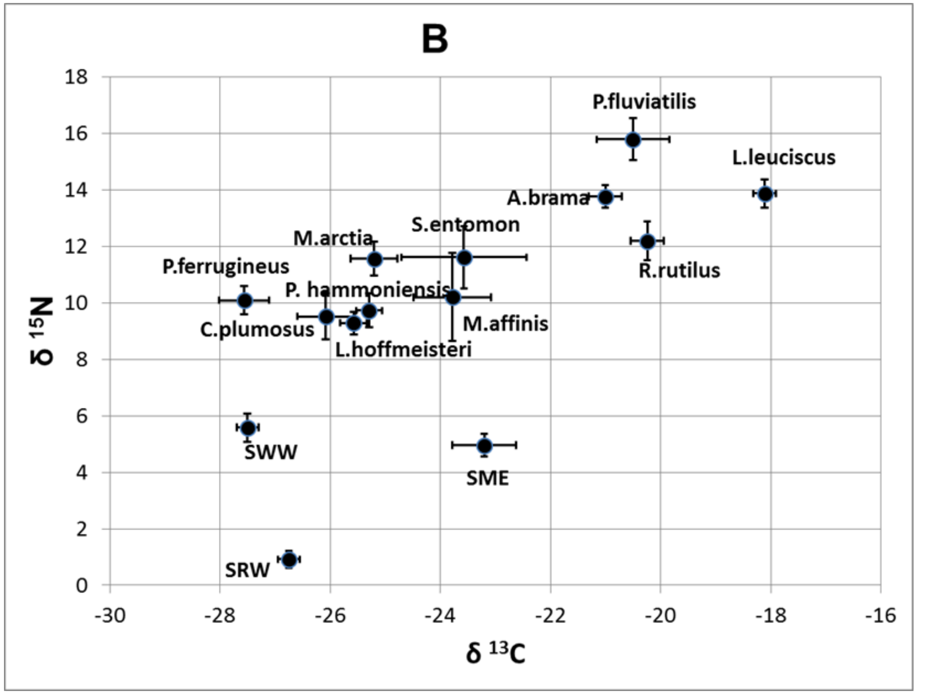
The portion of chlorophyll *a* in seston at the mouth of the Neva River and near the outlet manifold was about two times less than the average in the seston from the Neva Bay. The portion of chlorophyll *a* in the seston in the Inner estuary was significantly higher than in the Neva Bay. This indicates that the autochthonous organic matter produced by phytoplankton was of a great importance in the seston of this part of the estuary.

There was a strong isotopic separation between different sources of carbon and nitrogen in the different parts of the Neva estuary. The $\delta^{15}N$ signature of seston enriched by sewage waters was higher than the signatures of seston coming from the river.

Isotope signatures of seston and benthic consumers in the Neva Bay (A) and in the Inner estuary (B).

SRW and SWW – isotope signature of seston from the Neva River and from waste waters, SNB and SME – average isotope signatures of seston in the Neva Bay and in the Inner estuary.



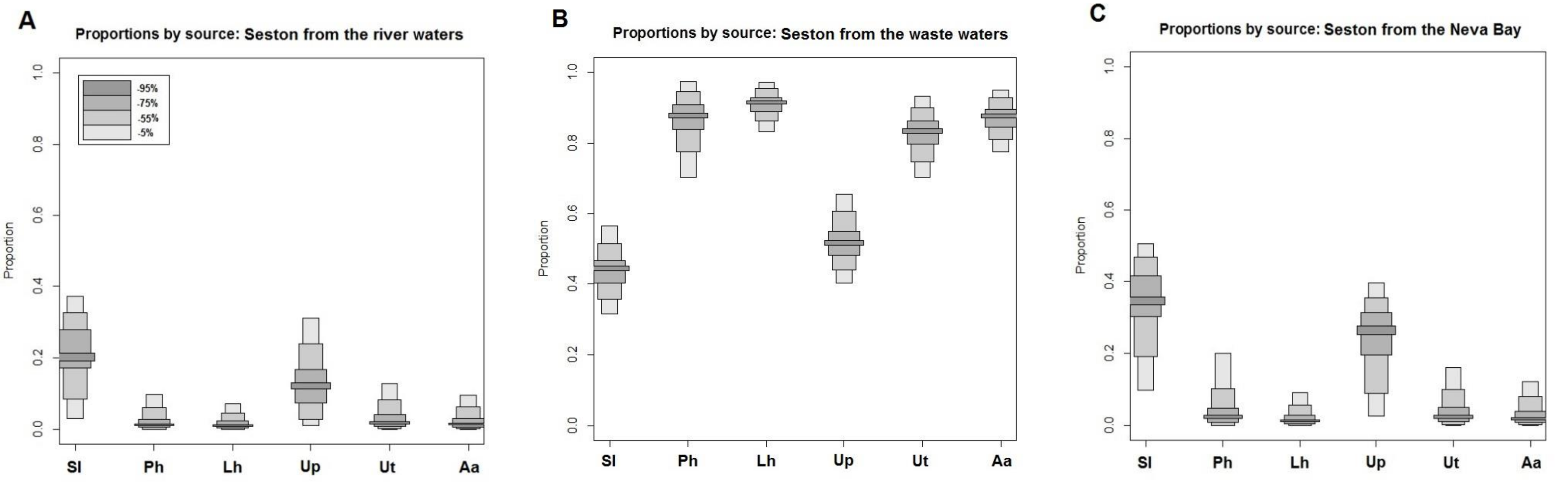


The isotopic signatures of consumers varied in a wide range, reflecting differences in the use of different resources and in the trophic level

Model SIAR estimates of use of different basal resources for non-predatory macroinvertebrate consumers in the Neva Bay.

Sl – *Stylaria lacustris*, Ph – *Potamothrix hammoniensis*, Lh – *Limnodrilus hoffmeisteri*, Up – *Unio pictorum*, Ut – *Unio tumidus*, Aa – *Anodonta anatina*.

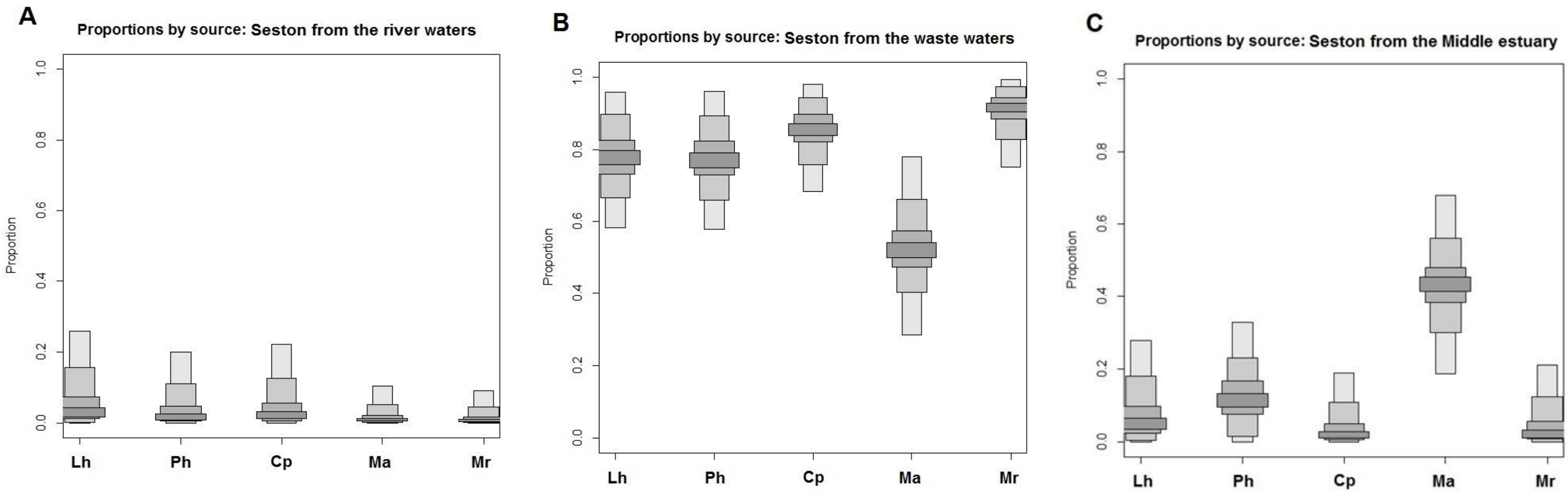
The dark grey, grey, light grey and white are 95%, 75%, 55% and 5% credibility intervals.



According to the SIAR modeling, the organic matter of wastewaters was an important source of carbon for the most of non-predatory macroinvertebrate consumers in the Neva Bay (B). On the contrary, contribution of the seston discharging by the river waters was relatively low (A). The use of seston from the Neva Bay, which was enriched by phytoplankton algae, was also lower than the use of seston from sewage waters. Only for oligochaete *S. lacustris* and mollusk *U. pictorum* this source of carbon was significant

Model SIAR estimates of use of different basal resources for non-predatory macroinvertebrate consumers in the Inner estuary.

Lh – *Limnodrilus hoffmeisteri*, Ph – *Potamothrix hammoniensis*, Cp – *Chironomus plumosus*, Ma – *Monoporeia affinis*, Mr – *Marenzelleria arctia*.

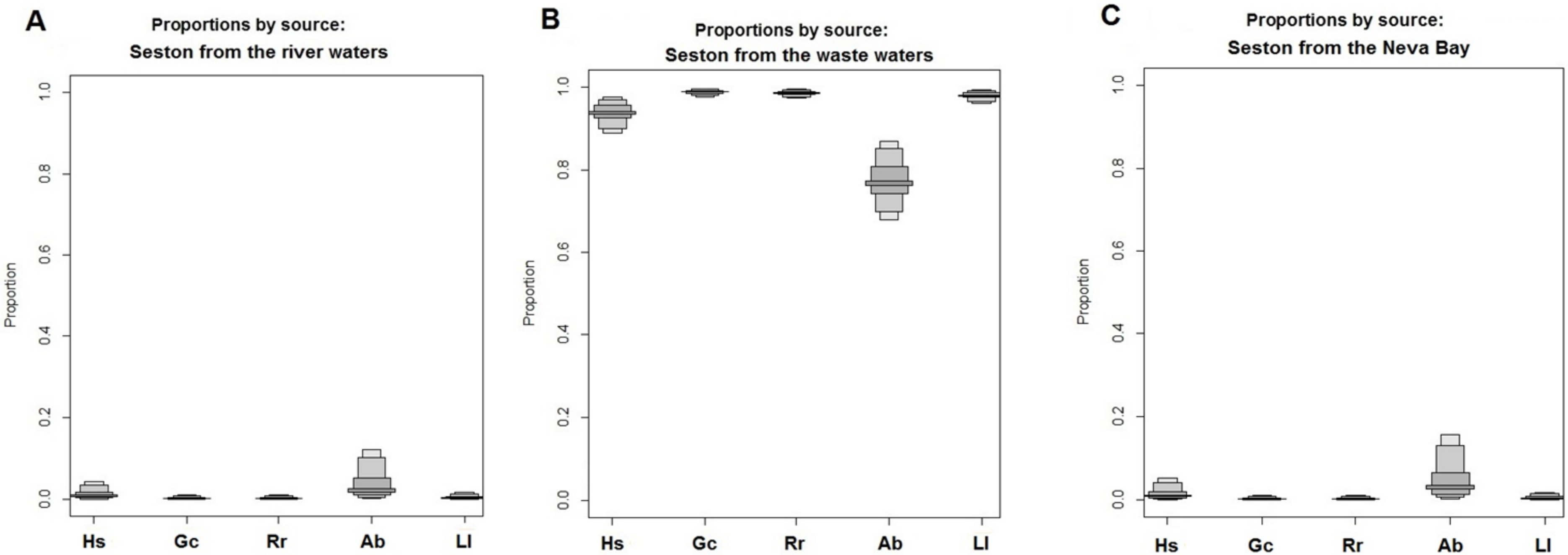


In the Inner estuary, the role of seston from the Neva River as a source of carbon for non-predatory macroinvertebrate consumers was negligible (A), carbon of waste water was an important source of carbon for the most of them (B) including *Marenzelleria arctia* . The use of seston from the Inner estuary enriched by phytoplankton was high only for crustacean *Monoporeia affinis* (C).

Monoporeia affinis

Model SIAR estimates of use of different resources for predatory macroinvertebrates and fish in the Neva Bay

Hs– *Helobdella stagnalis*, Gc – *Glossiphonia complanata*, Rr – *Rutilus rutilus*, Ab – *Abramis brama*, Ll – *Leuciscus leuciscus*

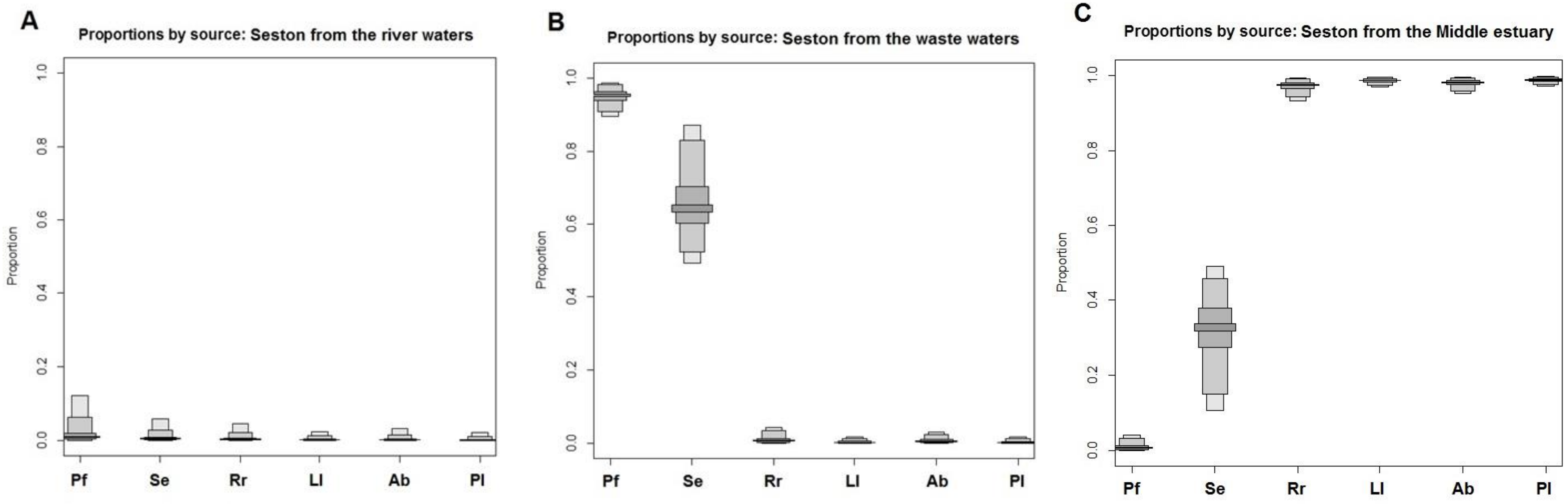


According to SIAR model predatory macroinvertebrates and fish in the Neva Bay also mostly relied on the carbon of sewage waters as a basal resource (B). They used this resource indirectly via benthic macroinvertebrates, tubificid worms, which are dominant in non-molluscan zoobenthos and in turn basically rely on wastewater-derived carbon

Leuciscus leuciscus

Model SIAR estimates of use of different resources for predatory macroinvertebrates and fish in the Inner estuary

Pf – *Procladius ferrugineus*, Se – *Saduria entomon*, Rr – *Rutilus rutilus*, Ll – *Leuciscus leuciscus*, Ab – *Abramis brama*, Pf – *Perca fluviatilis*



In Inner estuary, the main source of carbon for fish was the seston of open waters consisting mainly of phytoplankton (C). On the contrary, predacious invertebrates, crustacean *S. entomon* and chironomid larvae *P. ferrugineus*, mostly used waste waters as a basal source of carbon (B), feeding on *Marenzelleria arctia* and *Chironomus plumosus,* which used waste-water derived carbon for their production

Saduria entomon

Discursion

- The SIAR modeling showed that most of the non-predatory macroinvertebrates in the Neva Estuary nowadays used wastewater-derived carbon as a basal resource for their production.
- Organic matter consumed by bottom macroinvertebrates is a mixture of phytoplankton and detritus, coming from the waters of the Neva River and sewage. However, the **assimilation efficiency** of different components of this mixture can be different. POM from domestic wastewater is enriched by carbohydrates, lipids and proteins and their basic monomers: monosaccharides, amino acids, long chain fatty acids (Samer, 2015) that are easily utilize by invertebrates. Natural detritus coming with river waters mostly consists of recalcitrant compounds that are poorly assimilated by consumers (Wetzel, 2001; Karlsson et al., 2003). Phytoplankton-derived POM has an intermediate nutritional value, since it also includes substances resistant to biodegradation such as cellulose.
- Benthic non-predatory macroinvertebrates dominated nowadays in the Neva Estuary, tubificid worms, chironomid larvae and alien polychaete, are preadapted to or even benefit from high organic pollution. They succeeded previously dominated ingenious crustaceans, which mostly relayed on phytoplankton-derived carbon for their production.
- Results of this study confirm the importance of allochthonous organic matter for food webs in estuaries, but show the need to distinguish between different sources of this matter to develop effective remedial measures of their biodiversity

Acknowledgements

The investigations were supported by

- State Contract no. AAAA-A17-117021310121-0 wit the Russian Ministry of Science and Education
- the Presidium of the Russian Academy of Sciences, Program № 41 «Biodiversity of natural systems and biological resources of Russia»


Thank you for your attention!