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THE VASCULAR PLANTS AND EPILITHIC LICHENS OF FRESH-WATER COASTAL ECOSYSTEMS IN THE MONITORING OF HYDROSPHERE' CONDITION

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Abstract

The existential organization, the value of separate species or groups of species of the vascular plants and epilithic lichens in the vegetative cover composition, the estimation of their physiological potential have been investigated in our work. During 2009-11 years the lenthic ecosystems of Northwest of Russia (Karelia) – the second-largest lake in Europe – Onego Lake and the lothic ecosystems – the rivers Suna and Lososinka, differing on level of their exploitation and water composition have been investigated. The state of pigment apparatus at 5 species of vascular plants – 3 hydrophytes – *Potamogeton crispus, Sagittaria sagittifolia, Nuphar luteum* and 2 hygrophytes – *Carex acuta*, *Carex visicaria* – is analyzed. At *Carex visicaria* the change touches all parameters of the pigment apparatus while at *Carex acuta* the changes concern only the ratio of chlorophylls and do not influence on the values of light-gathered complex. At *Nuphar lutea and Sagittaria sagittifolia* the pigment apparatus only at underwater leaves has shown the significant response to change of Mg^{2+} contents. The pigment apparatus of surface leaves at *Nuphar lutea* has not shown the significant answer to chromaticity of water. At *Potamogeton crispus* the contents of pigments in surface and underwater leaves decreased at the increase in the contents of nitrogen. The analysis of the general projective covering and floristic composition of lichen cover has shown, that with the increase in the water the nitrogen and phosphorus contents, the number of species of lichens decreases. Thus, the coastal plants and the lichen cover can be used for the express train-analysis at specification of trophic characteristics of fresh-water reservoirs of the north of Russia.

Keywords: vascular plants, epilithic lichens, Northwest of Russia, pigment apparatus of high plants, fresh-water coastal ecosystems

1 INTRODUCTION

The multilateral studies of coastal freshwater ecosystems are carried out quite a long time; the greatest attention is paid to the study of species composition, to the definition of the indicator properties of plants, lichens and coastal communities to assess the status of the hydrosphere and its influence on terrestrial biota (Wetlands International, Annual Report, 2010; Peatlands….2012; Fresh Water: The Essence of Life, 2010). The spatial-temporal organization, the value of individual species or groups of species in the composition of plants and lichen cover, the evaluation of physiological potential of plants and lichens of the coastal areas as the structural-functional features of the wetland coastal ecosystems, which can be used in the monitoring system of the hydrosphere in terms of natural and human-induced changes deserve the special attention.

2 METHODOLOGY

2.1 Study area

During the 2010-11 years the water and coastal plants and epilitic lichens in the conditions of freshwater reservoirs on the territory of the North-West of Russia, on the watercourses and on the coast of the Onega Lake of Republic of Karelia, in the several places with different levels of exploitation and pollution were examined. Onega Lake is one of the largest lakes in Europe. The chemical composition of water of Onega Lake is formed by the river flow, underground and anthropogenic runoff and by precipitation. With the waters of the three major inflows (p.Shuya, p. Suna, p. Vodla) and with waste waters of large industrial centers - Petrozavodsk and Kondopoga towns into the Lake up to 70% of all dissolved substances have inflowed.

The water of the rivers Shuya and Lososinka, bearing in the Petrozavodsk Bay the persistent and labile organic matter (Lake Onego...1999), as well as drainage and flood runoff from the territory of the Petrozavodsk city also have a great impact for the state of the aquatic environment.

The surface runoff of the river Suna, the waste waters of the Kondopoga pulp-and-paper industrial complex, with high content of total phosphorus and nitrogen (Lake Onego...1999) strongly influenced on the chemical composition of water of Kondopoga bay.

Points for investigations: on the Suna river – the nature reserve «Kivach», the vil. Yanischpole, the mouth of the Suna river, on the coasts of the Onega Lake – Kondopoga city the higher plants have been studied; the epilitic lichens – on the 5 plots have been investigated: on the Suna river – the vil. Yanischpole, on the coasts of the Onego Lake – Kondopoga city, Petrozavodsk city: the Botanical garden of Petrozavodsk, on the Lososinka river.

2.2 The objects under study

Plant communities in the plots and the model species of hydrophytes group – *Nuphar lutea* (L.) Sibth. et. Sm., *Potamogeton crispus* L., *Sagittaria sagittifolia* L. and hygrophytes group – *Carex acuta* L., *Carex visicaria* L. and the epilitic lichens on the coastal boulders and/or rock massive abruptions. All these species are growing on the border of the land and water environments along the gradient moistening.

2.3 Methods

The work was carried out during 2009-2011 years.

Geobotanical. On each plots the geobotanical descriptions (Katanskaya, 1981; Lisicina, et al. 1993; Papchenkov, 2003) and description of lichens cover have been made.

Physiological. The overground leaves of *Carex acuta*, *Carex visicaria*, the submerged leaves of *Potamogeton crispus*, the submerged and floating leaves of *Sagittaria sagittifolia* and submerged and floating leaves of *Nuphar lutea* were collected in three-time replication. The content of pigments determined by spectrophotometry (SF-26, Russia) according to standard techniques (Lichtenthaler, Wellburn, 1983; Lichtenthaler, 1987; Maslova et al., 1986; Maslova, Popova, 1993).

21 indices of chemical characteristics of water: biogenic elements, trace elements (iron, manganese, zinc, heavy metals, aluminum), oil products, performance of the gas regime of the reservoir (dissolved oxygen, carbon dioxide), pH indicators, alkalinity, conductivity, permanganate oxidation, CHOD (chemical oxygen demand), color have been analyzed.

Statistics method. The correlation analysis has been used.

3. RESULTS

All natural water reservoirs of Karelia Republic belong to the oligotrophic group of reservoirs, have the high values of the color, but in many reservoirs the content of iron have been exceeded. The chemical analysis of water has showed that the meaning of all indicators is significantly lower than the maximum permissible concentrations.

However, there is the considerable variation and high maintenance for indicators on some of the plots. The content of nitrogen nitrate varies from 0.01 (the river Suna, the vil. Yanischpole) to 2.7 mg/l (the Lososinka river, Petrozavodsk), the nitrogen organic – from 0.4 (in samples of the water in Lake Onega in the Petrozavodsk town and in the Lososinka river outside the city) to 3.8 mg/l (the river of Lososinka in the Petrozavodsk city area).

The content of total phosphorus change from 0,009 (the river Suna in the territory of the nature reserve «Kivach») to 0.2 mg/l (the excess of MPC, the river Lososinka in the district of La Rochelle). All the experimental data about the state of biota with relatively content of nitrogen and phosphorus were considered.

3.1 State of the plant communities

A state of wetland vegetation along the Suna River in the area from non impact territories to its flowing into Kondopozhskaya bay was studied. The flora of macrophytes (higher plants) includes 88 species, 49 species of them or 44.3% are coastal hydrophytes, 39 species are related to the actual water plants.

In the middle current of the river Suna within the nature reserves «Kivach» (nitrogen organic 0,630 mg/l; nitrogen ammonium 0,030 mg/l; nitrogen nitrate 0.005 mg/l; total nitrogen 0,665 mg/l; phosphate ion 0.001 mg/l; total phosphorus 0,009 mg/l) 60% of the total plant cover are occupied by the emergent vegetation of the *Carex acuta*, C. *vesicaria, Phragmites australis,* with small abundance (15%) *Elodea canadensis* have been marked.

Hygrophytes, floating on the water surface and hydrophytes, attached to the bottom with a floating leaves on the water surface – *Potamogeton* sp., *Sagittaria* sp., *Nuphar lutea* are rather well represented.

In the lower current (nitrogen organic 0,740 mg/l; nitrogen ammonium 0,046 mg/l; nitrogen nitrate 0,010 mg/l; total nitrogen 0,796 mg/l; phosphate ion 0,017 mg/l; total phosphorus 0,035 mg/l) the abundance of the emergent species of genus *Carex* is reduced at 30%, but in 2 times (up to 70%) the abundance of short herbs species, from genuses *Potamogeton, Sagittaria, Sparganium* is increased, and also the abundance of short herbs gelophytes - *Carex pallescens, Carex acuta* and high herbs gelophytes – *Sium latifolium, Lysimachia vulgaris, Naumburgia thyrsiflora* is increased up to 20%.

In the mouth of the river Suna (nitrogen organic 0,80 mg/l; nitrogen ammonium 0.04 mg/l; nitrogen nitrate 0.015 mg/l; total nitrogen 0,855 mg/l; phosphate ion 0,028 mg/l; total phosphorus 0,055 mg/l) the abundance of *Sagittaria sagittifolia, Alisma plantago-aquatica, Elodea canadensis, Stratiotes aloides, Myriophyllum spicatum* 70% is increased up to 70% in comparison with the point in the middle current of the river Suna. This phenomenon may judge about the increasing of the anthropogenic impact in the area.

The great abundance of *Lemna minor* testifies about the large quantities of biogenic substances in the environment, the development of *Spirodela polyrhiza* testifies about not only eutrophication, but also about the agricultural pollution. Besides that, the area of quagmire of hydrophytes – *Spirodella* sp., *Hydrocharis morsus-ranae* also increases.

In the composition and structure of the coastal wetland communities in the Kondopoga area (nitrogen organic 0,850 mg/l; ammonia nitrogen 0,100 mg/l; nitrate nitrogen 0,270 mg/l; total nitrogen 1,220 mg/l; phosphate ion 0,078 mg/l; phosphorus total 0,145 mg/l) the anthropogenic influence is evidenced strongly.

The structure of wetland vegetation becomes more simply – with low abundance (10% – 20%) - *Sagittaria sagittifolia, Nuphar lutea, Alisma plantago-aquatica* were found. *Potamogeton crispus, P. lucens* have been found with abundance up to 40%. The founded regularities in the change in the structure of wetland plant communities associated both with natural changes of water quality (the increasing eutrophication of reservoirs) and the reduction of the habitats' diversity in the process of eutrophication (silting of the bottom, the leveling of the coastline). *Carex acuta, C. visicaria, Nuphar litea, Potamogeton crispus, Sagittaria saggittifolia* are the most sensitive species, responding on the eutrophication increasing.

3.2 State of the pigment apparatus of high plants

On the model plants on transect from the water line into the depth of the water pool the comparison was carried out. *Carex acuta* and *C. vesicaria,* have been found on all plots of the transect, which is linked with terrestrial runoff of sewage water from the contaminated areas and waterways. To the increasing in the content of different forms of nitrogen and phosphorus in the water, these species react differently.

In response to the increasing in the content of total nitrogen in 2 times (from 0,665 to 1,220 mg/l) and the increasing of the total phosphorus in 16 times (from 0,009 to 0,145 mg/l) Carex *vesicaria* increases the content both chlorophyll (on 160% from 1.8 to 4.8 mg/g dry weight) and carotenoids (on 120% from 0.4 to 1.0 mg/g dry weight). Under the same conditions the increasing the content of carotenoids (on 500% from 0.3 to 1.8 mg/g dry weight) on the background of slight changes in the content of green pigments for *Carex acuta* have been observed.

For *Carex vesicaria* the effect of the stimulation of the process of synthesis of pigments have been noticed, but for *C. acuta* this level of pollution leads to a defensive reaction, which in the stimulation of synthesis of carotinoids is expressed. *Carex acuta* for this part of the transect was the more sensitive species..

The rooting *Nuphar lutea* having the differences in the anatomic-morphological structure of leaves: are they submerged and floating. This plant growing at depth up to 2 m. The content of pigments in the floating leaves of these plants increases with the increase of the content of compounds of nitrogen and phosphorus in the water pool (the content of total nitrogen from 0,665 to 1,220 mg/l and the content of total phosphorus 0,009 to 0,145 mg/l has increased). The content of chlorophylls increased on 44% - from 2.5 to 3.6 mg/g dry weight, the content of carotenoids – on 66% from 0.6 to 1.0 mg/g dry weight, which testifies the stimulation of synthesis of pigments. The submerged leaves have shown the sensitive reaction to the

content of total nitrogen and phosphorus, the content of chlorophylls has increased sharply (on 88% from 4.9 up to 9.2 mg/g dry weight).

Potamogeton crispus has only the submersed leaves, *Sagittaria sagittifolia* has the 3 categories of leaves: submerged, floating, and above-water. These plants growing at depth up to 3 m. In the submerged leaves of *P. crispus* with the increasing pollution (the content of nitrogen from 0,665 to 1,220 mg/l, total phosphorus from 0,009 to 0,145 mg/l), the content of chlorophylls decrease on 10% (from 9.8 to 8.8 mg/g dry weight) and the content of carotenoids increase on the 140% (from 1.0 to 2.4 mg/g dry weight), that testifies the strengthening of protective functions of the photosynthetic apparatus of plants. In S. *sagittifolia* the content of all pigments both in submerged leaves (the content of chlorophylls increased on 40% from 7.7 to 10.7 mg/g dry weight, carotenoids - on 45% from 2.0 to 2.9 mg/g dry weight) and in floating leaves (the content of chlorophylls increased on 29% from 6.8 to 8.7 mg/g dry weight, carotenoids – on 93% from 1.4 to 2.7 mg/g dry weight) has been increased. In response to increasing pollution the synthesis of pigments is intensified. These peculiarities showed the increasing of the synthesis of pigments in response to increasing pollution.

3.3 State of lichens biota

The coastal boulders of glacial origin or rock solid abruptions in the form of sheep's foreheads of magmatic origin have inhabited by the epilitic lichens. 28 species of epilitic lichens have been revealed in the investigated area. Such characteristic of the lichens cover, as the number of lichens in the geobotanical relevees is the most dependent on the chemical composition of water.

With the increase in the concentrations of phosphate-ions up to 0.03 (Fig. 1) and total phosphorus up to 0.05 mg/l (Fig. 2) the number of species epilitic lichens significantly reduced, which confirms the previously installed pattern on the other water pools (Sonina, Kornilov, 2010; Kornilov, 2011).

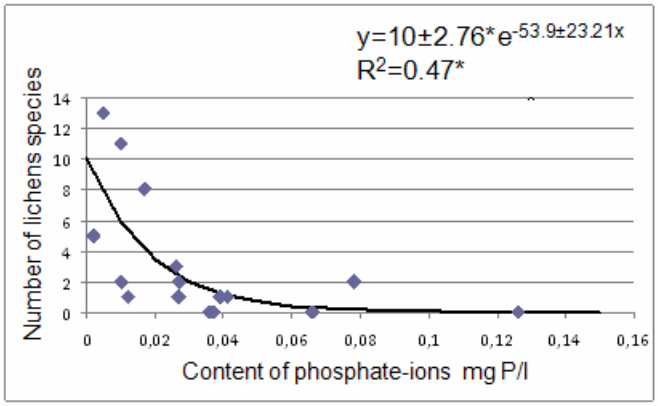

Figure 1. Dependence of the number of lichen species in эпиthe epilitic coastal cover in depending on the content in the water phosphate-ions

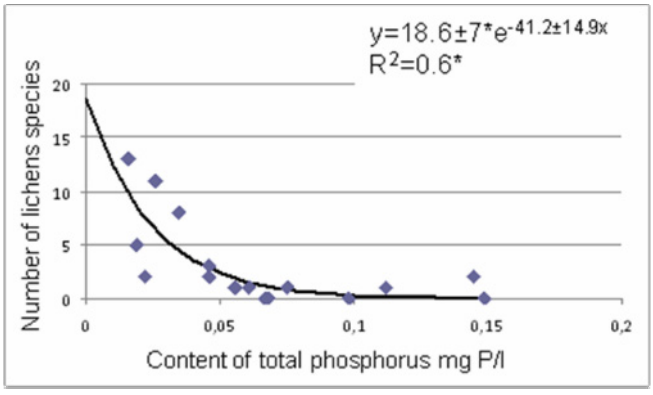

Figure 2. Dependence of the number of lichen species in epilitic coastal cover in depending on the content of total phosphorus in the water

With the increasing the concentration of nitrogen compounds in the water, the number of lichen species in the description has reduced (Fig. 3, 4), which confirms the previously established pattern in other water pools (Sonina, Kornilov, 2010; Kornilov, 2011).

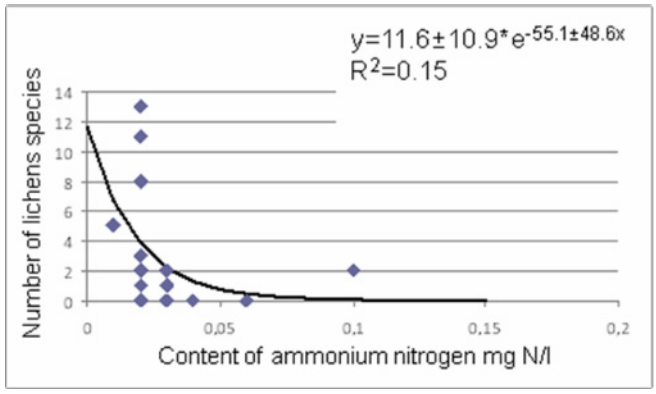

Figure 3. Dependence of the number of lichen species in epilitic lichens coastal cover depending on the content of ammonium nitrogen in the water

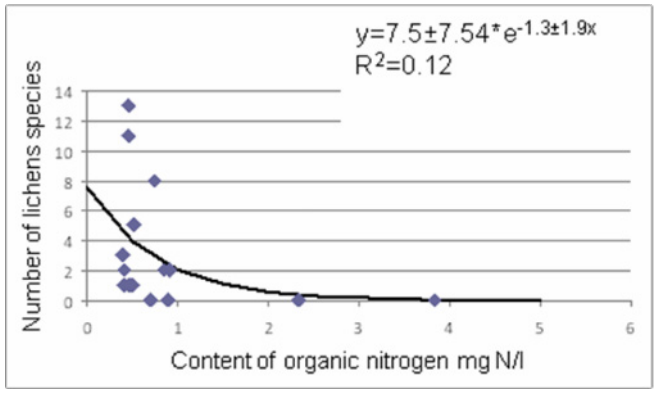

Figure 4. Dependence of the number of lichen species in epilitic coastal lichens cover depending on the content in the water of organic nitrogen

Thus, such characteristics of the lichen cover, as the number of lichen species in the description, responds to the changing content in water of nitrogen and phosphorus compounds, which are the indicators of trophicity of water reservoirs and can be used as an index of the contamination of the water pools sewage from industrial, household and agricultural waste.

4 CONCLUSION

Our research have shown that the increase in contents of nitrogen and phosphorus, as trophicity indicators of water pools causes significant changes in the composition of plant communities, of lichens biota and state of the pigment apparatus of plants. The number of lichen species in the description and abundance of species of higher vascular plants may be considered as promising indicators for the evaluation of the initial stage of anthropogenic impact, when the contents of the polluting elements do not exceed the maximum allowable concentration (MAC). The state of the pigment apparatus of the high plants deserves the special attention. *Carex acuta* is the most sensitive species to the conditions of the nitrogen and phosphorus pollution on the coastal area up to water level. *Potamogeton crispus* is the most sensitive species to the same conditions within the water pool. Since the changes of the physiological characteristics of the plants indicates the initial stages of violations in the aquatic environment (Kadukin et al., 1982; Zolotukhin et al., 2003; Mikryakova, 2002; Chukina, 2010), therefore, in our opinion, their using is the most prospective for forward-looking assessments of the state of the hydrosphere.

Based on results of our research, the wetland plant communities and the epilitic lichen cover as well as semi-aquatic plants, can be recommended for using in the monitoring studies and for forecasting the state of the hydrosphere, and first of all, the estimation of its influence on the functioning of the terrestrial biota.

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