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The Biomass of Macrophytes at Several Sites of the Upper Reaches of the Yenisei River

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The composition and biomass of aquatic plants have been investigated near several settlements at the upper reaches of the Yenisei River: from Krasnoyarsk city to the Angara River mouth. Submerged aquatic plants mainly represented the aquatic flora. The phytomass consisted mostly of plants from the deep-water zone of the river. The mean biomass of plants in the deep-water zone was 410 g/m^2, the impact of Potamogeton species in the deep-water biomass was 64-100 %. P.lucens dominated at the majority of deep-water sites (53-98 % in terms of dry biomass)

Keywords: macrophytes, biomass, Yenisei River

Introduction

Plants are the essential component of aquatic ecological systems. Macrophytes are capable to accumulate man-caused pollutants in their biomass (Lukina and Smirnova, 1988; Gudkov et al., 2002; Cecal et al., 2002; Bolsunovsky, 2004) and thus, to play the role of a biological filter.

Mass development of aquatic plants is observed in the Yenisei River, in the influence zone of Krasnoyarsk industry and power complex. The previous research of the Yenisei vegetation was carried out on the site from Krasnoyarsk Hydroelectric Power Station up to the Angara River mouth in 1985 (Priymachenko et al., 1993), the biomass of aquatic plants being not estimated.

Up-to-date data on the structure and biomass of the river vegetative cover is necessary for the estimation of the Yenisei ecological state, for the calculation of self-purification rates, as well as for the assessment of the role of aquatic plants in the migration of man-caused pollutants in the river ecosystem.

Therefore the purpose of this work was the estimation of an aquatic plants biomass in the Yenisei River.

Methods

The samples of aquatic plants were taken in the Yenisei River in September 2003 and 2004 along the right bank on the site from the village Yesaulovo (45 km from Krasnoyarsk) up to the settlement Strelka (330 km from Krasnoyarsk) (Fig. 1). The quantity indicators of the vegetative cover were investigated on seven sites near three settlements: villages B. Balchug (98 km from Krasnoyarsk), Zaharovka (276 km); Strelka (330 km) (Fig. 1).

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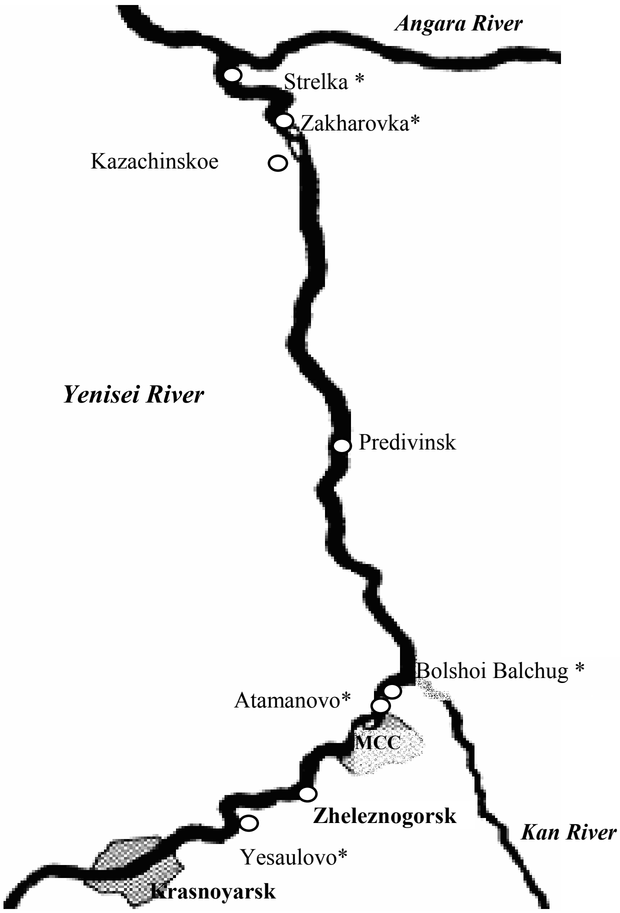

Fig.1. The map-scheme of the upper reaches of the Yenisei River. Plant sampling sites are marked by an asterisk

The plants biomass samples were taken manually and also with rakers withing the frameworks of 0.5 m^2. For a phytomass estimation there was used only the above-ground part of the plants. On each site the plants were sampled along the river bank in a strip of plants thickets in the shallow zone (on the depth of 0.4-0.7 м) and the deep-water zone (on the depth of 1 meter and more). In each zone 3-6 samples were taken, approximately equally spaced. Extent of sampling sites was 200-800 m.

After sampling the phytomass was washed in the running river water, then it was delivered to the laboratory where plants were sorted, dried in the air, and then dried at the temperature 80^{o}C up to the constant weight and it was weighed. For identification of taxons the keys were used (Beglijanova et al., 1979; Lisitsyna et al., 1993; Dobrochayeva et al., 1999; Gubanov et al., 2002).

Results

In the research of a vegetative cover 14 species of higher aquatic plants have been noted, among them 8 taxons (7 species and one hybrid) of *Potamogeton* genus, one representative of aero-aquatic flora (*Butomus umbellatus*), as well as one form of a water moss (Tabel 1).

The submerged macrophytes thickets have been met along the coastal line (including islands), and also in branches and creeks up to the depth of 3-4 meters. The length of *P.lucens* specimen reached 4.2 m. The width of a plants thickets strip

Table 1. Aquatic flora of the Yenisei River

Family*	The latin name
Ceratophyllaceae	*Ceratophyllum demersum* L.
Ranunculaceae	*Batrachium kauffmanii* (Clerc) V. Krecz.
Haloragaceae	*Myriophyllum spicatum* L.
Callitrichaceae	*Callitriche hermaphroditica* L.
Alismataceae	*Sagittaria sagittifolia* L.
Butomaceae	*Butomus umbellatus* L.
Hydrocharitaceae	*Elodea canadensis* Mich.
Potamogetonaceae	*Potamogeton pectinatus* L.
	Potamogeton filiformis Pers.
	Potamogeton friesii Rupr.
	Potamogeton gramineus L.
	Potamogeton x nitens Web. (*P.gramineus* L. x *P.perfoliatus* L.)
	Potamogeton natans L.
	Potamogeton lucens L.
	Potamogeton perfoliatus L.
Fontinaliaceae	*Fontinalis antipyretica* Hedw.

* - the order of families according to (Dobrochaeva, et al., 1999)

in the deep-water zone was 6-40 m, in shallow-water zone - 3-5 m (Tabel 2).

In the shallow-water zone the macrophyte vegetation was the most diverse in terms of species (up to 10 species on a site). The most part of a biomass here comprised *E.canadensis* and *P.pectinatus*, and also *B.umbellatus* near the settlement Strelka (Tabel 2). *B.umbellatus* has been noticed only in the submerged form. *Potamogeton* species contribute essentially to the plants biomass in the shallow zone (39-98 % of phytomass).

In the deep-water zone of the river the dominating species were *P.lucens* (53-98 % of plants biomass) on the majority of sampling sites (Tabel 2), or *Potamogeton x nitens* (on one site near Zakharovka village).

Thus, such taxons as *E.canadensis*, *P.lucens*, *P. x nitens* and *P.pectinatus* can be distinguished as the most frequently found and included in the number of dominants on the sampling sites (at least on 4 sites out of 7) (Tabel 2).

The plants biomass in the deep-water zone differed from that in the shallow zones of the river (Fig. 2). In the deep-water zone the dry biomass of plants varied within 310 - 470 g/m^2 (Fig. 2), in the shallow zone - 70 - 360 g/m^2. On a site in the deep-water zone (except channels) the phytomass on the area of 1 m^2 2.5-6.2 times exceeded the biomass of the plants collected from the same area in the shallow-water zone (Fig. 2). In the channels (near B.Balchug village and Zaharovka village) the biomass values varied within the range determined by sampling accuracy error.

The estimating calculation of the stock of aquatic plants dry biomass on the sampling sites has been made in view of the area of plants thickets and a biomass on 1 m^2. For three sampling stations the total plants biomass of deep-water and shallow zones was from 2600 up to 9400 kg / km in recalculation on running kilometer (Fig. 3), the impact of plants biomass in a deep-water zone was 85-99 %.

Table 2. The characteristic of the vegetative cover on sampling sites

Year, sampling site	Depth zone	The size of thickets, (length x width), m	Quantity of samples	Total biomass, g/m^2	Biomass dominants (%)	Number of species (*Potamogeton* species)	Amount of *Potamogeton,* % of total biomass
2003, s. Strelka, left bank, i. Lopatin	Shallow	260 x 5	6	169 ± 90	*Butomus umbellatus* (26.6) *Elodea canadensis* (25.4) *Potamogeton pectinatus* (23.1)	6 (3)	45
	Deep-water	260 x 10	4	473 ± 182	*Potamogeton lucens* (92.2) *Potamogeton pectinatus* (4.1)	6 (3)	98
2004, s. Strelka, left bank, i. Lopatin	Shallow	260 x 5	5	71 ± 23	*Elodea canadensis* (41.8) *Butomus umbellatus* (20.6)	10 (3)	39
	Deep-water	260 x 15	5	438 ± 131	*Potamogeton lucens* (98.4)	8 (3)	99
2003, v. Zakharovka, left bank, i. Zhuravlev	Shallow	350 x 3	3	79 ± 9	*Potamogeton filiformis* (80.7) *Potamogeton x nitens* (11.3)	3 (1)	92
	Deep-water	350 x 40	3	196 ± 13	*Potamogeton x nitens* (80.3) *Potamogeton filiformis* (19.7)	2 (2)	100
2003, v. Zakharovka, the branch	Shallow	20 x 15	3	223 ± 21	*Potamogeton perfoliatus* (66.0) *Potamogeton pectinatus* (24.8)	4 (2)	91
2004, v. Zakharovka, the branch	Shallow	20 x 15	3	259 ± 61	*Potamogeton perfoliatus* (77.8) *Potamogeton x nitens* (18.7)	7 (4)	98
2004, v. Zakharovka, the branch	Deep-water	500 x 10	3	312 ± 208	*Potamogeton lucens* (92.4), *Potamogeton pectinatus* (6.4)	6 (2)	99
2004, v. Zakharovka, right bank of the Yenisei R.	Shallow	800 x 3	3	99 ± 42	*Potamogeton pectinatus* (74.2), *Potamogeton x nitens* (18.7)	3 (2)	93
2004, v. Zakharovka, right bank of the Yenisei R.	Deep-water	800 x 6	3	379 ± 132	*Potamogeton lucens* (95.3), *Potamogeton pectinatus* (4.4)	5 (2)	100
2004, v. B. Balchug, stream entrance	Shallow	500 x 5	3	67 ± 16	*Potamogeton filiformis* (98.2)	4 (1)	98
2004, v. B.Balchug, i. Berezovyi stream	Shallow	30 x 10	1	362*	*Elodea canadensis* (99.0)	4 (1)	0
	Deep-water	100 x 15	4	465 ± 156	*Potamogeton lucens* (53.4), *Elodea canadensis* (13.9)	6 (2)	64

* the framework was taken in one of the numerous monodominant “spots” with total area of 35 m^2

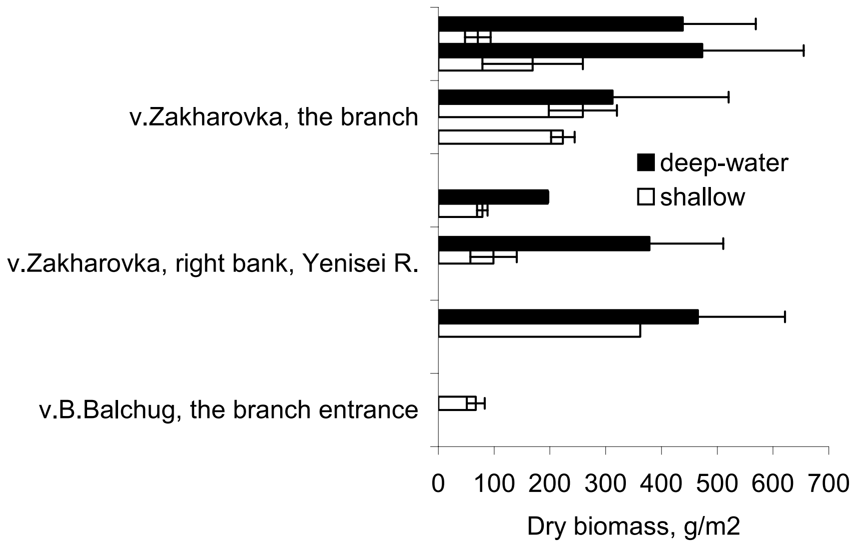

Fig.2. Dry biomass of plants on the area of 1 m^2 (mean value ± sd) in shallow (white columns) and deep-water (black columns) zones of macrophytes thickets

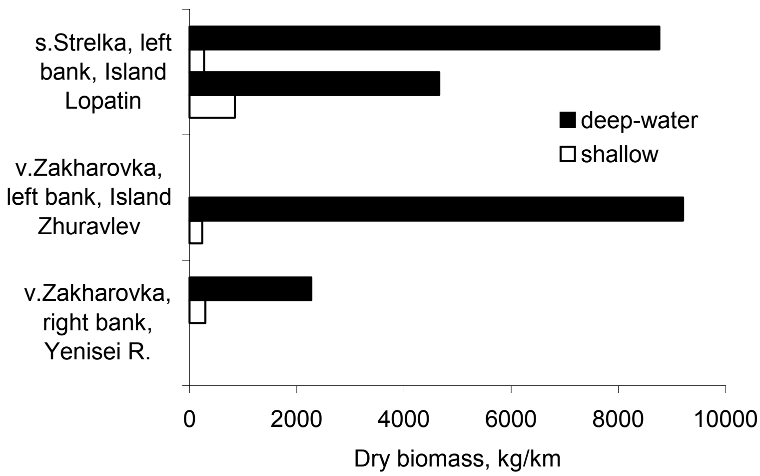

Fig.3 Total dry biomass of aquatic plants (kg) in deep-water (black columns) and shallow (white columns) zones of macrophytes thickets with calculation on running kilometer

Discussion

The previous research of the Yenisei vegetation on the same site was carried out in July, 1985 (Priymachenko et al., 1993). The researchers noted poor development of vegetation. In the vegetative cover aero-aquatic plants prevailed. According to our observation, in July the submerged plants are almost not developed. The submerged macrophytes biomass in the river Yenisei reaches maximum in September, in the period of seeds maturing. On the basis of the data for six sampling sites (Fig. 2), the maximal plants biomass in the deep-water zone of the river was 410±61 g/m^2 (m±sd, n=6). In V.G Papchenkov's opinion (Papchenkov, 2003a), in the estimation of the biomass production of submerged macrophytes the maximal biomass should be multiplied by 4 which is caused by intensity of abscission. According to the review of the above cited author this factor essentially varies for different plants species. The abscission intensity evidently depends on local hydrological conditions and climate. For the conditions of Siberia this coefficient will probably be lower than in the European part of Russia because of the shorter vegetation period.

In this research attention has been paid only to those aquatic plants which were found on the sites of radio-ecological monitoring of the Yenisei River. The purposeful research of aquatic flora of the Yenisei will probably allow revealing a greater number of macrophyte species. Thus, the previous researchers (Priymachenko et al., 1993) noted more species of water mosses, and also a number of aero-aquatic plants. Since the first third of the 20-th century all previous researchers also marked a high variety of *Potamogeton* species in the Yenisei River. Among other macrophytes the genus *Potamogeton* is known as the most exposed to interspecific hybridization (Papchenkov, 2003 a,b; Fant and Preston, 2004; Bobrov, Chemeris, 2004). Probably, in thorough research including modern methods, the list of representatives of this genus in the Yenisei River can be enlarged and first of all due to hybrid forms.

Conclusion

The research has shown that the vegetation of the Yenisei River on the site from Krasnoyarsk up to the Angara River mouth is represented basically by the submerged higher aquatic plants. Such species as *P. lucens*, *P x nitens*, *P.pectinatus* and *E. canadensis* can be considered as the most frequently founded and making essential contribution to the vegetative cover biomass.

The main part of a macrophytes biomass of the upper reaches of the Yenisei River is made up by the plants of a river deep-water zone. On the majority of sites of this zone *Potamogeton lucens* dominates, therefore, being a frequently met, dominating, easily determined component of aquatic vegetation, it can be used as the indicator while monitoring man-caused pollution of the Yenisei River.

On the basis of the data obtained it's possible to calculate the flow of man-caused pollutants through aquatic plants of the Yenisei River on the investigated site.

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