Effect of Limiting Abiotic Factors on the Distribution of Plants in Aquatic Ecosystems of the Southern Part of the Ob-Irtysh Interfluve

D.A. Durnikin and A.E. Zinovyeva

Abstract: The flora of more than 355 different-type lakes, 18 medium and minor rivers and numerous ponds and intermittent water bodies was studied using stationary and route methods. All of the water bodies in the southern Ob-Irtysh interfluves are distributed rather evenly as regards both latitude and longitude. The influence of limiting abiotic factors on the plants was studied. Data on the types of soils, salinity and vegetation depth of aquatic plants as functions of water transparency (by the Secchi disk) were obtained. Also, the active water reaction against the colorimetric pH scale was determined. Altogether, more than 280 water samples were taken. The hydro chemical analysis was performed in the field using a PHT-028 conduct meter, a universal monitor for measuring water quality (Kehlong) and in the Laboratory for Hydro chemical Research (Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences, Barnaul). It was shown that ecological studies of aquatic and coastal aquatic plants are of theoretical value for the development of general plant ecology and also create grounds for solving practical tasks, first of all, for elucidating the ecological role of aquatic and coastal aquatic plants and their direct use in the restoration of aquatic ecosystems.

Key words: Ob-Irtysh interfluves · Flora of water bodies · Aquatic plants · Coastal aquatic plants · Effect · Dependence · Salinity · Water hardness · Active reaction of water (pH) · Types of soils · Depth of water bodies · Plant ecology · Aquatic ecosystems

INTRODUCTION

The southern part of the Ob-Irtysh interfluve is a 160000 km² area between 51° and 57° N. Administratively, this area is a part of the Altai Territory and adjacent parts of the Novosibirsk and Omsk Regions and some area of the Kazakhstan Republic.

The studies were carried out in the Altai Territory and in the East Kazakhstan and North Kazakhstan Provinces (Kazakhstan Republic). The attention was focused on the species composition, taxonomy, ecology and vegetative propagation of aquatic and coastal-aquatic plants. The flora of numerous lakes and medium and minor rivers of the Barabinskaya forest steppe in the Novosibirsk and Omsk Regions was studied.

The major flora species of the water bodies in the southern Ob-Irtysh interfluve are angiosperms (97.6%); of these, 109 species are monocotyledons and 57 species are dicotyledons [1-2].

Apart from investigation of the floristic composition of the Ob-Irtysh interfluve water bodies, we studied the influence of limiting abiotic factors on the plants. In particular, data on the types of soils, salinity and vegetation depth as functions of water transparency (by the Secchi disk) were obtained. Also, the active water reaction against the colorimetric pH scale was determined. Altogether, more than 280 water samples were taken. The hydro chemical analysis was performed in the field and in laboratory.

Main Part: In recent decades, the influence of various abiotic factors (including salinity) on the biological diversity of continental aquatic ecosystems of various world regions has attracted considerable attention of scientific community [3-6].

When exploring the aquatic flora of the southern Ob-Irtysh interfluve, we took into account an important abiotic factor, water salinity, i.e., the amount of total dissolved solids (TDS). To identify the variations of the biological diversity of plants in the water bodies of the southern Ob-Irtysh interfluve as functions of salinity, we used the classification proposed by B. F. Sviridenko...
The salinity effects on the biological diversity of aquatic and coastal aquatic plants in the area of interest were estimated using correlation analysis techniques. It was found that these two characteristics are strongly correlated (negatively): increase in the salinity results in a decrease in the number of species ($r = -0.83$; test of validity, $t = 3.94$; significance level, $P = 0.01$). The typically fresh-water group includes 143 species. This is the most numerous group accounting for 84.1% of the total number of species. Among all species that belong to this group, 131 species (77.0%) are obligate, while the other are facultative (typically occurring in other groups of water) and comprise only 12 species.

The conditionally-fresh water group comprises 134 species (78.8% of the total number of species), of which 30 are obligate and 104 are facultative. The obligate group includes Potamogeton pectinatus, Typha laxmanii, Alisma gramineum, A. lanceolatum, Puccinellia dolicholepis, Juncellus pannonicus and so on. The facultative species present in this group typically occur mainly in fresh or slightly brackish water.

The slightly brackish water group is much smaller, consisting of only 43 species (25.2% of the total number of species). The smaller number of species compared to the above-mentioned groups is attributable to the fact that here salinity approaches the universal barrier, namely, the critical value that separates the fresh-water and brackish-water floristic communities. The salinity "junction" is the range from 8 to 16 g/L. The obligate slightly brackish water species include Potamogeton macrocarpus, P. marinus, Zannichellia repens and Najas marina.

The brackish water floristic community comprises species that vegetate in brackish (8.1-25 g/L) and saline (more than 25 g/L) waters. This is a group of few species that are not encountered in fresh, conditionally fresh, or slightly brackish waters. The brackish water group includes 15 species (8.8 % of the total number), all of them being facultative. Most interesting in the brackish water floristic complex are those species that are obligatory in saline water. These are highly specialized species that occur in sodium chloride water: Ruppia drepanensis, Ruppia drepanensis and Althenia filiformis [8].

The water hardness of the examined water bodies in the southern Ob-Irtysh interfluve is linearly correlated with the salinity, the correlation coefficient being 0.99. Due to the very strong correlation of these factors, the groups of plants formed in terms of their salt tolerance, reflect quite accurately the relation of these species to the total hardness. Hardness is a water characteristic caused by the presence of calcium $\text{Ca}^{2+}$ and magnesium $\text{Mg}^{2+}$ ions.

Most of species of the fresh-water floristic community reside in waters with hardness ranging from 0.8 to 82.0 mg-eq./L. The obligate typically fresh-water species were encountered in soft and moderately hard waters (0.8-6 mg-eq./L), in particular, these are Utricularia intermedia, Callitriche hermaphroditica, Myriophyllum sibiricum, M. spicatum, Ceratophyllum demersum, Persicaria amphibian, Nuphar lutea, Nymphaeae candida, Potamogeton natans, P. rutillus, Stratiotes aloides, Hydrocharis morsus-ranae, Nymphoides peltata and Utricularia vulgaris. These species may serve as an indication of water hardness, which is important from the technological standpoint. Also, this group includes conditionally fresh water species, which tolerate a wider range of water hardness (up to 18.2 mg-eq./L) and thus cannot be used to identify soft and moderately hard waters. The group of species related to slightly brackish and brackish waters occurs in the hardness range of 0.8-83.0 mg-eq./L. These are species that can vegetate in soft to highly hard waters. Among these species, noteworthy are Potamogeton pectinatus, P. macrocarpus, Typha laxmanii, Alisma gramineum and other.

Of particular interest are species of the brackish-water floristic community, which are able to vegetate in the hardness range from 84.2 to 425 mg-eq./L. The data on salt tolerance and relation of species to the total hardness, though tentative, are of interest in view of little knowledge available on the aquatic plant species ecology and undoubtedly this issue deserves more detailed investigation in the future.

In analysis of the relationship between the species and soils, four groups were distinguished: 1. Psammo-pelophiles. This group comprises species that vegetate on soils poor in organic matter (finely detrital sandy mud,
sand); 2. Pelobionts. This group includes typical inhabitants of various types of finely detrital muds (black organic, dark-gray organic, gray clayey); 3. Detrito-pelophiles. This group is composed of species located in coarsely detrital muds and peaty muds; 4. Eury-edaphiles. This group includes species encountered in all types of soils. Now we consider each of the distinguished edaphic-tolerant groups in more detail. While examining the species distribution among the soil types, one can note that the greatest number of species was encountered in various types of finely detrital muds. The total sum of species is 165, the obligate pelobiont group comprising 139 species (84.2% of the total number of species of this group), while the other species of this group are facultative, being typical of other edaphic-tolerant groups.

Obligate pelobionts include many flower type hydrophytes: Potamogeton alpinus, P. natans, N. major, P. perfoliatus, Hydriella verticillata, Stratiotes aloides, Lemna minor, all representatives of the Nymphaeaceae, Halorgaceae and Lentybulariaceae families, Batrachium genus and so on. Some representatives of this group occur as facultative species in the detrito-pelophile group. These are all Sparganium, Lemna, Nuphar, Nymphaeaceae, Ceratophyllum, Alopecurus aequalis and Potamogeton pectinatus.

The "hydrophyte kernel" pelobionts are represented by 54 species (93.1% of the whole hydrophyte kernel). Most species (51) are obligate and only 3 species (Zannichellia palustris, Z. repens and Najas marina) are facultative; they prefer sandy mud and are obligate for the group of psammo-pelophiles.

The group of psammo-pelophiles is represented by 107 species of which 23 species are obligate and 84 species are facultative. The obligate species of this edaphic-tolerant group include Ruppia drepanensis, R. maritima, Zannichellia pedunculata, Halerpestes sarmentosa, Cyperus fuscus, Carex bohemica and so on, the first three species are not encountered as facultative in any other edaphic-tolerant group. The facultative part is composed of species such as Typha laxmani, Potamogeton perfoliatus, Juncus articulatus, J. bufonius, Sagittaria sagittifolia, Bolboschoenus maritimus and so on. In the "hydrophyte kernel," this edaphic-tolerant group consists of 27 species, of which 7 are obligate and 20 are facultative. The obligate species are Ruppia drepanensis, R. maritima Zannichellia pedunculata, Z. repens, Z. palustris, Althenia filiformis and Najas marina. Potamogeton lucens, P. pectinatus, P. vaginatus, Caulinia flexilis, C. minor and so on are encountered in the psammo-pelophile group as facultative species.

The detrito-pelophile group is composed of 56 species comprising 10 obligate and 46 facultative ones. The species that are obligate to this edaphic-tolerant group include Equisetum fluviatile, Typha angustifolia, T. latifolia, Scheuchzeria palustris, Acorus calamus, Calla palustris, Calthai palustris, Callitricho hermaphrodita, Elatine alinastrum and Menyanthes trifoliata. The facultative species are Sparganium erectum, S. emersum, Hydrocharis morsus-ranae, Scyurus lacustris, Schochloa festucacea and other. The "hydrophyte kernel" of this tolerant edaphic group has no obligate species while, 21 facultative species include P. pectinatus, Stratiotes aloides, all species of the Lentybulariaceae and Nymphaeaceae families, Nymphyoidea peltata and other.

As regards the depth distribution of species in the water bodies of the southern part of the Ob-Irtysh interflue, the general trend is decreasing number of species on moving away from the water level towards the maximum depths. This trend is manifested in different ways in each particular water body and is related, first of all, to the morphometric characteristics of the water bodies. In most cases, in the flat land being explored, the average depths do not exceed 2-2.5 m. A representative of the "hydrophyte kernel" was found in the maximum depth of 2.8 m (Chany lake, Yarkovsky reach); this is P. pectinatus of the Potamogeton genus. The distribution of aquatic and coastal aquatic plant species is closely related to their biological properties, first of all, to the biomorph and to the water level variations, as was noted in scientific literature [7-10].

Due to pronounced water level variations, many plants often get to depths that are unnatural to them. For example, in the case of late spring flood, some coastal aquatic plants (Equisetum fluviatile, Alisma gramineum, Butomus umbelatus and so on.) may be completely submerged in the early period of vegetation and experience unnatural environmental conditions. Many populations of common reed (Phragmites australis), which usually have up to 5 m aerial sprouts and are rooted at up to 1 m depths, were found at unnatural depths of 4 to 5 m as they experienced a high flood. The greatest number of species are usually found in shallow water (0 to 1 m). This area has the optimal environmental conditions for the development of submerged and floating hydrophytes. The encountered species include Salvinia natans, Potamogeton pectinatus, P. perfoliatus, P. pusillus, P. berchtoldii, P. friesii, Zannichella palustris, Caulinia flexilis, Hydrilla verticillata,
Najas major, Hydrilla verticillata, Ruppia drepanensis, R. maritima, Zannichellia pedunculata, Z. repens, Althenia filiformis, N. marina and Caulinia flexilis and so on. Hydro-hygrophytes also find the optimal environmental conditions in shallow water, these are Alisma gramineum, Sagittaria sagittifolia, Butomus umbelatus, Scirpus lacustris, Acorus calamus and other.

The depths of 1-1.8 m accommodate Nuphar lutea, Nymphaeae candida, Potamogeton marinus, P. lucens, P. alpinus, P. praefolius, P. vaginatus, P. tenuifolius and so on. Some hydrophytes and hygrophytes are able to occupy ecotopes at up to 4-5 m depth (representatives of Ceratophyllum and Myriophyllum).

The total pH range in the water bodies in question is 6.5 to 10.3. All of the flora species found was assigned to four groups.

The Acidophilic Group: (pH 6.5-7.2) comprises species vegetating in boggy lakes or lakes that are becoming boggy with slightly acidic or nearly neutral water. This small group includes 65 species (38.2% of the total number of species) of which 11 are obligate and 54 are facultative. The obligate species confined to this group are Equisetum fluviatile, Typha angustifolia, T. latifolia, Scheuchzeria palustris, Acorus calamus, Calla palustris, Caltha palustris, Callitrche hermaphroditica, Elatine alsinastrum, Menyanthes trifoliata and Utricularia vulgaris. Among the facultative species present in this group note Nymphoides peltata, Cicuta virosa, Sium latifolium, Rorippa amphibia, Parnassia palustris, Ceratophyllum demersum and so on. In the “hydrophyte kernel”, the acidophilic group is represented by 28 species among which 2 species are obligate (Callitrche hermaphroditica, Utricularia vulgaris) and 26 species are facultative.

The Alkaliphilic Group: (pH 7.2-8.6) comprises species that vegetate in neutral and slightly alkaline water. This is the most numerous group consisting of 167 species (134 obligate and 33 facultative ones). The obligate species of this group may be present as facultative in other groups. As alkaliphiles, note Sparganium erectum, Potamogeton alpinus, P. berchtoldii, P. fiesii, P. pusillus, N. major and many other plants of the fresh-water floristic community. In the “hydrophyte kernel,” the alkaliphilic group has 49 obligate (84.4% of the total hydrophyte kernel) and 6 facultative species.

The Indifferent Group: (pH 6.5-10.3). The group has 4 taxons tolerant to the widest range of active reaction (pH) of the medium from slightly acidic to medium-alkaline. These are Potamogeton pectinatus, P. perfoliatus, Phragmites australis and Carex secalina.

Thus, the largest number of species in the area of interest find suitable vegetation conditions in neutral or weakly alkaline waters (167 species) at pH 7.2-8.6. Study of the role of limiting factors in aquatic ecosystems and their influence on plants is of enormous practical importance, first of all, for elucidation of the ecological role of aquatic and coastal aquatic plants, direct application of these plants and restoration of ecosystems.

It should be borne in mind that these factors are not independent of one another but interplay in a complex manner. Studies of this type are significant from both theoretical and practical standpoints as higher aquatic vegetation produces organic matter, largely accounts for water quality in water bodies, creates the specific environment for hydrobionts and finally determines many water body regimes.

CONCLUSIONS

- Analysis of the tolerance of aquatic flora species to water salinity and pH and to soils revealed the alkali-pelophilic fresh water type of flora in water bodies of the region.
The presence of representatives of saline-water complex, highly specialized species vegetating in sodium chloride waters (Ruppia drepanensis, Ruppia drepanensis and Althenia filiformis) is a specific feature of the aquatic flora of the southern part of the Ob-Irtysh interfluve.

A dependence of the greatest vegetation depth on water transparency was found only for submerged sessile hydrophytes of the fresh-water floristic community.

REFERENCES