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FEATURES OF OVERGROWING THE URBANIZED SEGMENT OF THE VORSKLA RIVER

We investigated the indices of overgrowing by higher aquatic vegetation (coenotic diversity, ecological structure, the degree of overgrowing, the type of overgrowing, belt structure) at five sites of the river Vorskla, located near the city of Poltava, which are subject to varying degrees of human impact.

The formation of the plant cover is provided by 15 dominant species, based on which we allocated 3 associations of submerged vegetation, 5 associations of vegetation with floating leaves (including 4 – free-floating), 7 associations of air-aquatic vegetation. In part of the thicket zone the communities of different ecological groups spatially prevail: the submerged vegetation is on the middle urban site, the air-water vegetation is at the peri-urban sites and the floating-leaf vegetation is on the extra-urban sites. Limit values of the index of the aquatorium overgrowing registered on the most transformed urban sites with a high degree of urbanization of the landscape. The aquatorium overgrowing type changes from the curb to the dispersed-spotty confined to sites with the most significant violation of the hydrological regime. The deviations in the belt structure of vegetation are the most typical for urban sites, where due to anthropogenic impact was an increase in structure heterogeneity of low air-water grasses belt and simplification (and in some places – the complete reduction) of high air-water grasses belt as well as belts of truly aquatic vegetation.

The factors of urbanized landscape, which have a leading influence on the development of higher aquatic vegetation, include violation of hydrological regime, change of morphometric parameters of riverbed, water pollution, recreation. The middle urban and lower urban sites of the Vorskla River are the most heavily transformed as a result of the combined effect of urbanized landscape.

Key words: *macrophytes, higher aquatic vegetation, overgrowing, the Vorskla River, urbanization, Poltava city.*

Introduction. Urbanization as a process of growing number of cities and the expansion of urban areas is an objective feature of modernity. At the same time it is one of the most complex and powerful forms of human impact on natural ecosystems [9, 10].

Quantitative development of autotrophic components of ecological community, «responsible» for solar energy conversion and accumulation of organic matter, is the most visible marker of ecosystem changes caused by the influence of urbanization. A typical component of urban landscape is the various water bodies, including big and average rivers in which ecosystems the leading photosynthetic activity belongs to macrophytes – higher water

plants and macroscopic algae. Therefore, analysis of indices of river overgrowing can be regarded as means to study the counteracting of aquatic ecosystems to combined effect of urbanization. One aspect of overgrowing is characteristic of vegetation cover at the present stage [5], so the purpose of this work is to study the indices of spatial distribution of higher aquatic vegetation (HAV) communities of the average river under the influence of urbanized landscape.

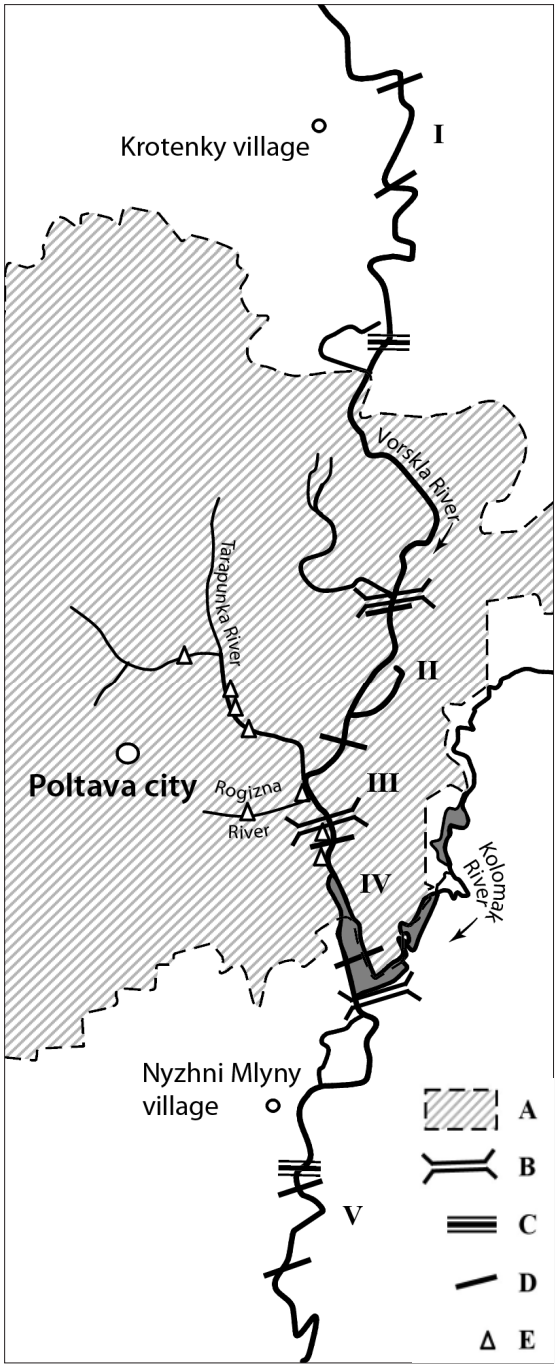

Fig. 1. **Map-scheme of the region of investigations in the Vorskla River:**
A – urban territory, B – bridges, C – sluices regulating river runoff, D – boders of the sites, E – stormwater canalization releases, I-V – numbers of sites.

Materials and methods. Vorskla is a typical average flat river, the left tributary of the Dnieper, which riverbed length is 464 km and basin area is 14,7 thousands km^2. Near the city of Poltava (the regional center of Ukraine with a population of 295 thousands people) river undergoes the combined effect of urban landscape through regulation of riverbed by sluices, widening, straightening and dredging the riverbed, construction of bridges, building and taking banks by dams, dumping storm water, using small fleet, recreation (recreation on the beach, swimming, fishing).

Gathering the materials by using the traditional hydrobotanical methods [3] conducted during the growing seasons of 2012-2013 near the city of Poltava on the segment of the Vorskla River stretching about 25 km. By the degree of anthropogenic influence it has been allocated five sites, which are consistently placed: I (the reference site) – 5 km upstream of the city (the river is close to the reference), II (the upper urban site) – the upper part of the urban segment (moderately urbanized area of recreation), III (the middle urban site) – the middle part of the urban segment (urbanized area with releases of storm sewer), IV (the lower urban site) – the lower part of the urban segment (wided and deeped plot below the discharge of all urban waste water), V (the site below city) – 5 km downstream of the city (the natural landscape outside settlements) (*fig. 1*).

To analyze the characteristics of spatial distribution of HAV communities on the sites of the Vorskla River with different degrees of urbanization we considered such hydrobotanical indicec as: coenotic diversity, ecological structure, the degree of overgrowing (ratio of the thickets area to the area of waters on the site), the type of overgrowing (character of distribution of plant communities in water area), belt structure (the sequence of plant communities from the water edge deep into the watercourse). Calculation of the area of communities and count of overgrowing degree was performed using the software resource Digimizer for space aerial images of river sites obtained through online application Google Earth by comparison with data of field investigations.

Results and their discussions.

Coenotic diversity. As was established earlier, the aquatic flora of studied segment of the Vorskla River counts 57 species of macrophytes, including 49 species of angiosperms, by 1 species of ferns, horsetails and hepatic mosses and 5 taxa of macrophyte algae [4]. Of these 15 species of higher plants are able to act as dominant of plant communities, that form coenotic diversity of studied river segment: *Ceratophyllum demersum* L., *Potamogeton pectinatus* L., *P. perfoliatus* L., *Nuphar lutea* (L.) Smith, *Salvinia natans* (L.) All., *Spirodela polyrrhiza* (L.) Schleid., *Hydrocharis morsus-ranae* L., *Lemna gibba* L., *Glyceria maxima* (C. Hartm.) Holmberg, *Typha angustifolia* L., *T. latifolia* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Sparganium erectum* L., *S. emersum* Rehman, *Sagittaria sagittifolia* L. It was allocated 3 associations of submerged vegetation, 5 associations of vegetation with floating leaves (including 4 of free-floating vegetation), 7 associations of air-aquatic vegetation.

Ecological structure. Due to the influence of urban landscape of Poltava city the researched segment of the Vorskla River, relatively short in length, significantly diverse in character of overgrowth of certain sites and quantitative participation of various ecological groups of vegetation in forming thickets.

On the site I, located upstream of the city, there is asymmetry location of thickets along the coast. A sharp drop in the depths observed under the high and snatchy right bank, so there the communities of mainly submerged plants and plants with floating leaves are concentrated. Shallows confined mostly to the left bank, where air-water vegetation is developed, achieving in some places 5-7 meters wide. Aspect of helophytes thickets most often determined by *Typha latifolia*, much less – by *Phragmites australis* and *T. angustifolia*.

The upper urban site (II) has a more even distribution the vegetation along the banks, but its zonal character is often violated on numerous beaches and vacation spots. Considerable areas are occupied by free floating communities based on *Salvinia natans* and *Spirodela polyrrhiza*. Partial transformation of riverbed in this site causes considerable development of ecotopes for air-water vegetation, which spatially dominates among other ecological groups. Its composition is gradually aligned by quantitative representation of communities of *Phragmites australis* and communities of both species of *Typha* as well.

The middle urban site (III) is the most shallow on the studied segment and subjected to excessive overgrowing. The vegetation is not only strips placed along the banks, but also forms considerable area of hydrophyte communities in the center of the riverbed. The synusiums of

free-floating hydrophytes, such as *Salvinia natans, Hydrocharis morsus-ranae,* acquire considerable spread. The helophyte belt well developed along both banks and is the most expressed near the road bridge. The thickets of *Phragmites australis* provide the massive aspect, the communities of *Typha latifolia* are less widespread, *Glyceria maxima* forms some separate curtains whereas communities of *Typha angustifolia* are minimally presented.

The lower urban site (IV) is the most transformed (straightened, extended end deepened), shallows are occupied here the lowest relative areas. The geobotanical zonality is poorly expressive in belts of vegetation with floating leaves and submerged vegetation. The thickets of helophytes form the massive aspect, mainly based on communities of *Phragmites australis* and *Typha angustifolia,* coenosis of *T. latifolia* are almost absent.

The site V, located downstream of the city, has pressureless hydrological regime and natural parameters of riverbed, which leads to changes in the character of aquatic vegetation. The belt of air-water plants is highly fragmented and represented by communities of low-grass helophytes (*Sparganium erectum, S. emersum, Sagittaria sagittifolia*). Significant areas are occupied by communities of submerged hydrophytes (especially on rapids), but the maximum share in the thickets belongs to communities of hydrophytes with floating leaves, mostly rooted, forming a wide strip along the bank, and to a lesser extent – free-floating (duckweeds), that are confined to places with a slow flowage (backwaters) and the additional inflow of nutrients (beaches).

Among the communities of true aquatic vegetation the coenosis of *Ceratophyllum demersum* (at the group of submerged vegetation) and *Nuphar lutea* (at the group of vegetation with floating leaves) show the highest constancy in researched sampling sites. The coenosis-forming role of other species within each ecological group was manifested situationally depending on specific conditions and usually was associated with one particular sampling site. In particular, attention is drawn to development in II, III and V sampling sites the communities of free-floating vegetation, within which there is such sequential replacement of associations along the studied segment: *Salvinia natans+Spirodella polyrrhiza → Spirodella polyrrhiza → Salvinia natans → Hydrocharis morsus-ranae → Lemna gibba*. This is probably related to the high content of nutrients in river sites undergoing the transformation of catchment areas (II and III sites) or exposed to direct flow of water pollution due to wastewater of different origin (sites III, V).

The spatial participation in a thicket zone the communities of *Ceratophyllum demersum* consistently increases from the reference site to the middle urban site where it reaches a maximum. At the lower urban site through an artificial reduction of littoral zone and a sharp decrease in water clarity to the least on the researched segment (70 cm) the area of submerged vegetation's distribution is minimal. At the site, located below the city, where the natural character of the riverbed take place, the proportionate of distribution the communities of *Ceratophyllum demersum* is slightly restored.

The spatial participation in a thicket zone the communities of *Nuphar lutea* is the highest at extraurban sites, while at urban sites II and III this index falls significantly. On two last mentioned sites this is primarily due to the intensive development of recreation, and in

particular, a system of city beaches, accompanied by considerable pressure on all aquatic biota and first of all – the vegetation with floating leaves. It confirmed by a marked increase in overgrowth of *Nuphar lutea* communities at lower urban site (30,0% of thickets zone), where the beaches do not occupy a significant share of the coast area. Moreover, in urban sites II and III among the communities with floating leaves the free-floating coenosis dominate by area and, compared to the communities of rooted hydrophytes with floating leaves, are much wider presented in upwater belt of urban water bodies [1, 2], thus reflecting the trend to urbanizational transformation of natural plant cover of the Vorskla River.

The air-aquatic vegetation on the first four studied sites mainly consists of communities of high-grass helophytes *Phragmites australis, Typha latifolia* and *Typha angustifolia*, which thickets areas are distributed within the individual sites unevenly: along the gradient of urbanization a spatial share of *Phragmites australis* communities gradually increases, a share of *Typha latifolia* communities conversely decline; the *Typha angustifolia* coenosis show general trend to increase their participation in forming of thickets from I to IV sites, but in the middle-urban site the share of their overgrowing are critically reduced.

The mentioned unevenness of spatial distribution of high-grass helophytes communities in urban sites is caused by the peculiarities of their morphometric parameters. Thus, in a muddy middle urban site, subjected to intensive shoaling, the littoral zone becomes less suitable for the development of *Typha angustifolia* communities, optimum depth of which is in the range of 0,8-1,5 (3) m [7]. In the lower urban site, by contrast, the depth sharply increase from the water's edge, which clearly is a limiting factor for the spread of *Typha latifolia* communities, adapted to vegetation at shallow ecotopes with depth at intervals of 0,1-0,2 (0,5) m [7]. At the site downstream of the city, located below the sluice-flow regulator, at a pressureless riverbed in the belt of air-aquatic vegetation dominants change: high-grass helophytes replaced by low-grass ones (*Sparganium erectum, S. emersum, Sagittaria sagittifolia*).

The overgrowing degree. In researched region the thickets zone of watercourse actually coincides with shallow zone because the conditions of sufficient clarity (to 1,5-2 m), the quiet stream (0,1-0,4 m/s) and a favorable substrate (sand, silt and their combination) the communities of HAV occupy all available for overgrowing shallow waters (to depths of 2-2,5 meters), excluding insignificant in size anthropogenically disturbed areas.

Calculating the area of individual communities allows to establish the features of overgrowth at sites by various ecological groups (table 1). So, the submerged vegetation dominate by area in the middle urban site (21,0% from square of aquatorium, 37,5% from square of thickets zone), the vegetation with floating leaves occupies the largest areas on sites upstream of the city (15,8% and 45,9% accordingly) and downstream of the city (25,2% and 52,4%); the thickets of air-aquatic vegetation spatially prevail on the peri-urbans sites – upper urban (10,4% from square of aquatorium, 39,4% from square of thickets zone) and lower urban (4,9% and 50,0% accordingly). Prevalence the thickets of submerged vegetation on the middle urban site on a background of the highest degree of its overgrowth may indicate the initial stage of waterlogging its waters [6].

Table 1

The aquatorium and shallow zone overgrowing degree on the studied segment of the Vorskla River

The ecological group of HAV	The overgrowing degree, %				
	I	II	III	IV	V
The submerged vegetation	8,2 / 23,8	11,7 / 27,5	21,0 / 37,5	2,0 / 20,0	13,1 / 27,2
The vegetation with floating leaves	15,8 / 46,0	14,1 / 33,1	19,0 / 33,9	2,9 / 30,0	25,2 / 52,4
The air-aquatic vegetation	10,4 / 30,2	16,8 / 39,4	16,0 / 28,6	4,9 / 50,0	9,8 / 20,4
Total:	***34,4*** / ***100,0***	***42,6*** / ***100,0***	***56,0*** / ***100,0***	***9,8*** / ***100,0***	***48,1*** / ***100,0***

Note: in the numerator – the data for the aquatorium, in the denominator – for shallow water.

Thus, at advancement from the central site (middle urban) to peri-urban and extra-urban sites in spatial dominance of different ecological groups it was founded such a symmetrical sequence: submerged vegetation – air-water vegetation – vegetation with floating leaves.

On the studied segment of the Vorskla River the value of the aquatorium overgrowing degree ranges from 9,8% to 56,0% (table 1) and on average in sites amounte to 38,2%.

It is noteworthy that the limit values of the overgrowth index (minimum on the lower urban site and maximum on the middle urban site) were registered within a city part of the studied watercourse on the relatively short (about 4 km) segment, which includes the most transformed areas with high degree of urbanization of landscape (sites III, IV). According to the used gradation scale of overgrowth degree [5], the overgrowing on the lower urban site is identified as very weak and on the middle urban site – as very intense, the rest sites (extra-urban and upper urban) grow moderately (at level of 34,4-48,1%).

The type of overgrowing. The most of researched sites is characterized by the curb type of overgrowing [5], in which thickets arranged narrower (2-3 m) or wider (6-8 m) stripes along the banks of river. The dispersed-spotty [5], or fragmented [8] type of overgrowing, which is typical for irregular, diffuse location of plant communities on the water area, recorded only at site below sluice regulating the river flow (V), as well as at middle urban site (III) where the processes of formation of plant cover go on (in the first case – from intensive sediment deposition, in the second case – due to siltation and waterlogging of the water area). So, the

aquatorium overgrowing type changes from the curb to the dispersed-spotty confined to sites with the most significant violation of the hydrological regime.

The belt structure, or horizontal geobotanical zonality (the placement of HAV thickets on depth gradient) generally monitored in all surveyed sites, but sometimes there is rejection of its structure due to the local characteristics of riverbed (the flow velocity, water clarity, the character of the soil, shore sinuosity, shallow development) or anthropogenic violation of coastal zone (beaches, moorings, places for fishing, drainage channels etc.) when some vegetation belts (in most cases a belt of high air-water plants and a belt of aquatic plants with floating leaves) fall out completely or become inexpressive.

The typical belt structure of thickets at studied sites is as follows. The first belt (from the edge to depth 0,3-0,5 m) is formed by curtains of low and middle-high overwater plants *(Carex* sp.*, Sagittaria sagittifolia* L.*, Alisma plantago-aquatica* L.*, Butomus umbellatus* L.*, Glyceria maxima)* involving hygrohelophyte component *(Bolboschoenus maritimus* (L.) Palla*, Iris pseudacorus* L.*, Acorus calamus* L.*, Rumex hydrolapathum* Huds.*, Lythrum salicaria* L.*, Sium latifolium* L.*, S. sisaroideum* DC.*)*, hygrophyte motley grasses *(Juncus articulatus* L.*, J. compressus* Jacq.*, Bidens frondosa* L.*, Lycopus europaeus* L.*, Sonchus palustris* L.*, Mentha aquatica* L.*, Ranunculus repens* L.*, Persicaria hydropiper* (L.) Delarbre*, P. maculosa* S.F. Gray*, Lysimachia nummularia* L.*, Solanum dulcamara* L.*, Veronica anagallis-aquatica* L.*)*, as well as some mesophilic elements *(Calystegia sepium* (L.) R. Br.*, Humulus lupulus* L.*, Melilotus albus* Medik.*, Geranium pratense* L.*)*, including the ruderal *(Ambrosia artemisifolia* L.*, Phalacroloma annuum* (L.) Dumort.*, Cirsium setosum* (Willd.) Besser*, Xanthium albinum* (Widder) H. Sholz) etc.

The second belt (to depth of 1-1,5 m) consists of communities of high overwater plants – *Phragmites australis, Typha angustifolia* and *T. latifolia,* rarely – some low-grasses helophytes *(Sparganium emersum, S. erectum, Glyceria maxima).*

The third belt (to depth of 1,5-2 m) presented by cenosis of hydrophytes with floating leaves – as rooted (mainly of *Nuphar lutea*), as well as free-floating (most often of *Spirodela polyrrhiza*). The fourth belt (to depth of 2,5 m) is formed by coenosis of submerged hydrophytes, based mostly on *Ceratophyllum demersum* including *Myriophyllum spicatum* L.*, Potamogeton pectinatus, P. perfoliatus* and some other species.

As a rule, the first vegetation belt has the highest degree of the coenotic and floristic diversity, which is caused by the ecotonic character of its location on the limit of terrestrial and aquatic habitats. Besides, in the condition of urban environment due to anthropogenic impact there may be enhance the heterogeneity of its structure, primarily through ruderal floristic elements (due to violation of plant cover the coastal zone) and reduce it for the rest belt zones (reduction of species richness) until their complete degradation (due to dredging, water pollution, recreation load, etc.).

Conclusions. Thus, the spatial distribution of HAV in studied sites of the Vorskla River is in close depending on the direction and intensity of anthropogenic transformation of river ecosystem in case of functioning the urbanized landscape.

The impact of factors of the urban environment is most favorable for the development of communities of high-grass helophytes, which have a quality advantage in forming of plant cover throughout the investigated segment and spatially prevail in the thickets zone of most

urban sites. Intensification of coenotical activity of free-floating macrophytes in some sites can be seen as an indicator of increasing of nutrient loading caused by the influence of urbanization.

The factors of urbanized landscape, which have a leading influence on the development of HAV, include violation of hydrological regime, change of morphometric parameters of riverbed, water pollution, recreation. The middle urban and lower urban sites of the Vorskla River are the most heavily transformed as a result of the combined effect of urbanized landscape, which is manifested in significant deviations from the reference state established there indices of HAV overgrowing.

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ОСОБЕННОСТИ ЗАРАСТАНИЯ УРБАНИЗИРОВАННОГО ОТРЕЗКА р. ВОРСКЛА

Исследованы показатели зарастания высшей водной растительности (ценотическое разнообразие, экологическая структура, степень зарастания, тип зарастания, поясное строение зарослей) на пяти участках р. Ворскла, расположенных в районе г. Полтавы и подверженных различной степени антропогенного воздействия.

Формирование растительного покрова обеспечивают 15 видов-ценозообразователей, на основе которых выделено 3 ассоциации погруженной растительности, 5 ассоциаций растительности с плавающими листьями (в т.ч. 4 – свободноплавающей), 7 ассоциаций воздушно-водной растительности.

В составе зоны зарослей пространственно преобладают сообщества различных экологических групп: на среднегородском участке – погруженная растительность, на периферийных городских участках – воздушно-водная и на загородных – растительность с плавающими листьями. Предельные значения показателя зарастания акватории – минимальные (9,8%) и максимальные (56,0%) – зарегистрированы на наиболее трансформированных городских створах с высокой степенью урбанизированности ландшафта.

Изменения типа зарастания акватории от бордюрного до рассеянно-пятнистого приурочены к участкам с наиболее существенным нарушением гидрологического режима (зарегулирование стока, заиление русла). Отклонения в поясном строении растительности наиболее характерны для городских участков, где вследствие антропогенного воздействия наблюдалось повышение неоднородности структуры пояса низких воздушно-водных трав и упрощение, а местами и полная редукция поясов высоких воздушно-водных трав и истинно водной растительности.

К наиболее существенным для развития высшей водной растительности факторам урбанизации на исследованном отрезке р. Ворскла можно отнести нарушение гидрологического режима, изменение морфометрических параметров речного русла, загрязнение воды, рекреацию. Вследствие комплексного влияния урболандшафта наиболее сильно трансформированы средне- и нижнегородской участки р. Ворскла.

Ключевые слова: *макрофиты, высшая водная растительность, зарастание, р. Ворскла, урбанизация, г. Полтава.*

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ОСОБЛИВОСТІ ЗАРОСТАННЯ УРБАНІЗОВАНОГО ВІДРІЗКУ р. ВОРСКЛА

Досліджено показники заростання вищої водної рослинності (ценотична різноманітність, екологічна структура, ступінь заростання, тип заростання, поясна будова заростей) на п’яти ділянках р. Ворскла, що розташовані у районі м. Полтави і зазнають різного ступеня антропогенного навантаження.

Формування рослинного покриву забезпечують 15 видів-ценозоутворювачів, за участю яких виділено 3 асоціації зануреної рослинності, 5 асоціацій рослинності із плаваючим листям (включаючи 4 асоціації вільноплаваючої), 7 асоціацій повітряно-водної рослинності.

Встановлено, що у складі зони заростей просторово переважають угруповання різних екологічних груп: на середньоміській ділянці – занурена рослинність, на периферійних міських ділянках – повітряно-водна та на позаміських – рослинність із плаваючим листям. Граничні значення показника заростання акваторії – мінімальні (9,8%) та максимальні (56,0%) – зареєстровані на найбільш трансформованих міських створах із високим ступенем урбанізованості ландшафту.

Зміни типу заростання акваторії від бордюрного до розсіяно-плямистого приурочені до ділянок із найбільш суттєвим порушенням гідрологічного режиму (замулення русла, зарегулювання стоку). Відхилення у поясній будові заростей найбільше характерні для міських ділянок, де внаслідок антропогенних впливів спостерігалося підвищення неоднорідності структури поясу низьких повтіряно-водних трав та спрощення або й місцями повна редукція поясів високих повітряно-водних трав і справжньої водної рослинності.

До найбільш суттєвих для розвитку вищої водної рослинності факторів урбанізації на дослідженому відрізку р. Ворскла можна віднести порушення гідрологічного режиму, зміну морфометричних параметрів річкового русла, забруднення води, рекреацію. Внаслідок комплексного впливу урболандшафту найсильнішої трансформації зазнали середньо- та нижньоміська ділянки р. Ворскла.

Ключові слова: *макрофіти, вища водна рослинність, заростання, р. Ворскла, урбанізація, м. Полтава.*