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Determination of the macrophyte index MIR as an indicator of water quality in the Pripet river

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ABSTRACT

Introduction. The river basin and the catchments of small rivers within it is a complete ecological, hydrological and economic unit with clear boundaries and a set of natural conditions. Increasing the stability of the geosystem of the river basin is impossible without monitoring the dynamics of the state of natural resources and factors of negative impact. A significant part of the water management complex of the Volyn region is the Pripet River basin which has a significant degree of development. The watercourse forms part of the state border between Ukraine and the Republic of Belarus, the tributary basins are located on the territory of both states. The source, lower course and mouth of the Pripet River are on the territory of Ukraine. Therefore, it is necessary to observe the strategic principles of rational nature management to restore and preserve the optimal ecological state of the Pripet River basin.

The objective of the work is to assess the ecological state of the Pripet River using bioindication methods and the Macrophyte Index for Rivers (MIR).

Methods. Research methods are expeditionary, mathematical statistics, bioindication, and determination of the Macrophyte Index for Rivers (MIR).

Results. Four test sites of at least 100 m length each were used to determine the ecological state of the waters of the Pripet River. Research found 48 species of higher aquatic and coastal aquatic plants in the test sites of the Pripet River. All species belong to the division *Magnoliophyta*, of which 21 species of the class *Magnoliopsida* (43.75%), and the larger share (27 species, 56.25%) to the class *Liliopsida*.

35 indicative species of macrophytes were selected in the test sites of the river to determine the Macrophyte Index for Rivers (MIR). According to the MIR classification, the river belongs to lowland watercourses, the macrophyte type M-VIII (organic rivers). MIR calculations established that the river water quality in the test site No. 1 (village of Polozhevo, upper reaches) has a satisfactory ecological state, MIR is 33.84; in the site No. 2 (v. Luchytsi) satisfactory ecological state, MIR is 34.04; in the site No. 3 (v. Liubyaz, border between Volyn and Rivne regions) good ecological state, MIR is 40.6; water quality in the site No. 4 (v. Senchytsi, border with Belarus) has satisfactory ecological state, MIR is 33.57.

Conclusions. According to the Macrophyte Index for Rivers, it was established that the Pripet River waters have a satisfactory or good ecological state. This gives reason to state that the research in the test sites and the MIR calculations fully reflect the ecological state of the watercourse, which allows the use of this research algorithm for other rivers of the basin.

Keywords*: river, bioindication, macrophytes, ecological status of rivers, macrophyte index, water quality classes, ecological assessment of water quality.*

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Introduction. The river basin and its structural elements within form a complete ecological, hydrological and economic unit with clear boundaries and a complex of natural conditions. Increasing the stability of the geosystem of the river basin is impossible without monitoring the dynamics of the state of natural resources and negative impact factors. The largest share of the territory of the Volyn region is occupied by the basin of the Pripet River which is also the most economically developed. The source and upper

course of the river are located here which then continues into the territory of the Republic of Belarus. In its lower reaches, the Pripet River returns to Ukraine where it flows into the Dnieper. Therefore, it is necessary to observe the strategic principles of rational nature management to restore and preserve the optimal ecological state of the Pripet basin [1, 7, 8].

The method of assessing the ecological state of rivers (Makrofitowa Metoda Oceny Rzek, MMOR) that is used in Poland is based on two techniques, the English Mean Trophic Rank (MTR) and the French Indice Biologique Macrophytique Riviere (IBMR) [19, 20, 26] which have been used in scientific research for quite a long time. MMOR was first described in 2006, and published as a textbook in 2010. The technique is based on the determination of quantitative and qualitative indicators of macrophytes that were found during the investigations of the water body sections. The Macrophyte Index for Rivers (MIR) is calculated from the results of the determined species composition of macrophytes, and the ecological state of the river is assessed in accordance with the EU Water Framework Directive [25, 29, 31].

The research in this direction in Ukraine is performed at the «Ukrainian Research Institute of Environmental Problems» and is based on the MMOR methodology. Scientists O. V. Vasenko and G. A. Korobkova have substantiated the possibility of using groups of aquatic macrophytes to assess the ecological state of the rivers of forest-steppe and steppe physiographic zones of Ukraine [4]. Similar studies concerning the assessment of the ecological state of ecosystems of the Pripet basin by higher plants were performed by M. O. Klymenko and Yu. R. Grokhovska [2, 3, 4]. The authors studied aquatic macrophyte groups to assess the ecological state of the Pripet River [10, 11,12, 17, 22].

A significant contribution to the study of water resources of the Volyn region, and the Pripet River basin in particular, was made by Yatsyk A. V., and V.O. Fesyuk [7,8]. The concerned the study of the features of the location and economic use of natural landscapes of the Volyn region , the characteristics of drainage systems of the Volyn region and their protection are, the formation of the water regime in the valley of the Pripet River under the conditions of anthropogenic load, studied water quality in the basin of the Turiya River, the valley of the Pripet River and its right tributaries, as well as the assessment of the anthropogenic load and the ecological balance of the landscapes of the basin of the Turiya River and the valley of the Pripet River within Volyn region, ecological problems of the river use and river protection in the Pripet basin in the Volyn region were studied by V. O. Fesyuk, Z. K. Karpyuk and M. R. Zabokrytska [7, 8].

The objective of this work is to assess the ecological state of the Pripet River using bioindication methods and determining the Macrophyte Index for Rivers (MIR)

Research methods and raw data. Four test sites, each at least 100 m long, were established along the river bed to research the ecological condition of the Pripet River. The first test site was located in the village of Polozhevo (upper course), the second site in the village of Luchytsi, the third in the village of Liubyaz on the border between the Volyn and Rivne regions, the fourth in the village of Senchytsi on the border with Belarus.

48 indicator species of macrophytes were selected to determine the Macrophyte Index for Rivers (MIR); they belong to the division Magnoliophyta, of which 21 belong to the class Magnoliopsida and 27 to the class Liliopsida.

Field studies at the territory of the river basin make it possible to calculate the Macrophyte index of rivers according to the formula [19, 26]:

$$\text{MIR} = \frac{\sum(Li \times Wi \times Pi)}{\sum(Wi \times Pi)} \times 10;$$

where

MIR is the macrophyte index for rivers;

L_i is the quantitative value of the indicator for the specified species;

W_i is the weight factor for the species *i*;

P_i is the coverage coefficient of the specified species on a 9-point scale.

The MIR indicator can vary from 10 (most degraded rivers) to 100 (very good ecological condition). For the lowland rivers, the MIR cannot exceed 60. The calculations of MIR used 151 indicator species of macrophytes. The methodology sets the boundary values of the MIR for 5 classes of ecological status, from very good to very bad, for each macrophyte type of rivers developed in accordance with the EU Water Framework Directive [19, 26, 28]. The studied test sections of the Pripet River were classified by comparing the calculated MIR to the classification values for the type of river, lowland, highland, or mountain (Table 1).

Comparative analysis of the ecological state of the water quality of the Pripet River according to hydrochemical parameters and determined by the MIR [19, 26] used the results of laboratory studies of the State Environmental Inspection in the Volyn region performed in accordance with the regulatory documents [9].

Research results. The Pripet River is one of the large rivers of Ukraine, the largest of the right tributaries of the Dnieper in terms of basin area, length and water content (Table 2). The Pripet is a trans-border river as it flows on the territory of two countries,

Table 1

Classification of the MIR values for determining the ecological status of rivers [4, 5, 19, 26]

Macrophyte type		Watercourse type	Ecological status				
			Very good	Good	Moderate	Bad	Very bad
M-1	Alpine streams	Highland or mountain watercourse	≥65.6	(65.6 – 50.7>	(50.7 – 38.8>	(38.8– 24.0>	<24.0
M-II	Silicon rivers		≥61.8	(61.8 – 48.1>	(48.1 – 37.0>	(37.0 – 23.3>	<23.3
M-III	Carbonate rivers		≥55.4	(55.4 – 42.0>	(42.0 – 31.4>	(31.4 – 18.0>	<18.0
M-IV	Highland water-courses of lowland nature		≥48.3	(48.3 – 37.7>	(37.7 – 27.0>	(27.0 – 16.4>	<16.4
M-V	Large highland rivers		≥46.5	(46.5 – 37.8>	(37.8 – 29.0>	(29.0 – 20.3>	<20.3
M-VI	Sandy rivers	Lowland watercourse	≥46.8	(46.8 – 36.6>	(36.6 – 26.4>	(26.4 – 16.1>	<16.1
M-VII	Stone-gravel rivers		≥47.1	(47.1 – 36.8>	(36.8 – 26.5>	(26.5 – 16.2>	<16.2
M-VIII	Organic rivers		≥44.5	(44.5 – 35.0>	(35.0– 25.4>	(25.4 – 15.8>	<15.8
M-IX	Large lowland rivers		≥44.7	(44.7 – 36.5>	(36.5– 28.2>	(28.2 – 20.0>	<20.0

Ukraine and the Republic of Belarus. The length of the Pripet River is 775 km, of which 261 km within the borders of Ukraine, of which 172 km flows in the Volyn region. The total catchment area is 114,300 km^2, of which 76,600 km^2 is within Ukraine, and 15,500 km^2 is within the Volyn region [3, 7, 8].

The Pripet originates between the villages of Budnyki and Rogovy Smolyari of the Luboml district of the Volyn Region on the Volyn Upland (on modern maps, the village of Budnyki belongs to the Kovel District). After 204 km from the source, the river leaves the territory of Ukraine, and the following 500 km flows in the Polissia lowland of the Republic of Belarus in a weakly defined valley, separating into distributaries in the area of the Pinsk marshes. The last 50 km the Pripet again flows in the territory of Ukraine joining the Dnieper River (Kyiv Reservoir) a few kilometers from Chornobyl [3].

The Pripet has a well-developed hydrographic network (10,500 rivers and streams). Most of the tributaries are completely or partially turned into channels. The right-bank tributaries flow mainly through the territory of Ukraine, while the left-bank tributaries flow through the Republic of Belarus (Table 2).

Table 2

The largest tributaries of the Pripet River

Left-bank tributaries	Length, km	Catchment area, km^2	Right-bank tributaries	Length, km	Catchment area, km^2
Pina	40	2 460	Tenetychka	20	
Yaselda	242	5 430	Vyzhivka	81	1 272
Bobryk the First	109	1 902	Turiya	184	2 900
Tsna	126	1 130	Stokhid	188	3 125
Lan’	147	2 190	Tsyr	57	507
Sluch	228	5 760	Veselukha	69	940
Bobryk the Second	44	710	Styr	483	13 130
Ptych	486	9 470	Vybiy	10	55
Tremlia	80	769	Goryn’	659	27 700
Ipa	109	1 010	Stvyga	178	5 440
Vit	70	991	Uborot’	292	5 820
Braginka	179	2 778	Mytva	47	430
			Slovechna	138	2 670
			Zholon’	113	1 460
			Uzh	256	8 080

The main tributaries of the Pripet within the Volyn region are the Stokhid, the Turiya, the Styr, the Vyzhivka, and the Tsyr rivers [3].

The valley of the Pripet is weakly defined in the upper reaches, and more clearly in the lower reaches. The floodplain is developed along the entire length of the Pripet. Two floodplain terraces are generally distinguished. The width of the floodplain in the upper reaches is 2-4 km or more, which in some years is flooded for several months. The width of the floodplain in the lower stream reaches 10-15 km (Fig. 1).

There is a significant number of lakes of various origins in the basin of the Pripet River: floodplain (Lake Liubyaz, Luky, Strybuzh), karst (Lake Velyke Domashne, Male Domashne, Pisochne, Luka), and glacial (Lake Bile, Skorin). The majority of the floodplain lakes is located in the northern and northwestern parts of the Pripet River, the largest being Lake Liubyaz. The karst lakes are located in the catchments of such rivers as the Turiya, the Vyzhivka, the Tsyr, and the Stokhid. The karst lakes are fed by atmospheric precipitation, surface runoff, and groundwater. All lakes have a mixed type of feed; depending on the type, precipitation, runoff, or groundwater dominates. The water level of the lakes coincides with that of the rivers.

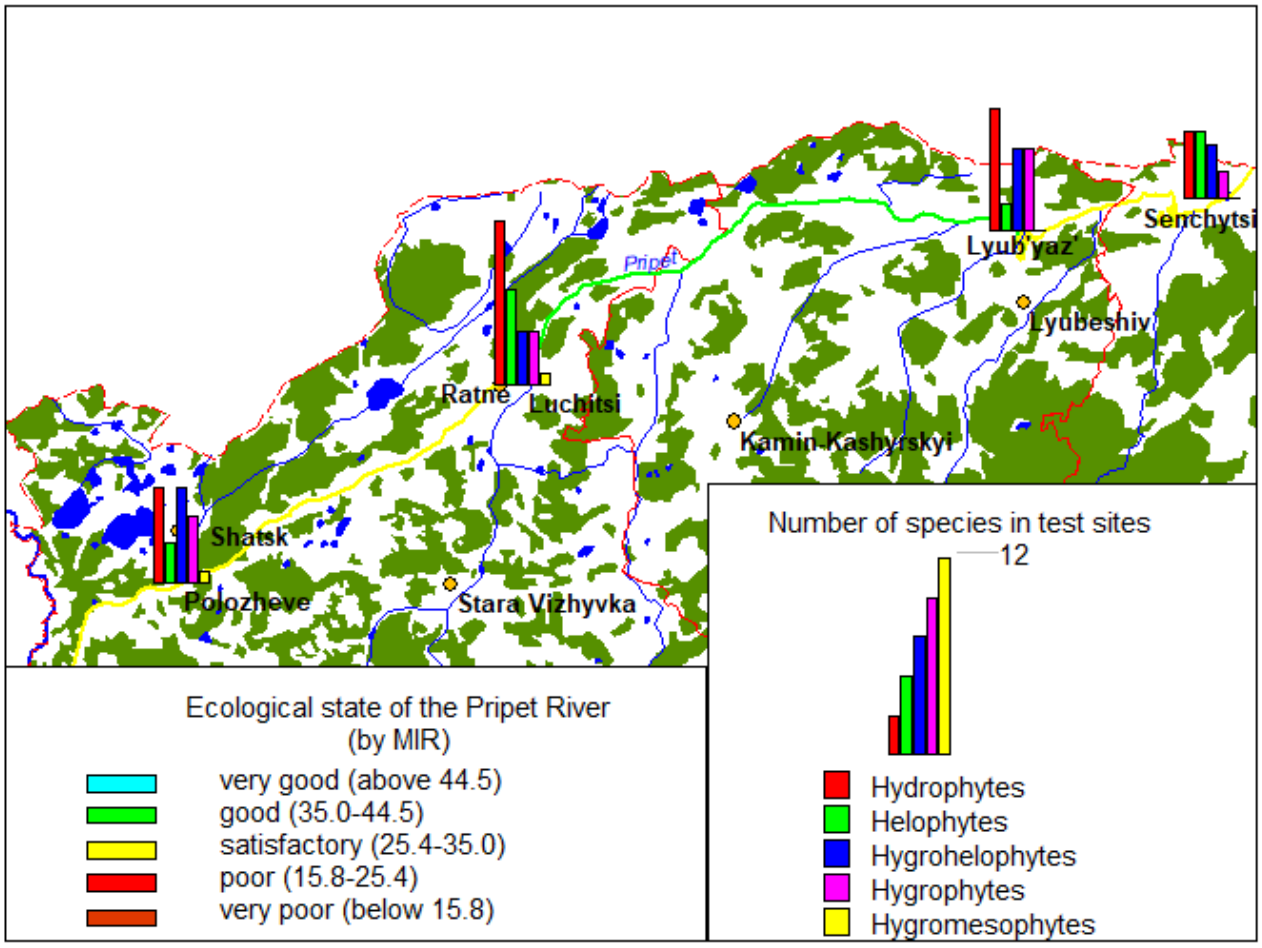

Fig. 1. Ecological state of the Pripet River by the macrophyte index MIR

The Pripet river basin has a moderately continental climate, with wet summers and mild winters. It is characterized by a long spring flood, a short-term summer low, which is disturbed by rain floods and almost annual autumn water level rises. The intensity of the water level rise during floods varies between 15-20 cm/day, and in some years up to 40 cm/day. A spring flood lasts on average 50-70 days [3, 7, 8].

The Pripet River remains one of the few rivers of the Volyn region whose floodplains have been preserved in their natural state. Practically the entire territory is included in the nature reserve, there are 10 hydrological reserves and the Pripet-Stokhid National Park. The Pripet floodplain is included in the list of wetlands of Ukraine subject to the Ramsar Convention.

We performed ecological and geobotanical research on the 4 test sites along the Pripet water course during May – September 2021. As a result of the field studies presented in Table 3, the features of the distribution of macrophyte species [13] (including indicator species) and the projective coverage of each species on the test sites were determined.

The research found 48 species of higher aquatic

Table 3

Qualitative and quantitative characteristics of macrophytes of the upper reaches of the Pripet River

№	Macrophyte species	Li	Wi	Projective coverage (P) in the test sites			
				Polozhevo	Luchytsi	Liubyaz	Senchytsi
1	*Cicuta virosa* L.	**6**	**2**	3		3	3
2	*Sium latifolium* L.	**7**	**1**	4	3		
3	*Bidens tripartita L.*			3			
4	*Myosotis scorpiodes* L.	**4**	**1**	3	3	3	3
5	*Rorippa amphibia* (L.) Bess.	**3**	**1**	3		3	3
6	*Ceratophyllum demersum* L.	**2**	**3**	6	5		3
7	*Ceratophyllum submersum* L.	**2**	**3**		4		
8	*Lycopus europaeus* L.				2	2	
9	*Mentha aquatica* L.	**5**	**1**		2	3	3
10	*Epilobium palustre* L.			2			
11	*Lythrum salicaria L.*			3			
12	*Nuphar lutea* (L.) Smith.	**4**	**2**	5	6	4	4
13	*Nymphaea alba L.*				2		
14	*Persicaria hydropiper* (L.) Delarb.	**3**	**1**		2		
15	*Polygonum persicaria L.*	**2**	**2**	2			
16	*Rumex aquaticus* L.			1			
17	*Rumex crispus* L.			3	3		
18	*Lysimachia nummularia* L.					3	
19	*Lysimachia vulgaris* L.	**4**	**1**	5		2	
20	*Myriophyllum spicatum* L.	**3**	**2**		4	3	
21	*Myriophyllum verticillatum* L.					2	
22	*Acorus calamus* L.	**2**	**3**	5	5	3	
23	*Alisma plantago-aquatika* L.	**4**	**2**		2		2
24	*Sagittaria sagittifolia* L.	**4**	**2**	5	5		2
25	*Lemna minor* L.	**2**	**2**	7		3	4
26	*Lemna trisulca* L.	**4**	**2**	1		2	
27	*Lemna gibba* L.	**1**	**3**	2			
28	*Spirodela polyrrhiza* (L.) Schleid	**2**	**2**		1		4
29	*Butomus umbellatus L.*	**5**	**2**		1		
30	*Hydrocharis morsus-ranae* L.	**6**	**2**		2	2	
31	*Elodea canadensis* Michx.	**5**	**2**	6	6		
32	*Vallisneria spiralis* L.					2	2
33	*Stratiotes aloides* L.	**6**	**2**		4	4	
34	*Potamogeton lucens* L.	**4**	**3**		2		
35	*Potamogeton natans* L.	**4**	**1**	5	2		
36	*Potamogeton perfoliatus* L.	**4**	**2**			2	
37	*Iris pseudacorus* L.	**6**	**2**	3	3	2	
38	*Carex acuta* L.	**5**	**1**			2	2
39	*Carex riparia* Curtis	**4**	**2**			2	
40	*Carex acutiformis* Ehrh.	**4**	**1**				2
41	*Scirpus sylvaticus* L.	**5**	**2**			2	
42	*Scirpus lacustris* L.	**4**	**2**		2	2	2
43	*Eleocharis palustris* (L.) Roem. & Schult.	**6**	**2**		2		
44	*Juncus effuses* L.				1		
45	*Glyceria maxima* (Hartm.) Holmb.	**3**	**1**	4	5	4	2
46	*Phragmites australis* (Cav.) Steud.			3			6
47	*Sparganium erectum* L.	**3**	**1**		2		
48	*Sparganium emersum* Rehm.	**4**	**2**		2		
	Total species: 48, 35 indicative species			22 total, 19 indic.	27 total, 24 indic.	22 total, 19 indic.	15 total, 14 indic.
	MIR value at the test site			33.84 (III)	34.04 (III)	40.6 (II)	33.57 (III)

and coastal aquatic plants in the test sites of the Pripet River. All species belong to the division *Magnoliophyta*, of which 21 species belong to the class *Magnoliopsida* (43.75%), and the larger share, 27 species, belong to the class *Liliopsida* (56.25%),

The largest number of species, 6, belongs to the *Cyperaceae* family (12.50%). Four species each (8.33%) belong to the *Polygonaceae*, *Araceae*, and *Hydrocharitaceae* families. Another 3 species (6.26%) belong to the *Potamogetonaceae* family. The other 18 families include 1-2 species each (Fig. 2).

In terms of the number of species of aquatic and coastal aquatic plants, site No. 2 (the village of Luchytsi) predominates where 28 species were found. There are 23 species each in the sites No. 1 (Polozhevo) and No. 3 (Liubyaz), and 16 species in the site No. 4 (Senchytsi).

Five ecotypes of macrophytes are identified in the classification: hydrophytes, or real water plants; helophytes, or air-water plants; hygrohelophytes; hygrophytes; hygromeso- and mesophytes [13]. The analysis of the species of higher aquatic and coastal aquatic plants at the test sites showed that the largest number of true aquatic plants, 12 species (42.86%),

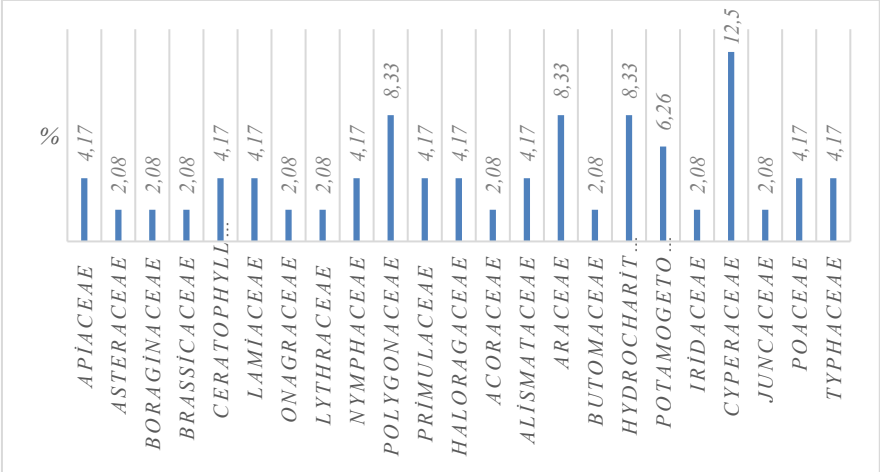

Fig. 2. Macrophyte families of the Pripet River

is located at site No. 2 (Luchytsi village). These are the following types: *Elodea canadensis, Ceratophyllum demersum, Nuphar lutea, Persicaria hydropiper, Myriophyllum spicatum, Spirodela polyrrhiza, Hydrocharis morsus-ranae, Nymphaea alba, Stratiotes aloides, Potamogeton lucens, Potamogeton natans, Ceratophyllum submersum.*

The smallest variety was found in site No. 4 (Senchytsi village), only 5 species: *Ceratophyllum demersum, Nuphar lutea, Lemna minor, Spirodela polyrrhiza, Vallisneria spiralis*.

Helophytes are also best represented in site No. 2 (Luchytsi village) where 7 species were found: *Alisma plantago-aquatica, Sagittaria sagittifolia, Butomus umbellatus, Scirpus lacustris, Glyceria maxima, Sparganium erectum, Sparganium emersum*. The fewest number of them are in site No. 3 (Liubyaz village) where specimens of the species *Scirpus lacustris* and *Glyceria maxima* were found.

Among the hygrohelophytes, the largest number, 7 species, was found in site No. 1 (Polozhevo village): *Cicuta virosa, Sium latifolium, Rorippa amphibia, Lythrum salicaria, Rumex aquaticus, Acorus calamus, Iris pseudacorus*.

The most hygrophytes in the list of flora, 6 species, were in test site No. 3 (Liubyaz village): *Myosotis scorpiodes, Lycopus europaeus, Mentha aquatica, Lysimachia nummularia, Lysimachia vulgaris, Scirpus sylvaticus*. Only two species, *Myosotis scorpiodes* and *Mentha aquatica*, were in test site No. 4 (Senchytsi village).

Hygromeso- and mesophytes are represented by only one species, *Rumex crispus*, in test sites No. 1 (Polozhevo village) and No. 2 (Luchytsi village) (Table 4).

Analysis of the species composition of macrophytes at the test sites along the Pripet River regarding the indicative value of the species showed that of 48 macrophyte species detected, 35 have indicative value. A total of 23 species were found at test site No. 1 (village of Polozhevo), 19 of which are indicative species. The highest projective coverage was for *Lemna minor* (40%), *Elodea canadensis* (20%), *Ceratophyllum demersum* (15%), *Nuphar lutea* (10%), *Lysimachia vulgaris* (10%), *Acorus calamus* (10%), *Sagittaria sagittifolia* (10%).

Test site No. 2 (village of Luchytsi) featured 28 species of higher aquatic and coastal aquatic plants, 24 of which are indicative. The largest projective coverage of the indicative species was for *Elodea canadensis* (15%), *Ceratophyllum demersum* (10%), *Acorus calamus* (10%), *Sagittaria sagittifolia* (10%). 23 species of plants were found on test site No. 3 (village of Liubyaz), 19 of them are indicative. Among them, *Nuphar lutea* (5%), *Stratiotes aloides* (4%) and *Glyceria maxima* (3%) have the largest projective coverage. Other species have projective coverage

Table 4

Ecotypes of aquatic and coastal aquatic plants of the Pripet River

	Ecotypes	Number of species (share in %) in the test sites			
		No. 1, Polozhevo	No. 2, Luchytsi	No. 3, Liubyaz	No. 4, Senchytsi
I	Hydrophytes, of which:	7 (30.44)	12 (42.86)	9 (39.13)	5 (31.25)
	Free-floating	3 (13.04)	2 (7.14)	3 (13.04)	2 (12.50)
	Immersed and rooted	1 (4.35)	4 (14.29)	5 (21.74)	1 (6.25)
	Rooted with floating leaves	2 (8.70)	4 (14.29)	1 (4.35)	1 (6.25)
	Immersed not rooted	1 (4.35)	2 (7.14)	-	1 (6.25)
II	Helophytes, of which:	3 (13.04)	7 (25.00)	2 (8.69)	5 (31.25)
	Low-herbed	1 (4.35)	6 (21.43)	1 (4.35)	3 (18.75)
	High-herbed	2 (8.70)	1 (3.57)	1 (4.35)	2 (12.50)
III	Hygrohelophytes	7 (30.44)	4 (14.29)	6 (26.09)	4 (25.00)
IV	Hygrophytes	5 (21.73)	4 (14.29)	6 (26.09)	2 (12.50)
V	Hygromeso- and mesophytes	1 (4.35)	1 (3.56)	-	-
Total:		23 (100)	28 (100)	23 (100)	16

from 0.5% to max 2%.

Sixteen species of higher aquatic and coastal aquatic plants were found at test site No. 4 (village of Senchytsi), 14 of them are indicative. Among these, *Nuphar lutea* (3%), *Lemna minor* (3%), *Spirodela polyrrhiza* (3%) have the largest projective coverage. Other species have a projective coverage from 0.5% to 1%.

An assessment of the ecological condition of the Pripet River was made from the investigation results by the Macrophyte Index for Rivers (MIR). The formula above and the classification table for 4 types of rivers (Table 1) were used to calculate the MIR.

Characteristics of 35 indicative species of macrophytes found in the surveyed sites in the Pripet River according to the methodology were used to calculate the MIR value. According to the MMOR, the indicator (**L**), weight factor (**W**), coverage factor (**P**) are ascribed to indicative types of macrophytes [4, 5, 19, 26]). The results of the survey of the test sections of the river which are presented in Table 3 show that 48 species have been identified in the Pripet riverbed, of which 35 are indicator species of macrophytes. The quantitative value of the indicator varies from 1 to 7. The determined according to the MIR indicator of the ecological state of the Pripet River at 4 test sections of the channel is presented in Table 5.

According to the classification of the MIR for determining the ecological state [19, 26], the Pripet River belongs to lowland watercourses, with the macrophyte type M-VIII (organic rivers). Research and analysis of the Pripet River waters in four test sites established that in the test site No. 1 in the village of Polozhevo (upper reaches), the calculated Macrophyte Index for Rivers is 33.84, the water quality has a satisfactory ecological state; in the test section No. 2 in the village of Luchytsi the MIR is 34.04, the water quality has a satisfactory ecological state; in the test site No. 3 in the village of Liubyaz (border between Volyn and Rivne regions) the MIR is 40.6, water quality has a good ecological state; in the test site No. 4 in the village of Senchytsi (border with Belarus) the calculated MIR is 33.57, the river water quality has a satisfactory ecological state.

The largest anthropogenic impact on the ecological state of the Pripet River comes from water use activities in the river valley which occur along its main channel and the channels of its tributaries, where the vast majority of settlements are located. Drainage reclamation substantially affects the processes taking place in the river valley, as a result of which agricultural landscapes were formed in place of wetlands. Drained land is mainly used in agricultural production. Among the main anthropogenic factors that shape the load on the river valley, the following can be marked out: the degree of use of land resources, the amount of biogenic substances removed from agricultural objects, the intensity of use of water resources and their quality, the water supply of the population.

Table 5

Ecological state of the Pripet River according to the MIR

Test site of the river course	**MIR value**	**Ecological state**
village of Polozhevo (upper course)	33.84	III (35.0–25.4>) / satisfactory
village of Luchytsi	34.04	III (35.0–25.4>) / satisfactory
village of Liubyaz	40.6	II(44.5–35.0>) / good
village of Senchytsi (border with Belarus)	33.57	III (35.0–25.4>) / satisfactory

In all test sections of the river bed, facts of violations of the Water Code in terms of preserving the water protection zone of rivers were revealed during the study, such as presence of farm buildings and agricultural land, and runoff of sewage from residential and commercial facilities into surface waters.

Among the main negative points that affect the hydroecosystem of the Pripet River valley are silting which is associated with erosion in the catchment; pollution; water course regulating and straightening; deterioration of the self-cleaning capacity of the reservoir. Environmental problems in the valley of the Pripet River are also created by spring floods and flash floods.

Conclusions. The following conclusions can be drawn from the research:

1. A large part of the water management complex of the Volyn region is occupied by the Pripet River basin which has a significant degree of economic development. The river forms part of the state border between Ukraine and the Republic of Belarus, and the tributary basins are located on the territory of both states. The adherence to the strategic principles of rational nature management is thus necessary to preserve and restore the optimal ecological state of the Pripet River basin.

2. The analysis of the species composition of macrophytes in the test sites of the Pripet River showed that out of 48 identified species, 35 (72.92%) have indicative value. By test sites, 23 species were found at site No. 1 (village of Polozhevo), of which 19 are indicative species; 28 species at site No. 2 (v. Luchytsi), of which 24 are indicative; 23 and 19 species, respectively, at site No. 3 (v. Liubyaz); 16 and 14 species, respectively, at site No. 4 (v.Senchytsi).

3. The ecological condition of the Pripet River determined by the MIR indicator showed that the river belongs to lowland watercourses (organic rivers), with the M-VIII type of macrophytes. It was established that the water quality of the Pripet River in the test site No. 1 (v. Polozhevo, upper reaches) has satisfactory ecological state, MIR is 33.84; in the site No. 2 (v. Luchytsi) satisfactory ecological state, MIR is 34.04; in the site No. 3 (v. Liubyaz, border between Volyn and Rivne regions) good ecological state, MIR is 40.6; water quality in the site No. 4 (v. Senchytsi, border with Belarus) has satisfactory ecological state, MIR is 33.57.

4. According to the MIR calculations, it was established that the waters of the Pripet River have a satisfactory or good ecological state. This gives reason to assert that the research on the test sites and the calculations of the Macrophyte Index for Rivers fully reflect the ecological state of the watercourse. The results obtained in the course of the research indicate that this research algorithm may be used for other rivers of the Polissia basin.

Bibliography

1. *Боярин М. В. Основи гідроекології: теорія й практика. Навчальний посібник [Текст] / М. В. Боярин, І. М Нетробчук. – Луцьк: Вежа–Друк, 2016. – 364 с.*
2. *Гроховська Ю. Р. Структурний аналіз водної флори Стир-Горинської частини басейну Прип'яті /Ю. Р. Грохоська // Екологічні науки. – № 3-4 (10-11) . – 2015. – С. 38-47.*
3. *Клименко М. О. Оцінка екологічного стану водних екосистем річок басейну Прип'яті за вищими рослинами : монографія [Текст] / О. М. Клименко, Ю.Р. Гроховська.– Рівне : НУВГП, 2005. – 194 с.*
4. *Коробкова Г. В. Використання макрофітних індексів для оцінки екологічного стану поверхневих вод України / Г. В. Коробкова // Людина та довкілля. Проблеми неоекології. – 2017. – № 1–2 (27). – С. 62–70.*
5. *Некос А. Оцінка екологічного стану річок басейну Західного Бугу за індексом макрофітів (MIR) / А. Н. Некос, М. В. Боярин, М. В. Луговська, О. О. Цьось, І. М. Нетробчук // Вісник Харківського національного університету імені В. Н. Каразіна, серія «Геологія. Географія. Екологія». – 2021. – (54). – с. 316-328. https://doi.org/10.26565/2410-7360-2021-54-24*
6. *Некос А. Н. Екологічна оцінка якості води р. Стир (в межах м. Луцьк) / А. Н. Некос, М. В. Боярин // Збірник матеріалів 16 Міжнародної конференції «Моніторинг геологічних процесів та екологічного стану навколишнього середовища» 17-19 листопада 2022. – том 2022р. – с.1-5. https://doi.org/10.3997/22144609.2022580157*
7. *Яцик А. В. Екологічна оцінка якості основних річкових басейнів Волинської області / А. В. Яцик, І. В. Гопчак // Водне господарство України. – 2005. – №5. – С. 13–17.*
8. *Сучасний екологічний стан та перспективи екологічно безпечного стійкого розвитку Волинської області. За ред. В. О. Фесюка [Текст] – К. : ТОВ «Підприємство ВІ ЕН ЕЙ», 2016. – 316 с.*
9. *Регіональна доповідь про стан навколишнього природного середовища у Волинській області у 2021 році. Луцьк [б.в], 2022. – 196 с. URL: http://eco.voladm.gov.ua*
10. *Цьось О. О., Боярин М. В., Клименко О. М. Вища водна рослинність, як індикатор екологічного стану гідроекосистем (на прикладі річки Вижівка) / О. О. Цьось, М. В. Боярин, О. М. Клименко // Вісник НУВГП. Серія «Сільськогосподарські науки». – Випуск 2 (90). – 2020. – С. 72–82. http://dx.doi.org/10.31713/vs220207*
11. *Цьось О.О. Структурний аналіз вищих водних та прибережно-водних рослин річки Вижівка. // О. О. Цьось, О. С. Музиченко, М. В. Боярин / Людина та довкілля. Проблеми неоекології. – 2018. – № 30. – С. 104–111. https://doi.org/10.26565/1992-4224-2018-30-08*

12. Цьось О. О. Становлення фітоіндикаційних підходів у системі моніторингу стану водних екосистем./ О. О. Цьось, О. С. Музиченко, М. В. Боярин // Таврійський науковий вісник. Серія «Сільськогосподарські науки». Випуск 118. – 2021. – С. 382-388. https://doi.org/10.32851/2226-0099.2021.118.49
13. Чорна Г. А. Рослини наших водойм. [Текст] / Г. А. Чорна. – К. Фітосоціоцентр, 2001. – 134 с.
14. Jusik, S. Development of comprehensive river typology based on macrophytes in the mountain-lowland gradient of different Central European ecoregions / S. Jusik, K. Szoszkiewicz, J. Kupiec // Hydrobiologia. – 2015. – № 745. – P. 241–262. https://doi.org/10.1007/s10750-014-2111-2
15. Połe´c, K. Changes in the Ecological Status of Rivers Caused by the Functioning of Natural Barriers / Połe´c, K., Grzywna, A., Tarkowska-Kukuryk, M., Bronowicka-Mielniczuk, U. // Water 2022. – № 14. – P. 15-22. https://doi.org/10.3390/w14091522.
16. Muratov R. An attempt to prepare Macrophyte Index for Rivers for assessment watercourses in Kazakhstan // Muratov, R.; Szoszkiewicz, K.; Zhamangara, A.; Jusik, S.; Gebler, D.; Beisenova, R.; Akbayeva, L. Meteorol. Hydrol. Water Manage. – 2015. – 2. № 3. – P. 27–32. DOI: https://doi.org/10.26491/mhwm/59592
17. Myroslav S. Malovanyy. Assessment of the environmental state of surface waters of right-bank tributaries of the upper reaches of the Pripet River by macrophyte index MIR / M. Malovanyy, M. Boiaryn , O. Muzychenko , O. Tsos // Journal of Water and Land Development. – 2022. –N 55 (X–XII). – P. 97–103. DOI: 10.24425/jwld.2022.142310
18. Marcinkowski P. Model-Based Analysis of Macrophytes Role in the Flow Distribution in the Anastomosing River System. // Marcinkowski, P., Kiczko, A., Okruszko, T. Water. – 2018. – №10. – 953 p. https://doi.org/10.3390/w10070953
19. Hanna Ciecierska, Maria Dynowska. Biologiczne metody oceny stanu srodowiska. Tom 2. Ekosystemy wodne. Podrecznik metodyczny. Olsztyn. – 2013. – 312 P.
20. AFNOR (Assosiation Francaise de Normalisation) Qualite de l'eau – Determination de l'indice biologique macropfytique en rivier (IBMR) – Norm francaise NFT, 2003. – P. 90 – 395.
21. Bytyqi, P. Macrophytes as biological indicators of organic pollution in the Lepenci River Basin in Kosovo. J. Freshw / Bytyqi, P., Czikkely, M., Shala-Abazi, A., Fetoshi, O., Ismaili, M., Hyseni-Spahiu, M., Ymeri, P., Kabashi-Kastrati, E., Millaku, F. // Ecol. 2020. – № 35. – p. 105–121.
22. Mariia Boiaryn. Ocena stanu ekologicznego powierzchniowych wód rzeki Turia na podstawie makrofitowego indeksu rzecznego (MIR) // Mariia Boiaryn, Oksana Tsos. – Chemia. Envirinment. Biotechnology. – 2019. – № 22. – P. 7–12. www.ceb-journal.com, http://dx.doi.org/10.16926/cebj.2019.22.01
23. Tarkowska-Kukuryk, M. Macrophyte communities as indicators of the ecological status of drainage canals and regulated rivers (Eastern Poland) / Tarkowska-Kukuryk, M., Grzywna, A. // Environ. Monit. Assess. – 2022. – P. 194–210.
24. Szoszkiewicz K. An Assessment of the MTR Aquatic Plant Bioindication System for Determining the Trophic Status of Polish Rivers // Szoszkiewicz K., Karolewicz K., Lawniczak A., Dawson F. Polish Journal of Environmental Studies. – Vol. 11. – № 4 (2002). – P. 421–427.
25. Szoszkiewicz K. The Macrophyte Index for Rivers (MIR) asan Advantageous Approach to Running Water. // Szoszkiewicz K., Jusik S., Pietruczuk K., Gebler D. Assessment in Local Geographical Conditions Water. – 2020. – № 12. – P. 108. https://doi.org/10.3390/w12010108
26. Szoszkiewicz, K. Metodyka Bada´n Terenowych Makrofitów na Potrzeby Rutynowego Monitoringu Rzek. [Text] / Szoszkiewicz, K., Zbierska, J., Jusik, S., Zgola, T. – Bogucki Wydawnictwo Naukowe: Poznan, Poland. – 2009. – 81 p.
27. Szoszkiewicz, K. Macrophyte and macroinvertebrate patterns in unimpacted mountain rivers of two European ecoregions / Szoszkiewicz, K.; Jusik, S.; Lewin, I.; Czerniawska-Kusza, I.; Kupiec, J.M.; Szostak, M. // Hydrobiologia. – 2018. – №808. – P. 327–342.
28. EU Water Framework Directive 2000/60/EC. Official Journal of the European Communities, 22.12.2000. L 327 / 1. – 118 P.

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References

1. Boyaryn M. V., Netrobchuk I. M. (2016). Fundamentals of hydroecology: theory and practice. Tutorial. Lutsk: Tower – Print, 364 [in Ukrainian].
2. Grokhovska Yu. R. (2015). Structural analysis of the aquatic flora of the Styr-Horynsk part of the Pripyat basin. Environmental sciences, 3-4 (10-11), 38-47 [in Ukrainian].
3. Klymenko M. O., Grokhovska Yu. R. (2005). Estimation of ecological condition of water ecosystems of rivers of the Pripyat basin by higher plants. Rivne. NYVGP, 194. [in Ukrainian].
4. Korobkova G. V. (2017). Use of macrophytic indices to assess the ecological status of surface waters of Ukraine. Man and the environment. Problems of Neoecology, 1–2 (27), 62-70. [in Ukrainian].
5. Nekos, M. Boyarin, M. Lugovska, O. Tsyos, I. Netrobchuk. (2021). Assessment of the ecological state of the rivers of the Western Bug basin according to the macrophyte index (MIR). Visnyk of V. N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", (54), 316-328. DOI: https://doi.org/10.26565/2410-7360-2021-54-24 [in Ukrainian].

6. *Nekos A., Boyarin M. Ecological assessment of the water quality of the Styr river (within the city of Lutsk). Collection of materials of the 16-th International Conference "Monitoring of Geological Processes and the Ecological State of the Environment". November 17-19 (2022), 1-5. DOI: https://doi.org/10.3997/22144609.2022580157 [in Ukrainian].*
7. *Yatsyk A. V., Hopchak I. V. (2005). Ecological assessment of the quality of the main river basins of the Volyn region. Water management of Ukraine, 5, 13–17 [in Ukrainian].*
8. *Fesyuk V. O. (2016). Current ecological condition and prospects of ecologically safe sustainable development of Volyn region. K., VAN Enterprise Enterprise LLC, 316 [in Ukrainian].*
9. *Regional report on the state of the environment in the Volyn region in 2021 (2022). Lutsk, 196. URL: http://eco.voladm.gov.ua [in Ukrainian].*
10. *Tsyos O. O., Boyaryn M. V., Klymenko O. M. (2020). Higher aquatic vegetation as an indicator of the ecological state of hydroecosystems (on the example of the Vyzhivka River). Bulletin of the NUVHP. "Agricultural Sciences" series, 2 (90), 72–82 [in Ukrainian]. DOI: http://dx.doi.org/10.31713/vs220207*
11. *Tsyos O. O., Muzychenko O. S., Boyaryn M. V. (2018). Structural analysis of higher aquatic and coastal aquatic plants of the Vyzhivka river. Man and the environment. Problems of Neoecology, 30, 104–111 [in Ukrainian]. DOI: https://doi.org/10.26565/1992-4224-2018-30-08*
12. *Tsyos O. O., Muzychenko O. S., Boyaryn M. V. (2021) Development of phytoindicative approaches in the system of monitoring the state of aquatic ecosystems. Taurian Scientific Bulletin. "Agricultural Sciences" series, 118, 382-388. https://doi.org/10.32851/2226-0099.2021.118.49 [in Ukrainian].*
13. *Chorna H.A. (2001). Plants of our reservoirs, 134 [in Ukrainian].*
14. *Jusik, S., Szoszkiewicz, K., Kupiec, J. (2015). Development of comprehensive river typology based on macrophytes in the mountain-lowland gradient of different Central European ecoregions. Hydrobiologia, 745, 241–262. DOI: https://doi.org/10.1007/s10750-014-2111-2*
15. *Połe´c, K., Grzywna, A., Tarkowska-Kukuryk, M., Bronowicka-Mielniczuk, U. (2022). Changes in the Ecological Status of Rivers Caused by the Functioning of Natural Barriers. Water, 14, 15-22. DOI: https://doi.org/10.3390/w14091522*
16. *Muratov, R.; Szoszkiewicz, K.; Zhamangara, A.; Jusik, S.; Gebler, D.; Beisenova, R.; Akbayeva, L. (2015). An attempt to prepare Macrophyte Index for Rivers for assessment watercourses in Kazakhstan. Meteorol. Hydrol. Water Manage, 3, 27–32. DOI: https://doi.org/10.26491/mhwm/59592 [in Polish].*
17. *Myroslav S. Malovanyy, Mariia Boiaryn, Oksana Muzychenko, Oksana Tsos (2022). Assessment of the environmental state of surface waters of right-bank tributaries of the upper reaches of the Pripet River by macrophyte index MIR. Journal of Water and Land Development, 55 (X–XII), 97–103. DOI: 10.24425/jwld.2022.142310 [in Polish].*
18. *Marcinkowski P., Kiczko, A., Okruszko, T. (2018). Model-Based Analysis of Macrophytes Role in the Flow Distribution in the Anastomosing River System. Water, 10, 953. DOI: https://doi.org/10.3390/w10070953*
19. *Hanna Ciecierska, Maria Dynowska (2013). Biological methods of assessing the state of the environment, 2. Water ecosystems. Methodical handbook. Olsztyn, 312 [in Polish]*
20. *AFNOR (Assosiation Francaise de Normalisation) Qualite de l'eau – Determination de l'indice biologique macropfytique en rivier (IBMR) – Norm francaise NFT (2003), 90, 395 [in French].*
21. *Bytyqi, P., Czikkely, M., Shala-Abazi, A., Fetoshi, O., Ismaili, M., Hyseni-Spahiu, M., Ymeri, P., Kabashi-Kastrati, E., Millaku F. (2020). Macrophytes as biological indicators of organic pollution in the Lepenci River Basin in Kosovo. J. Freshw. Ecol., 35, 105–121.*
22. *Mariia Boiaryn, Oksana Tsos (2019) Assessment of the ecological status of the Turia River surface waters on the basis of the River Macrophyte Index (MIR). Chemistry. Envirinment. Biotechnology, 22, 7–12 [in Polish] www.ceb–journal.com, DOI: http://dx.doi.org/10.16926/cebj.2019.22.01)*
23. *Tarkowska-Kukuryk, M., Grzywna, A. (2022). Macrophyte communities as indicators of the ecological status of drainage canals and regulated rivers (Eastern Poland). Environ. Monit. Assess, 194–210.*
24. *Szoszkiewicz K., Karolewicz K., Lawniczak A., Dawson F. (2002) An Assessment of the MTR Aquatic Plant Bioindication System for Determining the Trophic Status of Polish Rivers. Polish Journal of Environmental Studies, 11(4), 421–427 [in Polish]*
25. *Szoszkiewicz K., Jusik S., Pietruczuk K., Gebler D. (2020). The Macrophyte Index for Rivers (MIR) asan Advantageous Approach to Running Water. Assessment in Local Geographical Conditions Water, 12, 108. DOI: https://doi.org/10.3390/w12010108*
26. *Szoszkiewicz K., Zbierska, J., Jusik, S., Zgola, T. (2009) Methodology of Macrophyte Field Research for the Needs of Routine River Monitoring. Bogucki Scientific Publishing House: Poznan, Poland, 81 [in Polish].*
27. *Szoszkiewicz K., Jusik, S.; Lewin, I.; Czerniawska-Kusza, I.; Kupiec, J.M.; Szostak, M. (2018) Macrophyte and macroinvertebrate patterns in unimpacted mountain rivers of two European ecoregions. Hydrobiologia, 808, 327–342. DOI: https://doi.org/10.1007/s10750-017-3435-5*
28. *EU Water Framework Directive 2000/60/EC. Official Journal of the European Communities, 22.12.2000. L 327 / 1. 118.*

Визначення макрофітового індексу (MIR) як індикатора якості води у річці Прип'ять

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Найбільшу площу на території Волинської області займає басейн річки Прип'ять, який є найбільш освоєним з господарської точки зору. Крім того, вздовж водотоку частково проходить державний кордон між Україною та Республікою Білорусь, річка є транскордоною, басейни приток розміщені на території обох держав. Для відновлення та збереження оптимального екологічного стану басейну Прип'яті необхідним є дотримання стратегічних принципів раціонального природокористування. Визначено екологічний стан русла річки Прип'ять за Макрофітовим індексом річок (MIR), аналіз видового складу макрофітів дозволяє повязати їх з якістю поверхневих вод, як біоіндикаторів екологічного стану. Для визначення екологічного стану річок басейну Прип'яті та для проведення досліджень було закладено чотири тестові ділянки довжиною не менше 100 м. кожна. На тестових ділянках р. Прип'ять під час досліджень було виявлено 48 видів вищих водних та прибережно-водних рослин, усі види належать до відділу *Magnoliophyta*, з них до класу *Magnoliopsida* відноситься 21 вид (43,75%), більша частина відноситься до класу *Liliopsida* – 27 видів (56,25%). Для обчислення MIR (*Макрофітового індексу річок*) та визначення екологічного стану річки Прип'ять на 4 тестових ділянках відібрали згідно методики 35 видів біоіндикаторів та в результаті розрахунку (MIR) встановили, що якість води у річці, що на тестовій ділянці русла річки 1 в с. Положево (верхня течія) макрофітовий індекс річок (MIR) становить 33,84, якість води річки має задовільний екологічний стан; на тестовій ділянці 2 в с. Лучиці (MIR) становить 34,04, якість води річки має задовільний екологічний стан; на тестовій ділянці 3 в с. Люб'язь (кордон між Волинською та Рівненською областями) (MIR) становить 40,6, якість води у річці має добрий екологічний стан; на тестовій ділянці 4 в с. Сенчиці (кордон з Білоруссю) обрахований макрофітовий індекс річок (MIR) становить 33,57, якість води річки має задовільний екологічний стан. Річка Прип'ять належить до водотоків низинних (річки органічні), за типом макрофітів – M-VIII.

Ключові слова*: русло річки, поверхневі води, біоіндикація, видовий склад макрофітів, екологічний стан водотоків, макрофітний індекс річки.*

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