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LACUSTRINE ECOSYSTEMS OF THE STEPPE DNIPRO REGION: TYPOLOGY, ECOLOGICAL STATUS ASSESSMENT AND CONSERVATION VALUE

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Introduction. Lacustrine ecosystems are crucial and irreplaceable in biodiversity conservation and provide specific ecosystem services. Although systematic long-term studies on the inventory and typology of lakes worldwide have been conducted, the issue remains poorly understood in the Steppe Dnipro region of Ukraine. Although lacustrine systems are vulnerable and characterised by significant diversity, this requires early environmental assessment and implementation of management plans to ensure their conservation.

Aim and tasks. This study aimed to develop a typological scheme for open-type lake ecosystems in the Steppe Dnipro region with a set of typological criteria that can be combined to perform various applied environmental tasks, including the assessment of the ecological state of water bodies, inventory, environmental monitoring, and study of the dynamics of lake systems in the context of climate change.

Results. The regional typological scheme was developed based on international and regional experience in the field of ecosystem classification (New Broad Typology for European Rivers and Lakes). The criteria are based on the generalisation of long-term studies of lake ecosystems in the region as components of the regional ecological network. In total, 53 criteria were identified, and a separate typological scheme with fewer criteria was developed for man-made reservoirs. The typology was adapted for use in GIS projects, where each criterion has a range of values. Tabular examples of the application of the typological scheme to identify typologically similar water bodies and for the rapid assessment of their ecological status are presented.

Conclusions. The regional typological scheme allows for the distinction of water body types by various combinations of criteria. In practice, it is convenient to quickly create samples of lakes that are similar in certain respects for specific environmental or economic tasks. Further work with the scheme involves filling in the dataset, refining the parameters, and creating lake clusters using cluster analysis algorithms. After verification, the typological scheme can be transformed into a public web portal with the functions of an open database of data on lake-type reservoirs (with the possibility of updating and supplementing) and used to assess the ecological status and track current changes in the ecosystems of lakes and man-made reservoirs in the region.

Keywords: lake ecosystem, Steppe Podniprovia, freshwater bodies, ecological assessment, ecosystem services.

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1. Introduction.

Lake (lacustrine) ecosystems play a vital, irreplaceable role in the conservation and maintenance of biodiversity at the species and ecosystem levels and, on the other hand, provide specific and important ecosystem services to society. The study of lake ecosystems is critical in global climate change, which primarily affects the ecological status of lake ecosystems, which are even more sensitive than flowing (river) systems (Buffagni, 2020).

Lakes become especially vulnerable in the arid conditions of the steppe climate of the Steppe Dnipro region, where, in recent decades, there has been a steady trend towards shallowing, drying up, and degradation of lake systems (Wagner & Palamarchuk, 2025). An integrated approach to studying lakes as a specific type of ecosystem, and more broadly, as integral components of higher-level geosystems (catchment areas and landscape complexes) involves systematising data and creating a classification based on empirical studies of the diversity of lake-type ecosystems. Such a classification should serve as the basis for further planning and implementation of the most important tasks for modern applied limnology, such as developing differentiated management plans for managing lake ecosystems for their conservation, maintenance, and restoration. Despite the existing and well-developed general classification systems for lakes on the European subcontinent, such systems need to be reconsidered, compared, and adapted to local conditions at the regional level.

Based on research on the lake ecosystems of the Steppe Dnipro region as key elements in the national ecological network of the region (Maniuk, 2021), this study proposes an approach to the typology of lake ecosystems in the region, which is open for further development, testing, and verification. Such typology can be the basis for a detailed inventory and certification of the region's lake ecosystems, considering a set of indicative typological indicators, each of which is essential for understanding the role of lake bodies of water in conserving biodiversity, maintaining ecological balance in landscapes, and providing ecosystem services (Globevnik, 2019).

2. Literature Review.

The development of universal and practical classifications of water bodies, particularly standing ones, has traditionally received sufficient attention. One of the first classification schemes was the typology proposed for wetlands under the jurisdiction of the Ramsar Convention (Convention on Biological Diversity & Ramsar Convention Secretariat, 2006). This Convention interprets wetlands broadly and includes all excessively moist landscapes, including water bodies, in the concept of “wetlands”.

According to the Ramsar Convention (Convention on Biological Diversity & Ramsar Convention Secretariat, 2006), lake systems in the narrow sense (permanent or temporary reservoirs of non-flowing or slow water exchange from the smallest lakes) include not only lakes but also other types of wetlands, including some types of marshes with open water areas. This interpretation of lake systems can ensure the protection of more numerous, albeit small, lakes, which are represented both in relatively lake-supplied regional watersheds (Oril, Dnipro, and Samara rivers) and in more southern steppe regions where there are no large natural lakes (the basins of small rivers such as the Vorona, Osokorivka, Tomakivka, and Bazavluk).

Claiming to be universal, the Ramsar Convention’s guidelines for wetland inventory simultaneously provide for the development of detailed wetland classification schemes for individual regions (Guidelines, 2006). As a party to the Convention, this process is incomplete for Ukraine. Hence, studying the specifics of lake systems in the Steppe region and determining their place in the national wetland classifier remains an urgent priority.

After the Ramsar Convention was implemented, the world and Europe began developing classifications of habitats, biotopes, landscapes, and ecosystems. With the advent of the possibility of widespread use of GIS technologies, these processes have become more comprehensive. Despite the differences in classification methodology, the final results of the currently leading typological systems for lake systems are similar to each other.

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Each lake system classification was created for a specific purpose. For example, in the well-developed and tested, including in Ukraine, EUNIS habitat system, adopted as the basis for the implementation of the EU Habitats Directive (Council of the European Communities, 1992), more importance is given to those criteria that are important for ensuring the conditions for the existence of specific species of organisms and their communities. For geospatial inventories, the CORINE classification of land surface types is more convenient (Bossard et al., 2000).

Remote sensing methods effectively interpret the water surfaces of lakes, but further classification, especially for small water bodies, is difficult or impossible without ground surveys synchronised in time with images. However, the two classifications mentioned above cover the entire diversity of terrestrial ecosystems and do not specialise in aquatic systems. Instead, to achieve the goals of the EU Water Directive (European Parliament & Council of the European Union, 2000) and for large-scale assessment of the state of aquatic ecosystems, Lyche Solheim et al. (2019) presented the so-called “New Broad Typology of Rivers and Lakes in Europe”.

This typology is based on a multilevel assessment of each lake ecosystem using several indicators and further processing and generalisation of the results to identify existing typological units objectively. At different stages of setting up the typological system, datasets were collected from different EU countries according to certain typological features (descriptors), which were further processed using statistical analysis methods, and then cluster analysis was applied.

All lake systems in EU countries were divided into large groups by geographical region, and different descriptors were used for each region, which were more appropriate for specific physical and geographical conditions. Despite thorough methodological support, supported by large amounts of actual data, the possibilities of this typology are limited for Ukraine and even more so for the Steppe Dnipro region, where lake systems have certain differences that were not considered when developing the typological model.

The lake systems in the Steppe Dnipro region remain poorly understood. However, they have been the focus of several generations of researchers, primarily scientists from the Institute of Hydrobiology, who have successfully studied aquatic life complexes and their ecological conditions in rivers, reservoirs, and lakes in the Steppe Dnipro region for decades.

However, the available publications cover only certain aspects, mostly related to the species composition of aquatic organisms, distribution by ecotopes, population status, and macrophyte overgrowth dynamics.

The first attempts to typology the lakes of the region can be seen in the publications of Bellegarde (1938a), who studied the plant resources of the Pokrovsky floodplains of the Dnipro River (part of the Velykyi Luh) and identified three types of water bodies in the floodplains: large flowing water bodies (with a relatively poor floral composition), small flowing water bodies with richer flora, and standing water bodies. Bellegarde (1938b) divided the last category into unovergrown, semi-overgrown, and overgrown, with the richest macroflora being overgrown. These criteria (flow, size, and degree of overgrowth) have been successfully used in classification schemes for inland water bodies. Specific features of the nature of floodplain lakes were also described by

Stakhovsky (1938) included dynamic seasonal changes from a temporary rise in water level by several meters during spring floods to almost completely drying lakes in summer. Also valuable are the observations of Barabash-Nikiforov (1928), who noted that floodplain lakes (in the Dnipro River valley), even when completely dry in summer, retain moisture well in dry years, which ensures the rapid growth of plant phytomass on drained surfaces, and this provided good hayfields for the population at that time (provided that the grassy cover on the steppe pastures dried out completely).

Simultaneously, several schemes for the zoning of Ukrainian marshes were created, where the authors also included floodplain lakes without drawing a clear distinction between lakes and marshes.

Thus, according to Lavrenko (1928), the Steppe of Dnipro is fully included in the Buzko-Dnipro steppe region, which is characterised by very little wetland, up to 1% of the entire territory. This situation is generally fair for lake ecosystems in the region. However, neither at that time nor later, until the early 2000s, were special comprehensive studies of lake ecosystems in the Steppe Dnipro region were conducted.

With the beginning of the construction of the cascade of giant reservoirs on the Dnieper, attention was focused on the differentiation of water areas, and options for zoning the reservoirs were proposed. Baranovski et al. (2021) proposed a detailed zoning scheme for the Zaporizhzhia Reservoir based on the distribution of macrophytes in combination with the morphometric parameters of individual sites.

Reservoirs can be included in a broad interpretation of lake ecosystems; therefore, these studies are a valuable contribution to the development of a unified regional typological scheme for lake systems. The first step towards this was a new typological scheme for the lakes of the Northern part of the Steppe Dnipro region by Roshchyna and Baranovski (2019), based on hydrological and hydrobiological criteria, which is sufficiently indicative of the purposes set. The scheme itself, supplemented by a zoning map with the allocation of the three lake districts of Oril, Dnipro, and Samara, with four sub-districts, is reasonable and quite natural (Roshchyna & Baranovski, 2019), but is limited to lakes of natural origin.

Thus, the existing experience of lake typology is valuable for further developing a universal typological scheme for the entire Steppe Dnipro region, which should cover both natural and anthropogenic lake-type reservoirs.

3. Methodology.

Several methodological approaches were used to build a typological scheme for the lake ecosystems in the Steppe Dnipro region.

1. The basin approach (analysis of each catchment basin as an individual unit of geographical space organisation that combines individual features and common characteristics shared with similar basins).

2. The method of identifying typological criteria and typology units “from the detailed to the general” (a bottom-up approach). In this study, this principle was implemented in two aspects.

First, based on field research, common and individual features were empirically identified for a set of lakes in the studied region, which may be more significant in structuring the typological scheme. For example, the presence of shoreline shading is critically important, which is a criterion for distinguishing between two typological groups: “closed”, that is, wooded lakes, and “open” (steppe) lakes. In turn, for lakes in open areas, the length of the reservoir's existence and its limitation to mesorelief forms are key to further typology. Another example is that for forest lakes, the spring flood regime and the size of the lakes (area, length, and depth) are of key importance, on which the stability of the lakes to long dry periods without floods directly depends.

Second, a bottom-up approach was applied to create a digital database of lake systems. First, the attribute table in the GIS project was filled with values for the primary typological characteristics of lakes. Then, sets of significant and secondary significant criteria are calculated, and clusters of similar lakes according to different indicators are determined. These can then be combined into typological groups with higher ranks.

3. In a holistic approach, when distinguishing different types of lake ecosystems, it should be considered that each lake can manifest its emergent properties only if all the components that determine its existence "here and now" and the timeframe of its existence are present and combined in one place (geotope). Changes in at least one of the parameters can lead to a chain of changes in the entire ecosystem and trigger a mechanism of change in other ecosystems interconnected with a particular water body (Buffagni, 2020).

Standard field and instrumental methods were used to collect, process, and integrate primary data on lakes in the Steppe Dnipro region. ArcGIS, QGIS, and Google Earth were used to detect, decipher, and interpret patterns in lake ecosystems from satellite images.

These methods were combined with years of fieldwork studying the reservoirs of the Steppe Dnipro region during field expeditionary work. Additionally, the results of a critical audit of several water management projects in terms of environmental impact assessment, and in particular, on the hydraulic regime and ecological balance in the fluvial and lake systems of the basins of rivers such as Oril, Samara, Vovcha, Kilchen, Samotkan, Domotkan, Saksagan, and Mokra Sura, are considered (Maniuk, 21).

The classical principles of the typology of natural and artificial ecosystems, in particular the typological scheme of natural and man-made forests of the steppe zone by Belgard (1938), as well as methodological approaches to habitat inventory and classification, were considered when drawing up the working scheme (Onishchenko, 2016; Kuzemko et al., 2018). However, the proposed lake typology is neither a complete typology nor a strict classification. It is only a working scheme that requires further development and verification, including a thorough inventory of lakes and the creation of a database of their primary parameters, such as current depths, bottom profile, species composition and distribution of species and communities of living organisms, detailed mapping, hydrochemical indicators, water level fluctuations, temperature, and possible sources of anthropogenic pollution.

Such data should be accumulated for each lake-type body of water by creating a geographic information portal that can add data according to certain criteria. Although this typology is focused only on lake-type ecosystems, the principle of openness, which is ensured by the possibility of adding and combining typological criteria to a single regional database of water bodies, allows it to be expanded and/or integrated with similar systems for flowing ecosystems, which, in geospatial terms, are components of a single fluvial macro-system of the Dnipro basin.

At this stage, 53 typological criteria have been identified for the typology of lake ecosystems, grouped into 7 groups: morphometric, hydrological, geological and pedological, dynamic, habitat, ecological, and functional assessment.

The evaluation criteria were used to assess the conservation value and potential of each water body in terms of providing ecosystem services. The criteria can also be applied to natural and semi-natural lake-type water bodies with a moderate degree of anthropogenic transformation (e.g. fishery ponds and channel reservoirs).

Man-made reservoirs should be considered a separate typological class due to their particular regime and environmental impact, toxicity and profound transformations in all landscape components. A separate typological scheme with fewer criteria for man-made limnosystems that cannot be applied to natural lakes is proposed for man-made reservoirs.

By applying various combinations of criteria, it is possible to use a typological scheme for a wide range of applied tasks in environmental management, including the regional inventory of lake ecosystems, identification of more vulnerable types of water bodies that require priority measures for conservation/restoration, comprehensive monitoring of the ecological status of lakes, assessment of the distribution and quality of lake habitats for various systematic and ecological groups of organisms, determination of the overall degree of anthropogenic transformation of lakes, and instrumental assessment of the range of ecosystem services that lake systems can provide at the regional level and in individual catchment basins.

The experiences of similar assessment studies from different regions were considered when developing the assessment and comprehensive environmental criteria. In different ecological and geographical conditions, specific criteria may be important for assessing the state of water bodies, such as the strength and direction of the wind over the water surface (Kolada et al., 2024). Other indicators, such as nitrate and phosphate concentrations, are informative for assessing the ecological state in the milder, wetter, and cooler climates of Northern and Central Europe but become less informative (just for natural lakes) in the drier southern and southeastern regions (Doychev et al., 2024).

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4. Aim and Tasks.

The study aims to develop a functional and adaptable typological framework for lake ecosystems in the Steppe Dnipro region of Ukraine. This framework is designed to assess the ecological status of water bodies, conduct environmental inventories and monitoring, and analyse the dynamics of lake systems under climate change, anthropogenic pressure, and military activities. A distinct task is the possibility of applying a typological scheme to assess the importance of natural and man-made lakes for the conservation of natural biodiversity and the performance of ecosystem functions (i.e. services).

5. Results.

Steppe Dnipro of Ukraine is an ecological and geographical region with natural boundaries that covers a part of the Dnipro River basin within the steppe zone and is bounded by the external (relative to the Dnipro) watershed lines of such rivers as the Ingulets, Sukhyi Omelnyk, Oril, Samara, Vovcha, Konka, Bilozerka, and Rohachyk.

Below the confluence of the Ingulets into the Dnipro, Dnipro water is under the influence of seawater, and the landscapes differ significantly in the presence of end-sea sand arenas and other features associated with proximity to the Black Sea coast. It is advisable to allocate this part to a separate natural region of the Lower Dnipro (Lower Dnipro). Lake ecosystems are unevenly distributed within the region: the vast majority are concentrated in the middle and lower reaches of the two left-bank tributaries of the Dnipro, the Oril and Samara, and the Dnipro valley itself.

Without exception, all natural lakes in the region are confined to river terraces and are hydraulically connected to the water masses of the respective river systems. Outside the valleys of the three rivers, natural lakes are rarely found in the lower reaches of some small rivers and are often not sufficiently representative. As shown in Table 1, certain lake types, such as arene lakes, which are relict in nature and habitats for rare northern flora species in the region, are found only in the Samara and Dnipro valleys and are also limited in distribution.

Table 1. Typological Classification of Natural Lakes by River Basin in the Steppe Dnipro Region of Ukraine.

No	Major river basins	Floodplain lakes	Estuaries	Arena lakes	Gully lakes	Ponds
1	Oril	+	+	-	+	+
2	Samara and Vovchaya	+	+	+	+	+
3	Conca	-	+	-	-	+
4	Belozerka	-	+	-	-	+
5	Ingulets	+	-	-	+	+
6	Omelnyk Sukhyy	+	-	-	+	+
7	Omelnyk	+	-	-	-	+
8	Domotkan	+	-	-		+
9	Samotkan	+	-	-		+
10	Mokra Sura	+	-	-	-	+
11	Bazavluk	-	-	-	-	+
12	All other tributaries of the Dnipro within the region *.	-	+	-	-	+
13	Dnipro Valley	+	+ **	+	-	-

*Notes: * including Vorona, Osokorivka, Vilnyanka, Sukha and Mokra Moskovka, Yanchekrak, Karachekrak, Tomakivka, Kamyanka, Tyahyanka, etc.; ** only in Velykyi Luh, at the first stage of demutualization after prolonged flooding.*

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Another rare type is gully lakes, which are found in limited numbers in the upper reaches of rivers and waterlogged gullies, mainly in the northwestern region. The most famous and largest of these is the Black Swamp, or Black Lake, at the headwaters of the Ingulets River. The uneven distribution of lakes of different types is an important argument for developing conservation measures, as lakes that are rare or unique to some rivers have high conservation value. There are no stable data on the total number of lakes in the region, which is due not only to different interpretations of the term "lake" (as well as other related terms such as “swamp”, “estuary”, “pond”, “reservoir”), but also to the fact that the inventory of lakes at the regional level has not yet been completed.

Barabash-Nikiforov (1928) gives an underestimated number of more than 200 lakes for the region, without specifying whether the area of the lakes was taken into account in any way. At least, this statement does not apply to the chains of floodplain lakes in Pryorillia and Prysamaryia, as well as the large floodplain lakes of the Dnipro River itself, where the water level remained relatively stable throughout the season. Only in Middle Prysamaryia are there more than 100 lakes with a water surface area of more than 500 m2, most of which undoubtedly existed a century ago. The most recent published data from an inventory conducted by the State Institute for Water Management Design includes data on 1129 lakes in the Dnipro region, including 219 lakes with an area of three or more hectares (Chekhun et al., 2021).

An integral component of ecosystem diversity in the region is the numerous and diverse man-made reservoirs, which, in the current conditions, are important centres for biodiversity conservation and serve as both key areas and connecting ecological corridors. In the complete or almost complete absence of natural lakes in many regions of the Steppe Dnipro, a dense network of semi-artificial reservoirs has been created over the past century–ponds, which are built on virtually all small rivers and tributaries and cover the entire region more or less evenly.

Lakes in flooded quarries are also widespread and are characterised by considerable typological diversity and high recreational potential. Finally, the region with high industrial development is characterised by large man-made reservoirs associated with mining, which correspond to lake-type ecosystems in terms of the water regime. Although most are a source of highly toxic chemical compounds for the environment, they can also serve as habitats for some living organisms. Some of these may be the only possible habitats under these conditions. Therefore, the typological scheme should include all possible types of lake systems in the region. Different groups of typological criteria have been proposed for natural and man-made lakes.

For the natural type of lakes, seven typological groups are proposed (Table 2), which combine a different number of criteria, and the typological system itself allows the addition of criteria to each of the groups if necessary. Each group is assigned a code (capital Latin letter), and each criterion is indexed as a combination of the letter of the group to which it belongs and an Arabic numeral. Each criterion includes specific characteristics of the lake system, which are determined either quantitatively or qualitatively, depending on the specificity of the criterion. Furthermore, depending on the applied goals, typological scales are established when analysing a certain sample of water bodies.

A scale of change in indicators is provided for each criterion, which requires further development and testing to be effective. The further implementation of the typological scheme for natural lakes involves the simultaneous filling of data in the GIS project for every lake. The list of standard operations includes digitising the shoreline contours and gradually filling in the attribute table for each lake. As the data accumulate in the table and on the map, it will be possible to apply filters and machine processing to the lake ecosystem vector layer using various combinations of criteria.

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Table 2. Typological Criteria for Natural Lakes.

Code	Typologic group of criteria	Code	Criterion	Features of a lake system for a specific criterion (example)
1	2	3	4	5
A	Group of morphometric criteria	A1	Drainage basin affiliation	Qualitative: individual geographic name of basin (Dnipro, Samara, etc.); quantitative: basin order; basin area
		A2	The shape of the meso relief	Floodplain; suprafloodplain terrace; balka (smal steppe valley); drainless depression (pod)
		A3	Geographical coordinates	Numerical values of coordinates
		A4	The water level above the sea	Average annual level; maximum and minimum levels for the observation period ((in meters)
		A5	Area of water surface	Numerical values in hectares
		A6	Shape (aspect ratio) of the lake	Qualitative: round; lenticular; oval; linear straight; linear sinuous; annular, etc.; quantitative: numerical ratio
		A7	Depth, bottom profile	Qualitative: different types of bottom shape; quantitative: Depth average/maximum
		A8	The volume of the water column	Numerical values
B	Group of hydrological criteria	B1	Type of water exchange	Isolated; slow underground; slow surface; low flow etc.
		B2	Feeding the reservoir	Since all lakes in the region have a mixed type of feeding, the indicator involves determining the presence and ratio of different sources: snow, rainfall, spring runoff, horizontal infiltration, etc.
		B3	Hydraulic connections	One-level surface connection with the river (constant/periodic); below river level / above river level; above aquifer / at the same level; below river level / above river level; above aquifer / at the same level
		B4	Temperature conditions	Qualitative: types by the nature of the stratification of the water column; quantitative: numerical values (annual average, average for the growing season, winter average)
		B5	The pH value	Numerical values
		B6	Hydrochemical parameters of water	Includes over 20 indicators that are available for measurement in standardised laboratories;
		B7	Water mineralisation level	Qualitative: by predominant ions; quantitative: numerical values (in ‰);
C	Group of geological and pedological criteria	C1	Sediment type/thickness	Qualitative: sands, silty sands, peaty silts, etc.; terrigenous, organogenic, or chromogenic; quantitative: thickness in meters
		C2	Underlying bottom geologic rocks	Alluvium; clays/loams of lacustrine origin; loess; clays/sands of marine origin; aeolian sands, etc.
		C3	Mineralogical and chemical composition of bottom and shore substrates	Qualitative: terrigenous (siliceous / carbonate), organogenic, or chromogenic; for coasts - indicators similar to criterion C2
D	Group of dynamic criteria	D1	Origin (genesis) of the reservoir	River valley; Aeolian depression; suffosion depression, etc.
		D2	Age of existence	This criterion for the lakes of the Steppe Dnieper region requires separate development due to insufficient knowledge of the genesis of the lakes.
		D3	Shoreline variability	Qualitative: stable; pulsating (seasonal/perennial); regressive; progressive
		D4	Variability of hydrochemical parameters	Qualitative: stable; pulsating (seasonal/perennial); gradual salinisation/desalination; change in pH and other trends.
		D5	Variability of hydrobiological indicators	Disappearance or appearance of particular key species of organisms; changes in population size (periodic/irreversible); changes in dominant species
		D6	Trends	Sustainable, degradation, rapid degradation, deputation, restoration
E	Group of habitat criteria	E1	Conditions for phytoplankton	For this group, the criteria are defined similarly, only for different taxonomic groups of organisms (coenosis). The two key indicators include the assessment of the presence/absence of conditions for keystone species
		E2	Conditions for macroalgae	
		E3	Conditions for zooplankton	
		E4	Conditions for benthos	

Code	Typologic group of criteria	Code	Criterion	Features of a lake system for a specific criterion (example)
		E5	Conditions for invertebrate	(stenosis) and, if they are present, determining the presence/absence of a keystone species corresponding to these conditions. For example, the lake has conditions for golden carp (*Carassius carassius L.*), but its presence in this lake has not been determined.
		E6	Conditions for fish	
		E7	Conditions for amphibians	
		E8	Conditions for reptiles	
		E9	Conditions for birds	
		E10	Conditions for mammals	
		E11	Conditions for macrophytes	
		E12	Conditions for mycobiota	
		E13	Conditions for amphibious and coastal higher vegetation	
F	Group of evaluation (functional) criteria	F1	Water regulation	These criteria are established based on the results of a comprehensive assessment of indicators from previous groups (A–D), based on which evaluation score scales are calculated (an increase in scores means a greater water-regulating or climate-regulating effect)
		F2	Regulation of micro- (meso-) climate	
		F3	Ensuring conditions for the existence of populations of rare species/groups	The scoring considers the habitat area for key species and the threats specific to each habitat type. The most challenging thing about this criterion is considering the interests of different species and groups.
		F4	Support for resource-important species (medicinal, fodder, etc.)	
		F5	Recreational fishing	
		F6	Lake recreation	diversity of recreational and attraction properties, scales (correlating with morphometric criteria), but at the same time, limitations due to the presence of habitats and species vulnerable to recreational pressure
		F7	Aesthetic criterion	Based on the results of the average assessment of experts using standard methods (including the assessment of the feelings of the wilderness of the reservoir, “cleanliness", scenery perception, landscape background, sound and odour characteristics of the lake and shore
		F8	Water treatment	According to standard methods (sedimentation, clarification, hydrobiological oxidation, adsorption by sapropels, etc.)
		F9	Depositing carbon dioxide	A comprehensive assessment involves taking into account the intensity of photosynthesis and its seasonal fluctuations, the nature and intensity of biochemical and geochemical processes in the water column and in bottom sediments (respiration, inorganic oxidation), correlated with the temperature regime of the reservoir and with the peculiarities of circulation in adjacent coastal ecosystems.
		F10	Cultural significance (toponymic, sacred, memorial, etc.)	Includes interdisciplinary interaction with ethnologists, linguists, cultural scientists, historians, etc.
		F11	Conservation of genetic diversity	Determination of Environmental DNA formulas for nature lakes in the region
G	Group of environmental criteria	G1	Presence and nature of anthropogenic pollution	Presence in water and (or) sludge and concentration of pollutants such as phosphates, nitrates and nitrites, heavy metal salts, organic pollutants
		G2	Presence/nature of interventions in the lake / higher-level ecosystems	Presence of invasive species of organisms in the lake, considering their absolute number and population density (such as Lepomis gibbosus, Elodea canadensis, Pistia stratiotes L., etc.)
		G3	Presence of garbage	presence of garbage, distribution across the coastal area, water area and bottom
		G4	Level/causes of eutrophication	determined by standard methods
		G5	Level of protection (environmental status)	The formal status and the actual protection regime of the lake are determined. Criterion also presupposes monitoring changes in status and reasoning of optimal regimes (management plans) for each lake type and lake.

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This typological scheme is horizontal, that is, the combination of criteria for combining a set of lakes into typological groups can be arbitrary, which distinguishes this typological scheme from hierarchical bifurcation schemes, where only one criterion is applied at one level.

Another feature of the proposed typological scheme is its multi-functionality.

It can be used simultaneously as a tool for determining the place of a particular lake in both regional typology and other international classification systems, as a template for creating unified environmental passports for a water body, and as a tool for assessing the ecological status of a water body. Tables 3 and 4 provide an example of filling in the attributes for a group of morphometric criteria.

Table 3. An Example of Using the Typological Scheme According to Certain Criteria of Group A.

№	Criterion / Lake Name	A1	A2	A4		A5		A6		A7
1	Sokilka	Samara	floodplain	52 м	A4.3	19.1 hectares	A5.4	1/13	A6.4	2.5/4.0
2	Temne	Oril	floodplain	59 м	A4.4	80.0 ha	A5.5	1/32	A6.5	1.4/2.5
2	Solonyi Lyman	Samara	third terrace	59 м	A4.4	317 hectares	A5.7	1/1	A6.1	0.5/1.3
4	Lapayeve	Samara	floodplain	58 м	A4.4	3.1 hectares	A5.4	1/4	A6.3	2.0/4.0
5	Chorne (only Berestovate pool)	Ingulets	gully hollow	165 м	A4.7	1.9 hectares	A5.3	1/2	A6.2	4.0/7.0
6	Bilovod	Oril	floodplain	61 м	A4.4	8.4 hectares	A5.4	1/80	A6.6	1.7/2.5
7	Yurkivskyi Lyman	Conca	floodplain	27 м	A4.1	36.5 hectares	A5.5	1/1	A6.1	0.8/3m

The colour in Table 3 highlights those typological descriptors for which there is a match across lakes. In this case, a match for a maximum of two criteria exists. The greater the number of common indicators, the closer the different lakes are to each other in the typological scheme. The following example (Table 5) shows the results of the typological analysis for a group of environmental criteria, making it possible to assess the ecological state of a lake ecosystem quickly.

Based on the results of the lake typology using environmental criteria, it can be concluded that Lakes Bilovod and Temne are in a threatened state, while the Solonyi Lyman and Yurkivskyi Lyman are in a satisfactory state. In contrast, Lakes Sokilka, Lapaieve, and Chorne are in good environmental condition due to their favourable ecological status, limited interference with the hydraulic regime, and relative remoteness from densely populated areas.

Table 4. Value Scales for Individual Criteria of Group A and Corresponding Codes.

No	A4		A5		A6	
1	10-30 m above sea level.	A4.1	<0.1 ha	A5.1	1/1	A6.1
2	31-50 m above sea level.	A4.2	0.1-0.5 hectares	A5.2	1/2	A6.2
3	51-55 m above sea level.	A4.3	0.6-3 ha	A5.3	1/3-1/5	A6.3
4	56-65 m above sea level.	A4.4	3.1-20 ha	A5.4	1/ 6-1/15	A6.4
5	66-75 m above sea level.	A4.5	21-100 ha	A5.5	1/16-1/50	A6.5
6	76-90 m above sea level.	A4.6	100-300 ha	A5.6	<1/51	A6.6
7	> 90 m above sea level.	A4.7	> 300 hectares	A5.7	-	-

Table 5. Application of the Typological Scheme According to Selected Criteria of Group G (Environmental Assessment).

No	Criterion / Lake Name	G1	Degree of the indicator	G2	Degree of the indicator	G3	Degree of the indicator	G4	Degree of the indicator	G5 **	Art.	Σ score
1	Sokilka	+	2	-/+	0/2	-	0	+	2	+	-3	3
2	Temne	+	3	+/+	2/4	-	0	+	4	+	-1	12
2	Solonyi Lyman	+	1	+/+	2/4	+	1	+	2	+	-1	9
4	Lapaieve	-	0	-/+	0/3	-	0	+	3	-	0	6
5	Chorne (Berestuvate)	+	1	-/+	0/1	-	0	+	1	+	-1	2
6	Bilovod	+	3	+/+	3/4	+	3	+	5	-	0	18
7	Yurkovskyi Lyman	+	2	+/+	1/3	+	1	+	2	+	-1	8

*Notes: *for the assessment group of criteria, the table shows the results of the scoring (degree of the indicator), but the assignment of codes in the worksheets is provided for all groups of criteria. The higher the score, the worse the ecological status of the lake.** the score for this indicator is negative, since the higher the environmental status, the better the prerequisites for preserving the ecosystem of the reservoir.*

At this stage of the development of the typological scheme for man-made lake-type reservoirs, a somewhat simplified approach to the systematisation of all diversity is proposed, with the selection of more significant typological criteria that allow us to quickly determine the belonging of a reservoir to a particular typological group. Each typological criterion has been assigned numerical and alphabetic symbols, which allows for the description of a particular water body in a set of codes (typological formula). The same codes are conveniently used to fill in the attribute table in the GIS version of the typological scheme. Given the difference in approaches to the typology of artificial and natural lake ecosystems, two different vector layers with their own sets of attributes were created for them at this stage. The basic typological scheme for man-made reservoirs is presented in Table 6.

It is important to understand that both are natural (primarily). Certain artificial lake systems have provided the inhabitants of the Steppe Dnipro with a wide range of essential ecosystem services for decades. These services should be assessed flexibly, considering the interaction between the lakes' natural ecological and geographical features, their economic importance to local communities, and their cultural significance to the local population.

The criteria of group F (evaluative or functional in Table 2) authorises the conduct of further objective calculations regarding the volume and economic equivalent of such services for both individual lakes and certain types of lakes and, ultimately, for all lakes in the region. Similar approaches to assessing lakes as a special type of ecosystem are being developed in the countries of the European Union. In particular, the experience of ecological assessment of mountain and river lakes in Europe deserves attention (Ebner, 2024).

Lakes are integral to the historically valuable natural and cultural landscapes of the Priorylya (Oril River), Prysamarya (Samara River) regions, and the Dnipro-Protovch Valley. The nature of settlement and the planning structure of ancient settlements that have survived to this day are determined by the configuration of natural lakes, which were a source of various vital resources, from fish and waterfowl to building materials. The loss of lake systems is an objective threat that requires active action to prevent rapid dehydration and degradation of lakes. The proposed typological scheme authorises the collection and summation of all available data and stimulates much deeper research into lake systems, primarily to prevent their drying out.

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Table 6. Working Typological Scheme of Anthropogenic Lake-Type Ecosystems for the Steppe Dnipro Region.

Code	Types of water bodies	Typological criteria (indices)				
Tn	**Man-made newly formed**					
Tn1	**Flooded quarries**	**Main mineral resource**	**Degree of water mass insulation**	**Duration of existence**	**Depth of the reservoir**	**The area of the plain**
		Granitoid (g), Iron ore (f), Sandy (s), Manganese ore (m), Lignite (l), Ilmenite (i), Kaolin (k)	Fully insulated, on watertight ground (1), Vertical drainage/supply (2), Horizontal drainage/feeding, connection to the river basin (3)	Constant (t), Periodically drying (p), Endangered (d)	Ultra-deep (U), Deep (D), Shallow (S)	Large (l), Average (m), Small (s)
	Examples:					
	Tn1.g /3.t.M.s Zorianskyi Quarry, Dniprovskyi district	A permanent lake occupying a flooded migmatite quarry, partially drained through fractured crystalline rocks into the Dnipro Reservoir; it covers 0.7 ha and has an average depth of 3.0 m (maximum 8 m).				
	Tn2.m/2.d.S.m Pivnichnyi Manganese Quarry	Temporary lake in the section of Pivnichnyi Querry of the Pokrovsk iron ore mining and processing plant (GOK) on Palaeogene sediments, disappearing (gradual filling with overburden), average/maximum depth 1.2/2.5 m, area 4.2 ha.				
Tn2	**Sumps and storage facilities on man-made terrain**	**Functional purpose**	**Duration of operation**	**Level of environmental toxicity**	**Changes in the volume of water masses**	**The area of the plain**
		Sludge SFs (p) Tailings SFs (t)	Up to 10 years (1) 10-30 years (2) 30-50 years (3) Over 50 years (4)	The highest (h) High (s) Average (m)	Constant volume (C) Variable, up to 20% (V) Highly variable, 20-100% (H)	Large (l) Average (m) Small (s)
	Example:					
	Tn2.t/4.s.H.m Voykovo tailing dump	Tailings dump of the Pivdennyi GOK (iron ore processing plant) in a man-made pit on the site of the steppe watershed, operated since 1977, highly toxic tailings with significant periodic drying of the maps; the area of the operation site is 150 hectares.				
Tt	**Technogenic transformed**					
Tt1	**Man-made reservoirs in place of natural ones**	**Type of meso relief**	**Functional purpose**	**Water mineralisation level**	**Overgrowth of the pond with macrophytes**	**The area of the plain**
		Gully (b) Floodplains (f) Arena (a) Gender (d)	Tailings facilities (1) Sumps (2) Coolers (3) Tanks (4)	Very salty (h) Salty (s) Brackish (m) Close to natural levels (l)	Absent (O) Moderate, up to 30% (R) Significant, more than 30% (F)	Large (l) Average (m) Small (s)
	Examples:					
	Tt1.d/3.l.O.l Zelenodolsk reservoir	Kryvyi Rih TPP cooling reservoir in a flooded steppe floodplain, with the lowest level of environmental toxicity, a completely open floodplain (without macrophytes), and a large size - the main floodplain area is 1576.0 hectares.				
	Tt1.b/2.h.O.m Sedimentation pond in the Svydovok gully	The mine water (coal mine) sedimentation pond in the Svydovok gully is located on a small natural reservoir site with high water mineralisation, significant depths, and a completely open expanse, with an area of 36.5 hectares.				

6. Conclusions.

The proposed typological scheme for the lake systems of the Steppe Dnipro region is based on the principles of openness and horizontal structure, which allows the distinction of types of water bodies according to different sets of criteria, which in practice can be very convenient when it is necessary to quickly create samples of lakes that are similar in certain criteria for specific environmental or economic tasks.

The advantage of this typological scheme is that a single dataset, combined with the typological scheme, can be used for the scientific classification of water bodies in a region of Ukraine that has not yet been studied in this regard.

Additionally, it serves applied purposes such as monitoring lake ecosystems under changing conditions, objectively assessing their vulnerability, and developing adaptive management plans for their preservation.

Further studies with the scheme involve filling in the dataset, refining the parameters, and creating clusters (types) of lakes based on cluster analysis algorithms, further verifying the consequences. This typological scheme can be integrated and adapted to any modern classification scheme of water bodies, ecosystems, habitats, and landscapes.

This is possible because the criteria used in such classifications assign specific values to the attribute table of the integrated vector layer.

After passing the verification phase, the typological scheme can be transformed into a public web portal, which will simultaneously serve as an open information database on lake-type reservoirs (with the possibility of constantly updating and accumulating data on lake systems in the Steppe Dnipro region). It can also be used to conduct rapid assessments of the ecological state and track current changes in the ecosystems of lakes and man-made reservoirs in the region.

The gradual filling of the natural and artificial lake systems database will eventually make it possible to develop a working typology into a full-fledged ecological-geographic classification of lakes.

An equally important applied aspect is the possibility of using the typology and database for a complete disclosure of the recreational, tourist, and cultural potential of the lakes of the Steppe Dnipro region. Accurate knowledge of the natural parameters of water bodies, the degree of their vulnerability and uniqueness, and detailed certification is the basis for the development of such forms and a degree of recreational and tourist use that will not lead to the loss or deterioration of the ecological qualities and natural potential of the lakes.

REFERENCES

Barabash-Nikiforov, I. (1928). Essays on the fauna of the Steppe Naddnipryanshchina. Dnipropetrovs'k: State Publishing House of Ukraine.

Baranovski, B. A., Ivanko, I. A., Gasso, V. Y., Ponomarenko, O. L., Dubyna, D. V., Roshchyna, N. O., Karmyzova, L. O., Poleva, J. L., & Nikolaieva, V. V. (2021). Biodiversity of the Regional Landscape Park Samara Plavni within the first large reservoir in Europe Biodiversity of the Regional Landscape Park Samara Plavni within the first large reservoir in Europe. Biosystems Diversity, 29(2), 160–179. https://doi.org/10.15421/012121

Belgard, O. (1938). Vegetation of the Pokrovsky plains. A geobotanical sketch of the Novomoskovsk forest. Collection of Works of the Biological Faculty of Dnipropetrovs'k State University, 1(1), 133–148.

Bossard, M., Feranec, J., & Otahel, J. (2000). CORINE land cover technical guide – Addendum 2000 (Technical Report No. 40). European Environment Agency. https://www.eea.europa.eu/publications/tech40add/at_download/file

Buffagni, A. (2021). The lentic and lotic characteristics of habitats determine the distribution of benthic macroinvertebrates in Mediterranean rivers. Freshwater Biology, 66(1), 13–34. https://doi.org/10.1111/fwb.13596

Chekhun, O., Kuharuk, P., Dotsenko, V., Zaporozhchenko, V., & Tkachuk, T. (2021). Water resources and water quality in Dnipropetrovska oblast. In Development of the Prydniprovia Region: Agroecological Aspect (pp. 234–248). Dnipro: Lira. https://dspace.dsau.dp.ua/handle/123456789/5533

Convention on Biological Diversity & Ramsar Convention Secretariat. (2006). Guidelines for the rapid ecological assessment of biodiversity in inland water, coastal and marine areas (CBD Technical Series No. 22; Ramsar Technical Report No. 1). Montreal & Gland.

Council of the European Communities. (1992). Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities, L 206, 7–50. http://data.europa.eu/eli/dir/1992/43/oj

Doychev, D., Gartsiyanova, K., & Taneva, L. (2024). Environmental variables significance for ecological status assessment in the Bulgarian eastern continental shallow lakes. Inżynieria Ekologiczna, 25(10), 16–30. https://doi.org/10.12911/22998993/191540

Ebner, M. (2024). Assessing ecosystem services of mountain lakes. Landscape Online, 99, 1122. https://doi.org/10.3097/lo.2024.1122

European Parliament & Council of the European Union. (2000). Directive 2000/60/EC establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, L 327, 1–73. https://environment.ec.europa.eu/topics/water/water-framework-directive_en

Globevnik, L. (2019). Broad typology for rivers and lakes in Europe for large scale analysis [Dataset]. PANGAEA. https://doi.org/10.1594/PANGAEA.908578

Kolada, A., Kutyła, S., & Bielczyńska, A. (2023). Minor effect of wind exposure and littoral slope on macrophyte characteristics in non-impacted lowland lakes of Poland. Frontiers in Plant Science, 14, 1307453. https://doi.org/10.3389/fpls.2023.1307453

Kuzemko, A. A., Didukh, Y. P., Onyshchenko, V. A., & Scheffer, Y. (Eds.). (2018). National habitat catalogue of Ukraine. Kyiv: Klymenko.

Lavrenko, E. (1928). Bogs of Ukraine. Bulletin of Natural History, 3–4, 141–156.

Lyche Solheim, A., Globevnik, L., Austnes, K., Kristensen, P., Moe, S. J., Persson, J., Phillips, G., Poikane, S., van de Bund, W., & Birk, S. (2019). A new broad typology for rivers and lakes in Europe: Development and application for large-scale environmental assessments. The Science of the Total Environment, 697, 134043. https://doi.org/10.1016/j.scitotenv.2019.134043

Maniuk, V. (2021). Ecological network as a structural and functional basis for biodiversity conservation and sustainable land use. In Development of the Prydniprovia Region: Agroecological Aspect (pp. 677–710). Dnipro: Lyra. https://dspace.dsau.dp.ua/handle/123456789/5533

Onishchenko, V. (2016). Habitats of Ukraine according to the EUNIS classification. Kyiv: Phytosociocenter.

Roshchyna, N. O., & Baranovski, B. O. (2019). Hydrological and hydrobotanic typology of the lake of North-Steppe Dnieper region. Ecology and Noospherology, 30(2), 125–131. https://doi.org/10.15421/031921

Stakhovsky, V. (1938). To the question of the commercial fauna of the Buzulutsky plains and its economic use. Collection of Works of the Biological Faculty of Dnipropetrovsk State University, 1(1), 77–88.

Wagner, O., & Palamarchuk, P. (2025). "Water bodies are very vulnerable ecosystems". Why lakes are disappearing in the Dnipro region and whether it is possible to restore them. Dnipro Public Broadcasting. https://suspilne.media