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Research Article

Status of biodiversity, reed habitats, sustainable exploitation of natural resources, invasive species, and socio-economic implications in Danube Delta Biosphere Reserve in 2024

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Abstract

This paper presents the 2024 research results from the Danube Delta Biosphere Reserve (DDBR), including reed bed mapping and typology for fire management, assessment of sustainable use of vegetal resources, conservation status of invertebrates, fish, reptiles, amphibians, colonial waterbirds, and mammals of Community interest, evaluation of species invasiveness under climate change, and studies on human well-being and eco-tourism within a sustainable development framework.

Key words: Biodiversity, conservation, Danube Delta, natural resources, socio-economic systems

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Introduction

Wildfire ecology is studied globally, with regional focus reflecting fire frequency—North America, Australia, and South Africa invest heavily, while in Europe, research centers on the Mediterranean. Vegetation fires, long-standing drivers of ecosystem dynamics, are examined for their impact on habitats and fauna. In the Danube Delta, wildfires particularly affect reed-dominated landscapes. Reeds, central to aquatic ecosystems, provide ecological benefits but outcompete most plant species through dense growth, shading, thick litter, and aggressive rhizomes (Hawke and José 1996; Deák et al. 2015). Their expansion limits plant diversity and reduces habitat availability for many animals, though riparian reed stands filter nutrients and trap sediments (Cowie et al. 1992). Vegetation overgrowth is partly natural, but reed removal—by burning or harvesting—disrupts species reliant on these habitats. A balanced management strategy alternating between reed cover and harvested plots is recommended (Güsewell et al. 2000). Knowledge remains limited on species responses in burned, harvested, abandoned, or transitional zones in the DDBR.

Natural plant and fungal resources support both conservation and sustainable use, including edible mushrooms, medicinal herbs, honey plants, grazing areas, and reeds. The DDBR Administration assesses harvest potential before

issuing permits, and this research underpins a database to guide decision-makers in sustaining ecosystem stability and regional prosperity.

Under Article 17 of the Habitats Directive (92/43/EEC), EU Member States, including Romania, report every 6 years on habitats and species of Community interest, including invertebrates. Although the Natura 2000 network covers extensive areas, vague objectives and insufficient planning limit protection for some species. The DDBR, supported by the Danube Delta National Institute for Research and Development (DDNI) and international collaborations, is central to maintaining biodiversity.

Fish species of Community interest act as indicators of functional ichthyocoenoses, adding ecological and conservation value (Năstase et al. 2024). Freshwater fishery resources globally decline due to habitat degradation and overfishing, trends intensified in the DDBR by climate change—rising air and water temperatures, reduced precipitation, and falling water levels causing pond desiccation.

The DDBR hosts 16 reptile and 10 amphibian species, with five of Community interest—two amphibians (*Bombina bombina*, *Triturus dobrogicus*) and three reptiles (*Emys orbicularis*, *Testudo graeca*, *Vipera ursinii moldavica*)—the focus of research from 2024 onward.

Twenty-six colonial waterbird species breed in the DDBR (Platteuw et al. 2004, 2006), of which 20 are listed in Annex I of Directive 2009/147/EC. Their conservation requires Special Protection Areas, documented in Natura 2000 sites ROSPA0031 Danube Delta and Razim–Sinoie Complex.

Nine mammal species of Community interest occur in the DDBR, mostly rare or with small populations. All are listed in Annex II of the EU Habitats Directive, implemented in Romania via Annex III of Government Emergency Ordinance No. 57/2007, and occur within Natura 2000 sites ROSCI0065, ROSCI0066, and adjacent Sites of Community Interest (SCI).

Invasive plant species strongly affect local biocenoses under climate change. Evaluating invasiveness provides insights into population dynamics and interactions with native species (Gallardo et al. 2016).

The Danube Delta has experienced structural and functional changes, and limited research exists on local human well-being. This study evaluates socio-economic development in Jurilovca commune, promoting sustainable activities to enhance current and future quality of life. The analysis informs public policy and guides strategies to improve living standards across DDBR settlements, supporting sustainable development.

The DDBR integrates remarkable biodiversity with cultural heritage, creating a favorable framework for ecotourism that encourages responsible visitor behavior and supports sustainable development by balancing conservation, tourism, and local well-being.

Materials and methods

Burned areas were identified to study wildfire effects on the deltaic ecosystem. Terrestrial vegetation was surveyed using the Braun–Blanquet method (coverage scale: r = 0.05%, + = 0.5%, 1 = 1–10%, 2 = 10–25%, 3 = 25–50%, 4 = 50–75%, 5 = 75–100%), while aquatic vegetation was surveyed using the Kohler method (1 = very rare; 2 = common; 4 = abundant). Field observations of

reed types were conducted at six points selected based on reed type and 2023 burn events. Analyses included mapping reeds, updating phytocoenological succession, and monitoring species evolution in burned and harvested areas.

Harvesting potential was estimated through a comprehensive inventory of plant species and edible mushrooms, accounting for biomass per square meter across DDBR administrative units. Methods were tailored to each resource and applied annually to ensure consistency, supporting sustainable harvesting.

Invertebrates were studied through sampling, field observations of biology and behavior, and environmental data collection. Techniques included limnological nets for aquatic species and entomological nets for terrestrial species (Ionescu and Apetrei 1988; Sîrbu and Benedek 2004), transects, collection over set surfaces, high-resolution imaging, and GPS recording of distribution points. Only minimal numbers of specimens were sacrificed, especially for protected or endangered species, respecting ethical standards.

Fish population trends were estimated using catch per unit effort (CPUE) in relative abundance and biomass. All fishing gear types (electric, gillnets, seine, etc.) were employed, with qualitative species determination and density expressed per station. Commercial catch data were obtained from the DDBR Authority.

Herpetofauna data in 2024 were collected using diurnal aquatic and terrestrial transects and post-metamorphic terrestrial linear transects (Török et al. 2013), with GPS coordinates recorded via the ObsMapp application.

All DDBR colonial waterbird populations were surveyed. Field expeditions were organized by DDNI logistics, using optical equipment and drones when possible. Counts were conducted from boats or land with minimal disturbance and repeated in parallel by multiple observers. GPS points were recorded, and data were integrated in GIS.

Research on mammals was conducted from January to September 2024 in ROSCI0065, ROSCI0066, and surrounding areas during peak activity (sunrise, sunset, and night). Abundance was monitored via indirect methods (tracks, excrement, burrows, vocalizations) and direct observation (traps, binoculars, night vision, camera traps) (Bibby et al. 2000; Monterroso et al. 2013). Food remains, feathers, and impluviums were used for species identification. GPS coordinates and altitude were recorded. Dolphins along the Black Sea coast were monitored by periodic shoreline surveys (Zaharia 2013).

For the analysis of invasive plant species, phytocoenological relevés were conducted in 93 plots (25 m²) across selected lakes, identifying 28 taxa. Vegetation cover was quantified using Braun–Blanquet scales and classified via agglomerative hierarchical clustering (Minkowski method, Bray–Curtis dissimilarity). Dendrograms were generated in RStudio (packages: circle, dendextend, ggplot2, tidyverse, and vegan), and clusters were validated with mean silhouette width (Rousseeuw 1987) and IndVal analysis (Dufrêne and Legendre 1997; permutation test: De Cáceres and Legendre 2009; threshold = 0.5). Distribution maps were produced in QGIS 3.34.3. Environmental variables recorded included water transparency (cm), water depth (cm), water pH, water conductivity (µS/cm at 25 °C), water temperature (°C), and vegetation cover (%).

Jurilovca commune was selected as a case study. Socio-economic data were collected via analytical, cartographic, and statistical approaches to identify development drivers and constraints. Three field visits in June 2024 involved 125 questionnaires (~5% of the 2021 population), assessing community

development, perceptions, and potential revitalization strategies. Results guided proposals to enhance living standards and quality of life.

Ecotourism in the DDBR was investigated from March to October 2024 in Jurilovca and Murighiol. Data on visitor numbers, accommodation, and tourism dynamics were obtained from the National Institute of Statistics and the Ministry of Tourism websites. Field investigations focused on tourism indicators and activities, linking them to sustainable development objectives.

Results and discussion

Vegetation fires in the DDBR were mapped across five seasons (July 2019–2024), with the largest burned areas recorded in 2021–2022 and the smallest in the current season. Monthly peaks occurred in March, reaching 35,425 ha in 2021–2022. Composite maps from the last three seasons guided the selection of 90 observation points to monitor bird species and assess repeated fire impacts, considering fire patterns and accessibility.

Field surveys from **8–11 April 2024** at 31 points recorded 279 birds from 36 species. Additional assessments in April–May 2024 targeted five observation points in harvested or burned reed areas (*Scirpo-Phragmitetum*). Fire effects

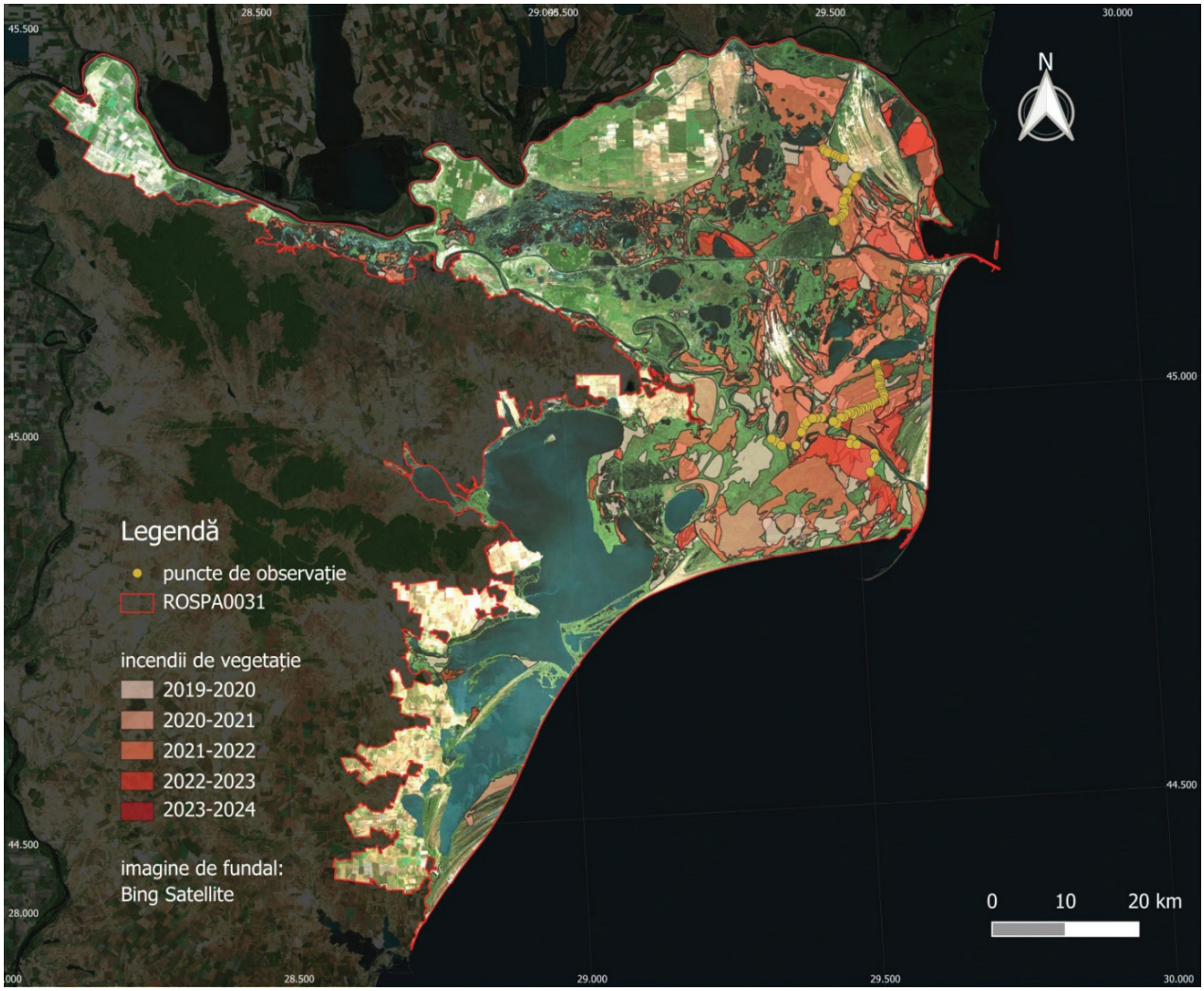

Figure 1. Wildfires mapped between 2019 and 2024.

varied with timing and soil conditions. Reed samples were analyzed biometrically, and vegetation was studied using the Braun–Blanquet method across four 1 m² profiles, with unburned, unharvested areas serving as references. Preliminary results indicate minimal natural vegetation changes after one season, while harvested or burned areas exhibited higher stem density but reduced height and diameter.

The effects of wildfires on deltaic biocenoses remain poorly explored in Romania. Given the ecological importance of the Danube Delta and the frequency of fires, a focused fire ecology study is proposed, emphasizing bird and mammal community responses. Initial remote sensing identified burned areas over two consecutive years, forming the basis for future research design and work plans.

Reed beds in the DDBR are dominated by *Phragmites australis*, forming biomass-based wetland ecosystems that mark early succession from open water to forest (Cowie et al. 1992; Valkama et al. 2008). Current drainage and eutrophication have halted natural wetland formation, leading to net habitat loss (Vadász et al. 2008). Limited grazing allows plant debris accumulation, gradually drying reed beds and transforming them through natural succession. Harvesting or burning slows debris accumulation and modifies succession patterns (Cowie et al. 1992; Hawke and José 1996).

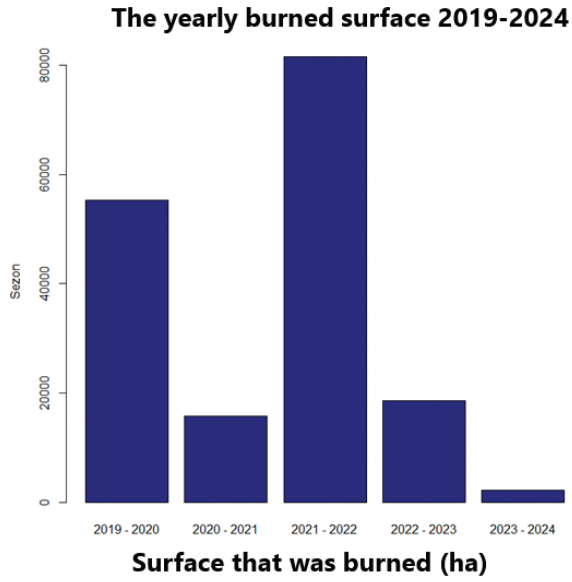

Figure 2. Total area of vegetation burning in each season.

Field sampling in June and September 2024 recorded water cover, salinity (June only), species presence, plant abundance, height, and cover (1 m² extrapolated to 10 m² to minimize trampling). Reed structure was characterized by stem density and diameter measurements for green and intermediate stems, complemented by height data.

Two interventions—harvesting and burning in 2024—were compared alongside 3-year and 10-year unmanaged reed beds. Parameters included vegetation height, density, cover, species richness, Shannon diversity, habitat heterogeneity, Ellenberg L, F, and N values, and reed structure metrics. Principal component analysis (PC-ORD; Jolliffe 2002; McCune and Mefford 2011) visualized differences between interventions, excluding highly correlated variables (>0.6).

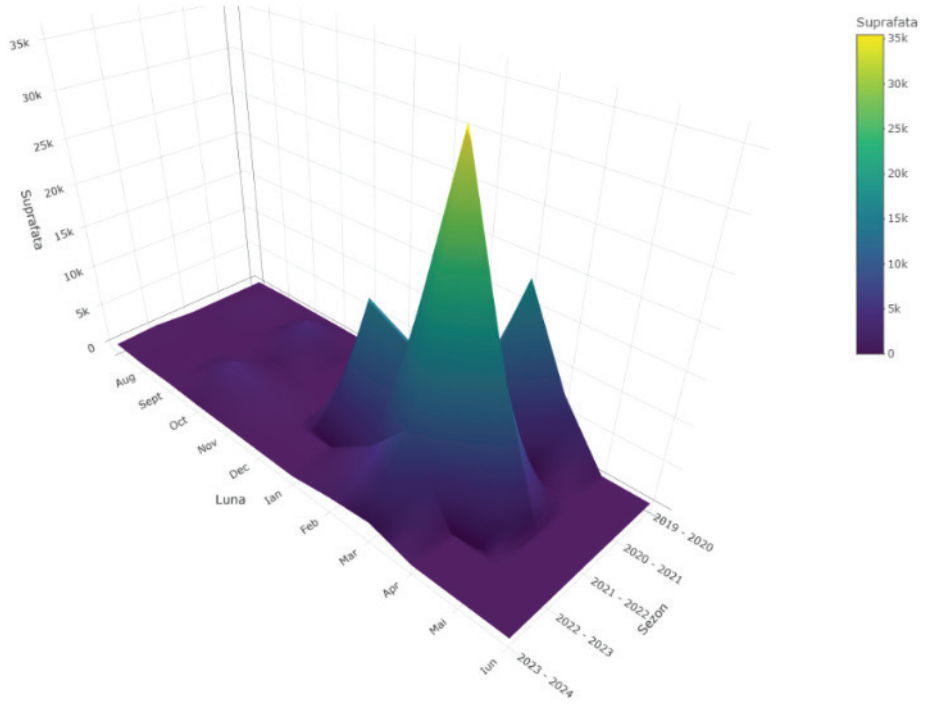

Figure 3. Areas burned by calendar month and season.

A total of 66 plant species were recorded across interventions, and only 22 species were present in all. Indicator species analysis showed *Alisma plantago-aquatica* associated with burned reeds; *Carex elata*, *Myosotis palustris*, *Carex disticha*, and *Calystegia sepium* with harvested reeds; and *Solanum dulcamara*, *Cicuta virosa*, and *Phalaris arundinacea* with 10-year reeds. The 3-year reeds had no dominant species.

Intervention effects varied seasonally. In June, species richness was highest in 3-year reeds, while in September, Shannon diversity peaked in 2024 harvested and 10-year reeds. Habitat structure differed significantly ($p < 0.001$) across age groups and interventions. Reed height was lower in 2024 burned and harvested areas compared to older beds in June, but by September only the burned reed remained shorter. Green stem density was highest in 2024 harvested reeds, and the ratio of new to intermediate shoots was lowest in 10-year beds. Burning reduced Ellenberg L values in June (shading understory), whereas harvesting increased L values, promoting coexisting species.

Results indicate that mosaics of differently managed reed beds—alternating harvesting and burning—maximize species richness and habitat diversity. Annual harvesting enhances reed regeneration and density, but biodiversity benefits last only a few years. Young and intermediate-aged reed beds show initial richness gains, aligning with prior studies indicating peaks 3–5 years post-harvest (Ostendorp 1999; Ausden et al. 2005). Long-term monitoring is required to refine management intervals and balance reed dominance with habitat diversity.

Regarding harvesting natural vegetal resources, in 2024, three legally harvestable edible mushroom species were identified in the DDBR, with suitable habitat limited to ~9,200 ha across agricultural land, forests, and mixed areas. Annual sustainable yields are estimated at 75 tons: *Agaricus arvensis* – 34 t, *A. sylvaticus* – 14 t, and *A. campestris* – 27 t.

Additionally, 87 medicinal herb species were recorded across the reserve, with a total harvestable dried biomass of ~22 t. Habitat-specific distributions include meadows, wetlands, forests, and fallow lands.

Beekeeping potential was assessed via 64 key plant species. Standardized recommendations estimate honey yields per vegetation type: wetland willow forests – 20 kg/ha, natural wetland meadows – 50 kg/ha, wetland pastures – 5 kg/ha, and reed beds (*Phragmites australis*) – 20 kg/ha. Eight optimized beekeeping routes were proposed to maximize production while sustaining colonies.

Natural pastures, encompassing ~27,500 ha (~4.7% of the DDBR), support 195 plant species suitable for livestock grazing. Estimated productivity averages 18.6 t/ha biomass and 0.71 LSU/ha, indicating moderate pasture quality.

Reed beds, covering ~170,000 ha, are managed via 19 concession areas, with ~49,000 ha effectively harvestable. Total annual potential reaches ~88,000 t, averaging 8.6 t/ha, based on recent assessments.

During the warm season of 2024 (March–October), surveys focused on the presence, distribution, and habitat identification of invertebrate species of Community interest across the DDBR, establishing reference sites for repeated monitoring. In the vernal period (March–May), detailed studies further characterized species distributions and their specific habitats.

Investigations were conducted both within and near the DDBR, covering the following localities: I.C. Brătianu, Grindu, Garvăn, Văcăreni, Luncavița, Rachelu, Revărsarea, Isaccea, Saon, Parcheș, Somova, Mineri, Tulcea, Nufăru, Bălteni, Murighiol, Plopu, Sarichioi, Zebil, Enisala, Jurilovca, Capul Doloșman, Histria, Istria, and Vadu.

At the western DDBR limits (I.C. Brătianu and Grindu), entomofauna species were scarce. In Garvăn and Văcăreni, characteristic habitats were surveyed, with particular attention to the butterfly *Lycaena dispar* (Haworth, 1802) (Fig. 4).

Research in 2024 targeted invertebrate species of Community interest, focusing on their presence, distribution, and associated habitats for repeated monitoring. The vernal period (March–May) primarily covered the outer DDBR, with low species representation due to cold temperatures and variable spring weather. The only invertebrate species consistently observed was the butterfly *Lycaena dispar* (Haworth, 1802), recorded at Zebil and Saon. Investigation sites included I.C. Brătianu, Grindu, Garvăn, Văcăreni, Luncavița, Rachelu, Revărsarea, Isaccea, Saon, Parcheș, Tulcea, Nufăru, Bălteni, Murighiol, Plopu, Sarichioi, Zebil, Enisala, Jurilovca, Capul Doloșman, Histria, Istria, and Vadu.

Surveys in Tulcea, Nufăru, Bălteni, Murighiol, Plopu, Sarichioi, Zebil, Enisala, Jurilovca, Capul Doloșman, Histria, Istria, and Vadu confirmed low species richness, attributable to climatic factors. At Zebil, a male *Lycaena dispar* was observed. Interior DDBR areas—Tudor Vladimirescu and Mila 23—yielded no invertebrates of Community interest.

During the summer–autumn period (June–October), investigations expanded to the same external areas, confirming habitat-specific distributions but maintaining low species diversity, with *Lycaena dispar* remaining the only invertebrate of Community interest reliably observed.

Investigations across Tulcea, Nufăru, Bălteni, Mahmudia, Murighiol, Dunavățu de Jos, Plopu, Sarichioi, Zebil, Enisala, Jurilovca, Capul Doloșman, Histria, Istria, and Vadu highlighted a poorly represented entomofauna, with low

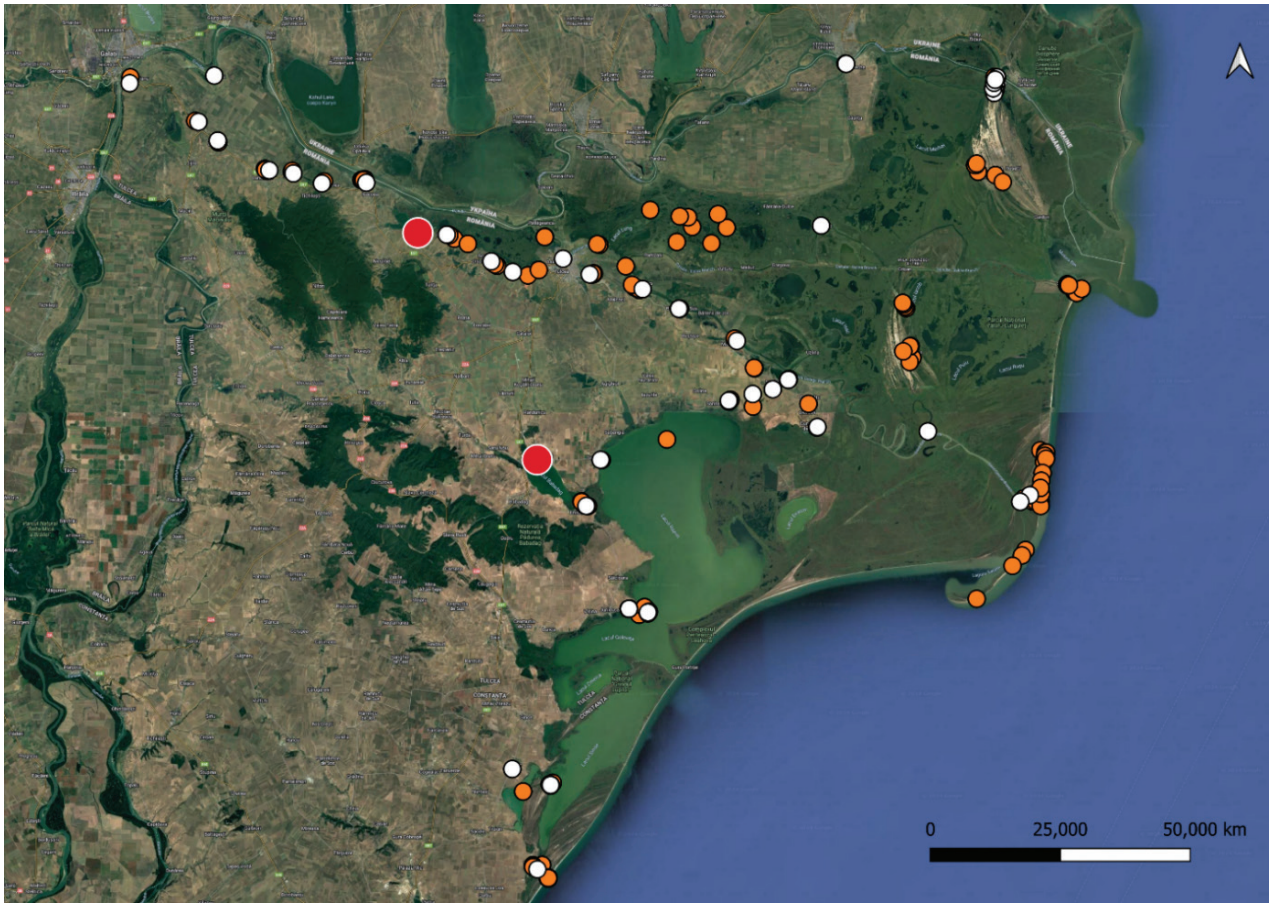

Figure 4. Observations and investigations of invertebrate species of Community interest on the territory of the DDBR and nearby areas: red dot – presence of *Lycaena dispar* (Haworth, 1802); white dot – field investigation points 2024; orange dot – previous investigation points (2010–2023) (satellite image support).

species richness influenced by preceding low temperatures and abundant rainfall. Habitats suitable for species such as *Anisus vorticulus* (Troschel, 1834), *Lycaena dispar* (Haworth, 1802), *Catopta thrips* (Hübner, 1818), *Coenagrion ornatum* (Selys, 1850), and *Ophiogomphus cecilia* (Fourcroy, 1785) were identified, though only a male *Lycaena dispar* was observed at Zebil.

In interior DDBR areas—Tudor Vladimirescu, Mila 23, Chilia Veche, Periprava, Nebunu Lake (Periprava), Sfântu Gheorghe Arm–Canal Erenciuc, Sfântu Gheorghe, and Gârla Turcească—no invertebrate species of Community interest were detected.

Overall, the summer–autumn 2024 surveys recorded only *Lycaena dispar* across all investigated sites, reflecting a species-poor entomofauna likely shaped by extreme climatic conditions: a cold spring followed by sudden and prolonged summer heat. These results provide an incomplete image of the DDBR's invertebrate fauna, as investigations focused on the outer delta and nearby areas.

Long-term monitoring over the past 14 years reveals significant knowledge gaps regarding the presence and distribution of invertebrates of Community interest, with species lists undergoing periodic adjustments in the Standard Form NATURA 2000–ROSCI0065 Danube Delta. This uncertainty complicates both the implementation of measures under the DDBR Management Plan and the assessment of species presence, distribution, and conservation status.

During the 2023–2024 study period, ichthyofauna sampling began in the Danube River and its branches and continued across the Somova–Parcheș lake complex, as well as in several lakes within the interfluvial lake systems (Uzlina, Roșu, and Roșuleț). A total of 61 fish species were captured, of which 14 are of Community interest (highlighted in bold), plus one additional species of Community interest not listed in the Standard Form of SCI RO0065—*Eudontomyzon mariae* (Table 1). Notably, the cryptic species *Romanogobio kessleri antipai* is also missing from the standard data sheet. Subsequent sampling phases will focus on identifying additional species of Community interest across other areas of the DDBR.

Table 1. Preliminary list of species caught in the freshwater of the DDBR during the 2023–2024 sampling period and some ecological classifications.

Species	Origin	Rheophily	Salinity	Adult feed	Tolerance to habitat degradation	Observations from
Abramis brama	native	stag-reo	fresh	bent	tolerant	
Acipenser gueldenstaedtii	native	migr	euryh	bent	intolerant	
Acipenser ruthenus	native	reo	euryh	bent	intolerant	
Acipenser stellatus	native	reo	euryh	bent	intolerant	
Alburnus alburnus	native	reo-stag	fresh	omni	tolerant	
Alosa immaculata	**native**	**migr**	**euryh**	**ihti**	**intolerant**	
Alosa tanaica	**native**	**migr**	**euryh**	**omni**	**intolerant**	
Ameiurus melas	exotic	Stag-reo	fresh	ihti	tolerant	fishermen
Anguilla anguilla	native	migr	euryh	ihti	intolerant	
Babka gymnotrachelus	native	stag	euryh	bent	intolerant	
Ballerus sapa	native	reo	fresh	bent	intolerant	
Barbus barbus	native	reo	fresh	bent	intolerant	
Benthophilus stellatus	native	stag-reo	euryh	bent	intolerant	
Blicca bjoerkna	native	stag-reo	fresh	omni	tolerant	
Carassius carassius	native	limn	fresh	omni	tolerant	
Carassius gibelio	native	euryt	fresh	omni	tolerant	
Chondrostoma nasus	native	reo	fresh	bent	intolerant	
Clupeonella cultiventris	native	migr	euryh	zoopl	tolerant	
Cobitis elongatoides	**native**	**euryt**	**fresh**	**bent**	**intolerant**	
Ctenopharyngodon idella	exotic	stag-reo	fresh	herbi	tolerant	
Cyprinus carpio	native	stag-reo	fresh	omni	tolerant	
Esox lucius	native	limn	fresh	ihti	intolerant	
Eudontomyzon mariae	**native**	**reo**	**fresh**	**no**	**intolerant**	
Gymnocephalus baloni	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Gymnocephalus cernuus	native	limn	fresh	bent	tolerant	
Gymnocephalus schraetser	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Heteroclarias gariepinus	exotic	Reo-stag	fresh	ihti	tolerant	fishermen
Hypophthalmichthys molitrix	exotic	stag-reo	fresh	fitopl	tolerant	
Hypophthalmichthys nobilis	exotic	stag-reo	fresh	zoopl	tolerant	fishermen
Huso huso	native	migr	euryh	bent	intolerant	
Lepomis gibbosus	exotic	limn	fresh	omni	tolerant	
Leucaspius delineatus	native	limn	fresh	omni	tolerant	
Leuciscus aspius	**native**	**reo-stag**	**fresh**	**ihti**	**intolerant**	
Leuciscus idus	native	reo-stag	fresh	omni	intolerant	

Species	Origin	Rheophily	Salinity	Adult feed	Tolerance to habitat degradation	Observations from
Misgurnus fossilis	**native**	**limn**	**fresh**	**bent**	**tolerant**	
Neogobius fluviatilis	native	stag-reo	euryh	bent	tolerant	
Neogobius melanostomus	native	stag-reo	euryh	bent	tolerant	
Pelecus cultratus	**native**	**reo-stag**	**euryh**	**zoopl**	**intolerant**	
Perca fluviatilis	native	stag-reo	fresh	ihti	tolerant	
Perccottus glenii	exotic	limn	fresh	ihti	tolerant	
Petroleuciscus borysthenicus	native	limn	fresh	omni	intolerant	
Ponticola eurycephalus	native	stag-reo	euryh	bent	intolerant	
Ponticola kessleri	native	stag-reo	euryh	ihti	intolerant	
Proterorhinus marmoratus	native	stag	euryh	bent	tolerant	
Pseudorasbora parva	exotic	stag	fresh	omni	tolerant	
Pungitius platygaster	native	limn	fresh	omni	intolerant	
Rhodeus amarus	**native**	**stag**	**fresh**	**herbi**	**intolerant**	
Romanogobio vladykovi	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Rutilus rutilus	native	euryt	fresh	omni	tolerant	
Sabanejewia bulgarica	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Salmo labrax	native	migr	euryh	ihti	intolerant	
Sander lucioperca	native	stag-reo	euryh	ihti	intolerant	
Sander volgensis	native	stag-reo	euryh	ihti	intolerant	
Scardinius erythrophthalmus	native	limn	fresh	omni	tolerant	
Silurus glanis	native	stag-reo	fresh	ihti	tolerant	
Syngnathus abaster	native	stag	euryh	zoopl	tolerant	
Tinca tinca	native	limn	fresh	omni	intermediar	
Umbra krameri	**native**	**limn**	**fresh**	**omni**	**intolerant**	
Vimba vimba	native	stag	fresh	bent	tolerant	
Zingel streber	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Zingel zingel	**native**	**reo**	**fresh**	**bent**	**intolerant**	
Total = 61						

(Symbols used: Origin: n = native, e = exotic; Rheophily: migr. = migratory, limn = l imnophilic, stag = stagnophilic, reo = reophilic; euryt = eurythopic; Salinity: fresh = freshwater, eury = euryhaline; Adult feed: omni = omnivorous, ihti = ihtiophagous, bent = bentophagous, zoobent = zoobenthophagous, herb = herbivorous, zoop l = zooplantonophagous, phyto = phytophagous; Tolerance to habitat degradation: tole = tolerant, into = intolerant, sensitive); bold-species of Community interest.

In spring 2024, official catch data provided by the Fisheries Resources Administrator (ARBDD) for the previous year were analyzed for the Danube Delta Biosphere Reserve (DDBR). In 2023, freshwater fish clearly dominated catches in the freshwater zones, followed by migratory species such as the Pontic shad. In contrast, catches of marine fish, crayfish, and other categories were negligible (Table 2).

Freshwater fish accounted for 91.5% of the total fishery resources in the DDBR. The most abundant species were gibel carp (*Carassius gibelio*, 40.4%), Asian carps (13.2%), breams (*Abramis brama* and *Blicca bjoerkna*, 10.8%), carp (*Cyprinus carpio*, 8.7%), and roach species (*Rutilus rutilus* and *Scardinius erythrophthalmus*, 5.3%). Predatory species included catfish (*Silurus glanis*, 5%) and pike (*Esox lucius*, 2.9%), which has slightly increased over the last two years compared with the continuous decline observed since 2019 (from 5.7% in 2019 to 2% in 2022). Another predatory species, zander (*Sander lucioperca*), continued its decreasing trend, representing only 1.6% of the official catches in 2024 (less than 41 tons).

Table 2. Structure by category and species of catches (in kg) of official fishery resources in 2023 from the DDBR.

No. Crt.	Species	Total	% from total	% from category
1	*Carassius gibelio*	1042361.3	40.4	44.2
2	*Abramis brama*	206746.8	8.0	8.8
3	*Rutilus rutilus*	107272.1	4.2	4.5
4	*Sander lucioperca*	40520.7	1.6	1.7
5	*Silurus glanis*	129409.8	5.0	5.5
6	*Esox lucius*	74202.3	2.9	3.1
7	*Cyprinus carpio*	224279.1	8.7	9.5
8	Asian carps	341467.9	13.2	14.5
9	*Scardinius erythrophthalmus*	28417	1.1	1.2
10	*Blicca bjoerkna*	71706.8	2.8	3.0
11	Other freshwater species	92277.7	3.6	4.0
	Total freshwater species	**2358661.5**	**91.5**	**100**
	Total marine species	**3342.5**	**0.1**	**100**
1	*Alosa immaculata*	214998	8.3	99.7
2	*Alosa tanaica*	746	0.03	0.3
	Total migratory species	**215744**	**8.4**	**100**
	Total fish resources from DDBR	**2577748**	**100**	**100**

Marine fish catches were negligible (0.1%), while migratory fish accounted for 8.3% of the total, dominated by Pontic shad (*Alosa immaculata*), which comprised over 99% of migratory fish catches (Table 2).

During the 2024 field investigations (March–October) in the DDBR, four of the five herpetofauna species of Community interest were identified, alongside other species not targeted in this study. The European Pond turtle (*Emys orbicularis*) was the most frequently observed, recorded at 11 points, whereas the steppe viper (*Vipera ursinii moldavica*) was the rarest, with a single observation inside the Perișor fish farm. The Dobrogean crested newt (*Triturus dobrogicus*) was not detected during this period. A map of all recorded observations for 2024 is provided below.

This study assessed the nesting populations of 26 colonial waterbird species distributed in 102 mono- and polyspecific colonies within the DDBR. In total, 61,834–63,915 pairs were inventoried.

Hydrological conditions in 2024 were characterized by medium to high water levels over extended periods, maintaining stable aquatic habitats. These conditions favored nesting for *Chlidonias niger*, *Chlidonias hybrida*, *Chlidonias leucopterus*, *Larus ridibundus*, and *Sterna hirundo*. However, in Lake Sinoie, insufficient drainage toward the sea caused flooding of colonies on Ceaplace Island and Prundul cu Păsări Islands, reducing available nesting habitat.

For *Larus cachinnans*, reproductive success was low due to predation. In the Musura colony, *Rattus norvegicus* caused high chick mortality, while in the Sărături Murighiol colony, reduced water levels facilitated predator access, resulting in mortality and nest abandonment.

Due to accessibility and technological limitations, identification and assessment of certain species nesting in dense shrub habitats were incomplete. High-resolution aerial imagery has proven effective for detecting, mapping, and

evaluating colonies in inaccessible wetlands. For accurate population assessments of *Ardea alba*, *Ardea purpurea*, and *Ardea cinerea*, aerial surveys conducted in early May are required. The same method is recommended for *Pelecanus crispus* and *Pelecanus onocrotalus* colonies to avoid disturbance and ensure precise population estimates.

Phalacrocorax carbo, an exclusively piscivorous species, is present throughout the DDBR and can be considered a bioindicator of fish resources. Although no management measures target its population, and no zoonotic mortality events have been reported, the decline observed in the past two years is most likely explained by persistently high-water levels limiting food access rather than reduced habitat capacity or interspecific competition.

The evaluation results have been integrated into a GIS database, providing a valuable management tool for colonial waterbird monitoring in the DDBR.

Research on the nine mammal species of Community interest was conducted in several sectors of the ROSCI0065 and ROSCI0066 sites, including the river delta, fluvio-maritime delta, coastal area, and lagoon area (Table 3).

During 2024, seven of the nine species were recorded: three in the river delta, two in the fluvio-maritime delta, two in the coastal area, and four in the lagoon area. *Mustela eversmanii* and *Vormela peregusna* were not observed.

The distribution and occurrence of the recorded species within ROSCI0065 and ROSCI0066 are detailed in Table 3.

Table 3. Species of Community interest in ROSCI0065 and ROSCI0066 between January and September 2024.

No	Species	River Delta	Investigation points		The lagoon area of RBDD	ROSCI0065 ROSCI0066 January-September 2024
			Fluvio-maritime delta	Coastal area of RBDD		
1	***Lutra lutra***	X	X		X	X
2	*Mustela eversmanii*					
3	*Mustela lutreola*	X	X		X	X
4	*Vormela peregusna*					
5	***Castor fiber***	X				X
6	*Spermophilus citellus*				X	X
7	*Mesocricetus newtoni*				X	X
8	*Phocoena phocoena*			X		X
9	*Tursiops truncatus ponticus*			X		X
	TOTAL	**3**	**2**	**2**	**4**	**7**

In 2024, *Lutra lutra* was recorded in 57 of the 130 surveyed locations, with 175 individuals observed, confirming it as the most frequently encountered mammal of Community interest (Lupu et al. 2022, 2023, 2024).

Mustela eversmanii was not observed directly or indirectly in or near ROSCI0065.

Mustela lutreola was recorded in eight of the 130 surveyed locations, with a total of nine individuals. Notably, this is the first year the species was observed during summer, whereas in previous years it was recorded only in autumn, winter, and spring.

Castor fiber was observed in three of the 130 surveyed locations. In recent years, it has been regularly recorded in the Somova–Parcheș aquatic complex (Kiss et al. 2012, 2013; Marinov et al. 2022).

Mesocricetus dobrogicus was recorded only in the Cape Iancina area, where surveys focused on alfalfa fields and steppe habitats at the ROSCI0065 limit. This Balkan endemic species occurs only in Romania and Bulgaria, restricted to low-lying areas along the right bank of the lower Danube (Hamar and Șutova 1966; Kryštufek et al. 2009).

Spermophilus citellus was observed in eight of the 130 surveyed locations, totaling 957 individuals. Within ROSCI0065, the species is absent from intra-deltaic areas but remains relatively common along the northern and western coasts of the Razim–Sinoie complex (Marinov et al. 2022).

In ROSCI0066, *Phocoena phocoena relicta* was observed in several coastal sectors (Cape Midia, Sulina Beach, Sacalin Island), with 46 individuals recorded, including three dead. While individuals are usually solitary or form small groups of two to four, larger aggregations can occur during migration or feeding (MacDonald and Barrett 1993).

In the same site, *Tursiops truncatus ponticus* was observed in multiple coastal areas, including Sulina (New Lighthouse), Sacalin Bay, Perișor Beach, and Cape Midia, with 46 individuals recorded in 2024.

Of the seven species of Community interest observed in the study area, only *Lutra lutra* was recorded in all natural and anthropogenic aquatic habitats.

For *Mustela lutreola*, 2024 marks the first year in which individuals were captured during summer, while in previous years the species had only been recorded in autumn, winter, and spring.

In *Phocoena phocoena relicta*, three dead individuals were found on Sulina Beach. Interviews with DDBRA staff indicate that between two and three porpoises drown daily in fishermen's nets, most frequently during the mackerel fishing season.

Castor fiber was observed in three areas of ROSCI0065 and ROSCI0066, compared to only one area in previous years.

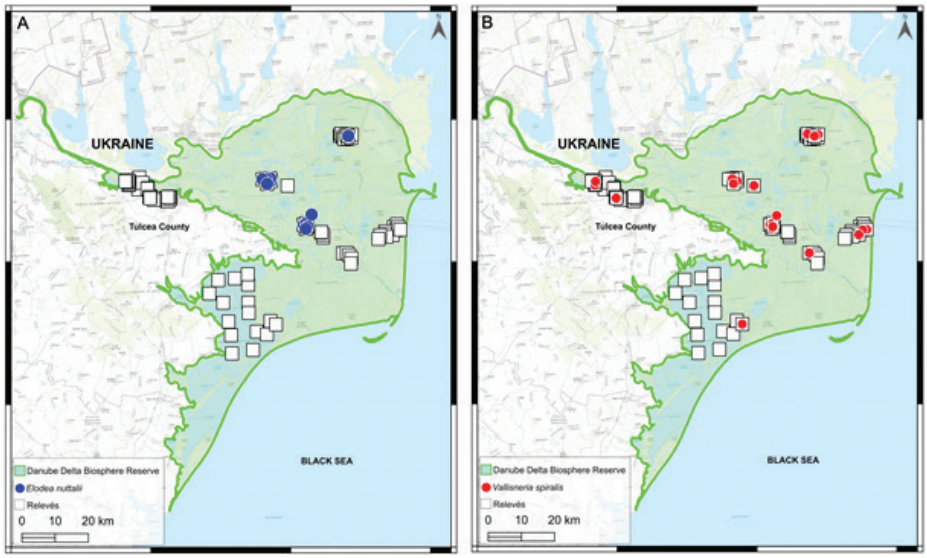

Figure 5. Distribution of the species *Vallisneria spiralis* (**A**) and *Elodea nuttallii* (**B**) in some lakes in the Danube Delta.

Mesocricetus dobrogicus was recorded exclusively in the Cape Iancina area, consistent with data reported in the literature.

The highest numbers of individuals in 2024 were recorded for *Spermophilus citellus*, concentrated in steppe habitats in the northwestern part of ROSCI0066.

The two species not recorded in 2024 were *Mustela eversmanii* and *Vormela peregusna*.

In the analyzed lakes, two invasive plant species were identified (Fig. 6): *Vallisneria spiralis* L. and *Elodea nuttallii* (Planch.) H. St. John.

Vallisneria spiralis was recorded in lakes Furtuna, Isac, Merhei Mare, Parcheș, Razim, Roșu, Roșuleț, and Uzlina (Fig. 7). The most favorable conditions for its development were observed in lakes Furtuna, Uzlina, and Parcheș, while in Roșuleț, Roșu, and Erenciuc the conditions proved less favorable. *Elodea nuttallii* was recorded in lakes Furtuna, Uzlina, Câșla, and Isac. Of these, only Lake Uzlina showed significant coverage, ranging from 0.5% to 62.5%.

Cluster analysis

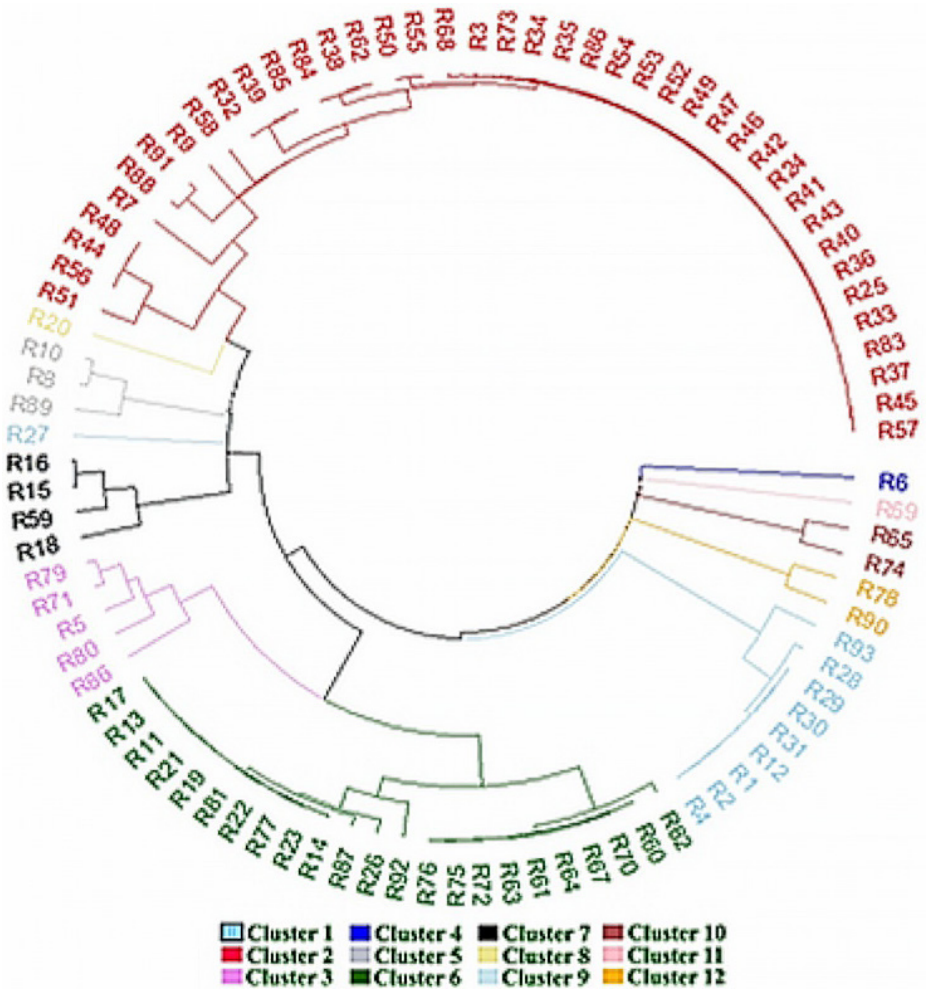

Figure 6. Dendrogram of vegetation data obtained from cluster analysis.

The cluster analysis includes 12 clusters (vegetation groups; Fig. 8): cluster 1 includes communities of *Nitellopsis obtusa*; cluster 2 consists of communities of *Ceratophyllum demersum*, *Potamogeton perfoliatus*, *Vallisneria spiralis*, and

Stuckenia pectinata; cluster 3 includes dominant communities of *Ceratophyllum demersum* and *Trapa natans*; cluster 4 describes communities of *Chara aspera*; cluster 5 includes communities of *Myriophyllum spicatum*; cluster 6 includes communities of *Ceratophyllum demersum*; cluster 7 includes communities dominated by *Vallisneria spiralis*; cluster 8 describes communities of *Elodea nuttallii*; cluster 9 includes communities of *Hydrocharis morsus-ranae*; cluster 10 includes communities of *Trapa natans*; cluster 11 includes communities dominated by *Nymphaea candida*; and cluster 12 includes communities dominated by *Nymphoides peltata*.

Based on the socio-economic study of Jurilovca commune and data from the 2002 and 2011 censuses, a population decrease of 452 individuals was recorded over nine years. Between 2011 and the present, the population has declined by 15.2% (Fig. 9). Assessing the current state of quality of life requires considering not only objective indicators reflecting living conditions but also subjective indicators capturing the population's perceptions, expectations, and responses to the socio-economic context, thereby representing the perceived quality of life.

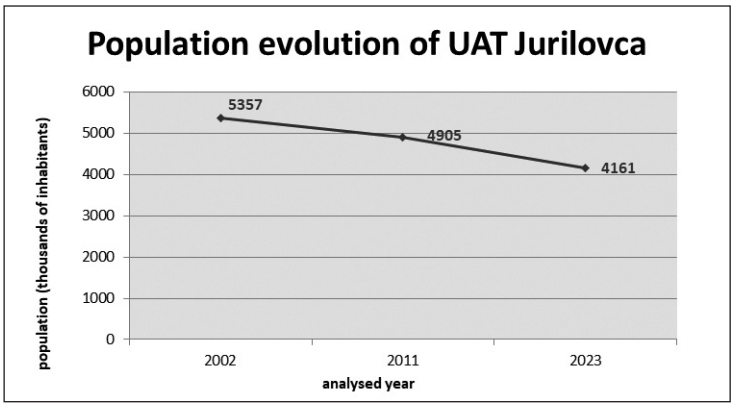

Figure 7. Population evolution of UAT Jurilovca.

Through questionnaires applied to the local population, the current state of community development in the Jurilovca commune was assessed. The questionnaire aimed to evaluate residents' satisfaction with life, identify representative features of the commune, analyze specific challenges, and understand perceptions of infrastructure, the local economy, public administration, and the community environment. The insights were used to develop solutions to improve the quality of life.

Analysis revealed that 52% of respondents believe their living conditions have remained unchanged compared to the previous year, and a similar proportion anticipate stagnation over the next 2–3 years. Less than half of respondents reported that their incomes are sufficient for a decent standard of living without enabling the purchase of higher-value goods, though they expressed satisfaction with their current financial resources.

Approximately half of the respondents indicated satisfaction with life in the commune and considered its economic development satisfactory. Key concerns included rising food and energy costs, the risk of military conflict in the area, children's future, and epidemics or pandemics. Regarding infrastructure, residents expressed high satisfaction with access to potable and domestic

water supply and sewage systems, which are considered essential indicators of urban quality of life.

In terms of the local economy, over 31% of residents reported satisfaction with access to financial and insurance services, as well as daily goods and services, and displayed confidence in the commune's economic development prospects.

Following the socio-economic study, consultation of the Jurilovca Local Development Strategy for 2021–2027, and analysis of completed questionnaires, priority issues and socio-economic development needs were identified. The creation of jobs for young people emerged as the primary need, with 67.2% of respondents considering it essential for raising the standard of living.

Based on these results, revitalization solutions were proposed to enhance residents' quality of life, focusing on infrastructure modernization, environmental protection, and stimulating the local economy through tourism, agriculture, and education.

During the spring months (March–May), research focused on the Jurilovca recreation and tourism area, analyzing tourism indicators and the degree of tourism implementation in the area.

The investigations showed a marked increase in accommodation units promoted on specialized websites, with a rise of approximately 350% in 2019 compared to 2013 and about 200% in 2024 compared to 2019. The number of accommodation places also increased, doubling in 2024 compared to 2019.

In 2024, the Jurilovca recreation and tourism area included 30 accommodation units with 533 accommodation places, representing 31% of the total units and 87% of accommodation places listed on tourism promotion websites. Among the localities in this area (Jurilovca, Vișina, Gura Portiței, Sarichioi, Enisala, Sabangia, Lunca, and Sinoe), Gura Portiței stands out. Despite having only one tourist service provider, it offers 388 accommodation places across several comfort categories (2- and 3-star villas/bungalows and cottages), all accredited in 2024.

Tourist arrivals and overnight stays, according to the National Institute of Statistics, totaled 4,721 tourists and 10,435 overnight stays in 2024, averaging about three days per visitor. This relatively long stay is primarily attributed to the beach at Gura Portiței, the quality of tourist facilities, and the area's limited accessibility, making it more of a holiday destination than a weekend getaway.

The main leisure activities in the Jurilovca recreation and tourism area center around key attractions. The Jurilovca tourist port, inaugurated in 2023, serves as a departure point for daily boat trips to Gura Portiței and the Danube Delta. It features 80 mooring places, a green area, and a designated picnic space. Other highlights include the holiday village and Gura Portiței beach, situated on the narrow land strip between the Razim-Sinoe Lagoon and the Black Sea, where deltaic and marine ecosystems meet. Cultural tourism is closely tied to the commune's location on the Razim-Sinoe Lagoon and the traditions of the Lipovans, whose calendar and religious celebrations, such as Pokrov on 14 October, play a central role in local life. These attractions contributed to Jurilovca being ranked 4th among Romania's top tourist destinations in 2024 by the International Federation of Tourism Journalists and Writers (FIJET)—https://clubpresaturism.ro/destinatiile-fijet-romania-2024-locul-4-jurilovca/.

During the summer months (June–August), research focused on the Murighiol recreation and tourism area, encompassing the communes of Murighiol, Mahmudia, Nufăru, Beștepe, and Valea Nucarilor. Field investigations updated

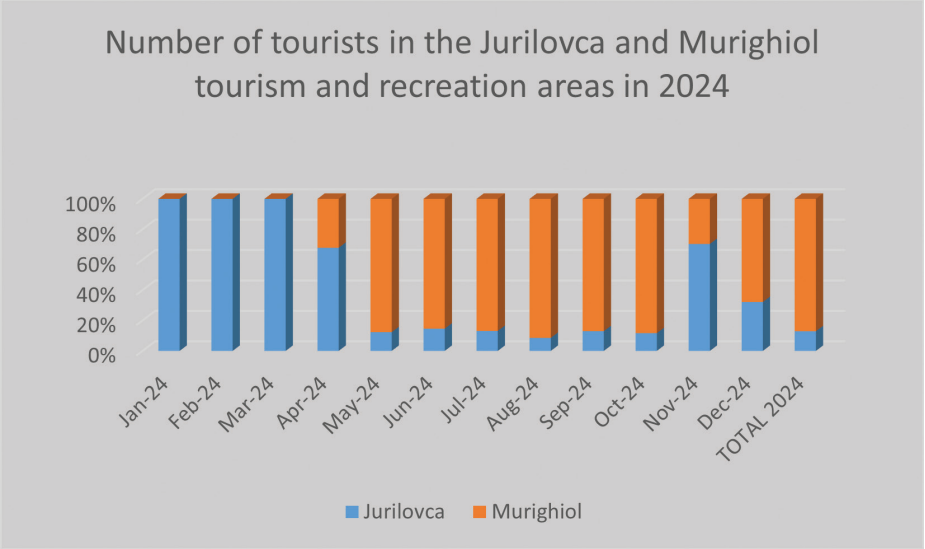

Figure 8. Comparative situation on the number of tourists between the tourism and recreation areas of Jurilovca and Murighiol.

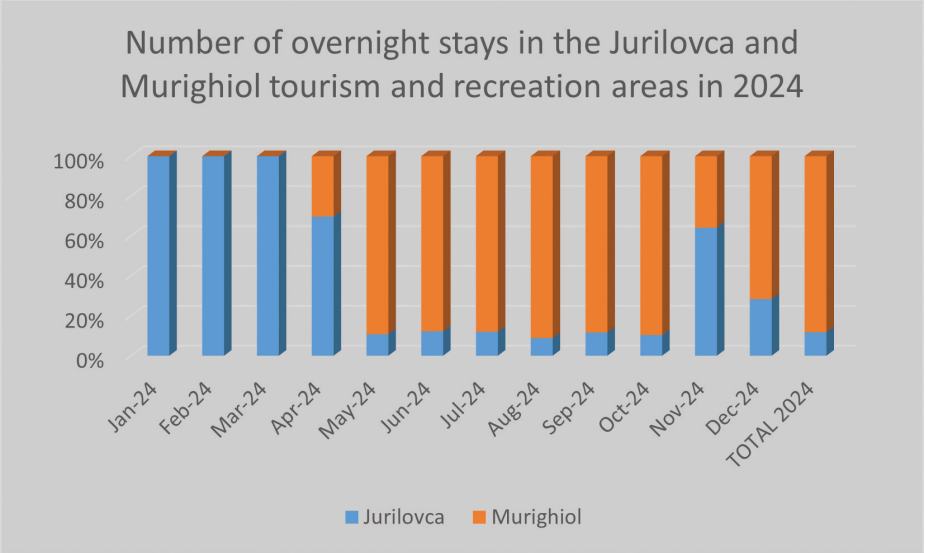

Figure 9. Comparative situation of the number of tourists between the Jurilovca and Murighiol recreation and tourism areas.

the database initiated in 2008, identifying a total of 479 accommodation units, doubling the 239 units recorded in 2019. These units provide 2,551 accommodation spaces with 4,545 places, representing an increase of 302.53% compared to 2019.

In 2024, the Murighiol recreation area registered a total of 31,765 tourists and 78,500 overnight stays, resulting in an average stay of two days per tourist. Comparatively, between the two areas studied—Jurilovca and Murighiol—the Murighiol area recorded higher numbers of both tourists and overnight stays, likely due to easier access and infrastructure.

Tourism in Murighiol is focused on canal trips, particularly in Dunavățu de Jos, and fishing activities in Murighiol, promoted via street panels and guesthouse reception areas. Emerging trends include relaxation and spa services,

with guesthouses offering swimming pools and playgrounds, positioning the area as a family-oriented destination for leisure, sunbathing, and tranquility. The expansion of fish restaurants with "à la carte" menus has also enhanced local gastronomic tourism.

Visitors can explore historical sites, such as Halmyris Fortress, and cultural attractions like the Museum of Folk Art "Casa Satului – Dunavăț," which showcases interiors reflecting the traditions of the ethnic groups in Murighiol commune. Nature and birdwatching enthusiasts benefit from strictly protected areas, such as Sărături Murighiol, with regulated access to preserve biodiversity.

A significant development for Murighiol tourism is its certification as the first tourist resort in Tulcea County under Government Decision No. 120/2024, recognizing the commune for national and local tourism development standards.

Conclusion

Vegetation management in the Danube Delta Biosphere Reserve (DDBR) reveals that burning and harvesting of reed beds have contrasting effects: burning reduces species diversity and selects for low-light-adapted communities, while harvesting stimulates reed regeneration and increases species richness. To maximize plant diversity and habitat heterogeneity, reed beds should be managed as mosaics of varying ages and treatment types.

Natural resource utilization, particularly reed harvesting, medicinal herbs, and beekeeping plants, represents a significant potential income source for local communities. Its full realization requires market development, active involvement of the DDBR Administration, and long-term monitoring to ensure sustainable management.

Biodiversity assessments show persistent knowledge gaps. Invertebrate surveys are limited to peripheral areas and climate extremes, leaving the status of Community interest species incompletely documented. Fish populations are dominated by freshwater species such as *Carassius gibelio*, with some predatory species like *Esox lucius* and *Sander lucioperca* in decline. Herpetofauna shows stable distributions, with some species widely spread and others restricted to fragmented habitats. Colonial waterbirds reached one of the highest population levels in the last five years, though high water levels occasionally limit available nesting areas. Annual monitoring of piscivorous birds like the great cormorant is crucial for linking bird population dynamics to fish productivity. Two invasive aquatic plants (*Vallisneria spiralis* and *Elodea nuttallii*) were identified in several lakes, highlighting the need for ongoing surveillance and management.

Socio-economic analyses in Jurilovca indicate a relatively satisfactory perceived quality of life, but challenges remain, including economic constraints, infrastructure gaps, demographic decline, and environmental pressures. Community involvement and strategic use of financial and technical resources can support sustainable development, improve living standards, and enhance the commune's attractiveness.

Tourism development in the DDBR continues to expand, with the Jurilovca and Murighiol areas showing distinct profiles. Murighiol benefits from easier access and modern facilities, attracting higher visitor numbers and shorter stays, emphasizing relaxation and comfort tourism. Jurilovca, with more

restricted access, fosters slow, cultural, and adventure tourism, achieving national recognition for its cultural and gastronomic offerings. Both areas exemplify the potential for tailored ecotourism that balances visitor experience with local economic and environmental sustainability.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

An AI tool was used to condense information to meet the requirements related to the maximum number of pages allocated for a paper published in the journal according to the instructions.

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Author contributions

Conceptualization: GL. Formal analysis: VA, LE, SDC, FS, MD, IC, BL, MM, AN, SC, AN, DA, MS, IF, MM. Investigation: DA, AN, IC, MD, SC, LE, GL, FS, VA, MM, SDC, AN. Methodology: AN, IF, SDC, VA, BL, IC, GL, LE, FS, AN, MM, SC, DA, MD. Project administration: GL. Visualization: MS, BL, MM. Writing – original draft: GL.

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Data availability

All of the data that support the findings of this study are available in the main text.

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