ISSN 2411-7374 (print)
ISSN 2782-6643 (online)

РОССИЙСКИЙ ЖУРНАЛ ПРИКЛАДНОЙ ЭКОЛОГИИ

2/2025

Российский журнал прикладной экологии
420087 г. Казань, ул. Даурская, 28
www.rjae.ru

УДК 556.557:504.455

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SPATIAL DISTRIBUTION AND HYDROGRAPHIC CHARACTERISTICS ANALYSIS IN DETACHED BAYS OF THE TETYUSHSKY REACH OF THE KUIBYSHEV RESERVOIR

The creation of the Kuibyshev Reservoir led to the formation of numerous bays, a significant portion of which underwent complete or partial isolation from the main water area. That resulted in a new natural-anthropogenic element in coastal landscapes. The aim of this work was to analyze the spatial distribution and morphometric parameters of isolated bays within the water area of the Tetyushsky reach of the Kuibyshev Reservoir. For the analysis, satellite imagery from Google Earth and Sentinel-2, as well as field research data from 2024, were utilized. Computations were performed in QGIS 3.28.3 GIS for the summer low-water period of 2024 at a normal water level of 52.7 m BS (Baltic System). The study identified 103 detached bays with a total water surface area of 246 hectares. The majority of the bays were located on left-bank islands formed after the flooding of the reservoir bed. Based on water surface area, they were classified as «small water bodies», characterized predominantly by oval and near-circular shapes and slightly indented shorelines. The dynamics of the water surface area showed the trend toward reduction, particularly for bays not connected to the main water area during the flood period. The significance of those findings was underscored by the location of the study objects within the territory of the «Spassky» Biosphere Reserve and the buffer zone of the UNESCO World Heritage Site – historical and archaeological complex of Bolgar.

Keywords: detached bays; Kuibyshev Reservoir; geographic information systems; monitoring of water bodies; morphometric indicators.

DOI: https://doi.org/10.24852/2411-7374.2025.2.66.70

The Kuibyshev Reservoir is one of the world's largest artificial water bodies, with the surface area of 5900 km² at a normal pool level (NPL) of 53 m above sea level (Baltic Height System). Its length is 510 km along the Volga River and 300 km along the Kama River (Kuibyshevskoe ..., 2008). The hydrological regime of the reservoir is characterized by seasonal flow regulation: it fills to NPL in spring, and during the rest of the year, water is drawn down, lowering levels by several meters and fully exposing shallow areas (Bamburov et al., 1991).

As the largest multipurpose reservoir in Russia, it plays a vital role in supporting economic sectors and socio-cultural needs. Its creation caused large-scale environmental changes in both the flooded zone and adjacent territories. One consequence was the formation of numerous bays – parts of the reservoir extending into land while maintaining hydrodynamic connectivity. Most have since become fully or partially isolated, creating new natural-anthropogenic elements of coastal landscapes used for economic and recreational purposes.

State water monitoring requires systematic observation of morphometric transformations. Thus, studying morphometric parameters of detached bays – a new type of inland surface water body – is a crucial scientific and practical task. This will enable forecasting near- and long-term changes in their ecosystems.

The reservoir comprises lake-like expansions divided into 8 development zones connected by narrow sections of the former riverbed. Data on detached bays, including morphometrics, are limited to the Volzhsky reach (Ziganshin, Ivanov, Khasanov, 2021, 2022; Ziganshin et al., 2024).

This article analyzes the key morphometric characteristics of detached bays in the Tetyushsky reach of the Kuibyshev Reservoir, located in the middle Volga after the confluence of the Volga and Kama rivers near Tetyushi. Its northern boundary is the Kama River mouth, and its southern boundary is just below the Maina River mouth (fig. 1).

The Tetyushsky reach is ~80 km long and 3–20 km wide at its broadest point. Its water surface area is 766 km² (~13.2% of the total reservoir area). Most (80%) lies in Tatarstan, with a smaller section (20%)

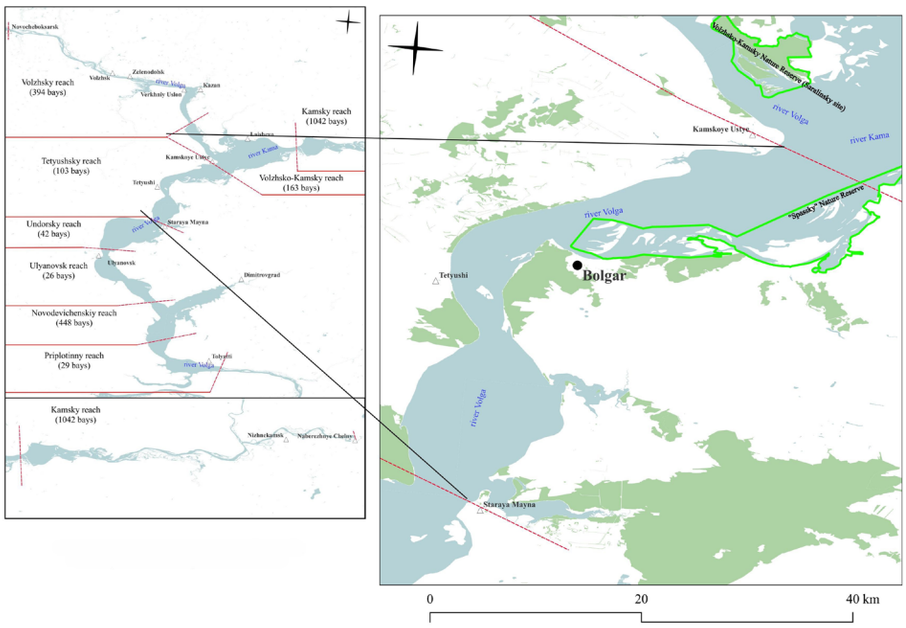

Fig. 1. Location of the Tetyushsky reach of the Kuibyshev Reservoir

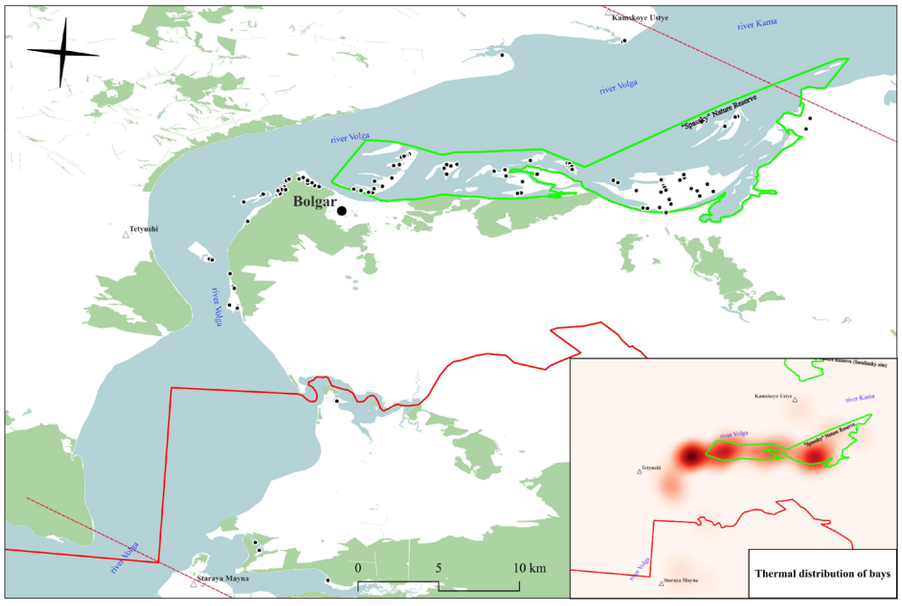

Fig. 2. Spatial distribution of detached bays of the Kuibyshev reservoir in the study area

in Ulyanovsk Oblast. Depths are significant (avg. 10 m), reaching 20 m in navigation channels. Coastal depths are 5–10 m on the right bank and 2–5 m on the left bank. Currents are weak (avg. 0.5 m/sec), especially in bays, promoting siltation. Littoral zones (≤2 m depths) cover <10% of the area. The bottom is sandy throughout; higher aquatic vegetation occurs only on the left bank. Volga's banks are asymmetric: the right bank is high (100–150 m), steep, and cliff-like (limestone/clay); the left bank is gentle, flood-prone, and erosion-susceptible.

Data sources included 2024 field surveys, Google Earth and Sentinel-2 satellite imagery. Calculations used QGIS 3.28.3 for the 2024 summer low-water period at poor level 52.7 m (Baltic System). Statistical processing employed Statistica 8.0.

Satellite imagery and field data revealed 103 detached bays (total area 246 ha) in the Tetyushsky reach during summer 2024. Most were on islands formed by reservoir filling along the left Volga bank (fig. 2). Sixty-four water bodies were within the UNESCO World Heritage Site buffer zone — the historical and archae-

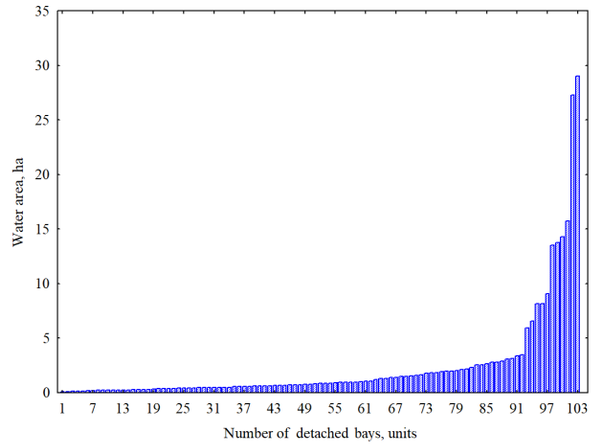

Fig. 3. Histogram of water areas distribution of detached bays in Tetyushsky reach

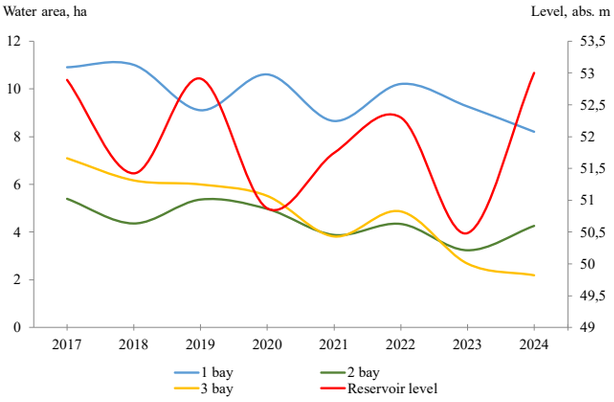

Fig. 4. Water area dynamics of detached bays based on reservoir level and spring flood connectivity (1 bay: periodically flooded; 2 bay: consistently flooded; 3 bay: unflooded)

ological complex of Bolgar and the «Spassky» State Nature Reserve.

The high right Volga bank was less prone to flooding negative landforms. Its hard rocks (limestone, sandstone) resisted erosion, reducing bay formation. Only three detached bays existed there: one formed by flooding the depression where village buildings (Kirelskoe) were demolished during reservoir creation; two others emerged from the separation of straits between islands and the mainland near Kamskoye Ustye.

Unlike the Volzhsky reach (where many bays were artificially isolated), detachment in the Tetyushsky reach occurred naturally. Abrasion-accumulative spits formed at bay inlets – flooded erosional features (hollows, gullies, ravines) or former straits – progressively isolating them from the main reservoir.

By water area (GOST R 59054-2020), those bays were «small water bodies» (<1 ha). Per I.S. Zakherenkov's lake classification (1964), they fell into: small lakes (10–100 ha), tiny lakes (1–10 ha), and ponds (0.1–1 ha). Most (94%) were in the latter two classes (fig. 3).

Only six water bodies had the water surface area exceeding 10 hectares. Most were located in the water area of Staromainsky Bay (Ulyanovsk oblast).

Water bodies with very shallow maximum depths predominated (tab. 1). The smallest maximum depths (1–2 m) were observed in detached bays situated within island complexes. The greatest depth (7 meters) was recorded in the bay near the village of Volzhskoye in Ulyanovsk oblast.

Changes in the water area of the water bodies were subjected to fluctuations in the reservoir water level, as well as the presence of a hydrological connection with the main water area of the reservoir during the spring flood season. The conducted analysis of water area changes for three model detached bays, each having different hydrodynamic connections with the reservoir's main water area, revealed a general trend of decreasing water surface area regardless of the water level or connection with the Kuibyshev reservoir. At the same time, for water bodies flooded by reservoir waters during spring floods, this trend followed a smoother pattern, and fluctuations in their water area largely depended on the reservoir's water level (fig. 4).

The elongation coefficient (lake length / mean width) in Tetyushsky reach bays varies from 1.4 to 24.9 (avg. 5.3). Unlike the Volzhsky reach (where bays are mostly furrow-shaped), most there trended toward oval/circular forms (tab. 2).

Statistical processing of the data using Spearman's correlation coefficient revealed the weak relationship between the elongation coefficient and the water surface area ($r=0.26$, $p < 0.05$).

Regarding shoreline indentation, the predominant portion of the detached bays in the Tetyushsky reach fell under the category of water bodies with slightly indented shorelines (Table 4). Those values differed significantly from those of the Volzhsky reach, where water bodies with strongly and moderately indented shorelines predominated (Ziganshin et al., 2024).

This study underscores the need for regular monitoring and detailed analysis of detached bays – especially in buffer zones of internationally significant sites – to develop measures ensuring regional ecological resilience.

The work was supported by a grant from the Academy of Sciences of the Republic of Tatarstan, awarded to young PhD holders (postdoctoral researchers) for the purpose of preparing a doctoral dissertation, conducting scientific research, and fulfilling employment duties at scientific and educational institutions of the Republic of Tatarstan under the State Program of the Republic of Tatarstan 'Scientific and Techno-

Table 1. Morphometric indicators of detached bays in the Tetyushsky reach

Indicator	Mean	Median	Min	Max
Area, ha	2.3	0.8	0.1	29
Length of coastline, m	678	474	113	3770
Length, m	280	198	34	1739
Width, m	103	73	28	608
Average width, m	56	40	12	273
Maximum depth, m	1.9	1.6	0.7	7.0

Table 2. Ranging of detached bays by elongation coefficient

Form	Elongation index	Quantity	% of total
Rounded	< 1.5	1	1
Close to a circle	1.5-3.0	25	24
Close to rounded	3.0-5.0	38	37
Close to oval	5.0-7.0	23	22
Oval-elongated	7.0-10.0	8	8
Elongated in the form of a «furrow»	> 10.0	8	8

Table 3. Distribution of detached bays by shoreline indentation

Indentation degree	Indentation coefficient	Quantity	% of total
Heavily indented	<1.5	99	96
Average Indented	1.5-2	4	4
Weakly indented	> 2	0	0

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Зиганшин И.И., Иванов Д.В., Сафин И.М. **Анализ пространственного распределения и гидрографическая характеристика отчлененных заливов Тетюшского плеса Куйбышевского водохранилища**.

Создание Куйбышевского водохранилища привело к образованию многочисленных заливов, значительная часть которых подверглась полной или частичной изоляции от основной акватории, сформировав новый природно-антропогенный элемент прибрежных ландшафтов. Целью работы является анализ пространственного размещения и морфометрических параметров отчлененных заливов в акватории Тетюшского плеса Куйбышевского водохранилища. Для анализа использовались спутниковые снимки Google Earth и Sentinel-2, и данные полевых исследований за 2024 г. Вычисления осуществлялись в ГИС QGIS 3.28.3 на летнюю межень 2024 г. при НПУ 52.7 м БС. В ходе исследования выявлено 103 отчленённых залива общей площадью водного зеркала 246 га. Большая часть заливов расположена на левобережных островах, образовавшихся после затопления ложа водохранилища. По площади акватории они относятся к категории «малые водоемы», характеризуются преимущественно овальной и близкой к округлой формой и слабоизрезанными берегами. Динамика площади водного зеркала демонстрирует тенденцию к сокращению, особенно у заливов, не связанных с основной акваторией в период половодья.

Ключевые слова: отчлененные заливы; Куйбышевское водохранилище; геоинформационные системы; мониторинг водных объектов; морфометрические показатели.

Раскрытие информации о конфликте интересов: Автор заявляет об отсутствии конфликта интересов / Disclosure of conflict of interest information: The author claims no conflict of interest

Информация о статье / Information about the article
Поступила в редакцию / Entered the editorial office: 09.04.2025
Одобрено рецензентами / Approved by reviewers: 23.04.2025
Принята к публикации / Accepted for publication: 07.05.2025

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