LOCAL RIVER WATER BASIN GOVERNANCE MONITORING DEVELOPMENTS IN LATVIA: TOWARDS STAKEHOLDER'S CO-MANAGEMENT

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Abstract. At the municipal level, environmental governance monitoring systems are essential for evidence-based decision-making, policy evaluation, and effective change management. In Latvia, these systems remain fragmented, unevenly integrated, and weakly linked to governance outcomes, despite institutional and legal developments, including the 2021 administrative-territorial reform focused on aggregation of smaller municipalities. This study assesses environmental governance monitoring systems in Latvia at municipal and river basin levels, with emphasis on water governance, and develops recommendations for improving municipal monitoring frameworks. It applies a multi-method approach: (1) analysis of national, regional, and municipal policy, planning, and monitoring documents; (2) a Dviete River Basin case study with environmental governance and communication audits; and (3) 21 semi-structured interviews with representatives of five stakeholder segments: state, municipalities, businesses, local communities, and mediator groups. Results show that environmental monitoring in Latvia is dominated by a top-down, sectoral, control-oriented approach, while bottom-up participation remains weak and poorly institutionalised, though it reveals local management and communication potential under limited governmental capacity. Monitoring systems exist, but implementation is inconsistent; indicators are often formal and weakly used in decision-making; and communication between governance levels and stakeholder groups is limited. The Dviete River Basin highlights key issues: outdated and incomplete datasets, weak integration of monitoring into municipal planning, inconsistencies between local and national evaluations, and lack of context-specific water governance indicators. Overall, findings stress the need for integrated, basin-sensitive, participatory monitoring systems linking data, indicators, communication, and governance, with stronger stakeholder engagement and citizen science for more effective water governance.

Keywords: environmental governance, water governance, monitoring systems, indicators, stakeholder participation.

Introduction

Water governance, and its evaluation through monitoring systems and indicators, is fundamental to sustainable water management and effective policy assessment. The OECD defines water governance as the set of political, institutional, and administrative processes that enable decision-making across levels and stakeholders [1]. Monitoring systems and indicators support evidence-based decisions, transparency, and evaluation of governance effectiveness. The OECD Water Governance Indicator Framework [1; 2], with 36 indicators across 12 principles, assesses performance through dimensions such as effectiveness, efficiency, and trust, including stakeholder engagement, transparency, coordination, and data accessibility. It is widely used to strengthen policy coherence and accountability.

Environmental governance is increasingly understood as a complex socio-ecological system (SES), where outcomes emerge from interactions between natural processes, institutions, and stakeholders [3]. This perspective emphasizes adaptability, cross-level collaboration, and continuous learning under uncertainty [4]. Governance can be analysed through its content, stakeholders, and instruments [5; 6], including structural and functional aspects such as processes, actors, power relations, organizational culture, resources, and policy frameworks [7]. Monitoring and indicator systems act as integrative instruments supporting governance evaluation.

The governance content dimension addresses environmental domains requiring integrated approaches that connect environmental, social, and economic factors. Monitoring systems enable data-informed decisions across governance levels [5; 8]. Advances such as in situ sensors, remote sensing, and citizen science demonstrate how multi-source data improves decision-making and international cooperation [9]. Hydrology is increasingly incorporated into citizen science, combining scientific and public knowledge, although cross-disciplinary frameworks remain limited [10].

The stakeholder dimension highlights the importance of engaging public institutions, local governments, businesses, civil society, and intermediaries such as NGOs, media, educators, and research institutions [8]. Effective monitoring depends on both top-down and bottom-up participation, as data generation and use require collaboration [11]. Citizen science helps address monitoring gaps, provides cost-effective data, and increases transparency and participation [12], with trust in such data sometimes

exceeding that in official sources [13]. However, challenges persist regarding data quality, sustained engagement, and integration into governance structures.

The governance instruments dimension includes policy, planning, economic, institutional, technological, and communication instruments, which are most effective when applied in an integrated way [5; 6]. These instruments should be supported by appropriate indicators. Technological developments such as remote sensing and artificial intelligence expand monitoring capacity and enable large-scale assessment [14]. Monitoring systems function both as independent instruments and as integrative elements linking stages of the governance cycle. Communication instruments are particularly important, as they enhance understanding and promote behavioural change [11]. Studies in Latvia highlight environmental communication as a governance instrument that informs, educates, and fosters participation, especially when applying the Action-Oriented Collaboration Communication Model [5].

The Water4All – Water Security for the Planet partnership applies a multi-level monitoring system aligned with policy and societal goals. Monitoring is structured through the Partnership Specific Impact Pathway (PSIP), linking inputs, activities, outcomes, and impacts [15; 16]. The Key Performance Indicator (KPI) framework operationalises this through indicators at input, process, outcome, and impact levels, covering coordination, stakeholder participation, policy integration, data sharing, and societal benefits. Input indicators reflect inclusiveness and capacity-building; outcome indicators address policy integration, governance practices, and transparency; and impact indicators capture long-term effects such as water access, water stress, and economic losses [15]. Governance indicators thus demonstrate the importance of collaboration, knowledge exchange, and institutional strength, further supported by Water-Oriented Living Labs integrating monitoring into adaptive decision-making [15; 16].

At the EU level, water governance is guided by the Water Framework Directive (WFD), implemented through River Basin District Management Plans (RBDMP) supported by monitoring systems [17]. WFD monitoring provides a structured overview of water status, supporting classification, risk assessment, and long-term change detection while remaining adaptable [18]. It includes multiple monitoring types and relies on biological, hydromorphological, and physico-chemical indicators. Although WFD promotes integrated management and stakeholder participation, challenges remain in data comparability, consistency, and engagement [19]. Monitoring is intended to be risk-based and cost-effective, but implementation is complex. In Latvia, monitoring is legally mandated and integrated into planning [20; 21], yet challenges persist in data quality, accessibility, and linking results to decisions, despite improvements after the 2021 administrative reform [21].

Across Europe, WFD implementation shows both progress and variability. While monitoring systems follow common principles, case studies from river basins such as the Adige, Anglian, Ebro, Evrotas, and Sava reveal differences due to institutional capacity, data availability, and governance contexts. Common issues include insufficient data, weak pressure-impact understanding, and gaps in indicators [22]. Stakeholder participation remains limited in practice, as monitoring is often expert-driven, reducing relevance and legitimacy. More effective systems require improved data, stronger participation, and interdisciplinary collaboration [22].

In Latvia, water governance challenges are reflected in outcomes, with only about 39.5% of surface waters achieving good ecological status and bio-chemical monitoring remaining uncertain [19; 23]. While policy integration is relatively advanced, governance-related monitoring, particularly indicators on institutional performance, stakeholder engagement, and decision-making, is underdeveloped. Indicator systems vary across levels: national frameworks lack detail, while regional and basin levels are more specific but still struggle to translate data into action [24; 25; 26]. Significant gaps remain in integrating indicators and linking monitoring results to policy decisions.

Overall, monitoring systems are central to adaptive and evidence-based governance, integrating governance dimensions and supporting participatory approaches. Their effectiveness depends on data quality, methodological robustness, institutional capacity, and stakeholder involvement. Citizen science offers a promising way to address monitoring gaps, enhance participation, and reduce information asymmetries when properly designed [12].

The aim of this study is to assess environmental governance monitoring systems in Latvia at municipal and river basin levels, with a focus on water governance, by analysing the structure, application, and integration of indicators and developing recommendations for improving municipal

monitoring frameworks. The objectives are: (1) to examine governance and monitoring frameworks; (2) to evaluate indicator application in municipalities; (3) to analyse vertical and horizontal integration; (4) to investigate practices through case studies; and (5) to identify gaps and propose improvements.

Research approaches and methods

Monitoring plays a crucial role in water governance, serving as an integral component of the 5P cycle process model [5], which structures governance into five sequential stages: problem analysis (P1), policy formulation (P2), planning and programming (P3), practice management (P4), and process monitoring and results reviewing (P5). As such monitoring processes are also required at the municipal level, this study selects three case studies to reflect different governance contexts in the Dviete River basin, located within a single municipality (Augsdaugava Municipality). In assessing the implementation of environmental governance, monitoring is considered a key communication instrument, alongside other governance instruments, highlighting the importance of its dissemination and the active involvement of society.

Dviete River basin case study research

The Dviete River Basin case study examines a socio-ecological territory in southeastern Latvia, located within Augsdaugava Municipality and forming part of the wider Daugava River basin. The area covers approximately 254 km² and is characterised by a floodplain landscape subject to seasonal inundation, a legacy of intensive agricultural use, and high ecological value, including its designation as a Natura 2000 site. These features make the basin a relevant setting for analysing water governance, monitoring approaches, and the application of indicators in environmental management.

The research was implemented within the University of Latvia in cooperation with the EU Horizon project BETTER LIFE, which is based on a socially engaged research (SER) approach. This approach promotes active collaboration between researchers and multiple stakeholder groups structured according to the Quintuple Helix model. In this study, the stakeholder framework is further refined through a governance segment cooperation model that differentiates between state and municipal administrations, recognising their distinct roles, interests, and perspectives. Special emphasis is also placed on mediator groups, media, educators, non-governmental organisations, and academia, which play a key role in facilitating communication and interaction among stakeholders. The model reflects both vertical and horizontal cooperation and highlights the necessity of coordinated interaction among state institutions, municipalities, businesses, society, mediators to ensure coherent environmental governance (Fig. 1).

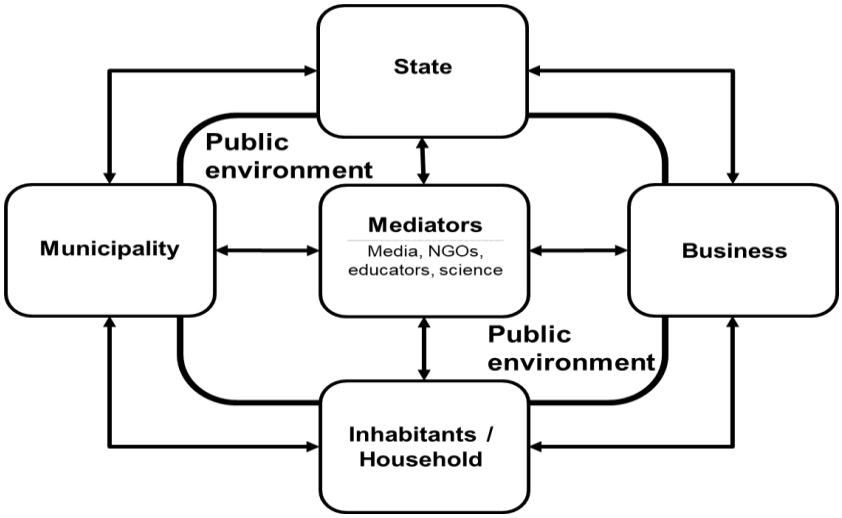

Fig. 1. **Hierarchically structured cooperation model of governance segments as groupings of all main stakeholder group representation [5]**

The Dviete River Basin was selected as a bottom-up participatory governance case, building on earlier research and data developed within the EU Horizon OPTAIN project. The study employed an integrated case study design combining qualitative and analytical methods. It included a comprehensive assessment of environmental governance and communication cycles, with a particular focus on

monitoring systems and indicators at both municipal and river basin levels. The main methods applied were: (1) analysis of national, regional, and municipal policy, planning, and monitoring documents; (2) environmental governance, communication, and municipal monitoring audits; and (3) in-depth semi-structured interviews with representatives of key stakeholder groups.

In addition to previous project-based research, a total of 21 in-depth semi-structured interviews were conducted. Most interviews took place face-to-face and involved representatives from all major stakeholder groups in line with the Quintuple Helix framework. These included participants from state institutions (3), municipalities (5), businesses (3), and local communities (2), as well as intermediary stakeholders such as non-governmental organisations (2), media (1), educators (1), and academia (2). This ensured a comprehensive representation of perspectives relevant to environmental governance and monitoring practices in the study area.

The study places particular emphasis on monitoring as a core element of environmental governance. Monitoring is approached not only as a technical instrument but also as a communication instrument that supports stakeholder engagement and informs decision-making processes throughout the different stages of water governance.

Results and discussion

The results section presents a comprehensive analysis both of statutory and voluntary planning and other document studies and, particularly, interview-based assessments across all five stakeholder core group segments: state administration, municipal administration, businesses, society, and mediators. Drawing on the semi-structured interviews, the findings reflect the perspectives, experiences, and evaluations of these groups regarding environmental and water governance, monitoring practices, and the use of indicators. This integrated approach allows for a comparative understanding of stakeholder views and highlights both common trends and divergences across governance levels and segments.

1. Statutory and voluntary water planning and monitoring development: across administration levels

The Civil Law establishes two forms of water ownership – public and private waters; public waters include the coastal zone of the sea, as well as specified rivers and lakes, while all other waters are considered private [27]. The list of public waters includes Latvia's largest rivers and lakes that are significant from the perspective of nature and fish resource protection, including water bodies located within protected natural areas, where approximately 40% of public lakes are situated. Public lakes and rivers are defined as inland public waters, the management of which is regulated by Section 15 of the Land Management Law [28], stipulating that the ministry responsible for environmental protection manages public waters located in nature reserves, national parks, and nature conservation areas if they are not privately owned or under the authority of another ministry, while local governments manage inland public waters located within their administrative territories that are not managed by state institutions and are not privately owned. The Local Government Law [29] provides that the autonomous functions of municipalities include spatial planning, sustainable management of natural capital, also municipal communal services (drinking and waste waters, waste, heating system), climate change mitigation, as well as the improvement and maintenance of public areas. The main objectives of water body management are to improve and preserve the ecological status of water bodies, protect biodiversity and landscape values, ensure the use of public waters for recreation and water sports, and promote the protection of public water resources, the development of fishing infrastructure, and the conservation and replenishment of fish resources.

The Water Management Law [31] defines principles for the protection, sustainable use, and governance of water resources in Latvia and establishes a framework for monitoring and river basin–based management, further detailed by related Cabinet of Ministers regulations. According to the law [31], surface waters are defined as all inland waters (excluding groundwater), as well as transitional, coastal, and territorial waters in relation to chemical quality. The law also establishes a river basin–based water management system aimed at the protection and maintenance of surface water quality. In addition, the Law on Water Management Services [30] defines water management services as abstraction, storage, treatment, and supply of water, as well as wastewater collection, discharge, and treatment, including related infrastructure such as centralized water supply, sewerage systems, and

wastewater treatment facilities. National level water resources management, according to WFD, is organised within four river basin districts – the Daugava, Lielupe, Venta, and Gauja - with the Dviete study area located in the largest, the Daugava River Basin District.

Planning system according to the planning System Law consists of 3 planning or administration levels. At the national level, Latvia's Sustainable Development Strategy 2010-2030 [35] recognises water as key natural capital but lacks dedicated indicators, reflecting it indirectly through aggregated measures. The National Development Plan 2021-2027 [24] introduces a water-related indicator under the "Green Course", though water remains a limited component within a broader climate and resource monitoring framework. Environmental policy planning in Latvia is generally organised within a 7-year planning cycle, aligned with national and municipal development programmes and supported by monitoring and reporting systems for implementation assessment.

At the regional planning level, the Latgale Planning Region Development Programme 2021–2027, as one of five planning regions in Latvia [25], treats water resources mainly as an infrastructure and service issue, focusing on access to centralised water service systems. In contrast, the Daugava River Basin District Management Plan [26], as one of the 4 Districts in Latvia, based on WFD, applies a comprehensive indicator system covering water quality, hydrology, sediment dynamics, and pollution, aligned with Sustainable Development Goals 6 (SDG 6). Under SDG 6, governance is mainly defined through integrated water resources management, transboundary cooperation, and the participation of local communities in water governance and decision-making processes. However, governance indicators remain limited despite gradual integration of the SES approach, challenges persist in translating monitoring results into timely municipal decisions, mainly due to the absence of mandatory integration requirements (according to national Water management law) of basin plans into municipal planning and limited cooperation between national authorities and municipalities.

The municipal statutory planning system in Latvia consists of three core planning documents: the Sustainable Development Strategy for a 25-year period, the Development Programme for a 7-year period, and the Territorial Plan. The system also includes an implementation monitoring and reporting framework, which evaluates progress and implementation results. This monitoring system applies three types of indicators: territorial development, performance, and policy outcome indicators.

Analysis of statutory planning documents across all 43 municipalities, including 10 state cities, shows that water management indicators have been structured into two substantial, even complementary, statutory municipal management sectors: water resources sector and communal water services sector. First sector traditionally consists of surface, underground, swimming and coastal (if any) waters, but the second sector's main categories are: water treatment, wastewater, drinking water, water supply infrastructure, rainwater. These indicators enable comprehensive assessment of service accessibility, quality, and environmental impact while reflecting local conditions. Most focus on expanding centralized systems and ensuring drinking water safety, key factors for public health and sustainable urban development (Table 1).

Table 1

Groupings, key indicators and recognized frequency of municipal water management indicators – overview from municipal statutory Development Programs

Indicator group	Key indicators (Examples)	Municipalities
1. Surface–under-ground Waters	Eutrophication reduction, water body management plans, fish resources and fishery control	9
1.1. Surface Waters	Eutrophication reduction, implementation of river basin management measures, and ecological status improvement of surface water bodies	-
1.2. Underground Waters	Groundwater abstraction volumes, compliance with drinking water quality standards, and protection of groundwater recharge areas	-
1.3. Bathing Waters	Number of official/unofficial bathing areas, Blue Flag status, and quality monitoring at bathing sites	11
1.4. Coastal Waters	Investments in coastal infrastructure, prevention of coastal erosion, and the Baltic Sea access	3

Table 1 (continued)

Indicator group	Key indicators (Examples)	Municipalities
2. Communal Water Services	Coverage and quality of communal water services, infrastructure condition and investments, and resident satisfaction with water and wastewater services	-
2.1. Water Treatment	Volume of treated wastewater, utilization of WWTP capacity, and sludge management	5
2.2. Wastewater Systems	Connections to centralized sewerage, network length, and decentralized systems	31
2.3. Drinking Water	Compliance with quality standards, resident assessment of water quality, and public drinking water	5
2.4. Water Supply (Infrastructure)	Network length, connection accessibility (%), service availability, and water losses	32
2.5. Rainwater	Stormwater drainage networks, restoration of melioration systems, and flood risk prevention	8

The analysis shows that municipal water-related indicator systems in Latvia are not standardized by legislation but derive from legally defined functions and sectoral requirements. The Local Government Law [29] assigns responsibility for water services, environmental quality, flood risk mitigation, and climate adaptation, further detailed in the Law on Water Management Services [30], covering water supply, wastewater, and stormwater. Additional regulations, including drinking water safety and monitoring requirements [31], define parameters and data obligations. At a broader level, the Water Management Law [31] and the EU WFD [32] introduce basin-based planning and systematic monitoring using biological, chemical, indicators. Together, these frameworks define key sub-sectors of municipal water governance: drinking water, wastewater, stormwater and flood management, and, where relevant, bathing water and environmental status.

Within this framework, municipalities develop their own indicator systems, resulting in common patterns. Indicators on drinking water supply and sewerage accessibility are most consistent, reflecting mandatory required services [33]. More technical indicators, such as sludge recycling or treatment capacity, are less common and mainly found in larger municipalities. At the same time, indicators on stormwater, flood risks, and climate adaptation are increasingly included in response to policy priorities [34]. Other indicators, such as public access to bathing water quality and others, are used selectively depending on local conditions. This supports a distinction between core indicators linked to legal functions and supplementary indicators reflecting local priorities.

Based on the strategic planning documents of Latvian municipalities, water resource management is a significant focus area involving also a wide range of voluntary municipal initiatives from infrastructure development to environmental protection. These initiatives reflect the local government commitment to sustainable development and climate change adaptation, addressing specific regional/local challenges such as flood risks, water quality, and the preservation of natural ecosystems. The following table summarizes the voluntary initiatives and planning documents identified (Table 2).

There are not to be found overall well-developed municipal water governance systems nor unified approaches applied for water sectorial planning and management, instead there is selective, each municipality's social-ecological system conditions and historical traditions-based various approaches combinations management. However, there is a stepwise growing number, especially after municipal aggregating reform in 2021, of rural and urban Latvian municipalities demonstrating high and goal-oriented activity in both statutory and voluntary water resource planning and subsequent management, especially in coastal and lake-rich areas. There is a shift from basic maintenance to more complex planning, including water body sectorial management concepts and thematic plans.

Key challenges include flood risks, coastal erosion and improving urban rainwater management. Municipalities are also involved in fish resource protection and recultivation**,** lake management, and emerging initiatives such as spring water research and sustainable sewage sludge management. Overall, water governance is increasingly integrated into climate adaptation and overall statutory development planning.

Table 2

Municipal initiatives in water resource management: Overview from municipal statutory Development Programs

Municipality	Initiative	Brief description	Main problems
Augsdaugava Municipality	Infrastructure/Wastewater	Action plan for the management of municipal sewage sludge	Efficiency of sludge management
Adazi Municipality	Nature Protection/Governance	Developed a water body concept and management plans for several lakes (Dunezers, Kadagas, Baltezeri, etc.)	Sustainable use of water bodies
Bauska Municipality	Infrastructure/Rainwater	Guidelines for sustainable rainwater management and a study on precipitation and snowmelt water trends	Impact of rainwater and snowmelt
Cesis Municipality	Governance/Nature Protection	Water bodies management concept and recommendations for the spatial development of the Gauja River	Management of river and lake resources
Daugavpils City	Nature Protection	Urban wetland management plan	Protection of urban wetlands
Jurmala City	Infrastructure/Resource Protection	Melioration and rainwater drainage development plan; water resource protection plan	Flood risks, aging melioration systems
Rezekne Municipality	Infrastructure/Safety	Requirements for the operation of hydro-technical infrastructures of Razna and Lubana lakes for flood prevention	Flood threats
Riga City	Infrastructure/Governance	Extensive plans for the development of water territories, waterfronts, and melioration; studies on coastal erosion	Coastal erosion, rainwater runoff, flood threats
Saldus Municipality	Monitoring/Research	Research on the fish fauna of the Paksite River; numerous lake exploitation rules	Fish resources and spring water quality
Smiltene Municipality	Research/Governance	Study on the causes of changes in the water flow of Raunas Staburags springs; development of lake management plans	Changes in spring water flow
Ventspils City	Monitoring	“Environmental SOS” app for citizen reports on environmental/water violations	Environmental pollution

2. Municipal water management and indicators in the Dviete River basin territory

A municipal environmental governance and communication audit identified major shortcomings in local practices, particularly in monitoring systems and their practical application. Therefore, this section examines environmental monitoring in the Dviete River Basin, focusing on water management, nature protection, and stakeholder participation. Before the 2021 municipal administrative-territorial reform, the basin was part of Ilukste Municipality (647.5 km²; ~7,500 inhabitants); after the reform, it was incorporated into Augsdaugava Municipality (2523.6 km²; > 35,000 inhabitants), significantly changing the governance and everyday management context.

During the previous planning period, Ilukste Municipality developed key documents, including the Sustainable Development Strategy, Territorial Plan (2019–2030), and Development Programme. Due to

identified inconsistencies in environmental planning and monitoring, especially concerning the Dviete River and its ecologically valuable valley, the National Environmental State Bureau (ESB) required additional monitoring reports [36] to be prepared at least twice using predefined indicators (Table 3). However, the 2020 report revealed major data gaps: some indicators lacked data, others relied on outdated or generalised information, and in some cases, data did not match defined indicators, reducing the reliability and usefulness of the monitoring system.

Table 3

Implementation of the Dviete River monitoring indicator environmental planning and 2020 report data [36]

Indicator group	Indicators	2020 report
Surface water quality	Amount of wastewater discharged into surface waters; Persistent pollution; Ecological-chemical quality of water bodies; Swimming water quality	231.7 tons of discharged wastewater; River water quality - medium (2013 data). No official swimming area
Water supply	Intensity of water resources usage; Drinking water analysis results	Total taken from natural water sources: 298,166 thousand m^3
Wastewater management	Collected and treated wastewater; Centralized sewage services reach Compliance of treated wastewater with regulations; Surface water quality after treated wastewater discharge	No information
Waste management	Amount of sorted waste; Total generated and collected waste;	Sorted waste: 151.07 tons; Total collected waste: 524.14 tons
Air quality	Actual emissions from boiler houses, industrial, other emission sources	Total emissions of pollutants: 5920.23
Polluted and potential sites, degraded areas	Number of polluted and potentially polluted sites, degraded-uncultivated,	No information
Specially protected nature-culture areas	Nature protection plans; Adoption of protection and use regulations	Nature protection plan done, use regulations for landscape area
Municipal protected nature and culture areas	Development of municipal binding regulations	No information

Surface water quality assessments based on 2013 data were classified as “medium”, while more recent evaluations in the Daugava River Basin Plan identifies the Dviete water body as ecologically poor, heavily affected by melioration, overgrown lakes, agricultural pressures, and wastewater impacts, while recommending continued monitoring within the protected Dviete floodplain area, revealing inconsistencies between local and national assessments. Information on nature conservation was also limited. The Ilukste Municipality Development Programme (2020–2026) included 72 indicators, but none comprehensively addressed environmental governance, water management, or nature protection, and ESB-required indicators were not integrated, indicating a disconnection between national requirements and local implementation.

After the 2021 reform, Augsdaugava Municipality introduced 85 indicators in its Development Programme (2022–2027) [37; 38], with annual reporting and a three-year review cycle. These are grouped into territorial development, performance, and policy outcome indicators, covering socio-economic changes, implementation progress, and public satisfaction [38]. Of these, 32 relate to environmental governance sectors, particularly water management and nature protection. The programme includes indicators and actions related to drinking water supply, stormwater and wastewater systems, melioration infrastructure, public waterbody and watercourse management, as well as access and recreation infrastructure near public waters, which also includes the Dviete area, including floodplain management, river restoration, and Lake Skuki water regime modelling [37].

However, the ESB monitoring report was not prepared in 2024, as its indicators were excluded and newly aggregated municipal authorities were unaware of the obligation. Water governance issues are

not clearly addressed in planning documents, and state-level monitoring data are infrequent and not directly communicated to municipalities.

Overall, the findings indicate the need for more coherent and integrated monitoring systems to support environmental governance, especially in water management and nature protection. Strengthening data-policy links is essential, and with limited municipal capacity, participatory approaches such as citizen science could improve data availability, engagement, and effectiveness.

In the Dviete River Basin territory, one local NGO plays an important role in nature/environmental management. Since 2004, the "Association of the Dviete Valley Municipalities" has been established, based on intermunicipal cooperation, to protect the unique natural and cultural heritage of the floodplain landscape of the Dviete Valley, while in the same year the Natura 2000 territory was established, with the association becoming a protagonist in its development and in initiating and co-running several EU and other nature conservation and environmental education projects. Finally, it turned out, that in the limited capacities and conditions of the National Nature Protection agency, this NGO is the only institution and voluntary taking care of this Natura2000 area. Local activist-based NGO is managing this Dviete Nature Park through habitat maintenance, infrastructure, big mammals and public engagement, what particularly is showing how local initiatives and bottom-up citizen capacities can complement formal nature protection management under limited national governmental top-down capacity. Such actors can also support citizen science monitoring with schools and other stakeholders, improving data, awareness, and participation. More broadly, similar NGO-based and community-led approaches exist across Latvia, including grassroots environmental agencies. Examples include the Aluksne Municipal Agency "ALJA," which manages public lakes and rivers, organizes licensed fishing, replenishes fish resources, and maintains recreational infrastructure; the association "Liepajas ezeri", founded by three municipalities to oversee environmental protection, habitat conservation, fish resource management, and licensed fishing in Lake Liepāja and the Trade Canal; the community-based "Kala Lake Council", which focuses on sustainable lake management, conservation activities, and recreational use; and the "Gauja Sustainable Development Association" in Cesis Municipality, responsible for implementing environmental governance tasks such as public education, community involvement, sustainable fishing promotion, and cooperation with local stakeholders, voluntary organisations, inter-municipal lake management associations, and municipalities.

The example of Aluksne Municipality further illustrates how local institutional structures are integrated into practical water governance. The latest publicly available strategic document related to water governance in the municipality is the Medium-Term Operational Strategy of the Aluksne Municipality Agency "ALJA" for 2021–2023, approved in 2021, as no newer strategy documents were available online at the time of the study. The strategy defines several operational and development indicators related to water body management, including customer satisfaction, the number of fishing licenses sold, participation in seminars and public events, attracted financial resources, implemented projects, infrastructure improvements, and professional development of agency employees. At the same time, the strategy emphasizes environmental governance priorities such as fish resource replenishment, shoreline maintenance, environmental protection measures, public education, and the development of recreational infrastructure around lakes and rivers. Overall, these examples demonstrate that practical water and environmental management solutions in Latvia are increasingly implemented through collaborative local action and delegated governance models, despite the limited capacities of public authorities.

Adazi Municipality, has established an integrated environmental governance framework through the concept "Management and Utilization Concept of Surface Water Bodies in Adazi Municipality" and several lake and river management plans. These documents are based on hydroecology, ecosystem-based planning, sustainable water resource management, environmental monitoring, and adaptive governance. Their strengths include evidence-based ecological assessments, monitoring systems, regulatory instruments, and interinstitutional cooperation aimed at balancing environmental protection with recreational and public use functions. Adazi Municipality uses 36 environmental governance indicators, including 12 directly related to water governance. These indicators cover households connected to centralized water supply and sewerage systems, bathing sites, infrastructure length, treated wastewater volumes, wastewater treatment capacity utilization, flood protection, infrastructure condition, and public evaluations of drinking water and service quality. Indicators are grouped into two

blocks: (1) surface and groundwater quality and (2) water management services. The first focuses on ecological and chemical quality, wastewater impacts, and residual pollution, while the second addresses infrastructure performance, service provision, drinking water quality, and compliance with wastewater regulations. Together, these indicators provide a comprehensive framework for evaluating sustainable water governance through environmental, technical, and public perception measures. The concept "Management and Utilization of Surface Water Bodies in Ādaži Municipality" [4-] includes objectives, recommended water body uses, ecological improvement methods, analyses of lakes and rivers, monitoring systems, cooperation mechanisms, and governance measures. It proposes systematic ecological, chemical, and biological monitoring, including phosphorus and nitrogen concentrations, phytoplankton composition, chlorophyll-a, water transparency, oxygen–temperature profiles, microbiological parameters, and cyanobacterial toxin monitoring. The concept also emphasizes intermunicipal cooperation, stakeholder responsibilities, and coordinated management actions to ensure sustainable and data-driven governance.

As a comparative example, Cesis Municipality adopted the Cesis Municipality Water Body (Lakes and Rivers) Management Concept in 2024. After evaluating several governance models, the municipality selected the delegation model for water body management. The concept defines 22 management tasks, including environmental education, community involvement, sustainable fishing promotion, water quality monitoring, ecological monitoring, fish stock restoration, recreational infrastructure development, and preparation of management plans [41]. It also introduces governance indicators linked to ecological status, biodiversity, accessibility, infrastructure quality, and stakeholder cooperation. In 2023, Cesis Municipality delegated water body management responsibilities to the association "The Gauja Sustainable Development Association," which is required to submit regular implementation reports to the municipality.

3. Stakeholder segments' representatives on monitoring system and process

The following sub-sections analyse stakeholder segment representatives' perspectives on environmental monitoring and indicator systems in Latvia, focusing on differences between top-down and bottom-up approaches, the use of indicators, public involvement, communication processes, and governance practices. The analysis is structured across five stakeholder segments - state, municipalities, businesses, local communities, and mediators (media, NGOs, educators, and academia) - highlighting both shared challenges and segment-specific experiences in environmental monitoring and governance.

3.1. State administration segment: national and regional environmental etc. segments insights

Based on analysed state segment interviews, Latvia's monitoring system is largely top-down dominated, fragmented, and thematically organized, with limited, unsystematic bottom-up participation and underdeveloped use of indicators as governance instruments.

Top-down monitoring at the national level is institutionally established and technically developed, especially in water resource management. Monitoring is conducted by specialized institutions (e.g., Latvian Environment, Geology and Meteorology Centre, Nature Conservation Agency, State Environmental Service) using automated systems (hydrological, meteorological stations) and manual methods (sampling, expert surveys). It is regulated, cyclical, and based on legal frameworks such as water management planning cycles. However, it remains selective, focusing on specific objects (e.g., large water bodies), indicators (chemical/ecological quality), and segments. This results in high-quality but fragmented data that do not cover the system comprehensively. Interviews show institutional roles often stop at data collection and transfer, fragmenting monitoring and decision-making.

Top-down monitoring mainly serves control and reporting purposes rather than proactive governance. It assesses compliance, identifies pressures, and supports international reporting, but less often enables adaptive, integrated management. Environmental quality is not fully or systematically monitored, as only selected parameters are measured, reflecting an underdeveloped indicator system.

Indicators do exist but are used unevenly and often formally. In water governance, they are tied to monitoring data and appear in planning documents, yet their selection is not always linked to implementation. Frequently, they remain "on paper" without effective monitoring or accountability, indicating weak links between indicators, monitoring, and policy execution.

Bottom-up monitoring is underdeveloped and mostly informal. The public is excluded from official programs due to regulatory constraints, though some participation exists (e.g., Vides SOS, dabasdati.lv, obstacle reporting). These inputs are used sporadically and supplementarily rather than systematically, despite recognized potential of public knowledge (e.g., anglers, local residents), especially where state monitoring is limited.

Overall, Latvia's monitoring system is in transition from a centralized model toward a more integrated approach that could include public data and modern modelling. However, key challenges remain: institutional fragmentation, weak practical use of indicators, and limited public integration, reducing monitoring effectiveness as a governance and decision-making instrument.

3.2. Municipality administration segment: local environmental executives and councillors

Based on analysed municipal segment interviews, local environmental monitoring and indicator systems are limited, fragmented, and largely dependent on national institutions, with weak institutionalization and uneven public involvement.

At municipal level, top-down monitoring is not an autonomous system. Municipalities generally do not conduct systematic monitoring, particularly of water quality or ecosystems; these tasks are handled by state bodies (e.g., State Environmental Service, Nature Conservation Agency, scientific institutes like BIOR). Municipalities act mainly as intermediaries or implementers – following instructions, supporting controls (raids, inspections), and facilitating information exchange. Monitoring is therefore situational and reactive rather than systematic.

Some monitoring-related activities exist (e.g., fisheries control, infrastructure checks, site inspections), but these align more with supervision than structured monitoring with defined indicators and long-term analysis. Activities are often project-based or tied to cooperation with scientists, not a permanent institutional function.

Indicator use at municipal level is particularly weak. While mentioned in planning documents, there is no clear system for their application, monitoring, or analysis. Some representatives report lacking knowledge about indicators or consider them another department's responsibility. This reveals a gap between planning and implementation and a largely formal use of indicators. Data collection (e.g., fish fund projects) is thematically narrow and funding-driven, limiting integrated indicator development.

Bottom-up monitoring is somewhat more present than at the state level but remains unsystematic and initiative-based. Public involvement occurs through consultations, events, educational activities (e.g., Bird Days), and informal communication (e.g., with anglers). Although this provides valuable local knowledge, it is not integrated into official monitoring and depends on individual or project initiatives rather than policy.

Public participation mainly takes the form of communication rather than systematic data provision. Residents share observations or engage in discussions, but their role as regular data contributors is not institutionalized, even though such direct input is seen as highly valuable.

Overall, municipal monitoring is marked by dependence on state data, weak practical use of indicators, and a fragmented, project-based approach. While there is clear potential to strengthen bottom-up monitoring through local knowledge and participation, this potential remains underused and not integrated into a unified system.

3.3. Entrepreneurship segment – local various business leadership insights

Based on analysed business segment interviews, the environmental monitoring and indicator system is weakly structured, fragmented, and largely based on external (state) control rather than business-initiated or integrated approaches, with a clear gap between formal requirements and practical use.

For businesses, top-down monitoring appears mainly as regulatory compliance control and administrative supervision, not as data-driven environmental analysis. Key institutions include the Rural Support Service (LAD), Ministry of Agriculture, and Nature Conservation Agency, but their role is perceived through payments, inspections, and rule enforcement (e.g., subsidies, permits). Control is often remote (drones, photos) or episodic, and businesses are not always informed about processes or results. Some monitoring (e.g., biodiversity assessments) occurs "invisibly," without communication with landowners, further distancing it from practical management.

At the same time, business-level monitoring of their own activities is limited. While simple checks (e.g., slurry leaks, basic water observations) are possible and sometimes done, they are not systematic, standardized, or integrated into broader data systems. Many businesses report lacking information about overall environmental monitoring (e.g., local water quality), indicating poor accessibility and communication of results.

Indicator use in this segment is particularly weak. Indicators as governance instruments are largely absent; instead, references focus on compliance and control. This suggests indicators are not used for decision-making or environmental assessment. Even where measurements exist, they are not structured into systems with clear targets, thresholds, or long-term analysis.

Bottom-up monitoring exists but is individual, informal, and irregular. It includes personal observations (e.g., animal behaviour, invasive species control, drainage maintenance) and occasional participation in projects (e.g., bird counts, meetings). Although this reflects strong local knowledge, it is not systematically integrated into official monitoring and depends on initiatives rather than policy.

A key issue is information asymmetry: while agricultural information (e.g., subsidies) is accessible, environmental monitoring data are often unavailable or not presented in a usable form, limiting their practical application.

Overall, for businesses, monitoring in Latvia functions mainly as an external control system, not an integrated, data-based governance instruments. Indicators are underdeveloped or unused, and bottom-up monitoring, though present, is neither institutionalized nor effectively applied in management.

3.4. Society segment: local community representants' insights

Based on analysed local community interviews, the environmental monitoring and indicator system is marked by weak institutionalization, low awareness, and minimal direct involvement, with individual observations, fragmented understanding, and significant communication gaps dominating.

From the community perspective, top-down monitoring exists but is seen as episodic and external control rather than a clear, systematic process. Residents are aware of inspections and supervision (e.g., by the Nature Conservation Agency) and species surveys but perceive them as irregular checks rather than consistent monitoring. Activities often focus on specific aspects (e.g., species presence) without broader assessment, and there is little understanding of how data are used in decision-making.

Bottom-up monitoring is notably weak. Interviews show the public is not involved in monitoring programmes, and many are unaware of such opportunities. Participation occurs mainly through clean-ups, events, or individual initiatives (e.g., local activities, hikes), but these are not structured as monitoring or used for data collection. Thus, local knowledge is not systematically integrated into governance, despite its potential value.

Regarding indicators, understanding is indirect and intuitive rather than structured. Indicators as a concept are largely absent, though there is a clear demand for reliable, science-based information (e.g., on nesting periods, water levels). This suggests a need for accessible, understandable data, as indicators are not perceived as practical instruments but as abstract elements.

A key issue is weak communication and limited information accessibility. Although environmental information exists (e.g., boards, seminars, consultations), much of the public neither perceives nor uses it. Communication is often not targeted, and reliance on websites or formal notices does not match local habits, while more effective personal communication in small communities is underused.

Additionally, environmental education and engagement, especially among adults, remain low. Existing initiatives (seminars, school activities, NGO projects) are fragmented and do not reach wider audiences. Scientific work is often not visible or understandable locally, further limiting engagement and data use.

Overall, the local community segment shows a weakly integrated monitoring system with low involvement and limited understanding of indicators. Top-down monitoring and informal bottom-up participation dominates, while key challenges, poor communication, limited information access and lack of public involvement restrict the development of an effective, inclusive governance system.

3.5. Mediator segment: media, NGO, education, research-engineering professionals' insights

Based on analysed mediator interviews (media, educators, NGOs, academia), the environmental monitoring and indicator system is fragmented, unevenly perceived, and weakly integrated across knowledge production, communication, and governance, with subgroup differences.

From this perspective, top-down monitoring is most clearly described by academia and NGOs as an institutionally organized process with defined responsibilities (e.g., Nature Conservation Agency, LVGMC). In academia, it is systematic and methodologically grounded, involving regular measurements, parameter analysis, monitoring stations, and publicly available data, though not fully comprehensive (e.g., lack of catchment-scale approaches). NGOs see it more as regulation and control (rules, permits) with limited capacity and funding. In media, it appears as inspections and reports, while in education it is largely absent or only generally perceived.

Bottom-up monitoring is uneven. Academia recognizes public input (e.g., hunters, anglers) as valuable and occasionally used. NGOs rely on voluntary initiatives and projects, dependent on motivation and resources. Media highlight public engagement (clean-ups, initiatives) but mainly as communication rather than structured monitoring. Educators link it to learning activities (student research, outdoor classes), which build awareness but are not part of systematic monitoring. Overall, bottom-up monitoring exists but is fragmented, project-based, and lacks coordination.

Monitoring itself is understood differently across the group. In academia, it is a core data-based analytical instrument; in NGOs, a practical but unsystematic activity limited by resources; in media, a process of gathering and verifying information for the public; and in education, mainly a learning instrument. Thus, it is not seen as a unified governance instrument.

Indicator use is limited and uneven. In academia, indicators are clear measurable parameters (e.g., nutrients, water levels). NGOs link them to planning but criticize them as formal and poorly applied. In media and education, indicators are largely absent, though there is demand for clear, accessible environmental information. This shows indicators are not effectively communicated across segments.

A key issue is weak communication and knowledge transfer. Media face access and misinformation challenges, NGOs lack resources, educators have limited continuity, and academia highlights fragmentation and project-based approaches. As a result, data and knowledge exist but are not effectively integrated into policy, communication, or practice.

Overall, the mediator segment shows that monitoring in Latvia is not only a technical issue but also one of knowledge circulation and cross-sector cooperation. Despite strong academic capacity, data and methods are not effectively transferred to other segments, limiting monitoring role as both a governance and communication instrument.

Conclusions

1. Following the 2021 territorial aggregation reform, there are exemplifications of the governance challenges arising from institutional restructuring, but municipal monitoring of water management and environmental governance in the Dviete River Basin has more potential but remains underdeveloped and lacks consistent state- and regional-level oversight either. The absence of comprehensive, multi-level data, both locally and nationally, creates significant uncertainty for planning and decision-making.
2. Within newly aggregated Augsdaugava Municipality, efforts have been made to strengthen the integration of environmental governance, but the monitoring system remains weak in practice. Key issues include the discontinuity between former Ilukste monitoring systems and current frameworks, the forced reliance on incomplete and outdated data, inconsistencies between national and local assessments, and the absence of context-specific indicators adapted to watershed characteristics.
3. Monitoring in the Dviete River basin remains largely formal and provides limited support for evidence-based decision-making or accurate assessment of ecological conditions. National level monitoring locally is conducted rare and narrow limited to bio-chemical ones, missing socio-ecological systems and integrated water resource management principles. Local municipal monitoring in the territory of the Dviete River basin is not river basin system approach oriented, with limited and narrow segment spectrum and fragmented. This all reflects broader limitations in

both monitoring system understanding and local practice, as well as administrative, technical, and financial capacity across governance levels.

4. Monitoring information is rarely translated into user-friendly and actionable formats, resulting in low awareness, information asymmetries, and limited integration into decision-making processes. Strengthening environmental communication, through improved data sharing, stakeholder engagement, and clear and open communication of indicators, is therefore essential for enhancing the practical impact of monitoring systems.
5. The analysis also identifies communication as a key critical constraint in the effectiveness of environmental monitoring and governance at and between all administrative levels, from national to local and vice versa. Although data are collected across segments, their accessibility, clarity, and usability remain limited due to weak communication and insufficient knowledge transfer among institutions, stakeholders, and the public.
6. Overall, studies reveal a structural mismatch between governance levels, indicating weak vertical integration. National top-down monitoring and indicator frameworks are not sufficiently translated into requirements or practical guidance for local planning, while local bottom-up practices lack the capacity to upscale and systematically integrate basin-level recommendations into territorial planning. This gap is further reinforced by the regulatory context, where river basin management plans are not mandatory for municipal planning, resulting in small and medium-sized catchments remaining insufficiently addressed.
7. In the current governance capacity deficiencies situations, there should be recognized timely steps to strengthen both vertical and horizontal integration mechanisms within environmental governance. This includes improving coordination across governance levels, as well as across segments and stakeholders, by enhancing local environmental monitoring systems through targeted water resources and water basin related indicator systems and, especially, participatory approaches such as bottom-up co-management options, citizen science as co-monitoring, as well as vertical and horizontal cross-stakeholders communication, in order to support more informed and integrated water resource management across governance levels.
8. Overall, the analysis of all stakeholder segments reveals that the monitoring system in Latvia is perceived in a fragmented and uneven manner, with each segment emphasizing different aspects rather than a shared, integrated understanding. While the state actors stress top-down, data-driven control, other segments highlight dependence, weak practical use, limited public involvement, or gaps in communication and knowledge transfer. This divergence indicates that monitoring is not yet functioning as a coherent, integrated governance instrument across sectors.
9. Stakeholders consistently indicate that an effective local monitoring system should be more integrated, participatory, data-accessible, and practically applicable. It is expected to move beyond fragmented control functions toward a system that ensures clear communication, locally relevant indicators, and stronger links between data collection and decision-making. Overall, stakeholders emphasize the need for a more inclusive and adaptive monitoring approach that connects institutions, communities, and practice.
10. The results should be interpreted with caution, as interviews with 21 active stakeholders do not fully represent all stakeholder groups. However, these actors significantly influence public discourse. Therefore, a local river basin monitoring system should go beyond stakeholder-identified aspects and ensure a comprehensive approach that includes not only full-spectrum water quality indicators but also places water governance indicators in a central and substantial role.
11. As a minimum, it is recommended to include a core set of water governance indicators aligned with the OECD Water Governance Indicator Framework (36 indicators based on 12 principles), such as stakeholder engagement, transparency of decision-making, coordination across levels, and communication and data accessibility. In addition, the system should incorporate at least two bottom-up indicators, for example, public participation intensity and frequency of citizen-reported environmental observations, to better capture local engagement and knowledge.

Acknowledgements

The authors acknowledge the contribution of the University of Latvia, particularly the Centre for Socio-Ecological Systems Governance, for their support in conducting this research. The study was

developed as complementary Dviete River basin research to the ongoing EU Horizon projects BETTER LIFE and OPTAIN, with acknowledgement and support by the Daugavpils University.

Author contributions

Conceptualization, R.E.; methodology, R.E., T.B., A.S.; validation, R.E. and A.S; formal analysis, T.B., R.E..; interviews and interview compilations, T.B.; data curation, R.E., T.B.; writing – T.B. original drafting, R.E. writing review and editing; visualization, T.B.; research program and project administration, A.S., R.E. All authors have read and agreed to the published version of the manuscript.

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