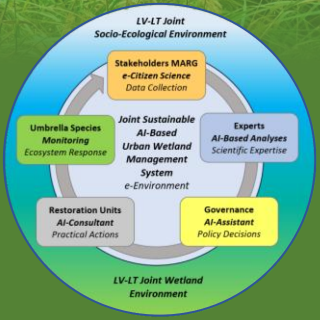
Interreg
Līdzfinansē EIROPAS SAVIENĪBA
Latvija – Lietuva

Joint Sustainable AI-Based Urban Wetland Management System



Innovative cross-border socio-ecological e-governance

Daugavpils University

2026

Developed in the INTERREG LV-LT Project "Joint nature-based preservation of climate change/humans-threatened urban LV-LT cross-border wetlands umbrella biodiversity by innovative solutions, reintroduction and joint management" UrbUmbrella Nr. LL-00232.

Pupins M., Nekrasova O., Čeirāns A., Arte I., Skute A. (**2026**): Joint Sustainable AI-Based Urban Wetland Management System. – Daugavpils University, 45 p.
https://doi.org/10.13140/RG.2.2.14935.02723

Laboratory of Nature Conservation and IT-AI Solutions,
Department of Ecology, Institute of Life Sciences and Technologies,
Daugavpils University

Cover photos: ***Upper***: *LV territory of the Joint Wetland Management System, Pond 2.*
Bottom: *One of the Umbrella Key Bioindication Species: Pelophylax kl. esculentus sun-basking in a shallow open shelf zone, LV.*

Daugavpils University, 2026

Contents

Abstract

Latvian and Lithuanian Urban wetlands are increasingly threatened by climate change, biodiversity loss, invasive species, and anthropogenic pressures. The Joint Sustainable Wetland Management System (JSWMS) developed for the transboundary region of Daugavpils (Latvia) and Zarasai (Lithuania). The system integrates bio-expertise, nature-based restoration strategies, and AI-driven stakeholder engagement into a unified transborder joint governance framework. The methodology combines innovative bioindication, eDNA monitoring, current and predictive bioclimatic modelling, and e-Engagement participatory digital platform to enable adaptive, data-driven decision-making. The proposed system represents a cyber-physical socio-ecological model that enhances LV-LT urban wetland biodiversity conservation, climate resilience, and cross-border environmental governance. Integrating scientific monitoring, AI-based technologies, and e-Engagement participatory governance provides a scalable and replicable model for sustainable LV-LT urban wetland management.

Introduction

Wetlands are among the most productive ecosystems globally, yet they are highly vulnerable to **climate change, urbanization, and biological invasions**. Cross-border wetlands present additional governance challenges due to **fragmented institutional frameworks and shared ecological processes**.

The JSWMS addresses these challenges by introducing **joint, AI-assisted, and e-Engagement participatory management system** that integrates ecological science with digital AI-technologies and social governance structures. The system is specifically designed for **urban wetlands connected across national boundaries**, where ecological processes transcend administrative borders.

1. THE RELEVANCE OF LATVIAN – LITHUANIAN JOINT URBAN WETLAND MANAGEMENT

1.1. The role of urban wetlands in contemporary environmental governance

Wetlands represent one of the most biologically productive and ecologically valuable ecosystems on Earth. Despite occupying only a relatively small proportion of the global terrestrial surface, wetlands perform a disproportionately large number of ecological functions that support biodiversity, climate regulation, and human well-being. These ecosystems provide a wide range of ecosystem services, including water purification, flood mitigation, carbon sequestration, nutrient cycling, and habitat provision for a diverse range of plant and animal species. Over the past several decades wetlands have experienced significant degradation and loss due to anthropogenic pressures such as urban expansion, land drainage, pollution, and climate change.

Urban wetlands occupy a unique position within socio-ecological landscapes. Located within or adjacent to densely populated areas, they serve as critical ecological infrastructure supporting environmental stability while simultaneously providing social, cultural, and economic benefits to urban populations. In recent years, urban wetlands have increasingly been recognized as essential components of sustainable urban development and climate adaptation strategies. Their capacity to regulate hydrological cycles, moderate local climate conditions, and support biodiversity makes them indispensable elements of resilient urban ecosystems.

Within the context of Northern and Eastern Europe, urban wetlands play a particularly important role due to the region's extensive freshwater networks, peatland landscapes, and complex hydrological systems. In the Baltic region, wetlands function as ecological buffers that stabilize water regimes, maintain habitat connectivity, and mitigate environmental pressures associated with urbanization and land-use change. So, the conservation and sustainable management of wetlands have become key priorities within European environmental policy frameworks, including the *European Union Biodiversity Strategy*, the *Water Framework Directive*, and the *Ramsar Convention on Wetlands*.

1.2. Urban wetlands as climate regulation and mitigation systems

Urban wetlands contribute significantly to climate regulation and climate change mitigation through several interrelated ecological mechanisms. One of the most important functions of wetlands is their ability to act as natural carbon sinks. Wetland soils, particularly those rich in organic matter such as peatlands and marshes, store large quantities of carbon accumulated over long periods of time. By preventing the release of stored carbon into the atmosphere, wetlands play a crucial role in regulating greenhouse gas concentrations and mitigating global climate change.

In addition to carbon sequestration, wetlands also influence local and regional climate conditions through hydrological and microclimatic processes. Wetland vegetation and surface water bodies regulate temperature fluctuations by absorbing solar radiation and facilitating evaporative cooling. These processes contribute to the stabilization of local microclimates and help reduce the intensity of urban heat island effects, which are increasingly prevalent in expanding urban environments.

Wetlands also function as natural climate adaptation systems by enhancing landscape resilience to extreme weather events. Their capacity to retain and slowly release water allows wetlands to buffer the impacts of heavy precipitation events and flooding. At the same time, during periods of drought, wetlands can maintain hydrological stability by sustaining groundwater levels and supporting surrounding ecosystems.

As climate variability continues to increase across Europe, the role of wetlands as natural climate regulators is expected to become even more important. Protecting and restoring urban wetlands therefore represents a key strategy for strengthening regional climate resilience while simultaneously enhancing biodiversity and ecosystem stability.

1.3. Hydrological regulation and water quality functions

Another critical ecological function of wetlands is their ability to regulate hydrological processes and maintain water quality. Wetlands act as natural hydrological regulators within river basins and catchment areas by storing excess water during periods of high precipitation and gradually releasing it during drier periods. This capacity reduces flood risk in downstream areas and stabilizes water flow regimes within interconnected aquatic systems.

The hydrological regulation functions of wetlands are particularly important in urban environments, where impervious surfaces such as roads, buildings, and infrastructure disrupt natural water infiltration processes. By absorbing and retaining stormwater runoff, wetlands reduce the pressure on urban drainage systems and help prevent flooding in densely populated areas.

Wetlands also perform essential water purification functions. Through a combination of physical, chemical, and biological processes, wetland ecosystems filter pollutants and excess nutrients from surface water. Wetland vegetation absorbs nitrogen and phosphorus compounds, while microbial communities within wetland soils facilitate the breakdown and transformation of organic pollutants. As a result, wetlands serve as natural water treatment systems that improve water quality and support the ecological integrity of connected freshwater ecosystems.

In addition, wetlands play a vital role in maintaining groundwater recharge processes. By facilitating water infiltration into underlying aquifers, wetlands contribute to the long-term sustainability of freshwater resources, which are increasingly under pressure due to climate change and urban development.

1.4. Biodiversity conservation and habitat connectivity

Wetlands are widely recognized as biodiversity hotspots that support a remarkable diversity of plant and animal species. The structural complexity of wetland habitats—including open water areas, reed beds, marshes, peatlands, and riparian vegetation—creates a mosaic of ecological niches that sustain numerous organisms across multiple trophic levels.

Many wetland species are highly specialized and dependent on specific hydrological and ecological conditions. As a result, wetlands provide critical breeding, feeding, and migratory habitats for amphibians, reptiles, birds, fish, and invertebrates. In temperate regions such as the Baltic states, wetlands serve as essential stopover sites for migratory bird species along major migratory routes.

Urban wetlands are particularly valuable for biodiversity conservation because they provide refuges for wildlife within heavily modified landscapes. By maintaining habitat patches within urban environments, wetlands help preserve ecological connectivity and support species movement across fragmented landscapes.

The conservation of umbrella species, whose habitat requirements encompass those of many other species, is an important strategy in wetland biodiversity management. Protecting habitats suitable for such species can indirectly safeguard entire ecological communities and maintain ecosystem stability.

1.5. Urban wetlands of Daugavpils and Zarasai: a cross-border socio-ecological system

The wetland landscapes surrounding the cities of Daugavpils (Latvia) and Zarasai (Lithuania) represent an ecologically interconnected system located within the broader Daugava River basin. These wetlands include a network of lakes, marshes, riparian habitats, and floodplain ecosystems that support high levels of biodiversity and perform essential ecological functions within the region.

The geographical proximity of Daugavpils and Zarasai creates a shared environmental context in which hydrological processes, species distributions, and ecological dynamics extend across national boundaries. Water flows, migratory species movements, and climate impacts operate at the landscape scale, making cross-border cooperation essential for effective environmental management.

Wetlands within this region provide numerous ecosystem services that benefit both local communities and regional ecosystems. These services include water regulation, nutrient retention, habitat provision for aquatic and semi-aquatic species, and climate stabilization. The wetlands also contribute to the cultural and recreational value of the region by supporting nature-based tourism, environmental education, and scientific research.

The wetlands of Daugavpils and Zarasai are increasingly exposed to environmental pressures associated with urban expansion, infrastructure development, pollution, invasive species introduction, and climate change. Changes in precipitation patterns and temperature regimes may alter hydrological conditions and affect species distributions within these ecosystems.

Addressing these challenges requires an integrated cross-border management approach that combines ecological monitoring, scientific expertise, and stakeholder participation. By coordinating conservation strategies between Latvia and Lithuania, it is possible to maintain ecological connectivity, protect biodiversity, and enhance the resilience of wetland ecosystems within the region.

1.6. The need for an integrated cross-border wetland management system

Given the complex socio-ecological dynamics of urban wetlands and the transboundary nature of the Daugavpils–Zarasai wetland system, traditional sectoral approaches to environmental management are insufficient. Effective conservation requires the integration of ecological science, governance mechanisms, technological tools, and public engagement.

An integrated wetland management system must therefore incorporate several key components:

- scientific monitoring and ecological modelling,
- nature-based restoration strategies,
- digital environmental monitoring platforms,
- stakeholder participation and citizen science,
- cross-border institutional coordination.

Such an approach enables adaptive management based on real-time environmental data and scientific analysis. It also strengthens collaboration between authorities, researchers, and local communities, ensuring that wetland conservation efforts remain socially inclusive and scientifically informed.

The development of a Joint Sustainable Wetland-Management System for the Daugavpils and Zarasai wetlands represents an important step toward achieving long-term ecological sustainability in the region. By integrating innovative technological solutions with participatory governance and ecosystem-based restoration practices, the system provides a comprehensive framework for protecting urban wetlands and enhancing their capacity to support biodiversity, climate resilience, and human well-being.

2. JOINT SUSTAINABLE WETLAND MANAGEMENT SYSTEM CONCEPT, METHODOLOGY AND INNOVATIONS

2.1. Theoretical framework

The Joint Sustainable Wetland Management System (JSWMS) is grounded in three major scientific paradigms:

Socio-Ecological Systems Theory: The system conceptualizes wetlands as coupled **Human–Natural Systems** (CHANS), where ecological dynamics and human decision-making are interdependent.

Adaptive Management Theory: The framework follows an iterative learning cycle:

- **Monitoring**
- **Evaluation**
- **Decision-making**
- **Adjustment**

This aligns with ecosystem-based management principles.

Nature-Based Solutions: The system prioritizes ecological restoration through:

- **Natural disturbance** emulation
- **Species-based** ecosystem stabilization
- **Habitat zoning**

2.2. Methodology and components

Research design

This study employs systems **design and implementation methodology**, combining:

- **Interdisciplinary** ecological assessment

- **Digital system** engineering (AI platform)
- **e-Participatory** governance modelling

The approach is **applied, transdisciplinary, and iterative**, where the iterative processes involve **refining and improving** a management process based on received **feedback** and/or **new information**, integrating **stakeholders** throughout the **system lifecycle**.

Core Methodological Components

Bio-expertise and monitoring. The system applies multi-layer ecological monitoring, including:

- **Bioindication** using Umbrella Key Species (wetland amphibians, reptiles)
- **Environmental DNA** (eDNA) analysis (for cryptic species)
- **Biodiversity** field surveys (regular field monitoring)
- AI-assisted **e-Citizen Science** ecological data processing (e-Citizen Science app)

These methods enable high-resolution ecosystem diagnostics and early detection of environmental changes.

Bioclimatic modelling. Current and Predictive modelling is used to:

- Identify current **climate impact** on wetland ecosystems using model **Umbrella Key Species**, as bio-indicators
- **Forecast climate changes** impact on habitat suitability and spatio-temporal dynamics of model Umbrella Key Species distribution
- **Optimize restoration strategies** as a Climate change mitigation

This ensures forward-looking, strategic climate-adaptive and joint management .

Nature-based restoration strategies. Restoration interventions are based on:

- **Umbrella species** concept (e.g., model species *Emys orbicularis, Triturus cristatus*)
- **Invasive species** natural control (e.g., model species *Trachemys scripta, Perccottus glenii*)
- **Natural disturbance** emulation (flooding, ecosystem engineering)
- **Spatial zoning** of wetlands (with different preservation level)

These interventions are continuously evaluated through monitoring and e-Citizen Science feedback loops.

AI-Driven participatory e-Platform. A central methodological innovation is the development of an AI-supported Joint digital platform integrating:

- **e-Citizen science** data collection (geolocation-based photo-reporting)
- Real-time **One-Click alerts** and reporting (anonymous photo-alert)
- **e-Learning** modules (Ecology, Ethology, Science)
- **e-Coworking** with ML AI Assistant
- Stakeholder **e-Engagement** into decision making
- **e-Feedback** interactive module

The AI-Driven platform enables e-Coworking and bidirectional information flow between stakeholders and decision-makers with real-time feedback.

Data Integration and Decision-Making. Data from multiple sources are integrated into a central base of the decision-support system, which allows to:

1. Aggregate **ecological and social** data
2. Perform **predictive analysis**
3. Generate **management recommendations**
4. Support **expert validation**

This ensures evidence-based, transparent decision-making because of Stakeholders and Police makers e-Coworking.

2.3. Innovations characteristics

Scientific Innovations

- **AI-driven** ecosystem **governance**
- **eDNA + bioindication** integration
- **Predictive bioclimatic modelling**

Technological Innovations

- Geolocated **e-Citizen Science**
- **AI e-learning** environment
- **Real-time** ecosystem regulation

Governance Innovations

- Cross-border **e-Co-management**
- **e-Participatory** decision-making
- **Open-data** environmental governance

3. JOINT SUSTAINABLE WETLAND MANAGEMENT SYSTEM CONTENT

3.1. Management system core components

Connected urban wetlands in Daugavpils, Latvia and in Zarasai, Lithuania represent complex socio-ecological systems that provide critical ecosystem services including biodiversity conservation, water purification, flood regulation, carbon sequestration, and climate regulation. Both wetland ecosystems are increasingly threatened by urbanization, overexploitation, pollutions, climate change, and invasive species, which disrupt ecological balance and reduce resilience. The cross-border wetland areas between Latvia and Lithuania require coordinated management because hydrological systems are connected (12 km of water way) and biodiversity networks transcend administrative borders.

The developed Joint Sustainable Wetland Management System (JSWMS) content includes an integrated governance and monitoring framework that combines ecological science, digital technologies and AI, participatory governance, nature-based restoration solutions and bioclimatic modelling-based conservation strategies. The JSWMS system is based on four **interconnected joint pillars**:

- **Innovative bio-expertise**: field monitoring and strategic bioclimatic modelling;
- **Nature-based** wetland restoration solutions and strategies;
- Active **e-engagement** of stakeholders and **e-citizen science** participation;
- **ML IT-AI based** Wetland Management decision assistance.

These components interact within the broader socio-ecological environment, integrating ecological processes with governance mechanisms and societal participation.

3.2. Management environments and cycle workflow

The developed **Joint AI-Based Urban Wetland Management System** introduces a cross-border collaborative governance model capable of supporting long-term wetland ecosystem and related biodiversity sustainability while maintaining socio-economic benefits such as ecological services through **ML AI-Assistance** for **Experts**, **Governance**, and **Restoration Units**; **e-Citizen Science**; **e-Engagement** and sustainable interactive environmental **e-Education** for **Multi-Actor Reference Groups** (Figure). The Project develops and introduces this innovative cross-border wetland management system between Latvia (LV) and Lithuania (LT). This system aims to protect, restore, and sustainably manage urban wetlands that are under threat due to climate change, invasive species, urbanization, and pollution, through interdisciplinary and MARG approaches incorporating: 1) **Innovative bio-expertise**, **monitoring** and **strategic bioclimatic modelling**, 2) **Nature-based wetland restoration** strategies, 3) **Active e-Engagement** of **all stakeholder groups** in the wetland management, the **Joint AI-Based Urban Wetland Management System** ensures long-term socio-ecological sustainability and wetlands biodiversity preservation in both Latvian and Lithuanian territories.

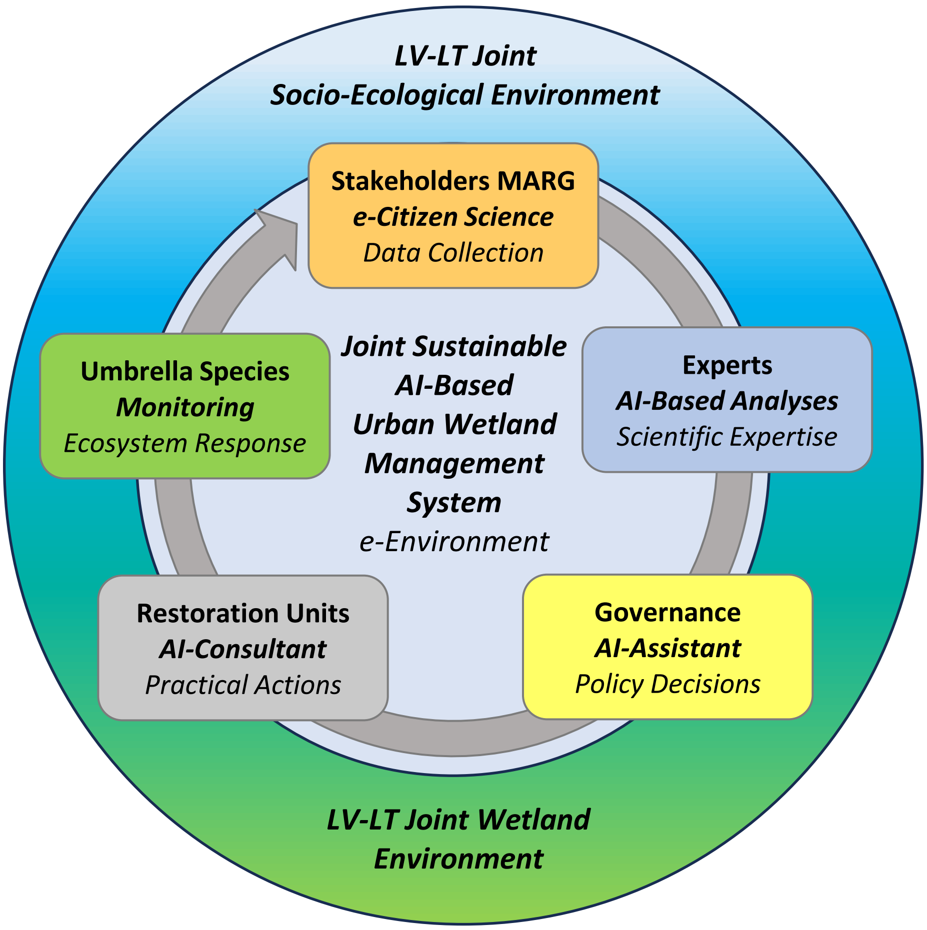


Figure: Joint AI-Based Urban Wetland Management System, workflow, its core components, functions and relationships.

3.3. Scientific expansion: Experts AI-Based Analyses

Component I: Bio-Expertise, Monitoring & Bioclimatic Modelling

Function: Generate evidence-based ecological intelligence

Subsystems:

- Bioindication using **Umbrella Key Species**
- **eDNA** monitoring systems
- **AI-assisted** biodiversity analytics
- Bioclimatic **predictive modelling**

Scientific Role:

- Detect **ecological shifts**
- **Predict climate-driven habitat** changes
- Optimize **restoration strategies**

Component II: Nature-Based Restoration System

Function: Restore ecosystem integrity using **ecological engineering**

Key Mechanisms:

- **Natural disturbance emulation** (flooding, beaver analogues)
- **Invasive species control** (e.g., *Trachemys scripta*)
- **Rare Umbrella species** reintroduction (*Emys orbicularis*)
- **Zonation** (human vs biodiversity areas)

Scientific Basis:

- Ecosystem **resilience theory**
- **Adaptive** management cycle
- **Trophic** and **habitat stabilization**

Component III: Stakeholder e-Engagement & AI Platform

Function: Enable **real-time participatory** governance

Digital Infrastructure:

- **AI-mobile application**
- **Geolocation-enabled** monitoring
- **e-Citizen science** photo-reports
- **e-learning** environment

Key Features:

- **Real-time** alerts (pollution, invasive species)
- **e-learning** ecosystem
- **Public think-tank** functionality

Core components' functions

Core components functions are:

1. Innovative bio-expertise, monitoring and strategic bioclimatic modelling

- Joint **bio-expertise efforts** using Umbrella Key Species innovative bioindication methods and monitoring to evaluate wetland health.
- Joint **strategic bioclimatic modelling** for Umbrella Key Species to mitigate climate impact threats in the wetlands for wetlands sustainability.
- **Cross-border collaboration** of experts from both countries to assess environmental changes and propose conservation measures.
- Development of a **joint decision-making** e-based framework to optimize restoration efforts and mitigate climate changes and invasive species impact.

2. Nature-based wetland restoration strategies

- Implementation of the **Umbrella Key Species concept**, focusing on nature-based solutions like **natural disturbances emulations**, such as emulated flooding and beaver impact, selective vegetation clearance, and ecosystem engineering to maintain wetland health.

- Introduction of **removing/isolation mechanisms for invasive species** like *Trachemys scripta* and *Perccottus glenii*, and the European pond turtles releasing as Umbrella Key Species ecological stabilizer.
- Establishment and dividing of **protected biodiversity and humans' zones** and the real-time e-regulation tool of the using of the zones, their over-exploitation and all forms of pollutions.

3. Active engagement of all stakeholder groups in the wetland management

- Direct **real-time involvement** of all stakeholders' groups (authorities, experts, other stakeholders and wide public) in the wetland management through the decisionmaking e-environment.
- A **cutting-edge IT-AI mobile application** designed for real-time Citizen science-based monitoring, biodiversity tracking, feedback, wetland management and humans' behavior real-time regulation.
- Integration of **geolocation services**, AI-driven data analysis, and e-Citizen science participation to enhance stakeholder engagement.
- Integration of **open data information services** and testing to enhance stakeholder learning and development.

3.4. Cross-border collaboration and impact

The joint LT-LV wetland management system is crucial due to the shared water systems between Daugavpils (LV) and Zarasai (LT) and joint problems. **Key benefits of the system** include:

- **Integrated conservation efforts**: Tackling biodiversity threats that extend beyond national borders.
- **Stakeholder engagement and education**: Interactive tools and e-learning platforms fostering cross-border participation.
- **Data-driven decision-making**: Predictive bioclimatic cross-border modeling for both territories ensuring effective wetland restoration and sustainable ecosystem management.

- **Sustainable eco-tourism regulation**: Encouraging responsible tourism while preserving wetland integrity.

The Project’s innovative wetland management system represents a transformative approach to ecosystem conservation. By merging modern technologies solutions with scientific research and public involvement, it establishes a scalable model for cross-border environmental governance. This initiative fosters ecological resilience, enhances biodiversity, and ensures the sustainable future of urban wetlands in the LT-LV region.

4. JOINT SUSTAINABLE WETLAND MANAGEMENT SYSTEM LAYERS

4.1. Conceptual definition

The Joint Sustainable Wetland Management System (JSWMS) is a transboundary, AI-assisted, socio-ecological governance framework designed for the integrated conservation, restoration, and adaptive management of urban wetlands across the Latvia–Lithuania border (Daugavpils–Zarasai region).

The system combines:

- **Ecological science** (bioindication, eDNA, modelling)
- **Nature-based solutions** (NbS)
- **Digital infrastructure** (AI + geolocation + citizen science)
- **Participatory e-governance**

The system operates as a multi-layer adaptive management loop ensuring long-term ecosystem resilience and biodiversity preservation.

4.2. System layers and subsystems

The system is composed of **six interacting layers**:

1. **Ecological Layer** – wetlands, species, habitats, hydrology.
2. **Scientific Layer** – monitoring, modelling, bio-indication, expert evaluation.
3. **Governance Layer** – authorities, municipalities, conservation agencies.
4. **Technological Layer** – digital platform, AI mobile applications.
5. **Societal Participation Layer** – e-citizen science, NGOs, stakeholders.
6. **IT**-AI based environment – ML AI assistance.

The layers is structured into **four interconnected subsystems**:

- **Bio-Expertise Subsystem** (Provides scientific ecological information through monitoring and modelling).
- **Restoration Subsystem (**Implements adaptive nature-based interventions).
- **Stakeholder e-Engagement Subsystem** (Facilitates participatory governance via digital tools).
- **Cross-border governance subsystem** (Provides cross-border collaboration and management).

These subsystems interact within a **shared socio-ecological environment**, ensuring system-wide coherence.

5. INNOVATIVE BIO-EXPERTISE AND STRATEGIC BIOCLIMATIC MODELLING

5.1. Bioindication using Umbrella Key Species

The monitoring framework is based on *Umbrella Key Species conception*: wetland organisms (amphibians and reptiles) whose ecological requirements reflect wetland ecosystem conditions, optimal for main other wetland species. Monitoring Umbrella Key Species enables efficient evaluation of wetland biodiversity and ecological health.

Key monitoring indicators include:

- **Population dynamics** of key species
- **Habitat quality** indicators
- **Hydrological regime** stability
- Presence of **invasive species**

Umbrella species monitoring enables scientists to identify **early warning signals** of **ecosystem degradation** and to propose adaptive management responses.

5.2. Cross-border bioclimatic modelling

Climate change significantly alters wetland hydrology and species distributions. The management system integrates **current** and **predictive bioclimatic modelling** to evaluate climate changes potential impacts such as:

- **temperature** increase
- **precipitation** variability
- seasonal **solar activity** dynamics
- rare and invasive **species spread** etc.

The modelling system incorporates geospatial datasets, big databases, ecological monitoring results, and climate projections to generate predictive scenarios supporting adaptive management strategies. The bioclimatic models below have been developed by the authors for the 4 model target species (*Project UrbUmbrella Consolidated Phase 1 Report*, Škute et al. 2025).

Rare Species *Triturus cristatus* and *Emys orbicularis*

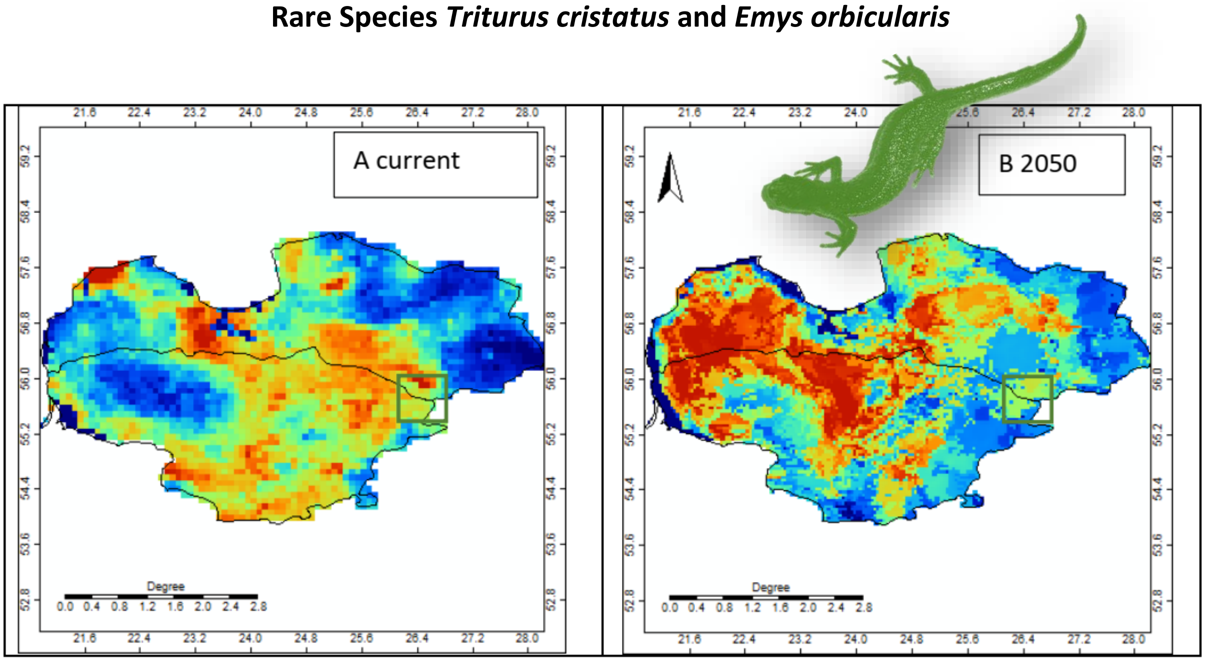


Fig. 3. Potential (probabilistic) model of *T. cristatus* in Latvia and in Lithuania and in Project UrbUmbrella territories of based on dataset WorldClim (SAGA, red color > 0.5): (A) current; (B) 2050. Green square – UrbUmbrella territories in Latvia and Lithuania.

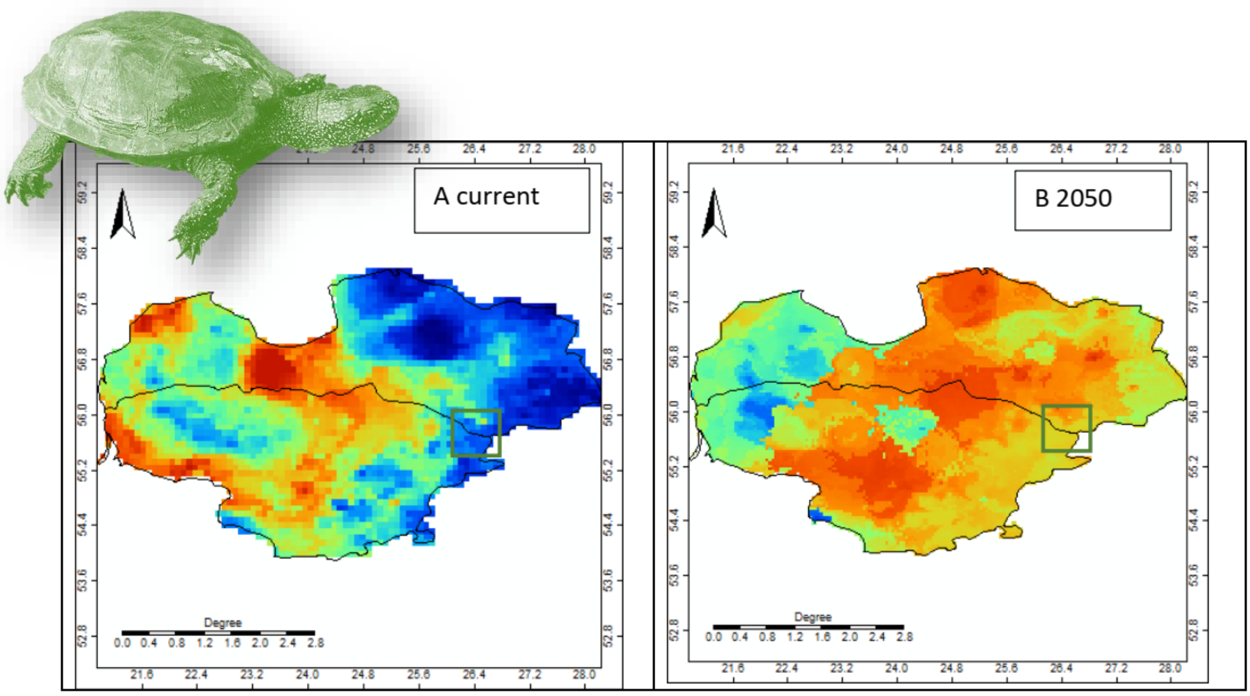


Fig. 6. Potential (probabilistic) model of *E. orbicularis* distribution in Latvia and in Lithuania and in Project UrbUmbrella territories based on dataset WorldClim (SAGA, red color > 0.5): (A) current; (B) 2050. Green square – UrbUmbrella territories in Latvia and Lithuania.

Invasive Species *Perccottus glenii* and *Trachemys scripta*

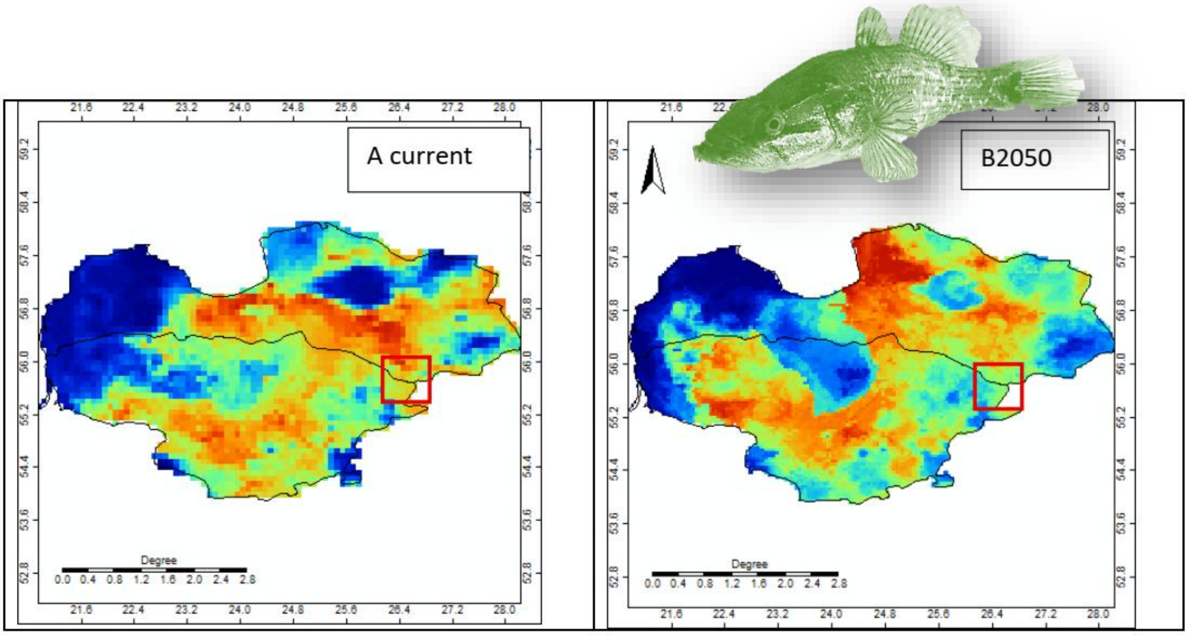


Fig. 9. Potential (probabilistic) model of the distribution of the invasive fish *P. glenii* in Latvia and in Lithuania and in Project UrbUmbrella territories using the WorldClim dataset: (A) current; (B) projected distribution for 2050. Red square – UrbUmbrella territories in Latvia and Lithuania.

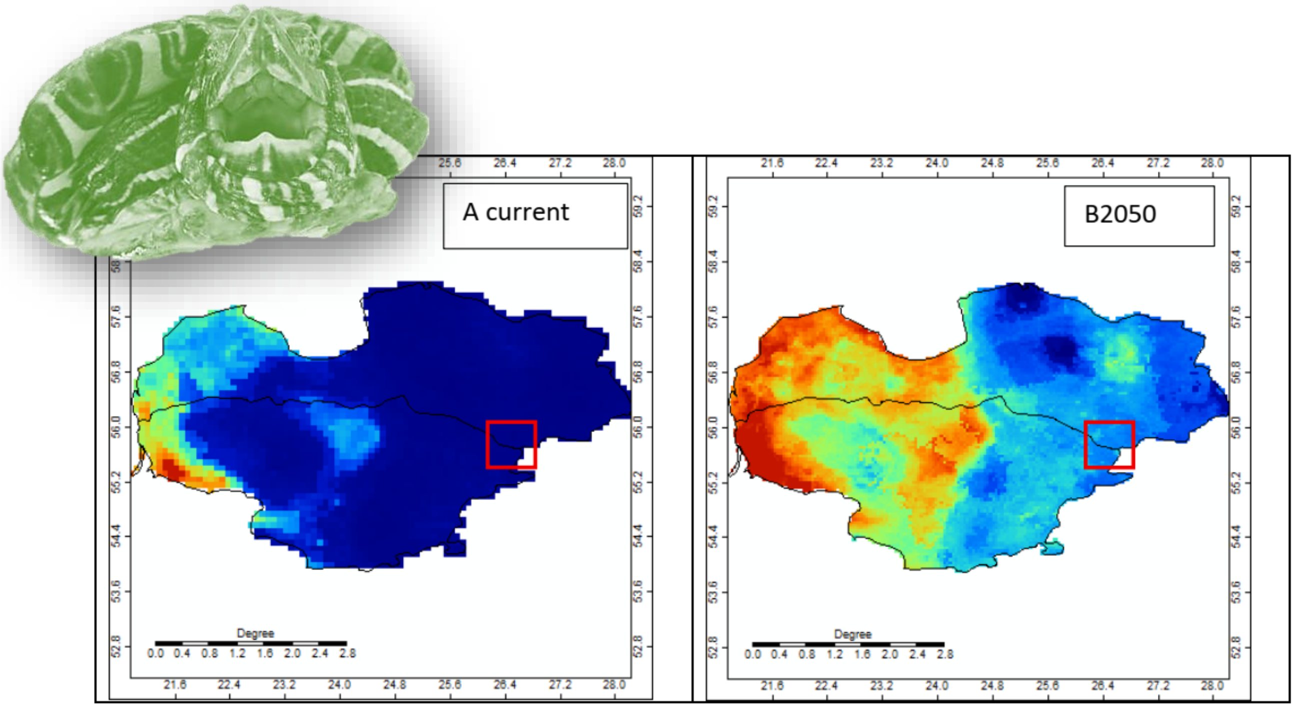


Fig. 11. Potential (probabilistic) model of the distribution of the invasive turtle *Trachemys scripta* in Latvia and in Lithuania and in Project UrbUmbrella territories using the WorldClim dataset: (A) current; (B) projected distribution for 2050. Red square – UrbUmbrella territories in Latvia and Lithuania.

As a result of the bioclimatic modeling, it was revealed that different animal species will respond differently, in a differentiated way, to climate change, particularly in Northern Europe, where the emergence of new invasive species is expected in the future.

For native rare species — the northern crested newt (*T. cristatus*) and the European pond turtle (*E. orbicularis*) — the key distribution drivers are mean annual temperature, precipitation during the warmest quarter, and extreme winter conditions. Both species show a tendency to shift their ranges northward and northeastward, making Latvia and Lithuania potentially important areas for population persistence by the mid-21st century.

At the same time, invasive species are projected to benefit from changing climatic conditions. The red-eared slider (*T. scripta*), which depends on mild winters and reduced climatic seasonality, is likely to become naturalized in Latvia and Lithuania by 2050, creating competition pressure on the native *E. orbicularis*. The invasive fish *P. glenii* demonstrates high adaptability to moderately cool climates with warm summers. Projections indicate substantial expansion of its range in the Baltic region, increasing predation pressure on amphibian larvae and destabilizing freshwater ecosystems (Pupins et al., 2023). Therefore, bioclimatic modelling and bio-indication are important parts of the Joint Management System.

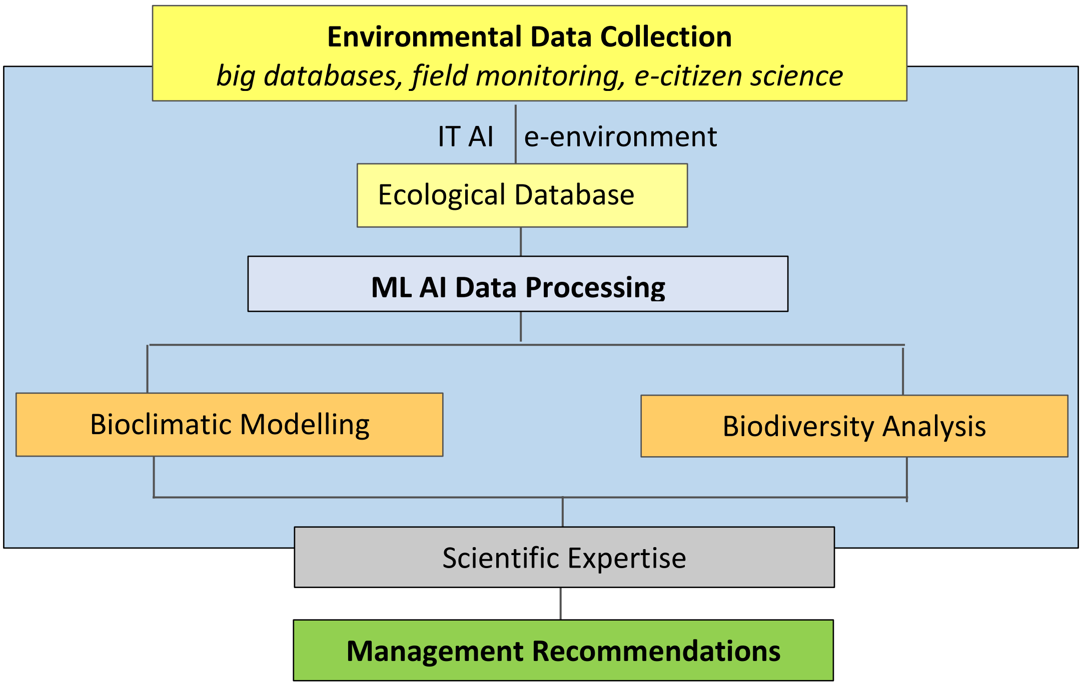


Figure: Scientific Monitoring and Modelling Framework. This monitoring architecture ensures evidence-based ecological management.

Comparison with recent studies (Nekrasova et al., 2024) supports these findings: *E. orbicularis* shows potential for range expansion under climate warming, while invasive American species (including *T. scripta*) display a high likelihood of northward spread.

In summary, climate change will simultaneously facilitate range expansion of both native and invasive species. For the Baltic countries, this presents a dual challenge: on the one hand, the formation of new favorable zones for the conservation of native taxa, and on the other, an increased risk of invasions and competition. These results highlight the urgent need for integrated monitoring, protected habitat creation, and early detection and control measures for invasive species.

The relevance of the bioclimatic modelling for the Joint Management System:

1. Climate change will have contrasting effects on native and invasive species in the Baltic region and in the Project UrbUmbrella territories in Latvia and in Lithuania.
2. For *T. cristatus* and *E. orbicularis*, north-eastern range shifts are projected, increasing the likelihood of persistence in Project UrbUmbrella territories by mid-century.
3. Invasive threats - *T. scripta* and *P. glenii* are expected to expand in Project UrbUmbrella territories and in Latvia and in Lithuania substantially, raising risks of competition and predation on native taxa.
4. Thus, the Project UrbUmbrella territories in Latvia and in Lithuania may become both a climatic refugium for threatened species and a hotspot of invasion risk, underscoring the need for integrated Joint Management System.

6. NATURE-BASED WETLAND RESTORATION SOLUTIONS AND STRATEGIES

Nature-based solutions form the core of ecosystem restoration and resilience enhancement. Instead of relying on artificial infrastructure, these approaches mimic natural ecological processes**.**

6.1. Ecosystem engineering and habitat restoration

Key restoration measures include:

- **Emulated flooding impact** to restore natural hydrological cycles
- **Beaver-like overgrowing removal and ecosystem engineering** to maintain water retention structures
- **Fire-like land overgrowing removing** through selective clearing
- **Rare native predators releasing** to manage invasive species

These actions recreate ecological disturbances that are essential for maintaining Latvian and Lithuanian wetland biodiversity.

6.2. Invasive species control

The presence of invasive species threatens wetland native biodiversity. The system includes targeted **control measures** such as:

- **isolation and removal** of invasive aquatic species
- habitat restoration supporting **native species recovery**
- **biological control** strategies
- continuous monitoring using **e-Citizen Science** reporting

The LV Focus is placed on **ecological stabilizer species** such as the **European pond turtle**, which functions as an **Umbrella Species** in Daugavpils urban wetland ecosystems.

6.3. Zonation of wetland areas

To balance conservation and human use, wetlands are divided into **four functional zones**:

- **Strict biodiversity protection** zones
- Ecological **buffer** zones
- **Sustainable** Use Zones
- **Educational** and **Public Access** zones

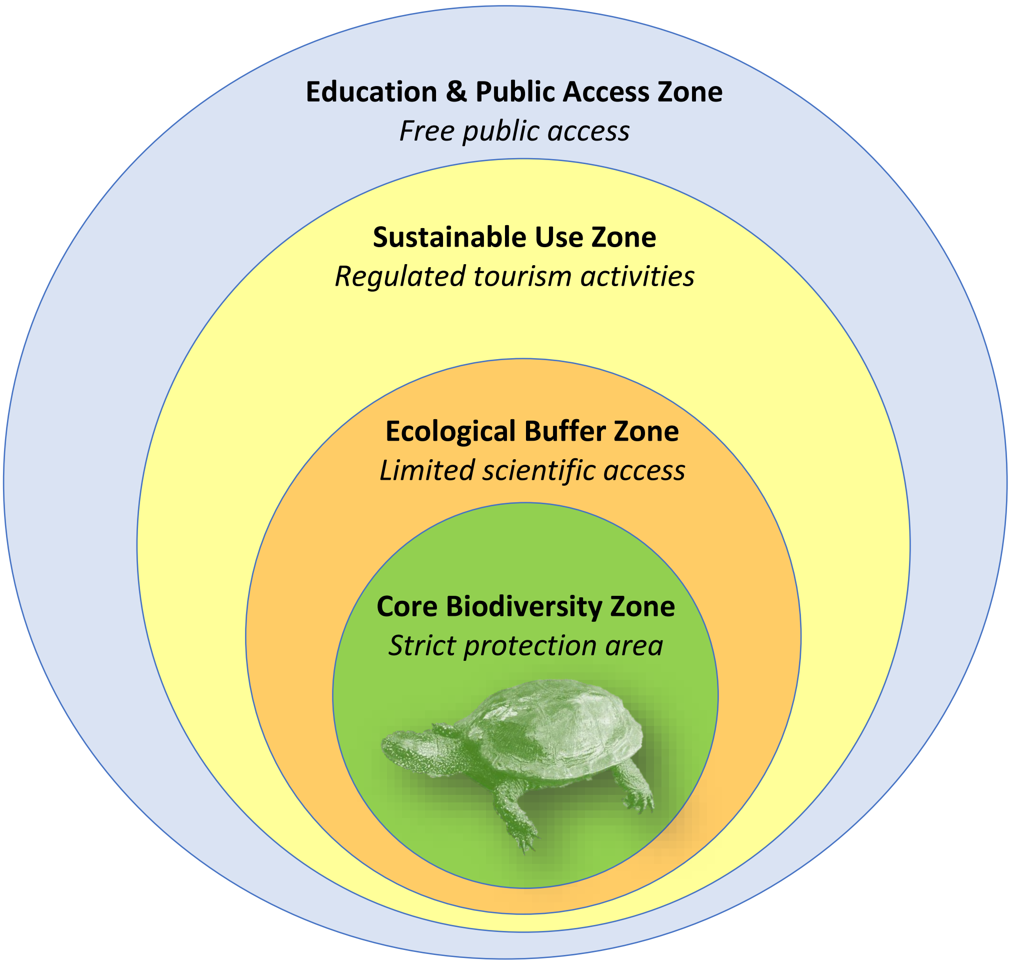


Figure: Urban wetland zonation framework. Real-time digital monitoring regulates human activities within these zones.

7. STAKEHOLDER PARTICIPATION AND GOVERNANCE

7.1. Socio-ecological integration

Socio-ecological integration ensures:

- **Feedback-driven** governance
- **Social** learning
- **Ecological** adaptation

7.2. Stakeholder Groups

The system directly and/or indirectly involves a wide network of **stakeholders** and **Multi-Actor Reference Groups** (**MARG**):

- Government Authorities
- National Environmental Ministries
- regional environmental agencies
- municipalities (Daugavpils, Zarasai)
- project area administrations
- Scientific Community
- universities
- research institutes
- ecological experts
- climate scientists
- Civil Society
- NGOs
- local communities
- environmental education organizations
- eco-tourism operators
- Technology Sector
- IT developers
- AI data analysts
- environmental monitoring system providers

7.3. Joint governance model

The structure is jointly governed and inseparable across partners.

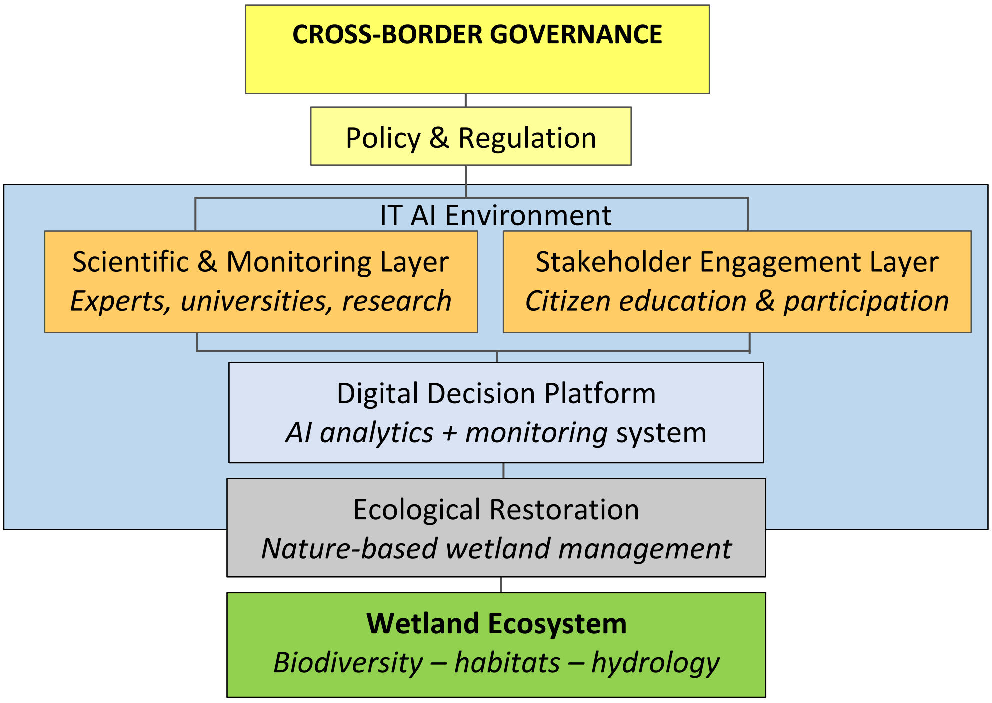


Figure: General structure of cross-border governance.

This integrated architecture ensures that ecological data flows upward toward decision-makers while management actions flow downward to the ecosystem.

Table. Roles and Responsibilities

Actor	Function
Municipalities	Policy integration, implementation
Scientists	Monitoring, modelling, recommendations
AI System	Data processing, decision support
Citizens	Data input, environmental observation
Supervisory Board	Scientific validation (if necessary)

7.4. Joint government structure

Institutional structure. The governance framework includes:

- **Local authorities** (Latvia and Lithuania)

- **Scientific experts** (Latvia and Lithuania)
- Joint International **Supervising Board** (Latvia and Lithuania)
- **Public stakeholders** and **NGOs** (Latvia and Lithuania)

The system operates as a **joint, inseparable cross-border governance mechanism**, ensuring coordinated management.

Participatory governance mechanism. Stakeholders are actively involved through:

- **e-Citizen science** contributions
- Real-time **One-Click reporting** systems
- Educational **e-Engagement** etc.

This enhances social ownership and environmental awareness.

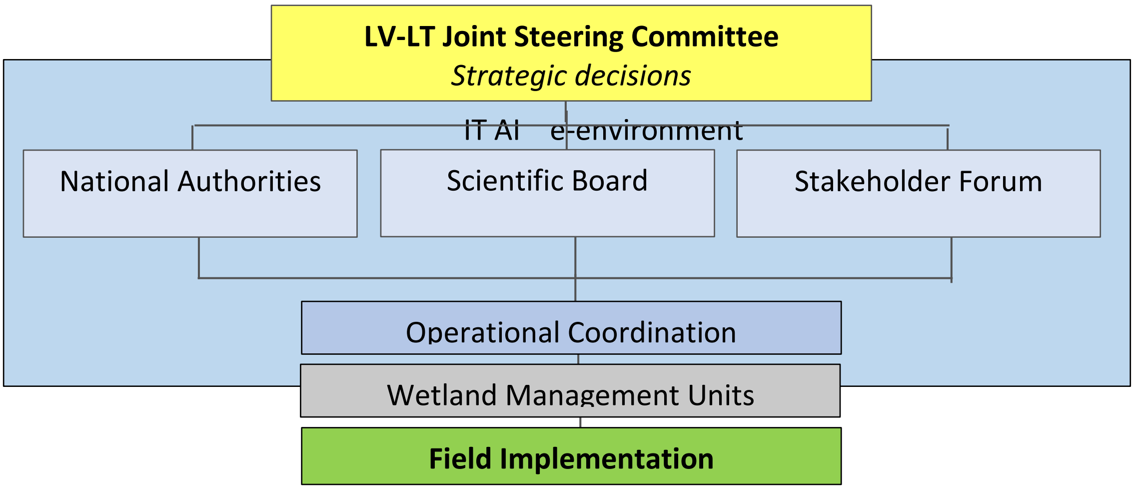


Figure: Cross-Border Governance Structure. The **Joint LV-LT Steering Committee** coordinates cross-border policy alignment and ensures that ecological management actions remain harmonized between Latvia and Lithuania.

Data Types in the participatory governance workflow

- **Ecological**: biodiversity, water quality
- **Spatial**: GIS/geolocation
- **Social**: citizen reports
- **Predictive**: climate models

8. DIGITAL PLATFORM AND AI-SUPPORTED DECISION SYSTEM

Digital System (AI + e-Platform Architecture) functional modules:

- **e-Citizen** science module
- Biodiversity **monitoring** tracking
- **e-Alert** system
- **Decision-support** AI-based engine
- **e-Educational** platform

Integrated digital AI-based ecosystem. The system includes a **digital e-environment platform** supporting monitoring, data analysis, and stakeholder interaction.

Key technological components include:

- **geolocation** services
- **environmental** sensors / big databases
- mobile e-**citizen science application**
- **AI-based decision-making** assistance

The platform core functions as an **AI-based decision-support system**, enabling authorities and scientists to evaluate ecosystem conditions in real time.

Mobile e-Citizen-Science Application. The mobile application enables public participation in environmental monitoring by allowing users to:

- **record** species observations
- upload **photos and environmental reports**
- **alert pollution** or **illegal activities**
- participate in **socio-ecological surveys** (questionary)
- provide **educational** materials

- **test** wetland knowledges

e-Citizen Science significantly expands monitoring capacity while fostering environmental awareness.

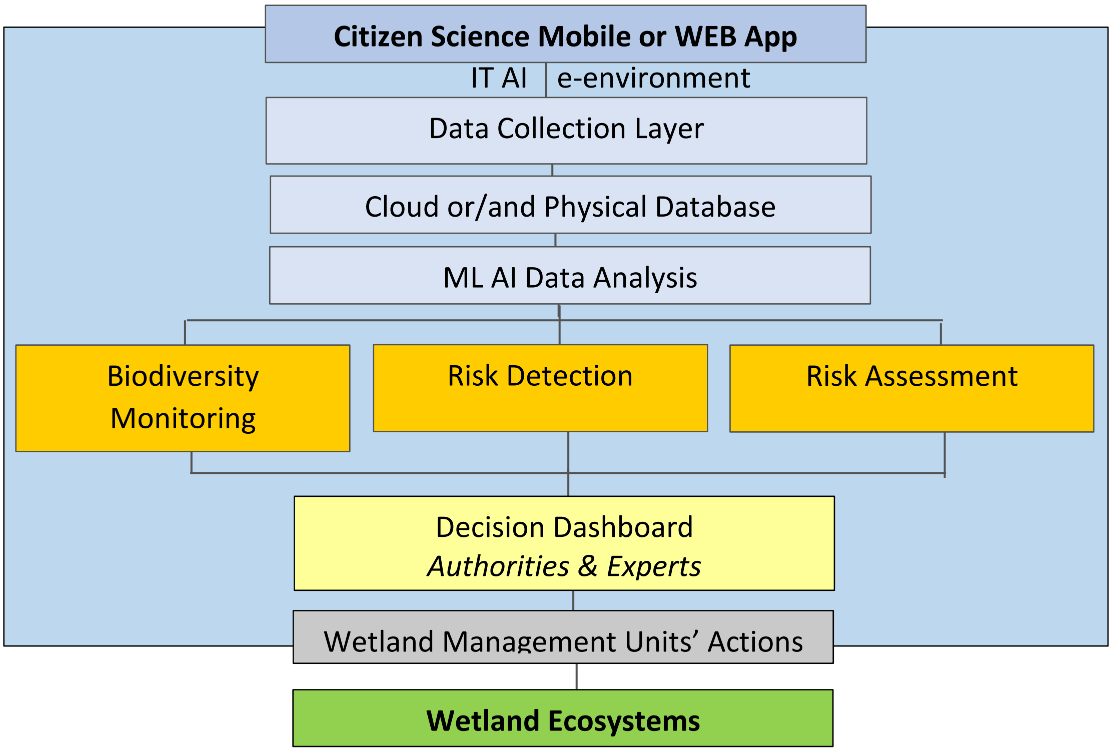


Figure: Digital platform architecture.

9. FEEDBACK LOOPS AND ADAPTIVE MANAGEMENT

Workflow System Structure (Operational Cycle). The JSWMS follows an adaptive iterative **management cycle loop** including:

1. **Data collection** (e-Citizen Science and monitoring)
2. AI-based **integration** (e-Platform)
3. Expert evaluation and recommendations (Certified Experts)
4. **Decision-making** (Citizen and Governances e-Coworking)
5. **Implementation** of restoration actions (Work Units, NGO)
6. **Monitoring and feedback** (e-Citizen Science and monitoring)
7. **Go to step 1.**

This cyclical process ensures iterative **continuous system optimization**.

Adaptive management cycles. A critical element of the system is the implementation of **adaptive management cycles**. Wetland ecosystems are dynamic and require continuous adjustment of strategies based on new scientific data.

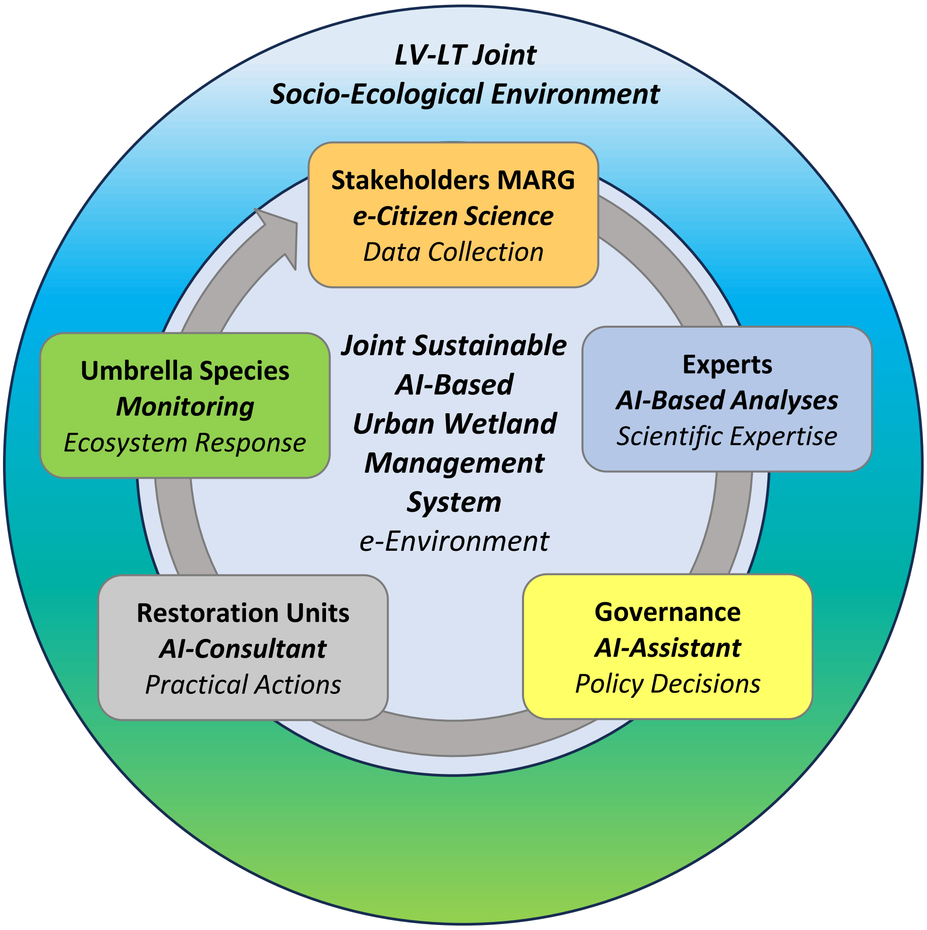


Figure: Joint AI-Based Urban Wetland Management System, workflow, its core components functions and relationships, and **Adaptive Main Feedback Loop** (Gray Arrow). The feedback loop ensures that the system remains flexible, evidence-based, and responsive to ecological change**.**

10. SOCIO-ECOLOGICAL BENEFITS AND OUTCOMES OF THE JOINT MANAGEMENT SYSTEM

10.1. Long-term benefits

The Joint Sustainable Wetland-Management System provides several long-term benefits:

Ecological benefits:

- **biodiversity** preservation
- improved **wetland resilience**
- **climate change** adaptation
- restoration of natural **hydrological cycles**
- **invasive species** control

Social benefits:

- **environmental education**
- citizen **e-engagement**
- improved **recreational opportunities**
- strengthened **environmental awareness**

Economic benefits

- **biodiverse** conservation
- improved **ecosystem services** supporting regional development
- **cross-border cooperation** opportunities
- urban territories **sustainable development**

10.2. Expected structured outcomes and results

Ecological outcomes

- Improved **biodiversity** status

- Enhanced **ecosystem resilience**
- Effective **invasive species control**

Governance outcomes

- Integrated **cross-border management**
- **Data-driven** policy implementation
- Increased **stakeholder participation**

Technological outcomes

- Operational **AI-based management** platform
- Scalable **digital infrastructure**

10.3. System implementation consolidated results

The JSWMS results in a transformative approach to environmental governance, integrating:

- Scientific **monitoring**
- **Digital** innovation
- **e-Participatory** processes

Its key strength lies in the integration of real-time data, predictive modelling, and stakeholder engagement, which collectively enable adaptive and resilient management.

Deliverables:

1. Joint Management System Document (This document)
2. AI-based Operational e-Platform (Web-based or App)

Consolidated outcomes:

- **Biodiversity** restoration
- **Climate** adaptation
- Sustainable **tourism regulation**
- **Replicable Joint Governance model**

10.4. Replicability and scalability

The system is designed as a **modular and transferable framework**, requiring only:

- Local **ecological data**
- **AI model** training
- **Institutional** integration

This makes it applicable across different geographical regions and wetland types.

The system is modular and scalable in accordance with the 5-steps works sequence:

IT AI e-Environment

1. **New Region**
2. → Input **Local Data**
3. → **Train AI**
4. → Deploy **e-Platform**
5. → Integrate **Governance**
6. → **Operate JSWMS**

Conclusions

The Joint Sustainable Wetland-Management System represents a **transformative model for cross-border environmental governance**. By integrating ecological science, IT AI and digital science, advanced monitoring technologies, nature-based restoration strategies, citizen science and participatory governance, the system creates a robust framework for sustainable wetland conservation.

The synergy between **bio-expertise, restoration interventions, and stakeholder engagement** ensures that wetland ecosystems remain resilient under increasing environmental pressures. Furthermore, the integration of digital tools and citizen science significantly enhances data availability and public involvement. As a scalable model, the proposed system can serve as a **reference framework for sustainable management of urban wetlands across Europe**, promoting biodiversity protection, climate resilience, and collaborative environmental stewardship.

The System demonstrates that **AI-assisted, participatory, and science-based governance** can effectively address complex environmental challenges in cross-border contexts. By integrating ecological monitoring, restoration strategies, and stakeholder engagement into a unified system, the JSWMS provides a **scalable model for sustainable wetland management and biodiversity conservation**.

The **Joint Sustainable Wetland Management System** represents a **next-generation environmental governance paradigm**, integrating:

- **Science** (innovative bio-expertise)
- **IT Technology** (innovative AI-based system)
- **Society** (innovative participatory e-Engagement)
- **Policy** (innovative cross-border e-Governance)

It operates as a self-adaptive, data-driven, participatory ecosystem management system, capable of addressing complex environmental challenges such as climate change, biodiversity loss, and anthropogenic pressure.

Additional publications

Čeirāns A., Pupiņš M. (**2020**): Abinieku un rāpuļu fona monitoringa metodiku rokasgrāmata. Otrais, pārstrādātais izdevums. - Latgales Ekoloģiskā biedrība: 34 lpp.

Čeirāns A., Pupins M., Kirjusina M., Gravele E., Mezaraupe L., Nekrasova O., Tytar V., Marushchak O., Garkajs A., Petrov I., Skute A., Georges J.-Y., Theissinger K. (**2023**): Top-down and bottom-up effects and relationships with local environmental factors in the water frog–helminth systems in Latvia. – *Scientific Reports*, 13: 8621. https://doi.org/10.1038/s41598-023-35780-7 .

Čeirāns A., Pupins M., Pupina A. (**2020**): A new method for estimation of the minimum adult frog density from a large-scale audial survey. - *Scientific Reports*: 10:8627. https://doi.org/10.1038/s41598-020-65560-6 .

Čeirāns A., Pupins M., Skute A., Nekrasova O., Kirjusina M., Combroux I., Grac C., Kvach Y., van der Zon K.A.E., Theissinger K., Georges J.-Y. (**2024**): Identification and use of suitable metrics for calling male countbased community assessments in amphibian monitoring in temperate Europe. – *Ecological Indicators*. Volume 168, 112771. https://doi.org/10.1016/j.ecolind.2024.112771 .

Dabas datu pārvaldības sistēma Ozols: https://ozols.gov.lv/ozols/ , skatīts 22. 09.**2025**.

Evarts-Bunders P., Evarte-Bundere G., Krasnopoļska D., Lakša D., Daudziņa K., Nitcis M. (**2015**): Reto un aizsargājamo augu sugu kartēšana Daugavpils pilsētas teritorijā. – *Latvijas Veģetacija*, 24: 29-60.

GBIF.org. (**2021**): GBIF Home Page. Retrieved from https://www.gbif.org .

Grabowska J., Kvach Y., Rewicz T., Pupins M., Kutsokon J., Dykyy I., Antal L., Zięba G., Rakauskas V., Trichkova T., Čeirāns A., Grabowski M. (**2020**): First insight into the molecular population structure and origins of the invasive Chinese sleeper, *Perccottus glenii*, in Europe. – *NeoBiota*: 57: 87-107. https://doi.org/10.3897/neobiota.57.48958 .

Jablonski D., Sillero N., Oskyrko O., Bellati A., Carranza S., Čeirāns A., Cheylan M., Cogălniceanu D., Crnobrnja-Isailović J., Crochet P.-A., Crottini A., Doronin I., Džukić G., Geniéz P., Ilgaz C., Iosif R., Jandzik D., Jelic D., Ljubisavljević K., Lymberakis P., Mikulíček P., Mizsei E., Moravecx J., Najbar B., Pupins M., Sourrouille P., Strachinis I., Szabolcs M., Thanou E., Tzoras E., Vergilov V., Vörös J., Gvoždíkx V. (**2021**): The distribution and biogeography of slow worms (Anguis, Squamata) across the Western Palearctic, with an emphasis on secondary contact zones. – *Amphibia-Reptilia,* 42(4), 519-530. DOI: https://doi.org/10.1163/15685381-bja10069 .

Kabuce N. (**2004**): Apdraudētās un aizsargājamās abinieku un rāpuļu sugas Latvijā un Eiropā. – Latvijas Vides aģentūra http://www.lva.gov.lv/daba/lat/ .

Kutsokon Y., Tkachenko M., Bondarenko O., Kvach Y, Pupins M., Snigirova A., Berezovska V., Čeirāns A. (**2021**): The role of invasive Chinese sleeper *Perccottus glenii* Dybowski, 1877 in the Ilgas Nature Reserve ecosystem: an example of a monospecific fish community. – *BioInvasions Records*, 10(2): 396-410. https://doi.org/10.3391/bir.2021.10.2.18 .

Kvach Yu., Kutsokon Ju., Roman A., Kirjušina M., Čeirāns A., Pupins M. (**2020**): Parasite Acquisition by the Invasive Chinese Sleeper (*Perccottus glenii* Dybowski, 1877) (Gobiiformes: Odontobutidae) in Latvia and Ukraine. – *Journal of Applied Ichthyology*, 36: 785-794. Article ID: JAI14100. https://doi.org/10.1111/jai.14100 .

Nekrasova O., Marushchak O., Pupins M., Skute A., Tytar V., Čeirāns A. (**2021**): Distribution and potential limiting factors for European pond turtle's (*Emys orbicularis*) populations of Eastern Europe. – *Diversity*, 13(7): 280. https://doi.org/10.3390/d13070280 .

Nekrasova O., Pupins M., Marushchak O., Tytar V., Martinez-Silvestre A., Škute A., Čeirāns A., Theissinger K., Georges J.-Y. (**2024**): Present and future distribution of the European pond turtle versus seven exotic freshwater turtles, with a focus on Eastern Europe. – *Scientific Reports*, 14:21149. https://doi.org/10.1038/s41598-024-71911-4 .

Nekrasova O., Pupins M., Tytar V., Čeirāns A., Marushchak O., Škute A., Theissinger K., Georges J.-Y. (**2025**): Ensemble modelling for smart conservation strategies for forest reptile species at their range edges in Europe amidst climate change. – *Geography and Sustainability*, 6 (2025) 100266. ISSN 20967438, 26666839. https://doi.org/10.1016/j.geosus.2025.100266 .

Nekrasova O., Tytar V., Pupins M., Čeirāns A. (**2022**): Range expansion of the alien red-eared slider *Trachemys scripta* (Thunberg in Schoepff, 1792) (Reptilia, Testudines) in Eastern Europe, with special reference to Latvia and Ukraine. – *BioInvasions Records*, 11 (1): 287–295. https://doi.org/10.3391/bir.2022.11.1.29 .

Nekrasova, O. D., Tytar, V. M., & Kuybida, V. V. (**2019**). GIS modeling of climate change vulnerability of amphibians and reptiles in Ukraine. NAS of Ukraine, Schmalhausen Institute of Zoology NAS.

Pupina A., Pupins M., Ceirans A., Pupina Ag. (**2019**): Chapter 65. Decline and Conservation of Amphibians in Latvia. – In: Heatwole H. (Editor), Wilkinson J.W. (Editor): Amphibian Biology, Volume 11: Status of Conservation and Decline of Amphibians: Eastern Hemisphere, Part 5: Northern Europe. – United Kingdom, Pelagic Publishing: pp. 122-141.

Pupina A., Pupins M., Skute A., Pupina Ag., Karklins A. (**2015**): The distribution of the invasive fish amur sleeper, rotan *Perccottus glenii* Dybowski, 1877 (Osteichthyes, Odontobutidae), in Latvia. – *Acta Biologica Universitatis Daugavpiliensis* 15 (2): 329-341.

Pupina A., Pupins M., Skute A., Pupina Ag., Karklins A. (**2015**): The distribution of the invasive fish amur sleeper, rotan *Perccottus glenii* Dybowski, 1877 (Osteichthyes, Odontobutidae), in Latvia. - *Acta Biologica Universitatis Daugavpiliensis*, 15 (2): 329 – 341.

Pupiņa Ag., Pupiņš M., Škute N. (**2018**): Daugavpils novada batrahofauna: sugu sastāvs, draudi, izpēte un aizsardzība. – in: Daugavpils novads. Vietas vērtība. – Apgāds "Zinātne": 279-293.

Pupins M. (**2007**): First report on recording of the invasive species *Trachemys scripta elegans*, a potential competitor of *Emys orbicularis* in Latvia. – *Acta Universitatis Latviensis* 273: 37-46.

Pupins M., Khvesko V., Čeirāns A., Garkajs A., Skute A. (**2025**): Latgales Zoo-Wetland mobile App. https://doi.org/10.13140/RG.2.2.31042.64961

Pupins M., Nekrasova O., Marushchak O., Tytar V., Theissinger K., Čeirāns A., Skute A., Georges J.-Y. (**2023**): Potential threat of an invasive fish species for two native newts inhabiting wetlands of Europe vulnerable to climate change. – *Diversity*, 15, 201. https://doi.org/10.3390/d15020201 .

Pupins M., Nekrasova O., Tytar V., Garkajs A., Petrov I., Morozova A., Theissinger K., Čeirāns A., Skute A. Georges J.-Y. (**2023**): Geographically isolated wetlands as a reserve for the conservation of amphibian biodiversity at the edge of their range. – *Diversity*, 15, 461. https://doi.org/10.3390/d15030461 .

Pupiņš M., Pupiņa A. (**2007**): Eiropas purva bruņurupuča *Emys orbicularis* (Linnaeus, 1758) sugas aizsardzības plāns Latvijā. – Latgales ekoloģiskā biedrība, Daugavpils: 104 p.

Pupiņš M., Pupiņa A. (**2008**): Eiropas purva bruņurupuča *Emys orbicularis* (Linnaeus, 1758) sugas aizsardzības plāns Latvijā. Apstiprināts 18.02.2008. ar Vides ministra rīkojumu Nr. 45. – Dabas aizsardzības pārvalde: 104 pp.

Pupins M., Pupina A. (**2011**): First records of 5 allochthonous species and subspecies of Turtles (*Trachemys scripta troostii, Mauremys caspica, Mauremys rivulata, Pelodiscus sinensis, Testudo horsfieldii*) and new records of subspecies *Trachemys scripta elegans* in Latvia. – *Management of Biological Invasions* 2: 69-81.

Pupins M., Pupina A., Pupina Ag. (**2016**): The first experience in new technologies of breeding and semi-natural eggs incubation of northern *Emys orbicularis* in glass-house aquaculture in Latvia. – *Acta Biologica Universitatis Daugavpiliensis*, 16 (2): 201-211.

Pupins M., Pupina A., Pupina Ag. (**2017**): Updated Distribution of the European Pond Turtle, *Emys orbicularis* (L., 1758) (Emydidae) on the Extreme Northern Border of its European Range in Latvia. – *Acta Zoologica Bulgarica*, Supplement 10: 133-137.

Siliņš J., Lamsters V. (**1934**): Latvijas rāpuļi un abinieki. – Rīga, A/S Valters un Rapa: 96 p.

Škute A., Evarts-Bunders P., Čeirāns A., Pupiņš M., Nekrasova O. (2025): Projekta UrbUmbrella Latvijas ekspertu konsolidēts 1. posma ziņojums. Pārbaudīti Latvijas lauka pētījumu dati un lokalizēti atjaunošanas plāni. – Daugavpils Universitāte, 75 lpp

Tytar V., Nekrasova O., Pupina A., Pupins M., Marushchak O. (**2018**): Species distribution modelling as a proactive tool for long-term planning of management of the Fire-bellied toad *Bombina bombina* (Linnaeus, 1761) and its main invasive threat *Perccottus glenii* (Dybowski, 1877) in Latvia under global climate change. – Abstract Book of 2nd International Conference „Smart Bio“. 2018.05.03.-05.05: p. 242.

Vilizzi, L., Suresh, V. R., Giannetto, D., Hill, J. E., Daniel, W. M., Monteiro, J. G., Edsman, L., Elmi, H. Sh. A., Awale, A. I., Najafi-Majd, E., Mammadov, R., Andriyono, S., Djumanto, Azmai, M. N. A., Saba, A., Kalamujić Stroil, B., Adrović, A., Vila-Gispert, A., Boix, D., Kopecký, O., Pavlů, V., Milošević, D., Caković, D., Holbech, H., Lundgreen, K., Lukas, J., Ahnelt, H., Linnamägi, M., Rohtla, M., Almeida, D., Mendoza, R., Fuentes Parada, N., Gilles, A. S., Jr., Pavia, R. T. D., Jr., Knudsen, E., Hansen, L. J., Goulletquer, P., Curd, A., Špelić, I., Jónsson, J. E., Thráinsson, H., Boggero, A., Pupins, M., Škute, A., Petrulaitis, L., Jukonienė, I., Herczeg, G., Ferincz, Á., Verreycken, H., Leuven, R. S. E. W., Malmstrøm, M., Velle, G., Makhkamov, T., Yuldashev, A., Pietraszewski, D., Marszał, L., Canning-Clode, J., Pasuch de Camargo, M., Preda, C., Memedemin, D., Bakiu, R., Bakiu, S., Slovák Švolíková, K., Števove, B., Duniš, L., Kristan, P., Simonović, P., Dekić, R., Puntila-Dodd, R., Jauni, M., Olsson, K. H., Ta, K. A. T., Bui, T. D., Yoğurtçuoğlu, B., Ağdamar, S., Yuldashov, B., Khydyrov, P., Vardakas, L., Koutsikos, N., Perdikaris, C., Lukashanets, D., Borodin, O., Uzunova, E., Dashinov, D., Lazkov, G., Ganybaeva, M., Ualiyeva, D., Zharmukhametova, R., Ristovska, M., Cvetkovska Gjorgjievska, A., Ganbaatar, B., Khadbaatar, S., Panov, V. E., Marenkov, O., Saidov, N., Okhonniyozov, M., Kvach, Y., Yuryshynets, V., Arakelyan, M., Khachatryan, H., Mumladze, L., Japoshvili, B., Pickholtz, R., Gavriel, T., Atique, U., Altaf, M., Iqbal, S., Al-Wazzan, Z., Chebaane, S., Hamdard, M. H., Osmani, A. R., Moghaddas, S. D., Javidpour, J., Nashath, M., Abdullah, F., Sharma, H. P., Shrestha, B. B., Vibhakaran, V., Galib, S. M., Khan, Md. A. G., Epa, U. P. K., Cassim, N., De Zoysa, M., Chaichana, R., Kanongdate, K., Chan, N., Ko Ko, L. M., Dorji, J., Dorji, C., Inkhavilay, K., Somvongsa, C., Soben, K., Nida1, Y., Tesfay, Y. B., Dullo, B. W., Oh, C., Park, Y., Li, S., Wei, H., Koyama, A., Isobe, A., Piria, M. (**2026**): Global framework for communication of biological invasion risks. – Management of Biological Invasions: 17, 1: 1–33. https://doi.org/10.3391/mbi.2026.17.1.01 .

Developed in the INTERREG LV-LT Project "Joint nature-based preservation of climate change/humans-threatened urban LV-LT cross-border wetlands umbrella biodiversity by innovative solutions, reintroduction and joint management" UrbUmbrella Nr. LL-00232.

Pupins M., Nekrasova O., Čeirāns A., Arte I., Skute A. (2026): Joint Sustainable AI-Based Urban Wetland Management System. – Daugavpils University. 45 p.