

to the Contract on the implementation and funding of fundamental and applied research project
(December 20, 2021 Council Decision No. 1-12-133, registry No. lzp-2021/1-0247)

Project Final Scientific Report

Project title:

Ecological and socioeconomic thresholds as a basis for defining adaptive management triggers in Latvian pond aquaculture

1. Scientific Excellence

The threshold concept is commonly invoked as a necessary component of environmental assessment and, more broadly, land-use decision making. Although ecological thresholds can play an important role in environmental assessment, they are not a simple solution to complex socioecological decisions, nor do they ensure objective decision making. In order to make preservation of the biological integrity of ecosystems, the preservation of key biological – ecological thresholds are suggested, they represent an operational, measurable entity inspired by contemporary trends in biological conservation, offering key indicators in design sustainability policies. Based on the topicality of threshold framework and according practical needs of Latvia pond aquaculture sector the following study hypothesis was proposed.

Hypothesis: *Latvia pond aquaculture threshold categories and components (triggers, feedback mechanisms and switch) can be identified by using interdisciplinary (environmental & socio-economic) field study and modeling for sustainability governance applying adaptive management principles and multi-actor approach.*

According to the Project tasks the Multi-Actor Reference Groups (MARG) was established at the beginning of the Project. MARG are formed from directly involved stakeholders representing decision-makers in both public and private sectors, namely aquaculture, environment, nature conservation bodies, etc. as well as individual aquaculture farmers and other business actors being dependent on the ecosystem services (water, biodiversity). Multi-disciplinarity of stakeholders adds value to define threshold characteristics and behaviors by identifying threshold components: triggers, feedback mechanisms and switch. Based on the results of the MARG surveys (including questionnaires, in-depth face-to-face interviews etc.), model species were selected for further studies to model pond aquaculture environmental & socio-economic performance: **1) opportunities 2) threats, and 3) ecosystem services and health** in climate and social events context to determine threshold occurrence, trajectory of the post-threshold state, and threshold reversibility. MARG identified challenges formed three research directions for further MARG based research – MBR (see Figure 1), which formed three groups of model species:

I. Opportunities model species group for pond aquaculture (new thermophilic species for Latvia pond aquaculture): *Lepomis gibbosus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Macrobrachium nipponense*

II. Threats model species group for pond aquaculture (invasive species which threatens Latvia pond aquaculture): *Perccottus glenii*, *Lepomis gibbosus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*.

III. Pond ecosystem health evaluation model species group: 1) bioindication species: amphibian society (*Pelophylax* group: *P. lessonae*, *P. esculenta*, *P. ridibunda*), *Rana temporaria*, *Rana arvalis*, *Bufo bufo*, *Pelobates fuscus*, *Triturus vulgaris*, *Triturus cristatus*, and 2) umbrella-key species *Emys orbicularis* and 3) pond ecosystem threat *Trachemys scripta* and similar species.

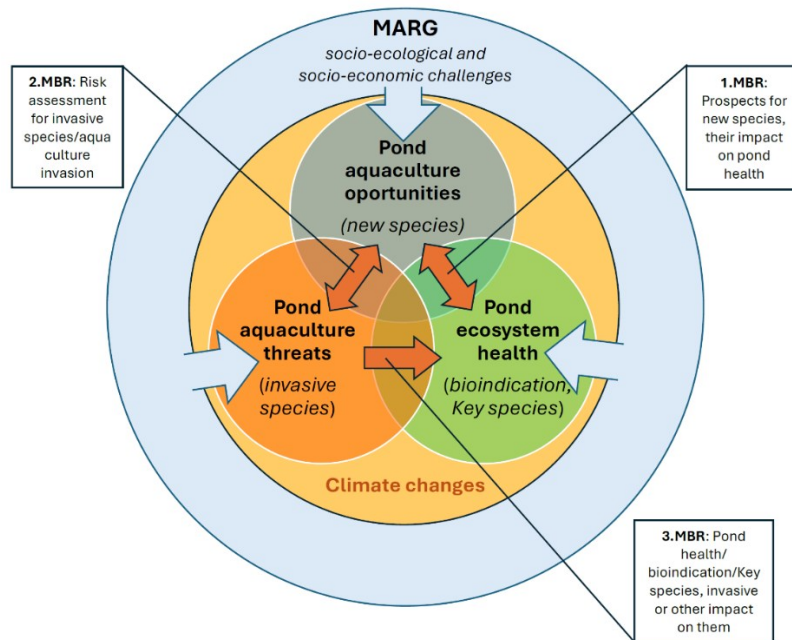


Figure 1 Project MARG Based Research (MBR): **1.MBR** – research direction that identifies triggers and thresholds for the introduction process of new thermophilic species into pond ecosystems under climate change impact; **2.MBR** – research direction that identifies triggers and thresholds for the relationship process between invasive species and aquaculture species in pond ecosystems under climate change impact; **3.MBR** – research direction that identifies invasive species impact triggers and thresholds for pond ecosystem services and health processes using bioindication and umbrella-key species methods.

Conclusions

1. The Multi-Actor Reference Group (MARG), as a collaborative and participatory method, provides an opportunity to ascertain the views of stakeholders and is well suited to pond aquaculture research, providing a valuable opportunity to assess the challenges to the sustainability of Latvian pond aquaculture under the influence of climate change.
2. The MARG Based Research (MBR) methodology allowed identify and classify three main groups of challenges (1.MBR – opportunities, 2.MBR – threats, and 3.MBR – ecosystem services and health) for Latvian pond aquaculture triggers, threshold categories, feedback mechanisms, and switches.
3. Results of 1.MBR showed perspectives for sustainable development trends for Latvia pond aquaculture - new thermophilic species, of which the following species are considered promising *Lepomis gibbosus*, *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Macrobrachium nipponense* [Articles 1, 2, 9, 11, 12].
4. Results of 2.MBR allowed to assess the negative impact from relationship process between invasive species and aquaculture species in pond ecosystems and mitigate its influence, i.g. some new aquaculture species can become invasive in natural water bodies [Articles 2, 7, 8, 9, 10, 11, 13].
5. Results of 2.MBR gave an opportunity to clarify and identifies invasive species impact triggers and thresholds for pond ecosystem services and health processes using bioindication and umbrella-key species methods [Articles 3, 4, 5, 6, 7, 8, 9, 10].

2. Impact

2.1. The project's scientific results

In accordance to FAIR principles, the Project research data and associated metadata were deposited in public repositories that assign persistent and unique identifiers (PIDs), such as Digital Object Identifiers (DOIs) or Accession Numbers. While each repository follows slightly different standards, data and metadata can be found with a range of parameters, such as the publication name, geographical coordinates, sample age, taxon, genomic marker gene, as well as search keywords provided by ourselves. A common depository was set up in the ZENODO database (<https://zenodo.org>), to which all respective researchers will have access prior to open publication of the data.

The scientific results planned in the project (9 SCOPUS articles submitted or accepted at the end of the Project) were exceeded for the Project's final reporting period: 13 SCOPUS articles already published: *ten* of them **Q1-Q2**, *two* SCOPUS articles **Q4**; *one* **Proceedings**.

Table No. 1 Original scientific articles published in journals indexed in the Web of Science Core Collection or SCOPUS databases and their relevance to the three MARG Based Research (MBR) directions

Original scientific articles published in journals indexed in the Web of Science Core Collection or SCOPUS databases, whose citation index reaches at least 50 percent of the industry average citation index (Q1, Q2)				
No	Scientific products (Article)	MARG Based Research (MBR)		
		1. MBR (Opportunities)	2. MBR (Threats)	3. MBR (Ecosystem health)
1.	Oreha J., Morozova A., Garkajs A., Kirjušina M., Gavarāne I., Kostousov V., Pupins M., Škute N. (2024): Genetic diversity and distribution of haplotypes of Freshwater Eel in Baltic Lakeland based on mitochondrial DNA D-Loop and Cytochrome b sequence variation. – <i>Diversity</i> , 16, 9, 522. ID: diversity-3098773. https://doi.org/10.3390/d16090522 ISSN 1424-2818. Web of Science, SCOPUS, Q1.	X		
2.	Nekrasova O., Lepeha A., Pupins M., Škute A., Čeirāns A., Theissinger K., Georges J.Y., Kvach Y. (2024): Prospects for the spread of the invasive Oriental river prawn <i>Macrobrachium nipponense</i> : potentials and risks for aquaculture in Europe. – <i>Water</i> , 16, 2760. https://doi.org/10.3390/w16192760 . ISSN 20734441. Web of Science, SCOPUS, Q1.	X	X	
3.	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. – <i>Ecological Indicators</i> . Volume 168, 112771. https://doi.org/10.1016/j.ecolind.2024.112771 ISSN 1470160X. Web of Science, SCOPUS, Q1.			X
4.	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. – <i>Scientific Reports</i> , 14:21149.			X

No	Scientific products (Article)	MARG Based Research (MBR)		
		1. MBR (Opportunities)	2. MBR (Threats)	3. MBR (Ecosystem health)
	https://doi.org/10.1038/s41598-024-71911-4 . ISSN 20452322. Web of Science, SCOPUS. Q1.			
5.	Čeirāns A., Pupins M., Kirjusina M., Gravele E., Mezaraupē 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. – <i>Scientific Reports</i> , 13: 8621. https://doi.org/10.1038/s41598-023-35780-7 ISSN 20452322. Web of Science, SCOPUS.Q1			X
6.	Tytar V., Nekrasova O., Pupins M., Skute A., Kirjusina M., Gravele E., Mezaraupē L., Marushchak O., Čeirāns A., Kozynenko I., Kulikova A. (2023): Modelling the distribution of the chytrid fungus <i>Batrachochytrium dendrobatidis</i> , with special reference to Ukraine. – <i>Journal of Fungi</i> , 9(6): 607. ISSN 2309608X. https://doi.org/10.3390/jof9060607 Web of Science, SCOPUS, Q1.			X
7.	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. – <i>Diversity</i> , 15 (3): 461. https://doi.org/10.3390/d15030461 ISSN 1424-2818. Web of Science, SCOPUS. Q1.		X	X
8.	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. – <i>Diversity</i> , 15 (2):201. https://doi.org/10.3390/d15020201 ISSN 1424-2818. Web of Science, SCOPUS. Q1.		X	X
9.	Nekrasova O., Pupins M., Tytar V., Fedorenko L., Potrokhov O., Skute A., Čeirāns A., Theissinger K., Georges J.-Y. (2024): Assessing Prospects of Integrating Asian Carp Polyculture in Europe: A Nature-Based Solution under Climate Change? – <i>Fishes</i> , 9, 148. EISSN 2410-3888. https://doi.org/10.3390/fishes9040148 . Web of Science, SCOPUS. Quartile: Q2.	X	X	X
10.	Nekrasova O., Tytar V., Pupins M., Čeirāns A. (2022): Range expansion of the alien red-eared slider <i>Trachemys scripta</i> (Thunberg in Schoepff, 1792) (Reptilia, Testudines) in Eastern Europe, with special reference to Latvia and Ukraine. – <i>BioInvasions Records</i> , 11 (1): 287–295. https://doi.org/10.3391/bir.2022.11.1.29 SCOPUS. Q2.		X	X
Original scientific articles published in journals or conference proceedings indexed in the Web of Science or SCOPUS databases				
11.	Tytar V., Nekrasova O., Pupins M., Skute A., Fedorenko L., Čeirāns A. (2022): Modelling the range expansion of pumpkinseed <i>Lepomis gibbosus</i> across Europe, with a special focus on Ukraine and Latvia. –	X	X	

No	Scientific products (Article)	MARG Based Research (MBR)		
		1. MBR (Opportunities)	2. MBR (Threats)	3. MBR (Ecosystem health)
	<i>North-Western Journal of Zoology</i> , 18 (2): 143-150. Article No.: e221403. https://biozoojournals.ro/nwjz/content/v18n2.html ISSN: 1584-9074. SCOPUS. Q4.			
12.	Oreha J., Morozova A., Garkajs A., Kirjušina M., Škute N. (2023) Genetic Diversity and Population Structure of the European Eel (<i>Anguilla anguilla</i>) in Baltic Lakeland. Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 14th International Scientific and Practical Conference. Volume 1, 161-165; https://doi.org/10.17770/etr2023vol1.7297 SCOPUS	X		
Conference materials - full text (except those indexed in SCOPUS and Web of Science Core Collection)				
13.	Nekrasova O. , Marushchak O., Pupins M. , Tytar V., Georges J.-Y., Theissinger K., Čeirāns A. , Skute A. (2022): Modeling the influence of invasive fish species <i>Perccottus glenii</i> (Dybowski, 1877) on the distribution of newts in Eastern Europe, exemplified by <i>Lissotriton vulgaris</i> (Linnaeus, 1758) and preserved <i>Triturus cristatus</i> (Laurenti, 1768), using a GIS approach. – <i>Biology and Life Sciences forum</i> . 7 pp. Proceedings of the The 2nd International Electronic Conference on Diversity (IECD 2022) New Insights into the Biodiversity of Plants, Animals and Microbes. 2022.03.15.-2022.03.31. MDPI, Basel, Switzerland. https://sciforum.net/paper/view/12440		X	X

2.2. Opportunities for research development

While developing the study and based on the results of the project research, several project applications were prepared, which expand the opportunities for research development (Figure 2).

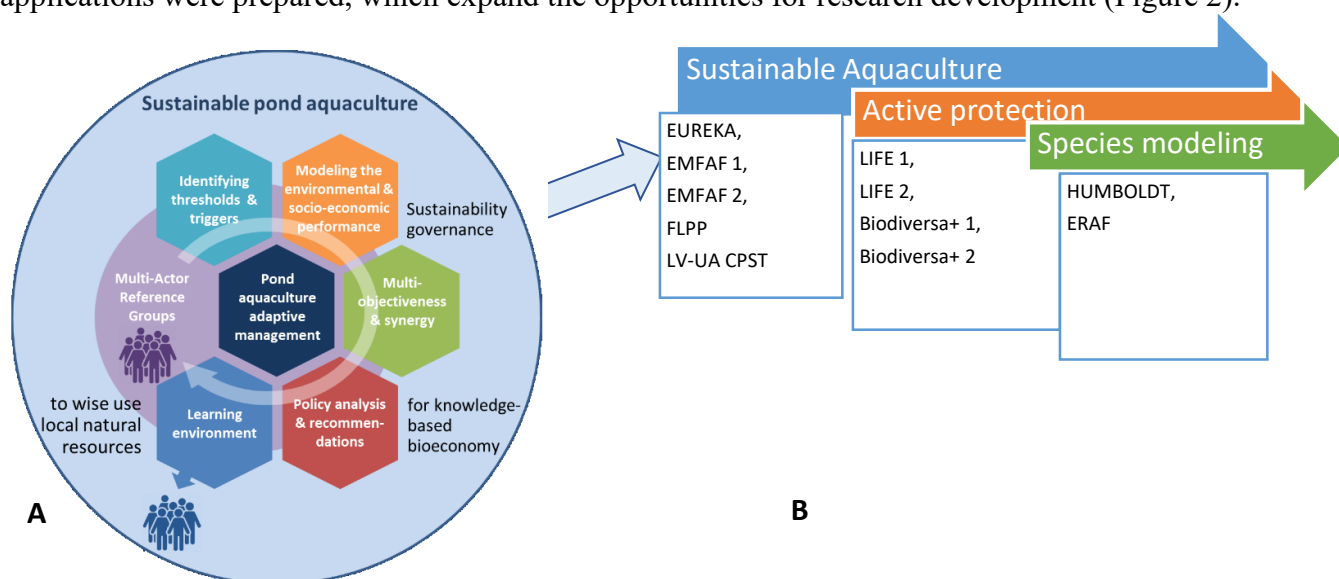


Figure 2 Project lzp-2021/1-0247 concept (A) and research development opportunities (B) in new project proposal (see full list of projects with titles below).

Developing the research opportunities, results and international cooperation with scientists from **32 research institutions** and **16 countries**: Austria, France, Germany, Hungary, Israel, Italy, Lithuania, Moldova, Netherlands, Poland, Romania, Slovenia, Spain, Tunisia, Turkey, Ukraine, to develop and submit **11 Project proposals**.

PROJECT PROPOSALS

- 1) **EMFAF 1**, in the European Maritime, Fisheries and Aquaculture Fund event "Innovation, pilot projects, cooperation with science in fisheries, aquaculture and processing and knowledge transfer in aquaculture" *Pilot project of innovative technology of aquaponics-polyculture mobile eco-container for climate-neutral production of organic aquaculture products in demand on the market* 16.10.2024;
- 2) **EMFAF 2**, in the European Maritime, Fisheries and Aquaculture Fund event "Innovation, pilot projects, cooperation with science in fisheries, aquaculture and processing and knowledge transfer in aquaculture" *Crayfish farming in vertical recirculation aquaculture systems (VRAS)* 27.06.2024.;
- 3) **ERAF**, *Bioclimatic-spatiotemporal modeling tools with artificial intelligence: an eco-innovative solution for mitigating the impact of climate change in Latvian freshwater aquaculture* 17.11.2024.
- 4) **FLPP**, Fundamental and Applied Research Projects of the Latvian Council of Science”, *Spatiotemporal effects modelling of climate change and invasive aquatic species expansion: ecological and socioeconomic threshold-triggered based smart management strategy development for Latvian pond aquaculture sustainability*, 27.04.2024.;
- 5) **LV-UA CPST**, Latvia - Ukraine Cooperation Program in Science and Technology, *Sustainable management of the safe renewable energy-producing for small-scale farms through innovation in biogas co-fermentation process*, 13.09.2024.
- 6) **Biodiversa+ 1** BiodivTransform, *Connectivity and Landscape Ecology Assessment Research for Pathways and Amphibian Transitions in Habitats (CLEARPATH)*, 06.11.2024.;
- 7) **Biodiversa+ 2** BiodivTransform, *Integrated Protected Areas Support System, A Bottom up Approach (IPASS)*, 06.11.2024.;
- 8) **LIFE 1** “*Comprehensive protection of herpetofauna in Natura 2000 areas in north-eastern Europe*”, (acronym: LifeHerpetofaunaPL24), Proposal number: 101198193; LIFE-2024-SAP-NAT-NATURE, 16.09.2024.
- 9) **EUREKA** “*Improvement of pikeperch culture using compensatory growth in the juvenile phase*” Application number 2269 (acronym: OPTI-PERCH), 12.09.2022.
- 10) **LIFE 2** “*Active protection of endangered aquatic and water dependent species and habitats in Northeast Europe*” (acronym: LIFE-BalTur), Proposal number: 101102967; LIFE22-NAT-PL-LIFE-Wetlands-PL2022. 02.10.2022.
- 11) **HUMBOLDT** (Application for MSCA4Ukraine) *Amphibians and reptiles of Eastern Europe under the conditions of climate and anthropogenic changes (chorological features, species distribution modeling and protection)*. 11.11.2022.

Research development (conducting and continuing joint research, developing new joint SCOPUS publications, submitting joint projects and advising new Latvian projects) is already underway and will continue with scientists from **32** institutions from **16** countries (see Table No. 1).

Table No. 2

No.	Collaborating institution/organization, country	Type of collaboration	Period
1.	CCAT Solution Grup, Romania	Submission and implementation of joint projects	2023-2028
2.	CNRS Institut Pluridisciplinaire Hubert Curien IPHC UMR7178, France	Joint research and development of joint <i>SCOPUS</i> publications. Submission and implementation of the joint project EU Biodiversa EMYS-R . Scientific supervision and consultations of the project (No. lzp-2021/1-0247).	2022-2027 2021-2025 2021-2024
3.	Collegium Civitas HIVE - Systems Collective Design Lab, Poland	Implementation of the joint project EU Biodiversa EMYS-R and other projects	2021-2026
4.	Consorci Centre de Ciència i Tecnologia Forestal De Catalunya (CTFC), Spain	Submission and implementation of joint projects	2023-2028
5.	Corvinus University of Budapest, Hungary	Submission and implementation of joint projects	2023-2028
6.	District administration Gernersheim / Departement for Enviroment and agriculture (Untere Naturschutzbehörde), Germany	Submission and implementation of joint projects	2023-2028
7.	Faculty of Sciences, Gabès University, Tunisia	Submission and implementation of joint projects	2023-2028
8.	Free University of Bozen-Bolzano, Italy	Submission and implementation of joint projects	2023-2028
9.	Gdansk University Department of Socio-Economic Geography, Poland	Joint research and development of joint <i>SCOPUS</i> publications. Submission and implementation of the joint project EU Biodiversa EMYS-R .	2022-2025 2021-2025
10.	Hebrew University of Jerusalem, Israel	Submission and implementation of joint projects	2023-2028
11.	Institute of Marine Biology, National Academy of Science of Ukraine, Odessa, Ukraine	Submission and implementation of joint projects. Scientific supervision and consultations of the project (No. lzp-2021/1-0247).	2022-2025 2022-2025
12.	Istanbul Technical University, Turkey	Submission and implementation of joint projects	2023-2028
13.	LOEWE Center for Translational Biodiversity Genomics (TBG), Germany	Joint research and development of joint <i>SCOPUS</i> publications. Submission and implementation of the joint project EU Biodiversa EMYS-R . Scientific supervision and consultations of the project (No. lzp-2021/1-0247).	2022-2027 2021-2025 2021-2024
14.	Martin Luther University Halle-Wittenberg, Germany	Submission and implementation of joint projects, e.g. IPASS and Better LIFE.	2020-2028

No.	Collaborating institution/organization, country	Type of collaboration	Period
15.	Moldova State University, Institute of Ecology and Geography, Moldova	Submission and implementation of joint projects	2023-2028
16.	Moldova State University, Institute of Zoology, Moldova	Submission and implementation of joint projects	2023-2028
17.	Network of Aquaculture Centres in Central and Eastern Europe (NACEE), Bulgaria, Hungary, Lithuania, Moldova, Poland, Ukraine, Latvia, Estonia.	Submission and implementation of joint projects. Scientific supervision and consultations of the project (No. lzp-2021/1-0247). International verification and dissemination of project results.	2022-2032 2022-2026 2022-2032
18.	Sakarya University, Turkey	Submission and implementation of joint projects.	2023-2028
19.	Schmalhausen Institute of Zoology, National Academy of Sciences of Ukraine, Kyiv, Ukraine	Joint research and development of joint <i>SCOPUS</i> publications. Implementation of the joint project EU Biodiversa EMYS-R and other projects	2022-2032 2022-2025
20.	SPOTTERON GmbH, Austria	Submission and implementation of joint projects	2023-2028
21.	UMR GESTE GESTion Territoriale de l'Eau et de l'environnement, France	Submission and implementation of the joint project EU Biodiversa EMYS-R .	2021-2025
22.	Universidad de Málaga, Spain	Submission and implementation of joint projects	2023-2028
23.	University of Primorska Università del Litorale, Slovenia	Submission and implementation of joint projects	2023-2028
24.	University of Utrecht, Netherlands	Submission and implementation of joint projects	2023-2028

2.3. Socio-economic impact of results

The socio-economic impact of the project results was also expressed in cooperation with Latvia's largest aquaculture company [A/S Nagli](#) and participation in the *Network of Aquaculture Centers in Central and Eastern Europe* ([NACEE](#)). For an example of the dissemination of the socio-economic impact of the project results, using DU's participation in the network of Aquaculture centers in Central and Eastern Europe.

As part of the project, a teaching tool was prepared on the method of collecting green frogs for scientific and environmental research, in cooperation with the NGO Latgale Ecological Society and foreign partners (see Table No. 2).

Two policy recommendations and reports on the impact of policies were prepared and presented at two international conferences in Riga and Daugavpils (80th International Scientific Conference of University of Latvia; International Conference on Biodiversity Research), and dedicated to status, triggers and prospects of the invasion of Chinese sleeper (*Perccottus glenii*)

in Latvia and recommendations for territory management of flora and fauna of the Augšdaugava protected landscape area - one of Latvia's largest Natura 2000 areas covering more than 520 km². **Latvia pond aquaculture threshold trajectory and reversibility GIS models** were presented and approved at an international conference in Berlin (36th Congress of the International Society of Limnology) and were dedicated to the distribution trends of invasive Asian carps (*Hypophthalmichthys molitrix* and *Aristichthys nobilis*) in Europe in the context of climate change.

Table No. 3

No.	Collaborating institution/organization, country	Type of collaboration	Period
1.	SIA "CEA FARM"	The results of the project will be used in EMFAF event "Innovation, pilot projects, cooperation with science in fisheries, aquaculture and processing and knowledge transfer in aquaculture" project proposal preparation	2024-2026
2.	SIA "Zivis un zaļumi"	The results of the project will be used in Pilot project of innovative technology of aquaponics-polyculture mobile eco-container for climate-neutral production of organic aquaculture products in demand on the market.	2024-2027
3.	Latvian Biogas Association (LBA)	The results of the project will be used in the ERAF project proposal "Bioclimatic-spatiotemporal modeling tools with artificial intelligence: an eco-innovative solution for mitigating the impact of climate change in Latvian freshwater aquaculture"	2024-2027
4.	A/S Nagli	The results of the project will be implemented and verified by realisation of the Project no. lzp-2021/1-0247. The planned socio-economic impact will be realized by involving a wide spectrum of interested parties (multi-actor approach).	2023-2027
5.	Network of Aquaculture Centres in Central and Eastern Europe (NACEE), Bulgaria, Hungary, Lithuania, Moldova, Poland, Ukraine, Latvia, Estonia.	The results of the project will be imported and verified using DU's participation in the network of Aquaculture Centers in Central and Eastern Europe.	2023-2028
6.	Schmalhausen Institute of Zoology, NAS of Ukraine, Kyiv, Ukraine ; Center for Translational	Pupins M., Čeirāns A., Nekrasova O., Theissinger K., Georges J.-Y. (2022): Method of collecting green frogs for scientific and environmental studies by hand net catching. – Latgales ecological	NA

No.	Collaborating institution/organization, country	Type of collaboration	Period
	Biodiversity Genomics, TBG - Senckenberg Nature Research Institute, Frankfurt, Germany ; Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France	society , 11 pp. DOI: 10.13140/RG.2.2.11505.35682.,	

2.4. Publicity and communication

Publicity and communication activities of the project were carried out according to the plan, participating with reports in international scientific conferences in Latvia and abroad:

1. **Belgium, Oostende. 22nd International Conference on Aquatic Invasive Species. 2022.04.18.-2022.04.22.** Nekrasova O., Pupins M., Marushchak O., Tytar V., Martinez-Silvestre A., Georges J.-Y., Theissinger K., Čeirāns A., Skute A.: Prospects for the invasion of six exotic aquatic turtles' species recorded in Eastern Europe: bioclimatic thresholds.
2. **Czech Republic, Prague. 6th European Congress of Conservation Biology. Biodiversity crisis in a changing world. 2022.08.22.-2022.08.26.** Pupins M., Nekrasova O., Tytar V., Marushchak O., Georges J.-Y., Theissinger K., Čeirāns A., Skute A.: Aquaculture of Asian fish species *Ctenopharyngodon idella*: prospects for adaptation in Eastern Europe in the context of climate change.
3. **Czech Republic, Hluboka nad Vltavou. 23th International Symposium of Association of Astacology. 2022.06.20.-2022.06.25.** Georges J.-Y., Kuhn I., Combroux I., Francesconi C., Grac C., Graf L., Lemonnier G., Meka J., Pardonnet S., Pupins M., Schmidt I., Skute A., Theissinger K.: When reintroduction turns to invasion: a fable about turtles and crayfish.
4. **Estonia, Tartu. Society for Ecological Restoration Europe conference, 2024.08.26-30,** van der Zon K., Georges J.-Y., Grac C., Pupins M., Razafindralay L., Skute A., Theissinger K., Combroux I. (2024): Wetland plants in pond networks: the same restorative action leading to different outcomes in two locations. – Book of abstracts.
5. **Germany, Berlin. 36th Congress of the International Society of Limnology. 2022.08.07.-2022.08.10.** Georges J.-Y., Pupins M., Nekrasova O., Tytar V., Skute A., Čeirāns A., Petrov I., Theissinger K.: Distribution trends of invasive Asian carps (*Hypophthalmichthys molitrix* and *Aristichthys nobilis*) in Europe in the context of climate change.
6. **Latvia, Riga. 80th International Scientific Conference of University of Latvia. Section: Innovative and Applied Research in Biology. 2022.02.18.** Boikova E., Enģele L., Evarte Bundure G., Grandāns G., Pupiņš M., Valainis U.: Natura 2000 excellence values and management challenges in the protected landscape area “Augšdaugava”.
7. **Latvia, Rēzekne. 14th International Scientific Practical Conference “Environment. Technology. Resources”. June 15 – 16, 2023.** Oreha J., Morozova A., Garkajs A., Kirjušina M., Kostousov V., Škute N., Genetic diversity and population structure of the European Eel (*Anguilla anguilla*) in Baltic Lakeland.

8. **Latvia, Daugavpils. International Conference on Biodiversity Research. 2022.10.20.**
 - 1) Grāvele E., Pupins M., Vasylenko V., Mickevičius S., Kirjušina M.: The helminthfauna study of *Rana temporaria* Linnaeus, 1758 in Latvia.
 - 2) N., Skute A., Nekrasova O., Tytar V., Pupins M., Čeirāns A., Marushchak O., Kvach Y., Zamorov V., Kirjusina M.: Status, triggers and prospects of the invasion of Chinese sleeper (*Perccottus glenii*) in Latvia.
9. **Lithuania, Kaunas. VIII Baltic Genetics Congress. March 22-24, 2023.**
 - 1) Oreha J., Morozova A., Garkajs A., Kirjušina M., Kostousov V., Škute N., European Eel (*Anguilla anguilla*) Mitochondrial DNA Diversity in Part of Baltic Lakeland.
 - 2) Nekrasova O., Marushchak O., Pupins M., Tytar V., Georges J.-Y., Theissinger K., Čeirāns A., Skute A. (2022): Modeling the influence of invasive fish species *Perccottus glenii* (Dybowski, 1877) on the distribution of newts in Eastern Europe, exemplified by *Lissotriton vulgaris* (Linnaeus, 1758) and preserved *Triturus cristatus* (Laurenti, 1768), using a GIS approach.
10. **Portugal, Lisbon. IUBMB-FEBS-PABMB Congress. 2022.07.09.-2022.07.14.**

Umbrasko I., Batjuka A., Petjukevics A., Pupins M., Škute N.: Evaluation of microbiome of free-living and Zoo turtles by immunological methods and Raman spectroscopy.
11. **Switzerland, World Biodiversity Forum 2024, Davos, 16-21 June 2024,** Nekrasova O., Marushchak O., Redinov K., Pupins M., Čeirāns A., A. Skute, Tytar V., Moysiienko I., Theissinger K., Georges J.-Y. (2024): Assessing ecocide impacts for developing a conservation strategy in Ukraine. Proceedings P. 95-96.
12. **Switzerland, World Biodiversity Forum 2024, Davos, 16-21 June 2024,** Georges J.-Y., Ceirans A., Combroux I., Grac C., Marushchak O., Meissner U., Meka J., Nekrasova O., Pupins M., Razafindralay L., van der Zon K.A.E., Skute A., Theissinger K. (2024): Benefits and adverse impacts of wetland restoration for species reintroduction. Proceedings P. 46.
13. **Switzerland, World Biodiversity Forum 2024, Davos, 16-21 June 2024,** Nekrasova, O.; Pupins, M.; Marushchak, O.; Meka, J.; Čeirāns, A.; Skute, A.; Tytar, V.; Theissinger, K.; Georges, J.-Y. (2024): Priority areas for biodiversity conservation in the context of global change. Proceedings P. 414.
14. **Switzerland, World Biodiversity Forum 2024, Davos, 16-21 June 2024,** Meka, J.; Marushchak, O.; Nekrasova, O.; Pupins, M.; Škute, A.; Theissinger, K.; Georges, J.-Y. (2024): How can reintroductions of threatened species mitigate biodiversity loss? Proceedings P. 304-305.
15. **Turkey, Antalia. Joint ESENIAS and DIAS Scientific Conference and ESENIAS Workshop. 2022.11.07.-2022.11.15.**
 - 1) Theissinger T., Jean-Yves Georges J.-Y., Pupins M., Nekrasova O., Tytar V., Marushchak O., Čeirāns A., Skute A.: Prospects for the distribution of the North American species signal crayfish *Pacifastacus leniusculus* in Europe.
 - 3) Tytar V., Nekrasova O., Kozynenko I., Marushchak O., Pupins M., Skute A. (2022): The spread of the invasive locust digitate leafminer *Parectopa robiniella* Clemens, 1863 (Lepidoptera: Gracillariidae): The Ukrainian context.
16. **United States, JMIH-2024 - Joint Meeting of Ichthyologists and Herpetologists, 10-14 July 2024, Pittsburgh, PA.** Nekrasova O., Marushchak O., Pupins M., Ceirans A., Skute A., Theissinger K., Georges J.-Y. (2024): Assessment and prospects for the impact of invasive fish on native european amphibians. Abstract Book P. 60.

17. **United States, Ann Arbor, Society for the Study of Amphibians and Reptiles, 27–30 June 2024 Meeting, University of Michigan.** Nekrasova, O., Pupins, M., Čeirāns, A., Bolotova, K., Škute, A., et al. (2024): The impact of climate change on the prospects for transcontinental two-way invasion of reptiles between Europe and America., Ann Arbor, MI, USA, ,

Table No. 4

No.	Activity (e.g. an interview in the media)	Description (in collaboration with whom, target audience if any, website, etc.)	Period/date
1.	Publication of the project and results on the DU website	The activity was carried out in cooperation with Daugavpils University administration and specialists, www.du.lv target audience: pond aquaculture specialists, scientists, students, society.	2022.–2025.
2.	Workshop for the leading aquaculture specialists of Latvia's largest pond farm A/S Nagli	The activity was carried out in cooperation with the administration of pond farming A/S Nagli, target audience: leading specialists	14.10.2022. 16.04.2024.
3.	Publicity of the project's innovative ecological studies and their results by integrating them into the "General Ecology" lecture course for students of the Bachelor of Environmental Science program	9 lectures, 9 seminars. The activity was carried out in cooperation with the administration of Daugavpils University and the lecturers of the target course, target audience: students of the environmental science bachelor's program	2022.–2024. September-December
4.	Publicity of the socio-economic results of the project by integrating them into the lecture course "Applied biology and bioeconomy I: Maintenance and protection of natural living resources" for students of the Master's program in Biology	3 lecture, 6 practical works. The activity was carried out in cooperation with the administration of Daugavpils University and the lecturers of the target course, target audience: students of the Biology Master's program	2022.–2024. October-December
5.	Publicity of the project and innovative research methods by integrating them into the lecture course "Field Research Methodology" for students of the Master's Program in Biology	6 lectures, 3 practical work. The activity was carried out in cooperation with the administration of Daugavpils University and the lecturers of the target course, target audience: students of the Biology Master's program	2022.–2024. October-December
6.	Publicity of the project and its innovative methods in aquaculture by integrating them into the lecture course	3 lectures, 3 practical work. The activity was carried out in cooperation with the administration of Daugavpils University and the lecturers of the target course, target audience: 17 students of the	2022.–2024. October-November

No.	Activity (e.g. an interview in the media)	Description (in collaboration with whom, target audience if any, website, etc.)	Period/date
	"Applied Biology and Bioeconomy I: Maintenance and Protection of Natural Living Resources" for students of the Master's Program in Biology from Malaysia and the Philippines	Biology Master's program from Malaysia and the Philippines as well as from Turkey and Kenya	
7.	Project launch press release: Project goals and methods	The activity was carried out in cooperation with the administration of Daugavpils University and reserchers, https://du.lv/project/ekologiskie-un-socialekonomiskie-slieksni-ka-pamats-lai-definetu-adaptivas-parvaldibas-trigerus-latvijas-diku-akvakultura/ target audience: mass media, society, specialists	2022.–2024.

2.5. Contribution to the capacity building of the project's scientific steam, including the students, as well as to the improvement of the study environment

The project has a significant contribution to building the capacity of the Project's scientific group, including students, as well as improving the study environment. The scientific group of the Project increased its scientific qualification and research capacity by publishing **13 SCOPUS articles** in journals (including **ten** in **Q1-Q2**) and developing innovative research methods, which were learned by all Project participants.

A significant improvement of the study environment was provided by the integration of the innovative research methods and results of the Project in the Daugavpils University study courses: *Basics of Aquaculture, Hydroecology, Environmental Impact Assessment, Methods of Environmental Monitoring, Field research methodology* and active participation of students in the implementation of the Project.

Table No. 5

Doctoral, master's or bachelor's theses supervised or advised by the principal investigator or the lead participants within the framework of this project (if the thesis is defended, indicate it in the last column of the table, specifying the date and the promotional council).

No.	Author	Title	Supervisor and consultant	Defense
1.	Nikita Bašmakovs	Using echosounding methods to determine quantities of fish in lake Svente	Artūrs Škute	Bachelor's thesis, defended 08/06/2022, at the meeting of the final examination commission for DU bachelor's theses
2.	Viktorija Adamoviča	Using the bioindication method in assessing biological diversity in pond ecosystems	Artūrs Škute	Bachelor's thesis, defended 05/06/2023, at the meeting of the final examination commission for DU bachelor's theses

No.	Author	Title	Supervisor and consultant	Defense
3.	Anastasija Čerkesa	Genetic structure of perch (<i>Perca fluviatilis</i> (L.)) population in the Daugava River near Plavinas city	Natalja Škute, Artūrs Škute	Master's thesis, defended 05/06/2023, at the DU master's theses final examination committee meeting
4.	Sandra Stankeviča	Data analysis of problematic wastewater treatment plants and development of a GIS database	Dainis Lazdāns, Artūrs Škute	Master's thesis, defended 04/06/2024, at the DU master's theses final examination committee meeting
5.	Līga Rasnača	Flood risk assessment in Jekabpils city in the context of climate change	Dāvis Gruberts, Artūrs Škute	Master's thesis, defended 04/06/2024, at the DU master's theses final examination committee meeting
6.	Aja Brakovska	<i>Daphnia cucullata</i> Sars, 1862, place in zooplankton coenoses, its genetic diversity in deep lakes of Eastern Latvia	Natalja Škute, Artūrs Škute	Doctoral thesis defense on January 19, 2024 at the meeting of the DU Biology Doctoral Council
7.	Līga Krasovska	Wetlands ecological hotspots: invasive and threatened species top-down and bottom-up interactions, triggers, and thresholds	Artūrs Škute, Mihails Pupinš, Natalja Škute	First-year PhD student, started studies in September 2024

3. Implementation

For the second half of the project, after the Project Interim Report the Project team continued:

1. focus research and publishing activity in line with the project topic and tasks planned in the project proposal,
2. invest effort in communication with key stakeholders including the public,
3. develop and follow a data management plan that adheres to the principles of FAIR or similar open science

1. To focus research and publishing activity in line with the project topic and tasks planned in the project proposal

Goal of the project, *to ascertain of pond aquaculture ecological and socioeconomic thresholds and triggers by using environmental & socio-economic performance modeling and Multi-Actor Reference Groups (MARG) for environmental and sustainability governance guidance* was achieved (see Table No.1 and Figure 1 for the scientific products relation to the project topic) and guidelines were developed, has DOI and published at Daugavpils University Project website and ZENODO. Two PhD students were involved in the project implementation and one doctoral thesis was defended, the other doctoral student is continuing his studies (see Table No.5 for details).

2. To invest effort in communication with key stakeholders including the public,

Participation key stakeholders from different aquaculture companies (including RAS) in MARG events, developed new cooperation between the aquaculture company SIA “CEA FARM” and Daugavpils University who jointly developed new and effective solutions and methods for crustacean farming in vertical recirculation aquaculture systems (VRAS), introducing two new species (Australian red-clawed crayfish – *Cherax quadricarinatus* and freshwater giant shrimp – *Macrobrachium rosenbergii*) with high market value in Latvian aquaculture. In collaboration with the aquaculture company SIA “Zivis un zaļumi”, a new EMFAF project proposal was prepared, developing new and effective solutions and methods in the Aquaponics-Polyculture mobile eco-container ecosystem.

The Latvian Biogas Association (LBA) supports the application of the Daugavpils University project “Bioclimatic-spatiotemporal modeling tools with artificial intelligence: an eco-innovative solution for mitigating the impact of climate change in Latvian freshwater aquaculture”. One of the project activities directly follows from the main results of our current Project and is related to research into biogas production technologies aimed at reducing production costs and more efficient use of aquaculture by-products (biomass of pond overgrowth, including invasive plant species), promoting the transition of local companies to more environmentally friendly production methods.

To expand communication with key stakeholders including the public the *Environmental and Sustainability Governance (ESG) guidance* and *Web-based interactive Learning environment* (both in Latvian) were developed and published at DU Project homepage in open access.

3. To develop and follow a data management plan that adheres to the principles of FAIR or similar open science

Data management plan was developed and followed according Open Science principles: Open access, FAIR data and others. A common depository was set up in the ZENODO a CERN Data Centre-backed research data repository for the long-tail of science, enabling researchers to preserve and share their research output from any science, regardless of the size and format. ZENODO is an innovative and easy to use web-platform, which allows for upload, curation and sharing of the research data through an easy-to-use web interface and integration with other collaboration and data sharing services. ZENODO ensures the discovery and citability of the research output by assigning a Digital Object Identifier (DOI) to every upload.