Interreg
Latvija–Lietuva
European Regional Development Fund

EUROPEAN UNION

Joint management of Latvian – Lithuanian trans-boundary river and lake water bodies (TRANSWAT) LLI-533

Report of the ecological status of transboundary lakes

LATVIJAS VIDES, ĢEOLOĢIJAS UN METEOROLOĢIJAS CENTRS
LITHUANIAN ENERGY INSTITUTE
BIOR
UNIVERSITY OF LATVIA

This document has been prepared as part of the project TRANSWAT, which is funded by the European Union under the Interreg V-A Latvia–Lithuania Programme 2014-2020. Project duration is 2 years (01.10.2020-30.09.2022). Total project size is 607 466,51 EUR. Out of them co-funding of European Regional Development Fund is 516 346.53 EUR.

2022

Table of Contents

List of used abbreviations 4
1. Introduction 5
2. Ecological quality of Lake Ilzu (Garais)/Ilge 8
2.1. Lake water body type 8
2.2. Major pressures in the lake catchment 8
2.3. Overview of previous monitoring results 9
2.4. Phytoplankton indicators 10
2.5. Macrophytes indicators 11
2.6. Benthic invertebrates' indicators 11
2.8. Physico-chemical indicators 13
2.9. Hydromorphological indicators 14
2.10 Indicators not covered by the WFD 17
2.10.1. Zooplankton organisms 17
2.10.2. Composition of lake sediments 19
2.11. Summary ecological quality according to the WFD criteria 21
3. Ecological quality of Lake Lielais Kumpinišku/ Kampiniskiai 23
3.1. Lake waterbody type 23
3.2. Major pressures in the lake catchment 23
3.3. Overview of previous monitoring results 24
3.4. Phytoplankton indicators 24
3.5. Macrophytes indicators 25
3.6. Benthic invertebrates' indicators 26
3.7. Fish indicators 27
3.8. Physico-chemical indicators 28
3.9. Hydromorphological indicators 29
3.10. Indicators not covered by the WFD 31
3.10.1. Zooplankton organisms 31
3.10.2. Composition of lake sediments 32
3.11. Summary ecological quality according to the WFD criteria 34
4. Ecological quality of Lake Galiņu/Salna 35
4.1. Lake waterbody type 35
4.2. Major pressures in the lake catchment 35
4.3. Overview of previous monitoring results 36
4.4. Phytoplankton indicators 36
4.5. Macrophytes indicators 37
4.6. Benthic invertebrates' indicators 38
4.7. Fish indicators 39

4.8. Physico-chemical indicators 39
4.9. Hydromorphological indicators 41
4.10. Indicators not covered by the WFD 43
4.10.1. Zooplankton organisms 43
4.10.2. Composition of lake sediments 43
4.11. Summary ecological quality according to the WFD criteria 45
5. Ecological quality of Lake Skirnas 47
5.1. Lake waterbody type 47
5.2. Major pressures in the lake catchment 47
5.3. Overview of previous monitoring results 48
5.4. Phytoplankton indicators 48
5.5. Macrophytes indicators 49
5.6. Benthic invertebrates' indicators 50
5.7. Fish indicators 51
5.8. Physical and chemical indicators 51
5.9. Hydromorphological indicators 53
5.10. Indicators not covered by the WFD 55
5.10.1. Zooplankton organisms 55
5.10.2. Composition of lake sediments 56
5.11. Summary ecological quality according to the WFD criteria 57
6. Ecological quality of Lake Laucesas/Laukesas 59
6.1. Lake waterbody type 59
6.2. Major pressures in the lake catchment 59
6.3. Overview of previous monitoring results 60
6.4. Phytoplankton indicators 61
6.5. Macrophytes indicators 61
6.6. Benthic invertebrates' indicators 62
6.7. Fish indicators 63
6.8. Physico-chemical indicators 64
6.9. Hydromorphological indicators 65
6.10. Indicators not covered by the WFD 68
6.10.1. Zooplankton organisms 68
6.10.2. Composition of lake sediments 68
6.11. Summary ecological quality according to the WFD criteria 70
7. Comparison of ecological quality in the studied transboundary lakes 72
8. Comparison of the results of transboundary lake status assessment using Latvian and Lithuanian fish sampling data and fish-based methods 74
9. References 76

List of used abbreviations

Chl-a	chlorophyll-a
CPUE	catch per unit of effort
d.w.	dry weight
EQR	ecological quality ratio
LHS	lake habitat survey
LLMI	Lithuanian Lake Macroinvertebrate Index
LLMMI	Latvian Lake Macroinvertebrate Multimetric Index
QEs	quality elements
RBSP	river basin specific pollutant
TN	total nitrogen
TP	total phosphorus
WFD	Water Framework Directive
WWTP	wastewater treatment plant

Kokorīte, I. (red.) (2022)

List of authors in alphabetical order:

Aleksejevs Ē., Čičendajeva M., Dimante-Deimantoviča I., Dobkeviča L., Grīnberga L., Jēkabsone J., Kokorīte I., Križickis E., Medne R., Ozoliņš D., Skuja, A., Virbickas, T.

This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of project partners and can under no circumstances be regarded as reflecting the position of the European Union.

1. INTRODUCTION

Water Framework Directive 2000/60/EC (WFD) sets comprehensive requirements to the procedure of assessment of ecological status of surface water bodies.

To enable correct status assessment, surface waters are subdivided into four categories (rivers, lakes, coastal waters, transitional waters), each of those is further subdivided into types based on abiotic factors such as altitude, geology, size, etc. using system A or system B described in Annex II of the WFD. For each type, near-natural or reference conditions have to be established that correspond to a state without any significant anthropogenic impact.

Classification of status of water bodies is based on comparison with reference conditions mentioned above: the greater the deviation from reference conditions, the worse is the status class. For surface water bodies, WFD foresees classification into five ecological status classes (high; good; moderate; poor; and bad). Classification has to be performed on the basis of the so-called quality elements (QEs) that form three major groups: biological, physico-chemical, and hydromorphological QEs that are listed in Annex V of the WFD. For lakes, QEs listed in the WFD Annex V are as follows:

- **biological QEs**: phytoplankton; other aquatic flora (namely, macrophytes and phytobenthos); benthic invertebrate fauna; and fish fauna;
- **chemical and physico-chemical QEs** supporting the biological elements: transparency; thermal conditions; oxygenation conditions; salinity; acidification status; nutrient conditions; as well as specific pollutants (RBSP) if discharged into particular water body;
- **hydromorphological QEs** supporting the biological elements: quantity and dynamics of water flow; residence time; connection to groundwater body; lake depth variation; structure and substrate of the lake bed; structure of the lake shore.

From that list, Member States are able to choose those quality elements that are relevant for their established surface water types. For instance, acidification of surface waters is not recognized as a common problem in Latvia, therefore evaluation of acidification status of lakes is not included into ecological status assessment.

For each quality element, national methodology for status classification has to be developed. To ensure comparability of national approaches (that is, what exactly is considered a slight or significant deviation from reference conditions), intercalibration task is performed by an international working group called WG A ECOSTAT.

When status class is known for all relevant quality elements, overall status of a particular water body is assessed following a scheme provided e.g., in the WFD Guidance Document No.13 “Overall Approach to the Classification of Ecological Status and Ecological Potential” (Fig. 1.1.).

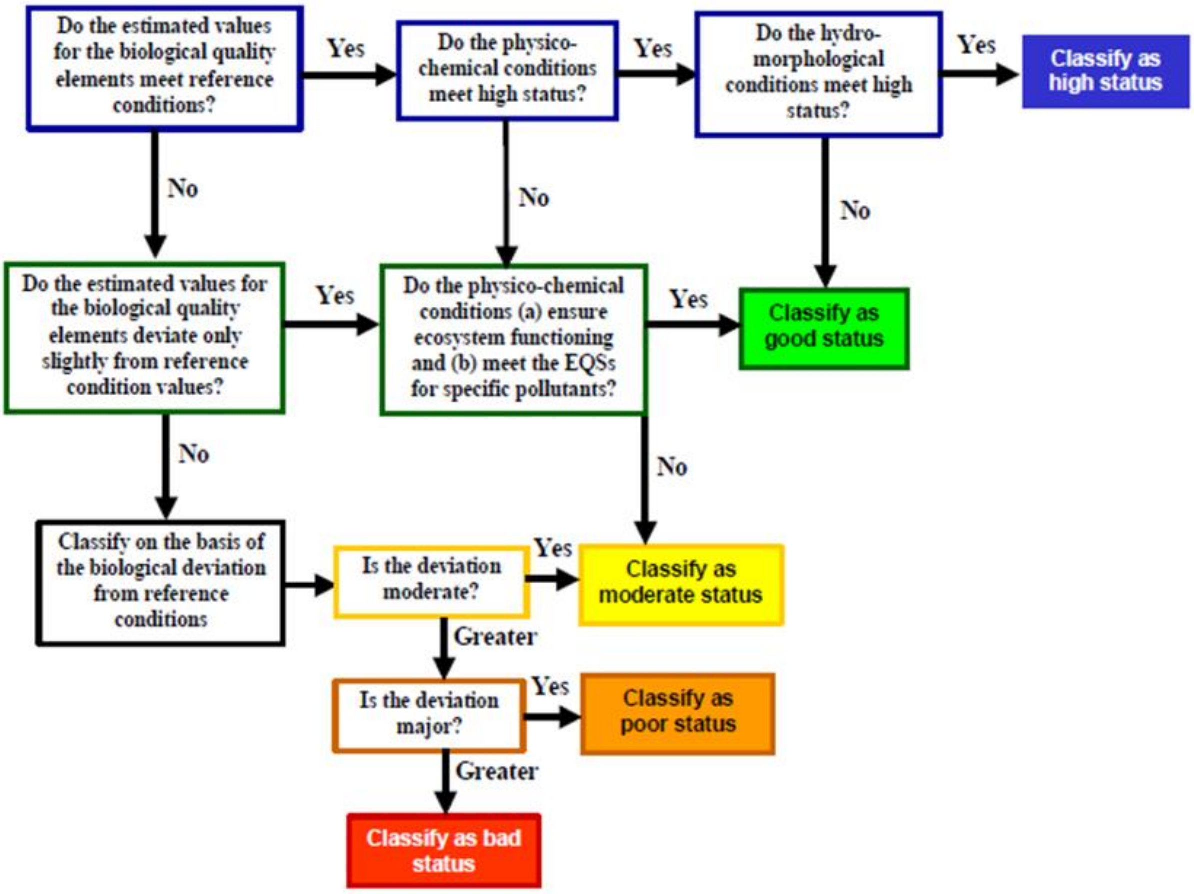

Figure 1.1. Indication of the relative roles of biological, hydromorphological and physico-chemical quality elements in ecological status classification. Cited from: WFD GD No.13.

Biological quality elements are considered most important in overall status assessment because they provide an indication of the resulting impact of different pressures and their combinations on the water ecosystem. With the “one-out, all-out” principle in mind, still the overall status of a water body cannot be classified as poor or bad if biological QEs correspond to high or good status. On the other hand, overall status can be classified as high only where all three groups of QEs show high status.

Surface waters and groundwater present a continuous environment around the globe. Therefore, the Water Framework Directive introduces a catchment approach in management of water resources and requires international cooperation to achieve at least good status of water bodies. For countries that are EU Member States, that includes coordination of national typologies, participation in the intercalibration exercise, as well as coordination of monitoring and classification of status of transboundary water bodies.

Joint assessment of status of Latvian-Lithuanian transboundary lake water bodies, complemented with assessment of significant pressures in their whole catchment, is a basis for selection of appropriate measures or management activities, to improve status of these water bodies or prevent existing good status from deterioration in the future.

Within the scope of the TRANSWAT project, assessment of status of transboundary lakes is supplemented by evaluation of zooplankton cenosis and of the lake sediments.

Zooplankton is not included as a biological quality element for the WFD and there have been a lot of debates about that since no doubt it is an important element of the lake pelagial ecosystem. Zooplankton is proved to be an indicator of a strong value and there are both recommendations to include it in the WFD assessments and also to keep its monitoring in order to build solid long term data.

2. ECOLOGICAL QUALITY OF LAKE ILZU (GARAIS)/ILGE

2.1. Lake water body type

According to the lake typology in Latvia, Lake Ilzu (Garais)/Ilge belongs to the type L5. It is a shallow clearwater lake with high water hardness. Average depth of the type L5 lakes is in the range 2 – 9 m, water colour is <80 mg Pt/L and electric conductivity (an indicator of water hardness) is >165 µS/cm.

Monitoring results confirm the current lake type. Lake average depth is 2.4 m. According to measurements done in 2021, yearly average colour is 22 mg Pt/L (varies from 15.1 mg Pt/L to 45 mg Pt/L), and conductivity is 355 µS/cm (varies from 324 µS/cm to 448 µS/cm).

According to the lake typology in Lithuania, the lake belongs to type 1, that is a shallow polymictic lake.

2.2. Major pressures in the lake catchment

In Latvian side, according to Latvian 3rd cycle River basin management plans 2022-2027, the most significant pressure on the lake is the risk of transboundary pollution from Lithuanian side. Diffuse pressure from forests and agricultural lands are considered insignificant.

Lake Ilzu (Garais)/ Ilge is a natural lake without significant water level alterations caused by unnatural factors. Hydromorphological pressure is insignificant in Latvian side and drainage (amelioration) systems occupy only about 0.5 % of the total lake catchment. No hydrological structures such as dams, weirs or other can be found on inflowing and outflowing rivers and ditches. Forest lands take 39 % of the total transboundary catchment area, while 47 % of the area is occupied by agricultural lands. Arable land occupies only about 4.6 % and therefore are not considered as significant pressure. Arable land is considered a significant pressure if its area in the catchment area exceeds 35 %.

The modelling results show that the greatest share of nitrogen loads within the catchment originate from agricultural lands and forests – 54 % and 34 %, respectively. Most important sources of phosphorus load are agricultural lands and forests as well, runoff from agricultural lands accounts for 56 % of P loads and runoff from forests for 33 % of the total load in the catchment.

Nitrogen (N) and phosphorus (P) load distributions by sectors in Lake Ilzu (Garais)/Ilge catchment for 2021 are shown in Figures 2.2.1. and 2.2.2.

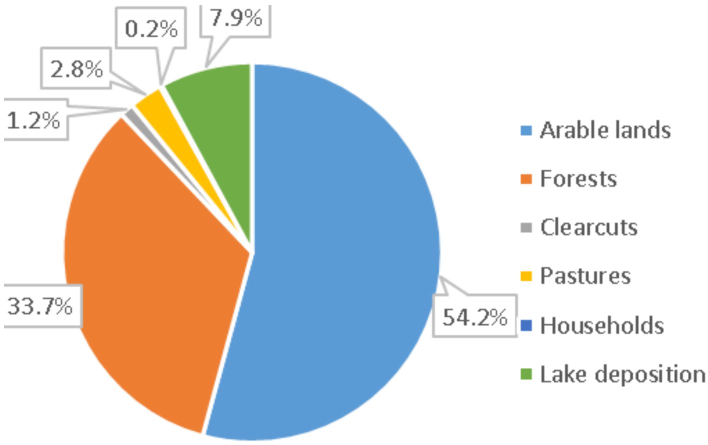

Figure 2.2.1. Nitrogen source apportionment in Lake Ilzu (Garais)/ Ilge catchment.

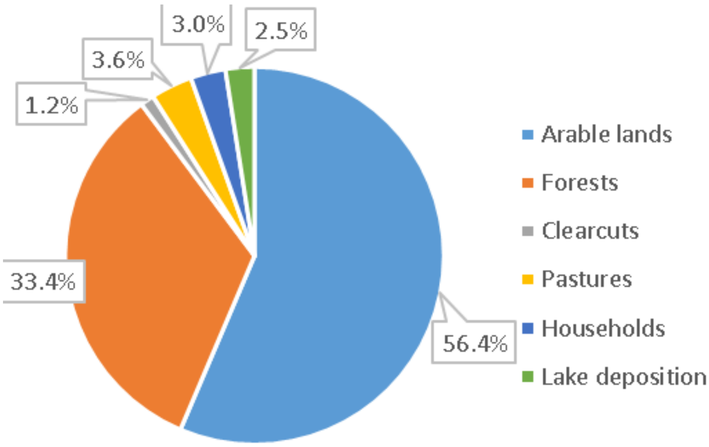

Figure 2.2.2. Phosphorus source apportionment in Lake Ilzu (Garais)/Ilge catchment

In Lithuania, the Lake Ilzu (Garais)/ Ilge has not been previously identified as a water body and has therefore not been monitored. The lake shore is subject to quite intensive economic activity, but there are no known point sources of pollution (no wastewater treatment plants that exceed the volume of wastewater discharged, which triggers the obligation to register the treatment plants and to monitor the quality of the wastewater). The diffuse pollution load is also not yet modelled. Nevertheless, according to an expert assessment, the lake is classified as being at risk in the River Basin Management Plan for the 3rd cycle.

2.3. Overview of previous monitoring results

In Latvian side, there is one surface water quality monitoring station in Lake Ilzu (Garais) – *Garais ezers (Rites pag.), vidusdaļa*. It is located in the middle part of the lake and monitoring has been carried out by the Latvian Environment, Geology and Meteorology Centre. During the first and second monitoring cycle this lake was one of the most frequently monitored water bodies in Latvia (Table 2.3.1.). The ecological status of the lake water body is very stable – moderate/poor. The ecological quality according to benthic invertebrates has slightly improved because new assessment methods have been developed. Ecological quality according to phytoplankton has not significantly changed and is moderate. Algal blooms could be observed periodically. Also, the physical-chemical quality (nutrients) has mostly changed minimally within the existing quality class.

Table 2.3.1. Long-term changes of Lake Ilzu (Garais) ecological quality (LEGMC data).

Year	Benthic invertebrates	Macrophytes	Phytoplankton	Biology, total	TN, mg/L	TP, mg/L	Secchi, m	Physico-chemical, total	Total status
2006	Poor		Good	Poor	1.4	0.042	1.3	Moderate	Poor
2007			Moderate	Moderate	1.3	0.049	0.6	Poor	Moderate
2008	Moderate		Moderate	Moderate	1.2	0.053	0.5	Poor	Moderate
2010			Moderate	Moderate	0.4	0.041	0.8	Poor	Moderate
2011	Good		Moderate	Moderate	0.9	0.053	0.5	Poor	Moderate
2014	Good	Poor	Moderate	Moderate	1.02	0.044	1.0	Moderate	Poor

2.4. Phytoplankton indicators

Phytoplankton samples were collected twice during the vegetation season – in May and August. Minor seasonal variations were observed, and Latvian phytoplankton EQR index value varied from 0.59 (moderate quality) to 0.80 (good quality). Annual average quality is good. Although blue-green algae blooms can be found in the lake, we didn't observe those in 2021. Chlorophyll-a concentrations varied from 11.9 µg/L (moderate quality class) to 35 µg/L (poor class).

According to the Lithuanian phytoplankton method, the ecological quality of the lake is moderate.

Although the phytoplankton methods of the two countries are intercalibrated, the EQR values still belongs to different quality classes (Table 2.4.1.). Phytoplankton shows decreased ecological quality in August. Chl-a concentrations are relatively high as well and indicates less than good ecological quality.

Table 2.4.1. Ecological status assessment by phytoplankton.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.70	Moderate	0.48

2.5. Macrophytes indicators

In the Lake Ilzu (Garais)/ Ilge, growth of macrophytes is limited by low water transparency caused by algae blooming or other suspended material. Species diversity is low, only 18 species are found. Dominating species are *Phragmites australis, Nuphar lutea, Potamogeton natans, Ceratophyllum demersum*. Emergent macrophytes dominate in the species composition (61% of all species), and only 3 submerged species are found (Fig. 2.5.1.).

Figure 2.5.1. One of the dominating macrophyte species (Ceratophyllum demersum) demonstrates low water transparency.

Macrophytes indicate poor ecological water quality in Lake Ilzas (Garais)/ Ilge (Table 2.5.1.). Colonization depth of submerged macrophytes is only 1.3 m. Charophytes are absent in the lake, and Potamogeton species occur very rare. One of the dominating species *Ceratophyllum demersum* is an indicator of eutrophic waters. For turbid lakes, macrophytes are not an appropriate indicator for quality assessment, but it is important to monitor species composition and abundance to understand changes in the ecosystem of lake.

Table 2.5.1. Ecological status assessment by macrophytes.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Poor	0.4	Moderate	0.25

2.6. Benthic invertebrates' indicators

The macroinvertebrates were sampled using a hand-net in May and October 2021 at three sampling points in the littoral zone. Sample processing, identification level of macroinvertebrate taxa and the ecological quality assessment was carried out according to the methodology described by Skuja and Ozoliņš (2016). The Lake Ilzu (Garais)/ Ilge is at good status (Table 2.6.1.) according to the LLMMI (Skuja and Ozoliņš, 2016) and LLMI (Šidagytė et al. 2013).

Table 2.6.1. Ecological quality of Lake Ilzu (Garais) according to benthic invertebrates.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.67	Good	0.58

In general, abundance and number of macroinvertebrate taxa was higher at the 1st and 3rd sampling sites. The overall benthic invertebrate taxonomic composition in littoral is characteristic of a eutrophic lake. In spring, altogether 55 macroinvertebrate taxa were identified. Larvae of Chironomidae were the most abundant taxa at all sampling sites. Mayfly nymphs *Caenis horaria* and water mites Hydrachnidia were also common. The highest taxonomic diversity was characteristic for caddisfly Trichoptera larvae (14 taxa).

In autumn, altogether 47 macroinvertebrate taxa were identified, similarly to spring season larvae of Chironomidae were the most abundant at all sampling sites. Larvae of damselflies were also abundant. Caddisflies were represented by 12 taxa.

2.7. Fish indicators

Fish sampling in Lithuanian part of the lake was carried out in August 2021. In total, 9 fish species were recorded. Catches were dominated by roach and bream, accounting for 84.8 % of the total number of fish and 72.1 % of the total biomass. The relative abundance of piscivorous perch was extremely low, although under reference conditions this species should be one of the dominant species in polymictic lakes. According to the Lithuanian lake fish index, the ecological status of the lake is moderate, but close to the moderate/poor status boundary.

Fish sampling in Latvian part of the lake was carried out at the end of August 2021. In total, 5 (12 in all gears) fish species were recorded. Catches were dominated by bream and roach, accounting for 93.1% of the total number of fish and 84.6% of the total biomass. The relative abundance of piscivorous perch was low (5,2% and 14.2%). According to the Latvian lake fish index, the ecological status of the lake is poor (Table 2.7.1.).

Table 2.7.1. Ecological quality of Lake Ilzu (Garais) according to fish.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Poor	0.35	Moderate	0.39

2.8. Physico-chemical indicators

In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

According to TP concentration, ecological quality of the Lake Ilzu (Garais) / Ilge is good, but TN concentration and Secchi depth measurement values indicate moderate ecological quality. According to Lithuanian methodology, the lake is in high status based on TP concentration, in good status according to TN, and moderate according to transparency. It should be noted that only summer season measurements of transparency were available for the assessment. Based on the WFD principle "one-out, all-out", the overall physico-chemical quality of the lake is estimated as moderate due to elevated TN concentration and low transparency (Table 2.8.1.).

Table 2.8.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (colour scheme as for the EU WFD: blue – high, green – good, yellow – moderate, orange – poor, and red – bad ecological quality).

Latvia		**Lithuania**	
parameter	*average value*	*parameter*	*average value*
TP, mg/L	0.033	TP, mg/L	0.033
TN, mg/L	1.14	TN, mg/L	1.14
Secchi depth, m	1.10	Secchi depth, m	1.10
TOTAL	**moderate**	**TOTAL**	**moderate**

Oxygen concentration is one of the most important indicators to describe lake ecosystem health. According to commonly used water quality standards, including those for priority fish waterbodies, healthy oxygen concentration must exceed 5 mg/L. In lake Ilzu (Garais)/Ilge O_2 concentration exceeds 5 mg/L only in shallowest parts until 2 m depth. Most of the lake area is deeper than 2 m and 74 % of the lake can be characterized as unsuitable for fish and other aquatic organisms (Fig. 2.8.1.).

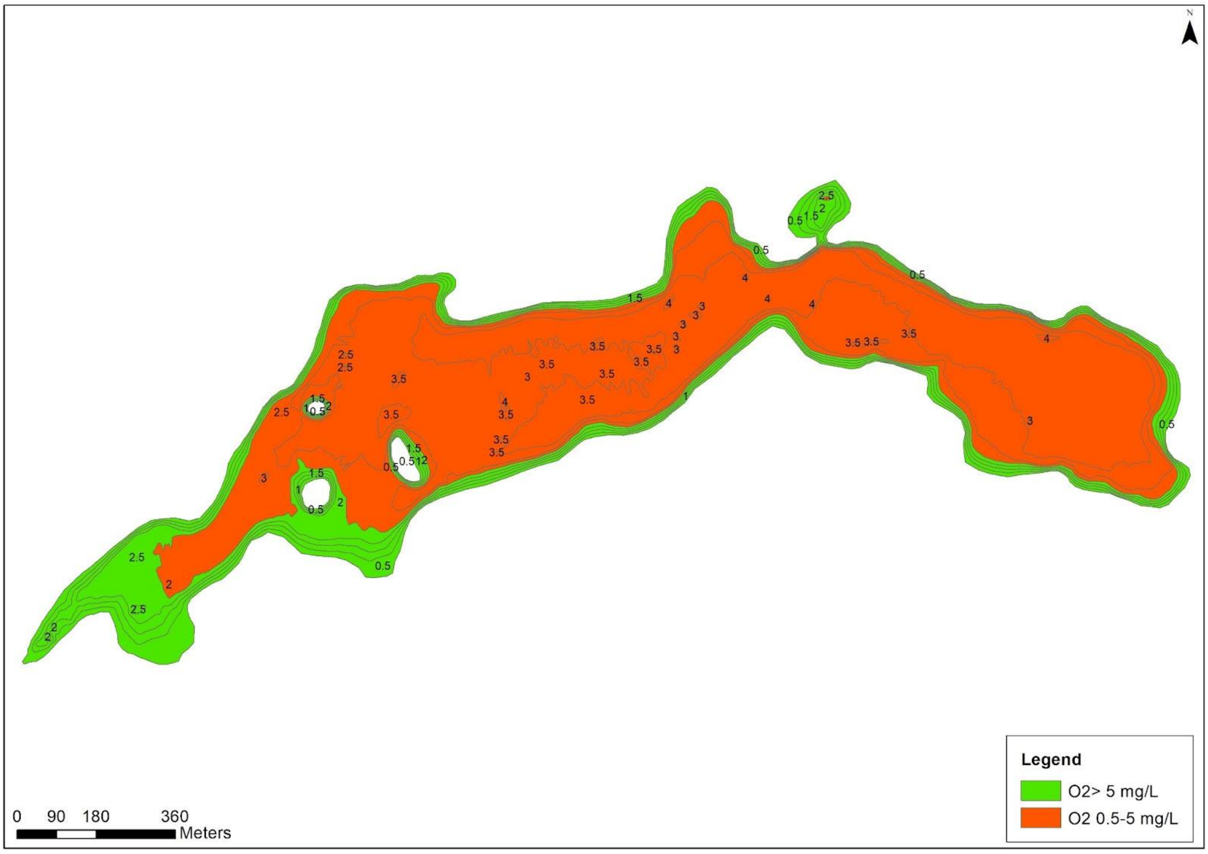

Figure 2.8.1. Changes in oxygen concentration depending on the depth of the Lake Ilzu (Garais)/Ilge.

2.9. Hydromorphological indicators

The EU WFD requires physical features of surface waters to be considered when assessing 'ecological status' and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history. The Lake Habitat Survey (LHS) as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs was adopted in Latvia in 2014.

Lake Ilzu (Garais)/Ilge is a natural lake without significant water level alterations caused by unnatural factors. Drainage (amelioration) systems are located in the northern part and occupy only about 0.5% of the total lake catchment. There are other hydrological structures *e.g.*, dams, sluices, impoundments found neither on the inflowing streams nor on the outflowing river. Thus, the Lake Ilzu (Garais)/Ilge corresponds to a lake waterbody in un-impacted hydrological condition or at high status.

Habitat Survey for the Lake Ilzu (Garais)/Ilge was carried out by boat in the late summer of 2014. Four sampling plots or Hab-Plots evenly spaced around the lake, were selected in order to record detailed habitat characteristics in the shore, riparian and littoral zones.

During the field survey boat docks and footbridges were recorded only within one of four Hab-Plots. However, this pressure regarding lake shore modification is not permanent and may be built in one place and disappear – in another. Artificial structures like 'hard engineering' and 'soft engineering' were not recorded along the lake shore.

Large areas of total non-natural land-cover were recorded within 15 and 50 m for the Lake Ilzu (Garais)/Ilge expressed as extent of total shoreline length. This type of feature includes commercial activities, roads and railways, parks and gardens, litter, pastures and observed grazing, tilled land, orchards. Accordingly, these pressures exceed 50 % of total lake shoreline length.

Less than 50 % of the lake shore is affected by erosion. However, 50–70 % of the lake area could be affected by deposition (excluding vegetated islands). These data are confirmed by recording sedimentation over natural substrate in the littoral zone within three Hab-Plots and by taking into consideration small average depth of the lake (2.4 m). The lake bottom consists mostly of gravel and sand covered by a thin layer of sand but in some places lake sediments are composed of silt and clay.

The Lake Ilzu (Garais)/Ilge is used mostly for recreational and management purposes: non-motor boat activities, angling from boat, angling from shore, fish cages, swimming, macrophyte control, powerlines. According to the latest orthophoto maps, about 70 m long and 2 m wide causeway as an in-lake barrier was built in the southwestern part, in Lithuania in order to provide access from the lake shore to the one of three lake islands for visitors and tourists.

Data on the physico-chemical character of the Lake Ilzu (Garais)/Ilge was collected at the deepest point (Index Site). During the field survey by boat on August 29th, 2014, lake's maximum depth was 3.5 m. Dissolved oxygen levels were reduced from 10.2 mg/L at the surface of the lake to 9.7 mg/L at the deeper layers. The Secchi depth was only 0.8 m at Index Site.

Analysis of natural and non-natural land-use information for Lake Ilzu (Garais)/Ilge catchment was made, taking into consideration the CORINE Land Cover data of 2018 and data of 2020 from the Rural Support Service of Latvia. Forest lands make up 38.9 % of the total catchment area, while 46.5 % of the area is occupied by agricultural lands. Arable land occupies about 4.6 %. Surface are of Lakes Ilzu (Garais)/Ilge and Apvalasai comprises 14.6 % of the total catchment area.

Table 2.9.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Ilzu (Garais)/Ilge according to Latvian methodology.

Hydromorphological Indicator	**Scores**	**Characteristics of the Impact**
Shore zone modification	2	Low risk of impact
Shore zone intensive use	6	High risk of impact
Hydrological regime	0	Un-impacted condition
Sediment regime	4	Moderate risk of impact
In-lake use	8	Severely impacted condition
Index Site condition	4	Moderate risk of impact
Catchment pressures	0	Un-impacted condition
Total	*24*	
Hydromorphological status	***Moderate***	

Developed scoring system for hydromorphological alterations and pressures in the frame of the LHS method illustrates that the difference of relevant scores for the Lake Ilzu (Garais)/ Ilge and for a lake in reference conditions reaches 48 %, i.e. 24 out of possible 50 scores when assuming the worst-case scenario (Table 2.9.1.). That means the Lake Ilzu (Garais)/Ilge can be classified as a lake waterbody in moderate hydromorphological status (class 3).

The hydromorphological quality elements and their scores according to the Lithuanian methodology are presented in Table 2.9.2. An increase in the sum of the scores indicates a deterioration of the hydromorphological conditions. The EQR value of the Hydromorphological Index of Lithuanian Lakes (EHMI) is 0.69, indicating a less than good status.

Table 2.9.2. Scoring of hydromorphological quality elements for the Lake Ilzu (Garais)/ Ilge according to Lithuanian methodology.

Hydromorphological Quality Element		**Score**
Water level and water exchange		1
Shore structure	Length of natural riparian vegetation (forest) belt	2
	Shoreline alterations	1
	Shore erosion	2
Predominant substrate in the littoral zone		2
Total		*8*
Hydromorphological status		***Less than good***

2.10 Indicators not covered by the WFD

2.10.1. Zooplankton organisms

Zooplankton organisms as possible indicators were considered in all lakes in relation to total phosphorus, chlorophyll a, and Secchi depth (Fig. 2.10.1.).

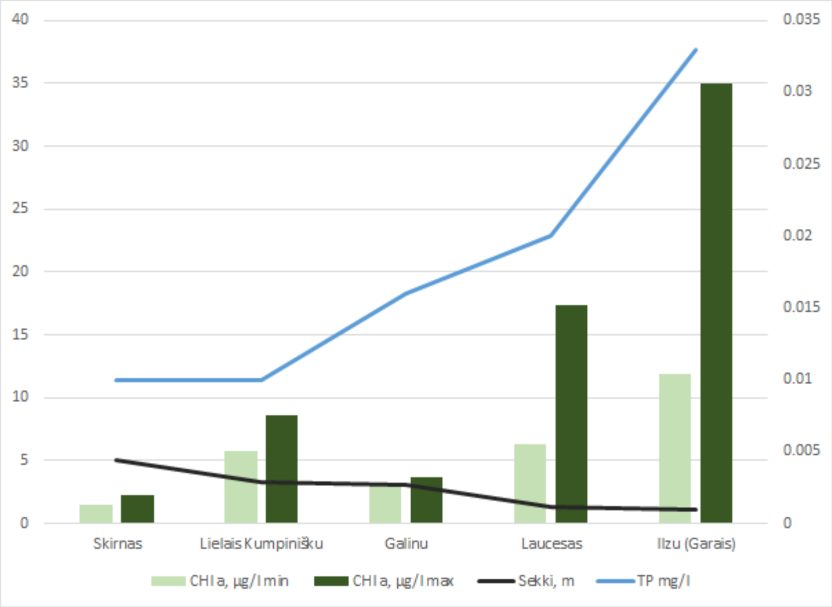

Figure 2.10.1. Chlorophyll a minimum and maximum values (mg/L), Secchi depth (m) on a primary y axis and TP concentration (mg/L) on a secondary y axis across studied lakes.

Despite rather poor status as stated by other indicators, the species number was relatively high (41 species in total both plankton and littoral biotopes), while in plankton species number decreased to 22.

Crustacean (Copepoda + Cladocera) species richness (12 species in plankton) versus TP concentration showed an obvious decline compared to other lakes with better ecological status (Fig. 2.10.2.). Differences are however not distinct as in other studies, e.g., Jeppessen et al (2011) since the whole total phosphorus range of studied lakes can be characterized as rather low TP concentration and according to data from other studies a significant species number drop could be expected by phosphorus amount above 0.05 mg/L.

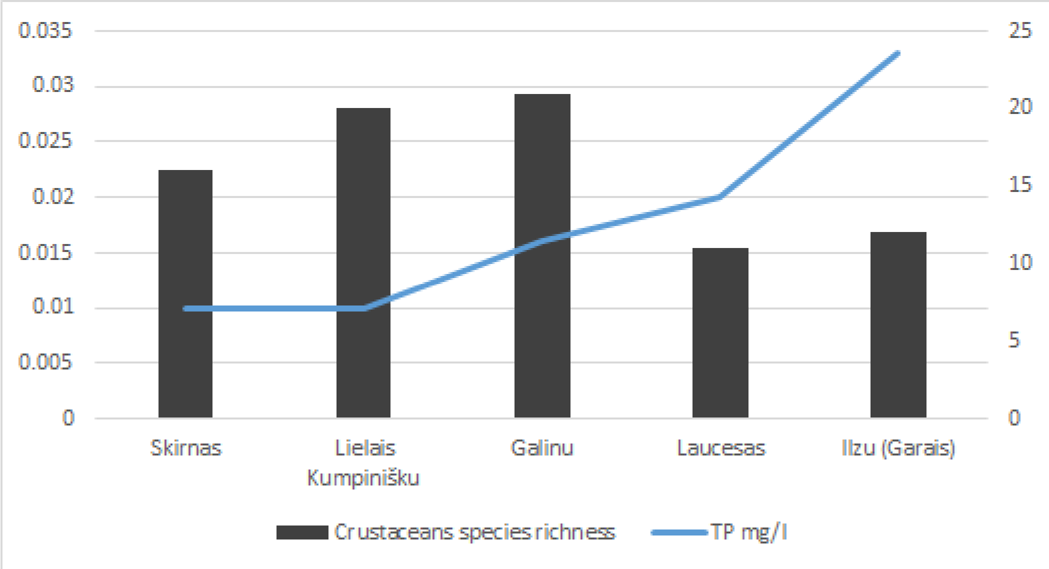

Figure 2.10.2. Species richness (n) of crustaceans (Cladocera and Copepoda) in lakes with different total phosphorus (mg/L) concentrations (on primary y axis).

The division among *Daphnia* spp., small cladocerans, calanoid copepods and cyclopoid copepods in the sample versus TP concentration showed an obvious decrease of calanoid copepods and a shift from calanoid to cyclopoids (Fig. 2.10.3.) what are characteristics for increasing eutrophication.

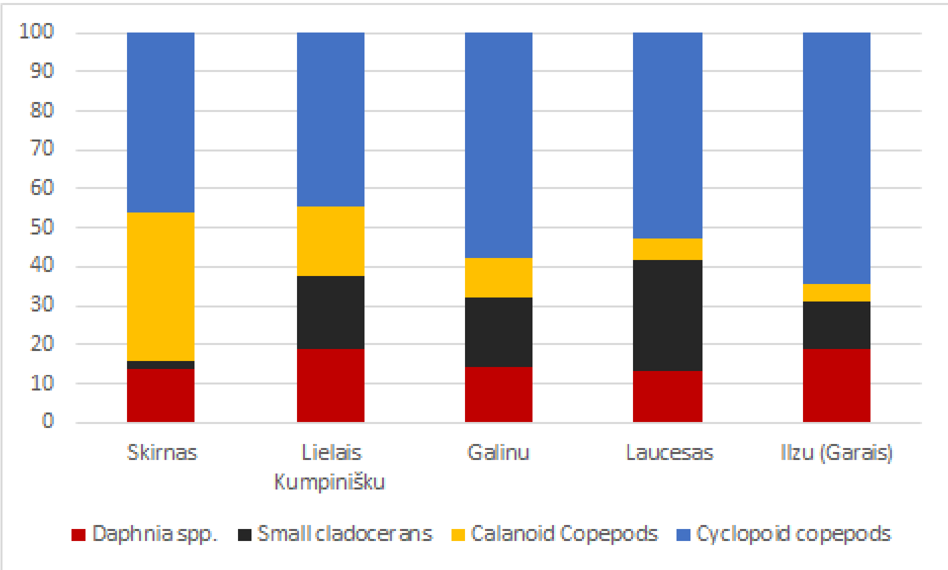

Figure 2.10.3. Percentage share of zooplankton groups abundance in studied lakes.

We could not observe the obvious Cladocera:Copepoda abundance ratio indicating changes. Compared to the lake with greatest transparency and lowest chl-a values (Lake Skirnas), Lake Ilzu (Garais)/Ilge had twice as high Cladocera share, still the Copepoda group was dominating. On the contrary, there was an obvious Cyclopoida:Calanoida ratio relation detected (Fig. 2.10.4.) with increasing Cyclopoida share in lakes with decreased Secchi depth, increased chl-a and total phosphorus values.

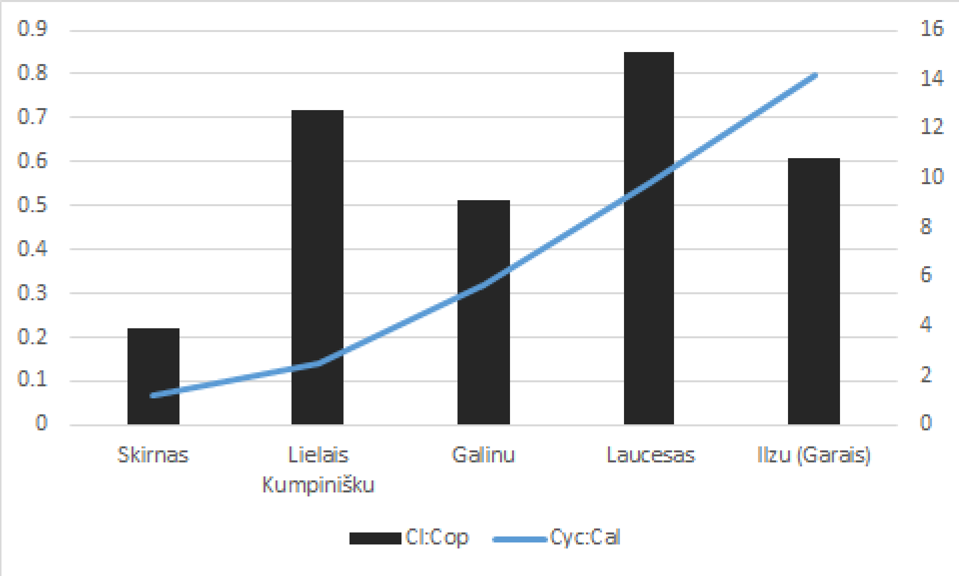

Figure 2.10.4. Cladocera:Copepoda and Cyclopoida:Calanoida ratio comparance in studied lakes.

According to previous studies in Latvian lakes (Urtāne, 1998; Čeirāns, 2007) we could observe dominance of such species indicating eutrophication development:

- *Daphnia cucullata* (common in Latvia, known from eutrophic lakes and ponds with high fish predation pressure, planktonic species);
- *Chydorus sphaericus* (very common, widely distributed and highly adaptive species from different kinds and trophy gradient water bodies).

On the contrary, for instance in the littoral part *Bosmina (Eubosmina) coregoni thersites* (known from this region of Latvia before, characteristics for mesotrophic-eutrophic lakes) was found to be dominant and according to previous studies this species should be suppressed as a response to eutrophication development (Urtāne, 1998), although there are different opinions about this species response due to eutrophication, more studies are required.

As to rotifers *Keratella cochlearis, K. quadrata*, *Polyarthra* sp. are known to show positive correlation with total phosphorus (Čeirāns, 2007).

In littoral samples a sudden increase of *Bosmina (Bosmona) longirostris* was observed in August, this common species dominance is also known to increase with a rising trophic state. Overall majority of the littoral species were also found in plankton samples due to strong littoral impact, the lake was elongated, shallow and overgrowing.

As to copepods it was typical for lakes with increased trophy – a high proportion of *Mesocyclops lecukrati* and *Thermocyclops oithonoides* within the Copepoda group.

2.10.2. Composition of lake sediments

Sediment analysis reveals that Lake Ilzu (Garais)/ Ilge sediments have a high content of organic matter (40.01 to 40.58 % by weight of dry mass) if compared to average value of all five studied transboundary lakes (Table 2.9.). Organic matter content in 18 priority salmon fish lakes comprised 4.3 – 46.2 %. Only in eutrophic Lake Zosna, organic matter content was higher than 40 % (Jankevica et al. 2012). Higher carbon content (%), if compared to other transboundary lakes, is due to the presence of organic matter as the share of carbonates is comparatively lower (Table 2.9.).

Nitrogen content in Lake Ilzu (Garais)/ Ilge sediments is 1.97 – 1.98 % by weight of dry mass, and it is 1.6 times higher than average in the five transboundary lakes (Table 2.10.1.).

Table 2.10.1. Sediment quality of Lake Ilzu (Garais) / Ilge (data from sampling in 2021).

Sampling site	**organic matter, %**	**carbonates, %**	**mineral matter, %**	**N, %**	**C, %**
L.Ilzu (Garais), E side, deeper part	40.01	3.49	56.50	1.97	22.66
L.Ilzu (Garais), W side, near islands	40.58	2.64	56.78	1.98	23.33
AVERAGE in 5 transboundary lakes	28.57	5.04	66.39	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hardwater lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 2.10.2., and proportion of P forms is shown in Figure 2.10.5. Concentration of total P and its forms in Lake Ilzu (Garais)/Ilge is in general similar to that in other studied transboundary lakes. The largest fraction is the residual P, which comprises about 85% of total P content in the Lake Ilzu (Garais)/Ilge sediments. Considering the very high content of organic matter in the lake sediments (Table 2.10.1.), a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is higher if compared to that in other Latvian lakes (40-72 %; Jankēvica et al. 2012). The share of other easily available mineral P fractions (NH_4Cl-P and

NaHCO$_3$/ Na$_2$S$_2$O4-P) is small (Fig. 2.10.5.). Study by Jankēvica et al. (2012) shows that a share of NH$_4$Cl-P accounted for less than 0.35% of total P and that of redox sensitive P species varied from 0.9 – 15.6 % of total P content.

Table 2.10.2. Concentration (mg/kg d.w.) of phosphorus speciation forms in Lake Ilzu (Garais)/ Ilge sediments in August 2021.

Sampling site	**TP, mg/kg**	**NH$_4$Cl-P, mg/kg**	**NaHCO$_3$/ Na$_2$S$_2$O$_4$-P, mg/kg**	**NaOH-P, mg/kg**	**HCl-P, mg/kg**	**residual-P, mg/kg**
L.Ilzu (Garais), E side, deeper part	1197	2.09	49	61	62	1023
L.Ilzu (Garais), W side, near islands	1030	1.08	47	53	55	875
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

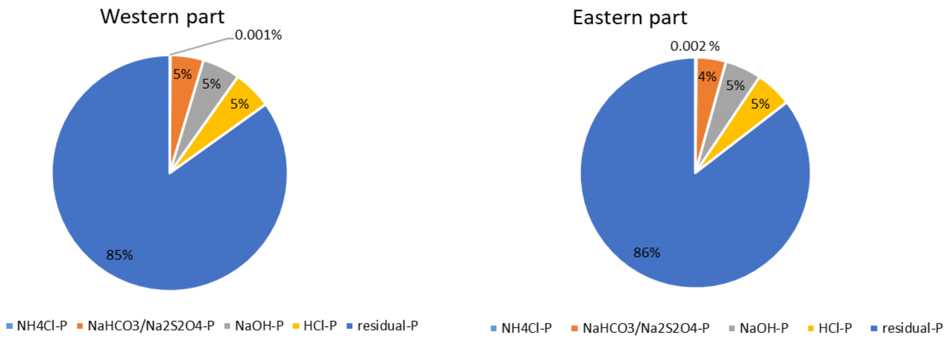

Figure 2.10.5. Proportion of phosphorus fractions in Lake Ilzu (Garais)/ Ilge sediments.

2.11. Summary ecological quality according to the WFD criteria

Although ***in Latvia*** Lake Ilzu (Garais)/Ilge has been periodically monitored since 2006, in 2021 a complete set of biological quality elements, including fish were monitored for the first time. Results confirm that phosphorus concentrations have a decreasing trend since 2014, nitrogen concentrations and transparency have not significantly changed over time. Total ecological quality is poor (Table 2.11.1) which is confirmed by two biological quality elements (fish and macrophytes). Also, oxygen conditions in lake are poor.

Table 2.11.1. Total ecological status assessment of Lake Ilzu (Garais)/Ilge in 2021 according to Latvian system.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Poor	Poor	Good	Poor	1.14	0.033	1.1	Moderate	Moderate	Poor

According to ***Lithuanian*** system of classification of ecological status, the ecological quality of the lake is assessed as moderate with high confidence because biological and physico-chemical elements indicate the same status class (Table 2.11.2.).

Table 2.11.2. Total ecological status assessment of Lake Ilzu (Garais)/Ilge in 2021 according to Lithuanian system.

Macro-inverte-brates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**Ntot, mg/L**	**Ptot, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Mode-rate	Mode-rate	Moderate	Mode-rate	1.14	0.033	1.1	Moderate	Less than good	Moder ate

Although the results obtained by the two countries are slightly different, they confirm that the lake is not in a good ecological status and additional measures must be implemented to improve the quality of the transboundary lake.

3. ECOLOGICAL QUALITY OF LAKE LIELAIS KUMPINIŠKU/ KAMPINISKIAI

3.1. Lake waterbody type

According to the lake typology in Latvia, Lake Lielais Kumpinišku/Kampiniskiai belongs to the type L5. That is a shallow clearwater lake with high water hardness. Average depth of the type L5 lakes is in the range 2 – 9 m, water colour is <80 mg Pt/L and electric conductivity (indicator of water hardness) is >165 µS/cm.

Monitoring results confirm the lake belongs to lake type L5. Average depth of the lake is 3 m. According to measurements done in 2021, yearly average colour is 15 mg Pt/L (varies from 12.7 mg Pt/L to 20.1 mg Pt/L), and conductivity is 352 µS/cm (varies from 310 µS/cm to 388 µS/cm).

Lake Lielais Kumpinisku has an 8-shaped form, *i.e.*, it consists of two morphometrically different parts which are connected by a narrow strait. Average depth of the Northern part of the lake is 1.2 m and it represents a very shallow clearwater lake with high water hardness (lake type L1). This part of the lake is overgrown by macrophytes. The Southern part of the lake is deeper. Average depth is 4.9 m and it corresponds to lake type L5. Macrophytes occur here along the shoreline and in shallow bays.

According to the lake typology in Lithuania, the lake belongs to type 2, that is a stratified lake.

3.2. Major pressures in the lake catchment

According to the ***Latvian*** 3rd cycle River basin management plans 2022-2027, the most significant pressure in the lake is diffuse pollution from forests and agriculture as well as transboundary pollution from Lithuania.

Lake Lielais Kumpinišku/Kampiniskiai is a natural lake without water level and flow regulations. There are no drainage or hydrological structures such as dams or weirs within the lake catchment. Agricultural areas occupy about 49 % of transboundary catchment, forests 46 %. Arable lands cover only about 5 % of lake catchment.

The modelling results show that the greatest share of nitrogen loads within the catchment originate from agricultural lands and forests – 60 % and 23 %, respectively. Most important sources of phosphorus load are agricultural lands and forests as well, runoff from agricultural lands accounts for 47 % of P loads and runoff from forests for 26 % of the total load in the catchment.

Figures 3.2.1. and 3.2.2. show nitrogen (N) and phosphorus (P) load distributions by sectors in Lake Kumpinišku/Kampiniskiai catchment for year 2021.

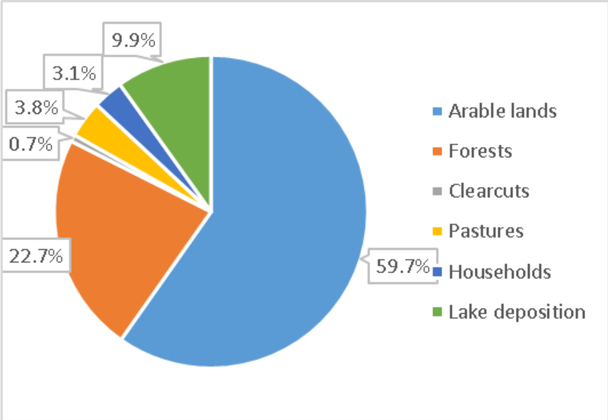

Figure 3.2.1. N source apportionment in Lake Kumpinišku/Kampiniskiai catchment.

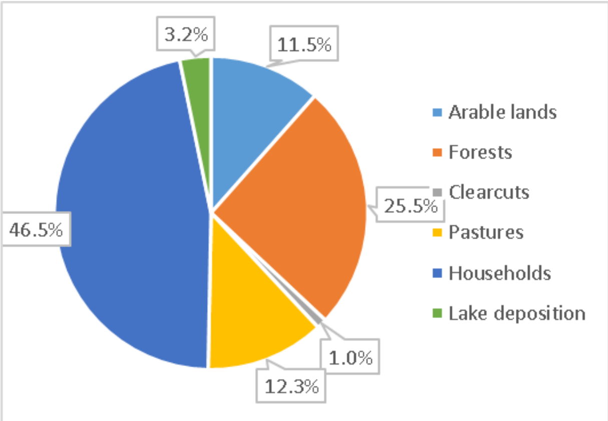

Figure 3.2.2. P source apportionment in Lake Kumpinišku/Kampiniskiai catchment.

In ***Lithuania***, Lake Lielais Kumpinišku/Kampiniskiai has not been previously identified as a water body and therefore has not been monitored. There are no known sources of pollution in the Lithuanian part of the lake basin. The diffuse pollution load has not yet been modelled. However, according to the expert assessment, the ecological status of the lake is classified as moderate.

3.3. Overview of previous monitoring results

Lake Lielais Kumpinišku/Kampiniskiai is a new water body and was delineated in 2019. Therefore, no previous monitoring results are available.

3.4. Phytoplankton indicators

Phytoplankton samples were collected twice during the season – in May and August. Seasonal variations were observed, and Latvian phytoplankton EQR index value varied from 0.75 (good quality) in August to 0.95 (high quality) in May. Annual average quality is good. Chlorophyll-a concentrations varied from 5.8 µg/L (high quality class) to 8.6 µg/L indicating a good quality.

According to Lithuanian phytoplankton method, the ecological quality of the lake is high. Although the phytoplankton methods of the two countries are intercalibrated, the EQR values show belonging to different quality classes (Table 3.4.1). Differences are small and both assessment systems classify the lake being as at least in a good quality. Latvian EQR value is very close to high/good class boundary which is 0.81.

Table 3.4.1. Ecological status according to phytoplankton.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.80	High	0.87

3.5. Macrophytes indicators

Diversity and abundance of macrophyte species differ in the Northern and the Southern part of the Lake Kumpinišku. The Northern part where water is shallow all area is overgrown with macrophytes (Fig. 3.5.1.). *Phragmites australis* and *Typha angustifolia* form dense stands on the nearshore zone, *Chara tomentosa, Nitellopsis obtusa, Myriophyllum verticillatum, Nuphar lutea, Potamogeton lucens, P. natans,* and *P. perfoliatus* occur very frequent in whole area. Species diversity in this lake part is high and totally 32 species are found.

Figure 3.5.1. The shallow Northern part of Lake Kumpinišku.

The Southern part of the lake is deeper and the colonization depth of macrophytes is 4 m. In deeper parts, vital stands of *Nitellopsis obtusa* are found (Fig. 3.5.2.), as well as sparse stands of *Potamogeton lucens*. Floating-leaved and emergent macrophytes occur on the nearshore zone.

3. 

Figure 3.5.2. Nitellopsis obtusa found in the Southern part of lake.

Ecological quality according to Latvian macrophyte method is good in the whole lake. The colonization depth of macrophytes and high abundance of macrophytes indicate high ecological quality, but total species composition (*Nuphar lutea, Typha angustifolia* occurs very frequently, but *Ceratophyllum demersum* and *Typha latifolia* are quite rare) indicates on a good ecological quality. According to Lithuanian macrophyte method, the ecological quality was classified as moderate in one of the studied transects due to the high abundance of pollution tolerant species (Table 3.5.1.).

Table 3.5.1. Ecological quality of Lake Kumpinišku according to macrophytes.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.8	Good	0.51

3.6. Benthic invertebrates' indicators

The macroinvertebrates were sampled in May and October 2021 at two sampling points in the littoral zone. The first sampling point is located in the shallow Northern part while the second is in the Southern part. Lake Kumpinišķu is at good status (Table 3.6.1.) according to the Latvian LLMMI (Skuja and Ozoliņš, 2016) and Lithuanian LLMI (Šidagytė et al. 2013).

Table 3.6.1. Ecological quality of Lake Kumpinišķu according to benthic invertebrates.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.71	Good	0.71

In Lake Kumpinišku, invasive species zebra mussel *Dreissena polymorpha* and spiny-cheeck crayfish *Orconectes limosus* were observed. Also, a legally protected medical leech *Hirudo medicinalis* was found in the shallow part of the lake (Council Directive 92/43/EEC Annex V, Regulations of the Cabinet of Ministers No. 396). The overgrown Northern part of the lake is more eutrophic and the number of macroinvertebrate taxa and abundance there is lower than in the deeper Southern part. Gastropoda was the species richest taxa in both seasons.

In spring, larvae of Chironomidae and mayfly nymphs *Caenis horaria* and *Cloeon dipterum* are the most abundant taxa. In autumn, in the Northern part of the lake larvae of Chironomidae, Ceratopogonidae and caddisflies *Holocentropus dubius* were dominant. The Southern part of the lake had high species richness with Chironomidae, mayflies *Cloeon dipterum*, *Ephemera vulgata*, *Caenis horaria* and pea clams *Pisidium* sp. as the most abundant taxa.

3.7. Fish indicators

Fish sampling in Lithuanian part of the lake was carried out in August 2021. In total, 8 fish species were recorded. Roach, white bream, and perch are the most numerous, accounting for 87.3 % (from 23.1 to 38.3 %) of the total number of fish in the catch per unit of effort (CPUE). But in the catches of white bream and roach, small individuals predominate, therefore the share of their biomass in the CPUE is much less than the share of abundance and is only 3.3 % (white bream) and 14.8 % (roach). The relative biomass of perch, which is 40.7 %, is the highest in the CPUE. According to the Lithuanian lake fish index, the ecological status of the lake is classified as good.

Fish sampling in Latvian part of the lake was carried out at the beginning of September 2021. In total, six (10 in all gears) fish species were recorded. Catches were dominated by roach and bream, accounting for 65.5 % of the total number of fish, but only 45.6 % of the total biomass. The relative abundance of piscivorous perch was relatively high (26.7 % and 45.3 %). According to the Latvian lake fish index, the ecological status of the lake is high (Table 3.7.1).

Table 3.7.1. Ecological quality of Lake Kumpinišku according to fish.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
High	0.83	Good	0.76

3.8. Physico-chemical indicators

In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

In Latvian methodology, according to TP concentration, ecological quality of the Lake Lielais Kumpinišku/ Kampiniskiai is high, but TN concentration and Secchi depth values indicate good ecological quality. According to Lithuanian assessment system, TP and TN content indicates a high ecological status, and Secchi depth – a good status. Based on the WFD principle "one-out, all-out", the overall physico-chemical quality of the lake is estimated as good (Table 3.8.1).

Table 3.8.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (color scheme as for the EU WFD: blue – high, green – good, yellow – moderate, orange – poor, and red –bad ecological quality).

Latvia		**Lithuania**	
parameter	*average value*	*parameter*	*average value*
TP, mg/L	0.013	TP, mg/L	0.013
TN, mg/L	0.64	TN, mg/L	0.64
Secchi depth, m	3.3	Secchi depth, m	3.3
TOTAL	**good**	**TOTAL**	**good**

Oxygen concentration is one of the most important indicators to describe lake ecosystem health. According to commonly used water quality standards, including priority fish, healthy oxygen concentration must exceed 5 mg/L. In lake Lielais Kumpinišku/Kampiniskiai, O_2 concentration exceeds 5 mg/L within all lake and there are no large differences between the shallow part in north and a deeper part in south (Fig. 3.8.1.).

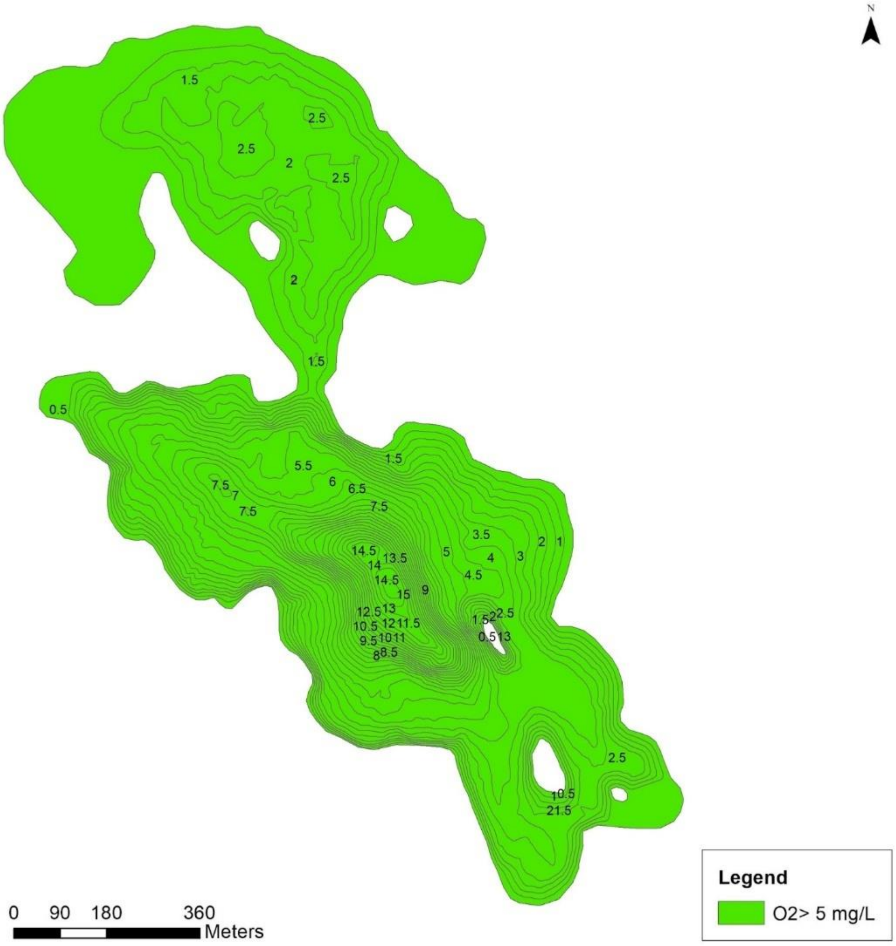

Figure 3.8.1. Changes in oxygen concentration depending on the depth in lake Lielais Kumpinišku/Kampiniskiai.

3.9. Hydromorphological indicators

The WFD requires physical features of surface waters to be considered when assessing ‘ecological status’ and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history. The Lake Habitat Survey (LHS), as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs, was adopted in Latvia in 2014.

Lake Lielais Kumpinišku/Kampiniskiai is a natural lake without water level and flow regulations and is classified as a waterbody in an unimpacted hydrological condition.

Morphological alterations and pressures of the Lake Lielais Kumpinišku/Kampiniskiai can be analysed only in context of using digital data, historical information and latest orthophoto maps because the LHS in the field was not carried out. According to the latest orthophoto maps, 4-5 footbridges as well as absence of ‘hard engineering’ indicate less than 10 % of lake shoreline length may be affected.

Anthropogenic impact and pressures, like commercial activities, residential areas, roads, pastures and tilled land, can be observed within 15 and 50 m. However, agricultural areas occupy about 51 % and the forest belt covers 49 % of the lake shoreline, by the CORINE Land Cover data of 2018.

The Lake Lielais Kumpinišku/Kampiniskiai is a shallow lake with an average depth 2.74 m and a maximum depth 14.9 m. Less than 50 % of lake area could be affected by deposition (excluding vegetated islands). Lake sediments are comprised mainly of clastic material (sediment of silt, sand and sandy clay sizes).

The Lake Lielais Kumpinišku/Kampiniskiai is used mostly for angling and swimming.

According to the CORINE Land Cover data of 2018 and data of 2020 from the Rural Support Service of Latvia, forests make up 35.3 % and arable land – only 4.9 % of the lake catchment area.

Table 3.9.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Lielais Kumpinišku/Kampiniskiai according to Latvian methodology

Hydromorphological Indicator	**Scores**	**Characteristics of the Impact**
Shore zone modification	0	Un-impacted condition
Shore zone intensive use	6	High risk of impact
Hydrological regime	0	Un-impacted condition
Sediment regime	2	Low risk of impact
In-lake use	4	Moderate risk of impact
Catchment pressures	0	Un-impacted condition
Total	*12*	
Hydromorphological status	***Good***	

Developed scoring system for hydromorphological alterations and pressures in the frame of the LHS method illustrates that the difference of relevant scores for the Lake Lielais Kumpinišku/Kampiniskiai and for a lake in reference conditions reaches 26 %, i.e. 12 out of possible 46 scores when assuming the worst-case scenario (Table 3.9.1.). Thus, the Lake Lielais Kumpinišku corresponds to a lake waterbody in good hydromorphological status (class 2).

The hydromorphological quality elements and their scores according to the Lithuanian methodology are presented in Table 3.9.2. An increase in the sum of the scores indicates a deterioration of the hydromorphological conditions. The EQR value of the Hydromorphological Index of Lithuanian Lakes (EHMI) is 0.81 indicating the overall good status.

Table 3.9.2. Scoring of hydromorphological quality elements for the Lake Lielais Kumpinišku/Kampiniskiai according to Lithuanian methodology

Hydromorphological Quality Element		**Score**
Water level and water exchange		1
Shore structure	Length of natural riparian vegetation (forest) belt	2
	Shoreline alterations	1
	Shore erosion	0
Predominant substrate in the littoral zone		2
Total		*6*
Hydromorphological status		***Good***

3.10. Indicators not covered by the WFD

3.10.1. Zooplankton organisms

The zooplankton description below refers to figures in description of zooplankton in Lake Ilzu (Garais)/ Ilge.

All together in plankton and littoral biotopes there were 48 species found, of those in plankton particularly there were 28 species (8 rotifera, 15 cladocerans and 5 copepods). Crustacean (Copepoda + Cladocera) species richness (20 species) versus total phosphorus was among highest in studied lakes similar to other lakes with good ecological status (Fig. 2.10.2.).

The division among *Daphnia* spp., small cladocerans, calanoid copepods and cyclopoid copepods in the sample versus total phosphorus showed decrease of calanoid copepods and increase of Cladocera compared to Lake Skirnas (Skirnas lake Secchi depth and chl-a values indicate decreased trophy level), still calanoid copepods were present in considerable amount in relation to cyclopoid copepods (Fig. 2.10.3.) indicating better ecological status compared with lakes Galiņu, Laucesas and Ilzu (Garais).

Cladocera:Copepoda abundance ratio did not provide any clear information, while Cyclopoida:Calanoida ratio reflected total phosphorus, Secchi depth and chlorophyll a values relation among studied lakes (Fig. 2.10.4.).

Species such as *Keratella cochlearis, Daphnia cucullata, Bosmina (B.) longirostris* were dominating and *Chydorus sphaericus* was also among most frequent species, this indicates a positive response to eutrophication development (Urtāne, 1998; Čeirāns, 2007).

This lake has become a new finding for copepod *Cyclops bohater* so far known from only one lake in Latvia, species was found in low numbers, however it was regularly detected throughout sampled material in different life history development stages. *Cyclops bohater* has characteristics with its large body and could serve as a potential indicator species since its biotope is oligotrophic and slightly eutrophic water bodies.

The littoral samples data were not sufficient to make conclusions on potential indicator species.

3.10.2. Composition of lake sediments

Due to the morphological features of Lake Lielais Kumpinišku, composition of its sediments is diverse. Sediments from the shallow, macrophyte-overgrown part have a high content of organic matter (38.86 % by weight of dry mass), carbon content (21.08 %) and nitrogen (1.65 %) if compared to the deeper part (organic matter 23.76 %, carbon 12.63 %, and nitrogen 1.07 %) and average value of all five studied transboundary lakes (Table 3.10.1.). Organic matter content in sediments from the shallow part of the lake is among the highest if compared to a previous study done by Jankevica et al. (2012). The study revealed that content of organic matter in 18 priority salmon fish lakes comprised 4.3 – 46.2 %.

Table 3.10.1. Sediment composition of Lielais Kumpinišku/Kampiniskiai (data from sampling in 2021).

Sampling site	**organic matter, %**	**carbonates, %**	**mineral matter, %**	**N, %**	**C, %**
Lielais Kumpinišku/ Kampiniskiai, shallow part	38.86	1.43	59.71	1.65	21.08
Lielais Kumpinišku/ Kampiniskiai, deeper part	23.76	3.07	73.17	1.07	12.63
AVERAGE in 5 transboundary lakes	28.57	5.04	66.39	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hardwater lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and

organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 3.10.2., and proportion of P forms is shown in Figure 3.10.1. Concentration of total P in sediments of the L. Lielais Kumpinišku is slightly lower than in other studied transboundary lakes. The largest fraction is the residual P, which comprises about 83% and 76% of total P content in sediments of the shallow and deep part, respectively. Considering the high content of organic matter in the lake sediments (Table 3.10.1), a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is higher if compared to that in other Latvian lakes (40-72 %; Jankēvica et al. 2012). The share of easily available mineral P fractions (NH_4Cl-P and $NaHCO_3$/ $Na_2S_2O_4$-P) is small (Fig. 2.10.1). Study of sediment quality in Latvian salmonid lakes by Jankēvica et al. (2012) showed that a share of NH_4Cl-P accounted for less than 0.35 % of total P and that of redox sensitive P species varied from 0.9 – 15.6 % of total P content.

Table 2.10.2. Concentration (mg/kg d.w.) of phosphorus speciation forms in Lake Lielais Kumpinišku/Kampiniskiai sediments in August 2021.

Sampling site	**TP mg/kg**	**NH_4Cl-P, mg/kg**	**$NaHCO_3$/ Na_2S_2O4-P, mg/kg**	**NaOH-P, mg/kg**	**HCl-P, mg/kg**	**residual-P, mg/kg**
Lielais Kumpinišku/ Kampiniskiai, shallow part	716	5.98	32	26	61	592
Lielais Kumpinišku/ Kampiniskiai, deeper part	824	0.64	48	87	64	624
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

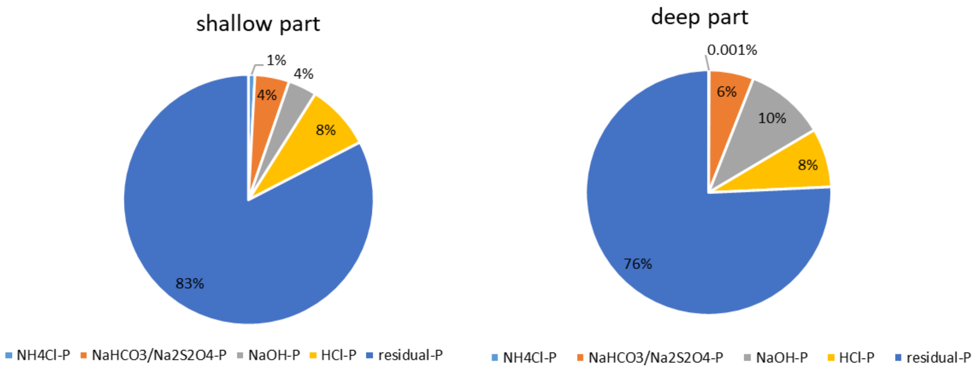

Figure 2.10.1. Proportion of phosphorus fractions in Lake Lielais Kumpinišku/ Kampiniskiai sediments.

3.11. Summary ecological quality according to the WFD criteria

In **Latvia**, Lake Lielais Kumpinišku/Kampiniskiai is a new water body that was delineated in year 2019 and first surface water monitoring was done in 2021 within the Transwat project. According to Transwat project results, total ecological status of the lake is good (Table 3.11.1.) and oxygen concentrations is relatively high in all depths. According to the 3rd cycle River basin management plans, ecological status of the lake was classified as moderate, but it was done using expert judgment, not real monitoring data. The mismatch is most likely due to the fact that the lake basically consists of two parts and monitoring was carried out in only one of them (southern part).

Table 3.11.1. Total ecological status assessment of Lake Lielais Kumpinišku/ Kampiniskiai in Latvia, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Good	High	Good	Good	0.64	0.013	3.3	Good	Good	Good

According to **Lithuanian** system of classification of ecological status, the ecological quality of the lake is also classified as good (Table 3.11.2.) with high confidence because biological and physico-chemical elements indicate the same status class. According to 3rd cycle River basin management plans, ecological status of the lake was classified as moderate, but classification was based on expert judgment. The lake was not previously delineated as a water body in Lithuania and therefore monitoring has never been carried out.

Table 3.11.2. Total ecological status assessment of Lake Lielais Kumpinišku/ Kampiniskiai in Lithuania, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TPt, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Good	Good	High	Good	0.64	0.013	3.3	Good	Good	Good

Ecological status assessment in both countries confirms that the lake is in good ecological status.

4. ECOLOGICAL QUALITY OF LAKE GALIŅU/SALNA

4.1. Lake waterbody type

According to the lake typology in Latvia, Lake Galiņu/Salna belongs to the type L5. That is a shallow clearwater lake with high water hardness. Average depth of the type L5 lakes is in the range 2 – 9 m, water colour is <80 mg Pt/L and electric conductivity (indicator of water hardness) is >165 μS/cm.

Monitoring results confirm the lake belongs to lake type L5. Average depth of the lake is 3.9 m. According to measurements done in 2021, yearly average colour is 47 mg Pt/L (varies from 31 mg Pt/L to 110 mg Pt/L), and conductivity is 405 μS/cm (varies from 313 μS/cm to 471 μS/cm).

According to the lake typology in Lithuania, the lake belongs to type 1, that is a shallow polymictic lake.

4.2. Major pressures in the lake catchment

According to ***Latvian*** 3rd cycle River basin management plans 2022-2027, this lake does not have any significant pressure within Latvian side.

Lake Galiņu/Salna is a natural lake without water level and flow regulations. Forests make up 72 % and agricultural lands – 22 % of the lake catchment area.

The modelling results show that the greatest share of nitrogen loads within the catchment originate from forests and agricultural lands – 57 % and 33 % respectively. Most important sources of phosphorus load are forests and agricultural lands as well, runoff from forests accounts for 53 % of P loads and runoff from agricultural lands for 32 % of the total load in the catchment.

Figures 4.2.1. and 4.2.2 show nitrogen (N) and phosphorus (P) load distributions by sectors in Galinu/Salna Lake catchment for 2021.

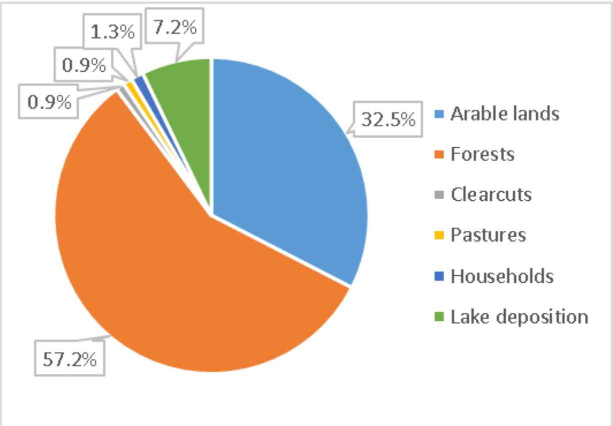

Figure 4.2.1. N source apportionment in Lake Galinu/Salna catchment.

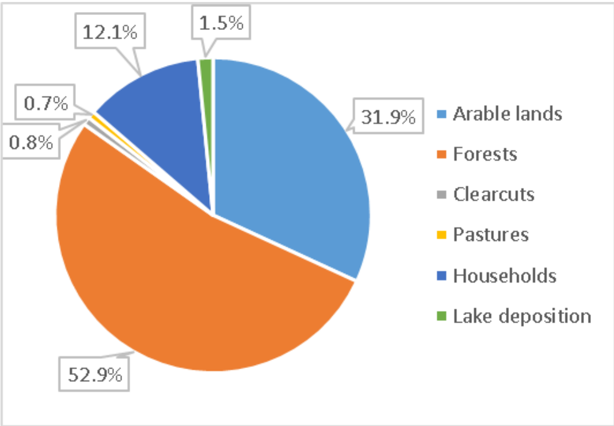

Figure 4.2.2. P source apportionment in Galinu/Salna Lake catchment.

In Lithuania, Lake Galinu/Salna has not been previously identified as a water body and therefore has not been monitored. There are no known sources of pollution in the Lithuanian part of the lake basin. The diffuse pollution load has not yet been modelled. According to the expert assessment, the ecological status of the lake is good.

4.3. Overview of previous monitoring results

In Latvian side, there is one surface water quality monitoring station in Lake Galinu/Salna – *Galiņu ezers, vidusdaļa*. It is located in the middle part of the lake in Latvian side and monitoring has been carried out by the Latvian Environment, Geology and Meteorology Centre. Lake was monitored once in the 2nd monitoring cycle and once in the 3rd monitoring cycle. According to previous monitoring results, the ecological status of the lake is moderate to poor. Downgraded ecological quality is due to one biological quality element: macroinvertebrates (Table 4.3.1). Lake does not have any significant pressures in Latvian side and physico-chemical quality is also high/good, and therefore, the reduced ecological status is of low confidence.

Table 4.3.1 Changes in ecological status of Lake Galiņu/Salna.

Year	**Macro-invertebrates**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**Total status**
2012	Moderate	High	Moderate	0.80	0.017	2.5	Good	Moderate
2019	Poor	High	Poor	0.92	0.027	4.2	Good	Poor

4.4. Phytoplankton indicators

Phytoplankton samples were collected twice during vegetation season – in May and August. No seasonal variations were observed, and Latvian phytoplankton EQR index value varied from 0.90 to 1 indicating a high quality. Annual average quality is high. Chl-a concentrations varied from 3.2 µg/L (high quality class, close to reference values) to 3.7 µg/L (high quality).

According to Lithuanian phytoplankton method, the ecological quality of the lake is also high (Table 4.4.1).

Table 4.4.1 Ecological status according to phytoplankton.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
High	0.95	High	0.95

4.5. Macrophytes indicators

In the Lake Galiņu composition of macrophyte species is characteristic for slightly eutrophic lakes. The colonization depth of macrophytes is high (3.9 m) and species diversity is also high, but without charophyte species, indicating a good ecological status (Table 4.5.1.). Species typical for eutrophic lakes such as *Ceratophyllum demersum, Sagittaria sagittifolia, Myriophyllum verticillatum* occurs frequently. Overgrowing with macrophytes is characteristic for the bays where water exchange is lower, sediments deeper and macrophyte stands are dense (Figs. 4.5.1. and 4.5.2.).

In deeper parts of lake macrophyte stands are sparser, here *Fontinalis antipyretica, Batrachium circinatum* and *Potamogeton lucens* are dominating.

Figure 4.5.1. Macrophyte stands in the bay in eastern part of the lake.

Figure 4.5.2. High abundance of submerged macrophytes in the bay in Lithuanian part of the lake.

Table 4.5.1. Ecological quality according to macrophytes.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.60	Good	0.55

4.6. Benthic invertebrates' indicators

The macroinvertebrates were sampled in May and October 2021 at 2 sampling points in the littoral zone. Lake Galiņu is at good status (Table 4.6.1.) according to both, the Latvian LLMMI (Skuja and Ozoliņš, 2016) and Lithuanian LLMI (Šidagytė et al. 2013) assessment methods.

Table 4.6.1. Ecological quality of Lake Galiņu according to benthic invertebrates.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.67	Good	0.53

In general, water louse *Asellus aquaticus*, mayfly nymphs from family Leptophlebidae and species *Caenis horaria* dominate the littoral macroinvertebrate communities. The abundance varied from 156 to 387 specimens per sample, while the number of taxa was 22 in spring and 34 in autumn. Invasive mussel species *Dreissena polimorpha* and *Orconectes limosus* were found in the lake.

4.7. Fish indicators

Fish sampling in Lithuanian part of the lake was carried out in August 2021. In total, 8 fish species were recorded in the lake during the fish survey. The most numerous are roach, white bream and rudd, accounting for 85.8 % (from 25.8 to 34.0 %) of the total number of fish and 80.4% (from 11.4 to 38.1 %) of the total biomass in the CPUE. Piscivorous species pike and perch make up about 10 % of the total abundance and 12.5% of the biomass in the catch per unit of effort. According to the Lithuanian lake fish index, the ecological status of the lake is classified as good.

Fish sampling in Latvian part of the lake was carried out at the beginning of September 2021. In total, six (8 in all gears) fish species were recorded. Catches were dominated by roach, accounting for 77.1 % of the total number of fish and 69.5 % of the total biomass. The relative abundance of piscivorous perch was relatively low (19.2 % and 23.9 %). According to the Latvian lake fish index, the ecological status of the lake is moderate.

Table 4.6.1. Ecological quality of Lake Galiņu according to fish.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Moderate	0.50	Good	0.67

4.8. Physico-chemical indicators

In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

In Latvia, according to TP concentration, ecological quality of the Lake Galiņu / Salna is high, but TN concentration and Secchi depth values indicate good ecological quality. According to Lithuanian method, lake ecological quality is high by all parameters. Based on the WFD principle “one-out, all-out”, the overall physico-chemical quality of the lake is estimated as good (Table 4.8.1).

Table 4.8.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (color scheme as for the EU WFD: blue – high, green – good, yellow – moderate, orange – poor, and red – bad ecological quality).

Latvia		**Lithuania**	
parameter	average value	parameter	average value
TP, mg/L	0.016	TP, mg/L	0.016
TN, mg/L	0.90	TN, mg/L	0.90
Secchi depth, m	3.10	Secchi depth, m	3.20
TOTAL	**good**	**TOTAL**	**high**

Oxygen concentration is one of the most important indicators to describe lake ecosystem health. According to commonly used water quality standards, including priority fish, healthy oxygen concentration must exceed 5 mg/L. In lake Galiņu/Salna O_2 concentration exceeds 5 mg/L depth until 4 m depth. In areas deeper than 4 m a sharp decrease in O_2 concentration begins and anoxia can be observed. About 59 % of lake area can be characterized as suitable for aquatic organisms, but 41 % of lake area O_2 depletion can be observed (Fig. 4.8.1.).

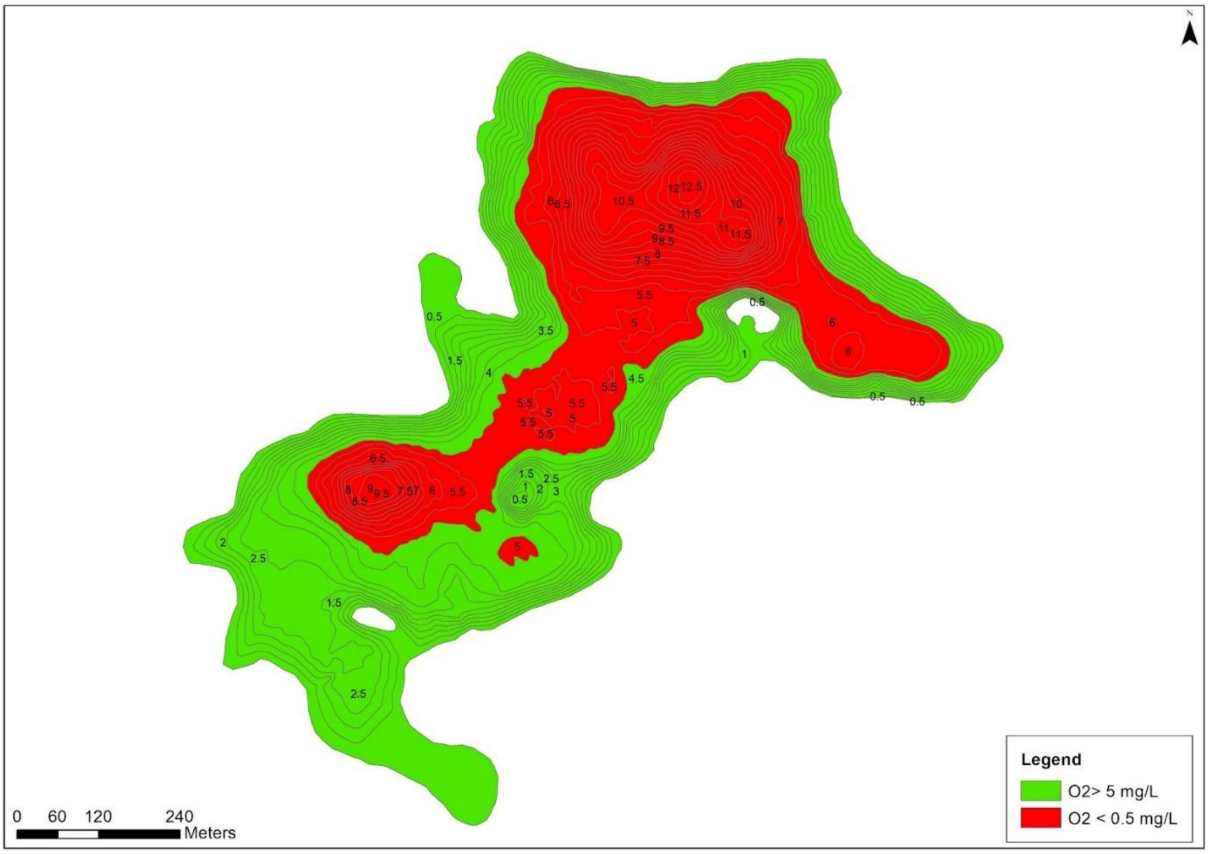

Figure 4.8.1. Changes in oxygen concentration depending on the depth of the lake Galiņu/Salna.

4.9. Hydromorphological indicators

The WFD requires physical features of surface waters to be considered when assessing ‘ecological status’ and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history. The Lake Habitat Survey (LHS), as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs, was adopted in Latvia in 2014.

Lake Galiņu/Salna is a natural lake without water level and flow regulations and is classified as a waterbody in un-impacted hydrological condition.

In Latvian part, the LHS for the Lake Galiņu/Salna was carried out on foot on September 25th, 2019. Four sampling plots or Hab-Plots were selected in order to record detailed habitat characteristics in the shore, riparian and littoral zones. No shore modification was recorded during the field survey. However, according to the latest orthophoto maps, 2-3 boat docks and footbridges may occur at some sites of Lake Galiņu/Salna shoreline.

The percentage of anthropogenic impact and pressures, like residential areas, roads, and pastures, within 15 and 50 m of the lake shore is considered as very low (<10%). Less than 25 % of Lake Galiņu/Salna shoreline could be affected by erosion. Lake sediments of the littoral zone are composed mainly of sand and gravel covered with a thin layer of silt.

The Lake Galiņu/Salna is used for recreational and management purposes: non-motor boat activities, angling from boat, swimming, macrophyte control.

Data on the physico-chemical character of the Lake Galiņu/Salna was collected at a relatively deep point (10.7 m). The Secchi depth value reached 4.1 m on September 25th, 2019. Dissolved oxygen levels ranged from 8.9 mg/L to 7.5 mg/L up to a depth of 3 m. It should be noted that the Lake Galiņu/Salna is a stratified lake where the metalimnion occurs at depths of 2.5 – 8 m.

According to the CORINE Land Cover data of 2018, forests make up 71.6 % and agricultural lands – 22.4 % of the lake catchment area.

Table 4.9.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Galiņu/Salna.

Hydromorphological Indicator	**Scores**	**Characteristics of the Impact**
Shore zone modification	0	Un-impacted condition
Shore zone intensive use	0	Un-impacted condition
Hydrological regime	0	Un-impacted condition
Sediment regime	2	Low risk of impact
In-lake use	6	High risk of impact
Index Site condition	0	Un-impacted condition
Catchment pressures	0	Un-impacted condition
Total	*8*	
Hydromorphological status	***Good***	

Developed scoring system for hydromorphological alterations and pressures in the frame of the LHS method illustrates that the difference of relevant scores for the Lake Galiņu/Salna and for a lake in reference conditions reaches 16 %, i.e. 8 out of possible 50 scores when assuming the worst-case scenario (Table 4.9.1.). Therefore, the Lake Galiņu/Salna corresponds to a lake waterbody in good hydromorphological status (class 2).

The hydromorphological quality elements and their scores according to the Lithuanian methodology are presented in Table 4.9.2. An increase in the sum of the scores indicates a deterioration of the hydromorphological conditions. The EQR value of the Hydromorphological Index of Lithuanian Lakes (EHMI) is 0.875 indicating good status.

Table 4.9.2. Scoring of hydromorphological quality elements for the Lake Galiņu/Salna according to Lithuanian methodology.

<table>
<tr><th colspan="2">Hydromorphological Quality Element</th><th>Score</th></tr>
<tr><td colspan="2">Water level and water exchange</td><td>1</td></tr>
<tr><td rowspan="3">Shore structure</td><td>Length of natural riparian vegetation (forest) belt</td><td>1</td></tr>
<tr><td>Shoreline alterations</td><td>0</td></tr>
<tr><td>Shore erosion</td><td>1</td></tr>
<tr><td colspan="2">Predominant substrate in the littoral zone</td><td>2</td></tr>
<tr><td colspan="2">Total</td><td>5</td></tr>
<tr><td colspan="2">Hydromorphological status</td><td>Good</td></tr>
</table>

4.10. Indicators not covered by the WFD

4.10.1. Zooplankton organisms

The zooplankton description below refers to figures in description of zooplankton in Lake Ilzu (Garais)/ Ilge.

All together in plankton and littoral biotopes there were 43 species found, of those in plankton particularly 29 species (8 rotifera, 13 cladocerans and 8 copepods).

Crustacean (Copepoda + Cladocera) species richness (21 species) versus total phosphorus was highest in studied lakes similar to other lakes with good ecological status (Fig. 2.10.2.), i.e., Lake Skirnas and Lake Lielais Kumpinišku.

The division among *Daphnia* spp., small cladocerans, calanoid copepods and cyclopoid copepods in the sample versus total phosphorus showed decrease of calanoid copepods and increase of Cladocera compared to Lake Skirnas (Secchi depth and chl-a values in Lake Skirnas indicate lower trophy level), still calanoid copepods were present in larger ratio in relation to cyclopoid copepods (Fig. 2.10.3.) indicating better ecological status compared with lakes Laucesas and Ilzu (Garais)/ Ilge.

Cladocera:Copepoda abundance ratio did not provide any clear information, while Cyclopoida:Calanoida ratio reflected total phosphorus, Secchi depth and chlorophyll a values distribution among studied lakes (Fig. 2.10.4.).

Species such as *Daphnia cucullata, Bosmina (B.) longirostris* were dominating and *Chydorus sphaericus* was found throughout the water column, this indicates a positive response to eutrophication development (Urtāne, 1998; Čeirāns, 2007).

This lake has become another new finding for copepod *Cyclops bohater* so far known from only one lake in Latvia and now found in three of studied project lakes. This species could serve as a potential indicator species since its biotope is oligotrophic and slightly eutrophic water bodies.

In littoral samples frequently found and dominant species was cladoceran *Acroperus angustatus* – so far found in Latvia only once, its distribution is not clear since it is often confused with similar species *A. harpae*. Another dominating littoral species was predator cladoceran *Polyphemus pediculus*, considered to be oligosaprobic.

It is also worth mentioning a large predator cladoceran *Bythotrephes* sp. was found in the pelagic water column, its dominance decreases if eutrophication increases (Urtāne, 1998), therefore it could serve as a potential indicator species. It is known its abundance is increasing in line with lake re-oligotrophication (Bledzki &Rybak, 2016).

4.10.2. Composition of lake sediments

Content of organic matter, carbon and mineral matter in Lake Galiņu/Salna in general corresponds to average values of all five studied transboundary lakes (Table 4.10.1.) and are in range to results of a previous study done by Jankevica et al. (2012). The study revealed that content of organic matter in 18 priority salmon fish lakes comprised 4.3 – 46.2 %. Content of carbonates in L. Galiņu/Salna is 2.21 to 2.89 % which is considerably lower than average value of all five studied transboundary lakes.

Table 4.10.1. Sediment composition of Lake Galiņu/Salna (data from sampling in 2021).

Sampling site	**organic matter, %**	**carbonates, %**	**mineral matter, %**	**N, %**	**C, %**
L. Galiņu/Salna, LT side	35.25	2.89	61.86	1.04	19.45
L. Galiņu/Salna, LT side	24.82	2.21	72.97	0.96	12.63
AVERAGE in 5 transboundary lakes	28.57	5.04	66.39	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hardwater lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 4.10.2., and proportion of P forms is shown in Figure 4.10.1. Concentration of total P in sediments of the L. Galiņu/Salna is comparable to that in other studied transboundary lakes. The largest fraction is the residual P, which comprises about 76 % of total P content in sediments. Considering the high content of organic matter in the lake sediments (Table 4.10.1), a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is higher if compared to that in other Latvian lakes (40-72 %; Jankēvica et al. 2012). The share of easily available mineral P fractions (NH_4Cl-P and $NaHCO_3$/ $Na_2S_2O_4$-P) is small (Fig. 4.10.1). Study of sediment quality in Latvian salmonid lakes by Jankēvica et al. (2012) showed that the share of NH_4Cl-P accounted for less than 0.35 % of total P and that of redox sensitive P species varied from 0.9 – 15.6 % of total P content.

Table 4.10.2. Concentration (mg/kg d.w.) of phosphorus speciation forms in L. Galiņu/Salnai sediments in August 2021.

Sampling site	**TP, mg/kg**	**NH_4Cl-P, mg/kg**	**$NaHCO_3$/ Na_2S_2O4-P, mg/kg**	**NaOH-P, mg/kg**	**HCl-P, mg/kg**	**residual-P, mg/kg**
L. Galiņu/Salna, LT side	1169	0.71	22	214	40	892
L. Galiņu/Salna, LT side	809	0.44	39	113	44	612
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

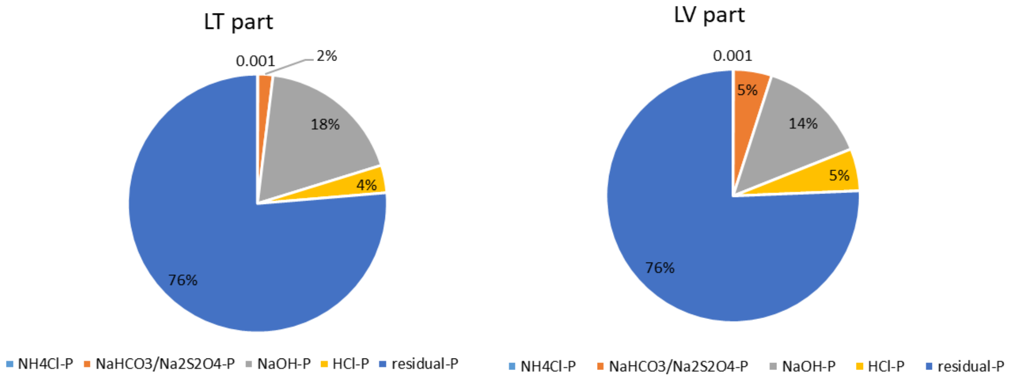

Figure 4.10.1. Proportion of phosphorus fractions in Lake Galiņu/Salna sediments.

4.11. Summary ecological quality according to the WFD criteria

The results obtained in Transwat project confirm previous results that the lake is in good ecological status according to ***Latvian*** methods. Nutrients concentrations and transparency are similar to previous results, but biological quality (macroinvertebrates) have significantly improved within a two-year period. Also, other monitored biological quality elements and oxygen concentration confirm that biological quality of the lake is at least good (Table 4.11.1).

Table 4.11.1. Total ecological status assessment of Lake Galiņu/Salna in Latvia, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Good	Moderate	High	Good	0.9	0.016	3.1	Good	Good	Good

According to the ***Lithuanian*** ecological status classification system, the ecological quality of the lake is classified as good with medium confidence because at least two biological elements indicate the same ecological status that is one status class lower than that according to the physico-chemical elements.

Table 4.11.2. Total ecological status assessment of Lake Galiņu/Salna in Lithuania, 2021.

Macro-invertebrates	Macro-phytes	Fish	Phyto-plankton	Biology, total	TN, mg/L	TP, mg/L	Secchi, m	Physico-chemical, total	HyMo	Total status
Good	Good	Good	High	Good	0.9	0.016	3.1	High	Good	Good

According to the results obtained by both countries, the lake is in good ecological status.

5. ECOLOGICAL QUALITY OF LAKE SKIRNAS

5.1. Lake waterbody type

According to the lake typology in Latvia, Lake Skirnas belongs to the type L5. That is a shallow clearwater lake with high water hardness. Average depth of the type L5 lakes is in the range 2 – 9 m, water colour is <80 mg Pt/L and electric conductivity (indicator of water hardness) is >165 µS/cm.

Monitoring results confirm the lake belongs to lake type L5. Average depth of the lake is 5.8 m. According to measurements done in 2021, yearly average colour is 9 mg Pt/L (varies from 8.2 mg Pt/L to 11.8 mg Pt/L), and conductivity is 359 µS/cm (varies from 329 µS/cm to 452 µS/cm).

According to the lake typology in Lithuania, the lake belongs to type 2, that is a stratified lake.

5.2. Major pressures in the lake catchment

According to Latvian 3rd cycle River basin management plans 2022-2027, this lake does not have any significant pressures within Latvian side. Lake Skirnas is a natural lake without water level and flow regulations. Agricultural lands occupy ~ 63 % (arable lands 8 %) and forests 32 % of the lake transboundary catchment area.

Modelling results show that the greatest share of nitrogen loads within the catchment originate from lake deposition, forests, agricultural lands and pastures: 29 %, 24 %, 21.2 % and 20.8 %, respectively. Most important sources of phosphorus load are households, forests and agricultural lands. Pressure from households accounts for 40 % of P loads, runoff from forests – for 20 % and runoff from arable lands for 19 % of the total load in the catchment.

Figures 5.2.1. and 5.2.2. show nitrogen (N) and phosphorus (P) load distribution by sectors in Lake Skirnas catchment for 2021.

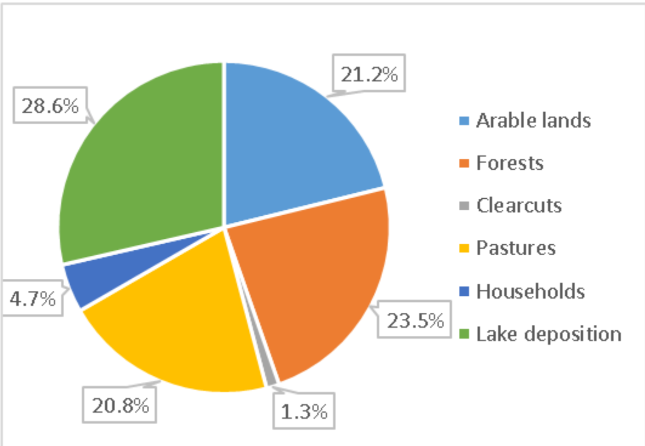

Figure 5.5.1. N source apportionment in Skirnas Lake catchment.

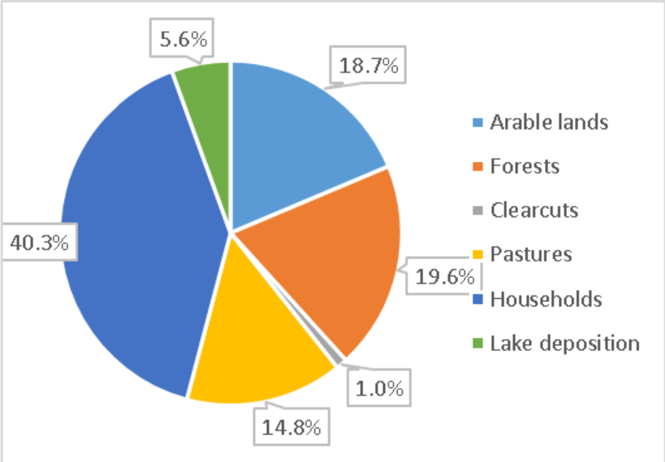

Figure 5.5.2. P source apportionment in Lake Skirnas catchment.

In Lithuania, the Lake Skirnas has not been previously identified as a water body and therefore has not been monitored. There are no known sources of pollution in the Lithuanian part of the lake basin. The diffuse pollution load has not yet been modelled. According to the expert assessment, the ecological status of the lake is good.

5.3. Overview of previous monitoring results

In Latvian side, there is one surface water quality monitoring station in Lake Skirnas – *Skirnas ezers, vidusdaļa*. It is located in the middle part of the lake in Latvian side and monitoring has been carried out by the Latvian Environment, Geology and Meteorology Centre. Lake was monitored once in the first monitoring cycle and once in the third monitoring cycle. Both times fish were not monitored. The ecological status of the lake water body is very stable – good. For 11 years, there have been insignificant changes in nutrient concentration. Also, results of biological quality elements have changed insignificantly within high/good class boundary (Table 5.3.1.).

Table 5.3.1. Changes of Lake Skirnas ecological quality.

Year	Macro-invertebrates	Macro-phytes	Phyto-plankton	Biology, total	TN, mg/L	TP, mg/L	Secchi, m	Physico-chemical, total	Total status
2007	Good	High	Good	Good	0.70	0.018		Good	Good
2018	High	Good	Good	Good	0.60	0.016	4.3	Good	Good

5.4. Phytoplankton indicators

Phytoplankton samples were collected twice during vegetation season – in May and August. Minor seasonal variations were observed, and Latvian phytoplankton EQR index value varied from 0.85 to 1 indicating high ecological quality. Annual average quality is high. Chlorophyll-a concentrations varied from 1.5 µg/L to 2.2 µg/L, corresponding to the type-specific reference values.

According to Lithuanian phytoplankton method, the ecological quality of the lake is also high (Table 5.4.1).

Table 5.4.1. Ecological quality according to phytoplankton.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
High	0.93	High	0.96

5.5. Macrophytes indicators

Ecological quality in the Lake Skirnas is high (Table 5.5.1). Species diversity is high (34 macrophyte species), including different charophyte species (*Chara filiformis, C. globularis, C. rudis, Nitellopsis obtusa*) and eight Potamogeton species (*Potamogeton lucens* and *P. perfoliatus* dominating). Water transparency is high, therefore the colonization depth of submerged macrophytes is also high – 5 m.

Macrophyte development is limited by steep bottom, but in the shallow parts of the lake species composition is characteristic for low impacted lakes (Figs. 5.5.1. and 5.5.2.). Dominating macrophyte species in the Lake Skirnas are *Fontinalis antipyretica*, *Phragmites australis*, *Nuphar lutea, Potamogeton lucens, Scirpus lacustris* and charophyte species.

Figure 5.5.1. SW part of the Lake Skirnas.

Figure 5.5.2. Impacted shore in the SE part of the lake.

Table 5.5.1. Ecological quality according to macrophytes.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
High	1.0	Good	0.52

5.6. Benthic invertebrates' indicators

The macroinvertebrates were sampled in May and October 2021 at two sampling points in the littoral zone. Lake Skirnas is at good status (Table 5.6.1.) according to Latvian LLMMI (Skuja and Ozoliņš, 2016) and Lithuanian LLMI (Šidagytė et al. 2013) assessment methods.

Table 5.6.1. Ecological quality of Lake Skirnas according to benthic invertebrates.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.82	Good	0.69

The abundance of macroinvertebrates varies from 189 to 509 specimens in a sample. The most abundant taxa are larvae of Chironomidae, pea clams *Pisidium* sp., invasive zebra mussel *Dreissena polimorpha* and mayfly species *Cloeon dipterum* is also common.

In spring, altogether 55 taxa of macroinvertebrates were identified from the littoral samples while in autumn only 40 taxa were found. The highest number of species was represented by aquatic snails Gastropoda and caddisflies Trichoptera.

5.7. Fish indicators

Fish sampling in Lithuanian part of the lake was carried out in August 2021. In total, 7 fish species were recorded during the fish survey. In terms of numbers in catches per unit of effort, roach and perch dominated, accounting for 55.4 and 35.3 % of the total number of fish, respectively, and 46.8 and 27 % of the total biomass. However, roach dominated the catches in the littoral zone, while perch was predominant in the deeper layers of the lake. The proportion of bream biomass is also relatively high (15.5 %), large individuals prevail in the catch of the latter fish species. All metrics of fish that are used to calculate the fish index for stratified lakes meet the criteria for good or high ecological status. According to the Lithuanian lake fish index, the ecological status of the lake is high, although the index value is close to the boundary of high/good ecological status.

Fish sampling in Latvian part of the lake was carried out at the beginning of September 2021. In total, 6 (8 in all gears) fish species were recorded. Catches were dominated by roach, accounting for 62.3 % of the total number of fish and 62.8 % of the total biomass. The relative abundance of piscivorous perch was moderate (27.2 % and 23.9 %). According to the Latvian lake fish index, the ecological status of the lake is good.

Table 5.7.1. Ecological quality of Lake Skirnas according to fish.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.69	High	0.88

5.8. Physical and chemical indicators

In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

In Latvia, according to TP concentration and Secchi depth, ecological quality of the Lake Skirnas is high, but TN concentration indicates good ecological quality. According to Lithuanian system, all parameters indicate a high ecological quality. Based on the WFD principle “one-out, all-out”, the overall physico-chemical quality of the lake is estimated as good (Table 5.8.1).

Table 5.8.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (colour scheme as for the EU WFD: blue – high, green – good, yellow – moderate, orange – poor, and red - – bad ecological quality).

Latvia		**Lithuania**	
parameter	average value	parameter	average value
TP, mg/L	0.011	TP, mg/L	0.011
TN, mg/L	0.55	TN, mg/L	0.55
Secchi depth, m	5.00	Secchi depth, m	5.00
TOTAL	good	TOTAL	high

Oxygen concentration is one of the most important indicators to describe lake ecosystem health. According to commonly used water quality standards, including those for priority fish water, healthy oxygen concentration must exceed 5 mg/L. In Lake Skirnas O_2 concentration exceeds 5 mg/L until 7 m depth which forms ~62 % of lake area. When depth is larger than 8 m, anoxia can be observed and extreme O_2 depletion can be observed in 28 % of lake area.

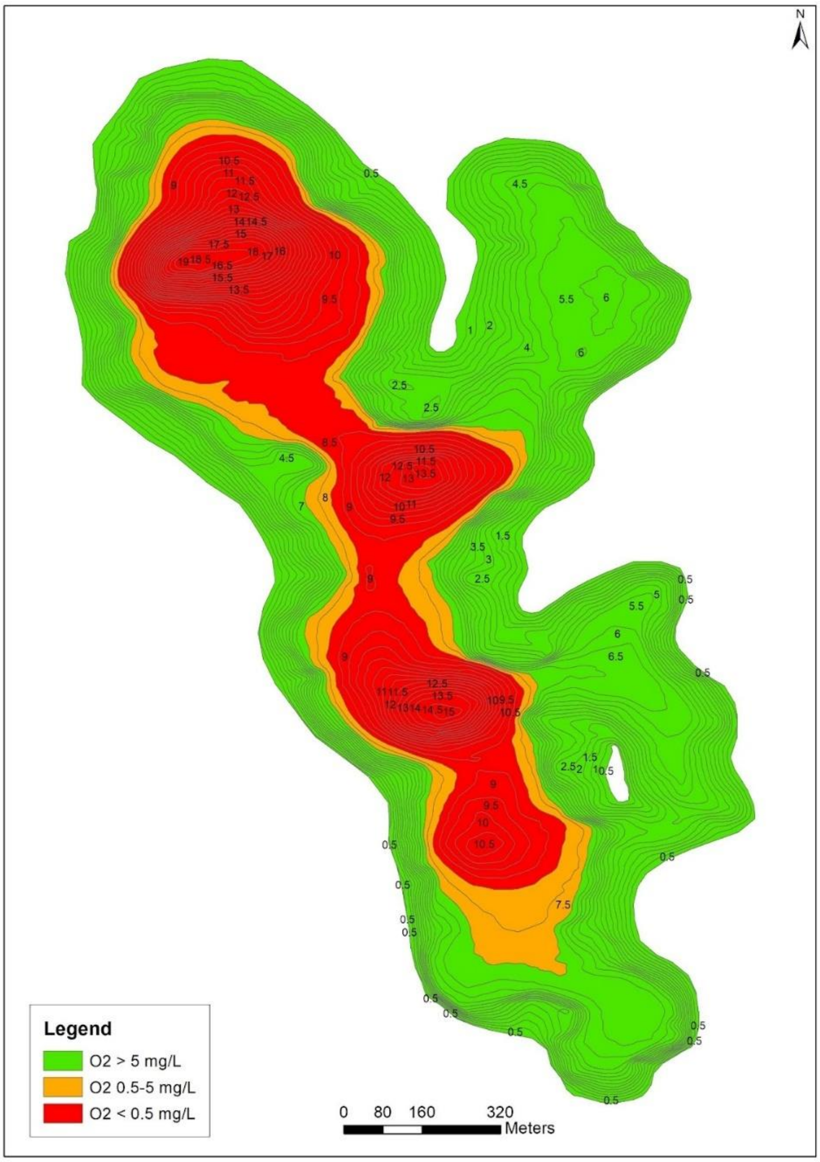

Figure 5.8.1. Changes in oxygen concentration depending on the depth of the Lake Skirnas.

5.9. Hydromorphological indicators

The WFD requires physical features of surface waters to be considered when assessing ‘ecological status’ and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history. The Lake Habitat Survey (LHS), as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs, was adopted in Latvia in 2014.

Lake Skirnas is a natural lake without water level and flow regulations and is classified as a waterbody in un-impacted hydrological condition.

Morphological alterations and pressures of the Lake Skirnas can be analysed only in context of using digital data, historical information and latest orthophoto maps because the LHS in the field was not carried out. According to the latest orthophoto maps, elements of ‘hard engineering’ are not recorded along the lake shoreline. Anthropogenic impact and pressures, like residential areas, roads, pastures and tilled land, can be observed within 15 and 50 m. However, agricultural areas occupy 70.4 % and the forest belt covers 29.6 % of the lake shoreline, according to the CORINE Land Cover data of 2018.

The Lake Skirnas is a shallow lake with an average depth 5.82 m and a maximum depth 18.7 m. Lake sediments consist mainly of sandy clay covered with a thin layer of silt.

The Lake Skirnas is used mostly for angling and swimming.

According to the CORINE Land Cover data of 2018 and data of 2020 from the Rural Support Service of Latvia, forests make up 31.6 % and arable land – 8.3 % of the lake catchment area.

Table 5.9.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Skirnas according to Latvian methodology.

Hydromorphological Indicator	**Scores**	**Characteristics of the Impact**
Shore zone modification	0	Un-impacted condition
Shore zone intensive use	6	High risk of impact
Hydrological regime	0	Un-impacted condition
Sediment regime	2	Low risk of impact
In-lake use	4	Moderate risk of impact
Catchment pressures	0	Un-impacted condition
Total	*12*	
Hydromorphological status	***Good***	

Developed scoring system for hydromorphological alterations and pressures in the frame of the LHS method illustrates that the difference of relevant scores for the Lake Skirnas and for a lake in reference conditions reaches 26 %, i.e. 12 out of possible 46 scores when assuming the worst-case scenario (Table 5.9.1.). Thus, the Lake Skirnas corresponds to a lake waterbody in good hydromorphological status (class 2).

The hydromorphological quality elements and their scores according to the Lithuanian methodology are presented in Table 5.9.2. An increase in the sum of the scores indicates a deterioration of the hydromorphological conditions. The EQR value of the Hydromorphological Index of Lithuanian Lakes (EHMI) is 0.81 indicating a good status.

Table 5.9.2. Scoring of hydromorphological quality elements for the Lake Skirnas according to Lithuanian methodology.

Hydromorphological Quality Element		**Score**
Water level and water exchange		1
Shore structure	Length of natural riparian vegetation (forest) belt	3
	Shoreline alterations	0
	Shore erosion	0
Predominant substrate in the littoral zone		2
Total		*6*
Hydromorphological status		***Good***

5.10. Indicators not covered by the WFD

5.10.1. Zooplankton organisms

The zooplankton description below refers to figures in description of zooplankton in Lake Ilzu (Garais)/ Ilge.

Lake Skirnas was less eutrophic considering its total phosphorus, Secchi depth and chl-a values. All together in plankton and littoral biotopes there were 37 species found, of those in plankton particularly 23 species (7 rotifera, 9 cladocerans and 7 copepods).

Crustacean (Copepoda + Cladocera) species richness (16 species) versus total phosphorus was higher than in lakes with moderate ecological status (Lake Laucesas and Lake Ilzu (Garais)/Ilge, still it was lower compared to that of other lakes with good ecological status (Lake Lielais Kumpinišku and Lake Galinu), see Figure 2.10.2.

The division among *Daphnia* spp., small cladocerans, calanoid copepods and cyclopoid copepods in the sample versus total phosphorus showed rather similar ratio share between calanoid copepods and cyclopoid copepods (slightly dominating) indicating the less eutrophic conditions among studied lakes, while cladocerans were suppressed (Fig. 2.10.3).

Cladocera:Copepoda abundance ratio did not provide any clear information, while Cyclopoida:Calanoida ratio reflected total phosphorus, Secch depth and chl-a values distribution among studied lakes (Fig. 2.10.4.).

Species such as *Keratella cochlearis* and *Daphnia cucullata* were dominating, this indicates a positive response to eutrophication development (Urtāne, 1998; Čeirāns, 2007).

This lake has also become a new finding for copepod *Cyclops bohater* so far known from only one lake in Latvia and now found in three of studied project lakes. This species could serve as a potential indicator species since its biotope is oligotrophic and slightly eutrophic water bodies.

In littoral samples frequently found and dominant species was cladoceran *Acroperus angustatus* – so far found in Latvia only once, its distribution is not clear since it is often confused with similar species *A. harpae*.

Also, a large predator cladoceran *Bythotrephes* sp. was found in the pelagic water column, its dominance decreases if eutrophication increases (Urtāne, 1998), therefore it could serve as a potential indicator species. It is known its abundance is increasing in line with lake reoligotrophication (Bledzki &Rybak, 2016).

This was the only lake where Calanoida group was represented by two species – *Eudiaptomus graciloides* (also being among dominating and frequently found species in this lake and being present in all studied lakes) and *Heterocope appendiculata* (species is known to dominate in lakes with a low trophic level according to Bledzki &Rybak, (2016)).

In this lake, there is also a new species record for a country – for the very first time a littoral benthic species *Paracyclops poppei* was found.

5.10.2. Composition of lake sediments

Content of organic matter, carbon and mineral matter in Lake Skirnas in general corresponds to average values of all five studied transboundary lakes (Table 5.10.1.) and are in range to results of a previous study done by Jankevica et al. (2012). Content of organic matter and carbon as well as nitrogen is slightly lower in L.Skirnas sediments than in sediments of other studied transboundary lakes.

Table 5.10.1. Sediment composition of Lake Skirnas (data from sampling in 2021).

Sampling site	**organic matter, %**	**carbonates, %**	**mineral matter, %**	**N, %**	**C, %**
L. Skirnas, LT side	18.1	6.18	75.7	0.81	10,55
L.Skirnas, LV side	24.0	4.18	71.8	1.09	13.23
AVERAGE in 5 transboundary lakes	28.57	5.04	66.4	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hardwater lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and

organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 5.10.2., and proportion of P forms is shown in Figure 5.10.1. Concentration of total P in sediments of the L. Skirnas is comparable to that in other studied transboundary lakes. The largest fraction is the residual P, which comprises about 78 % of total P content in sediments, probably, a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is also slightly higher if compared to that in other Latvian lakes (40-72 %; Jankēvica et al. 2012). The share of easily available mineral P fractions (NH_4Cl-P and $NaHCO_3$/ $Na_2S_2O_4$-P) is small (Fig. 5.10.1). Study of sediment quality in Latvian salmonid lakes by Jankēvica et al. (2012) showed that the share of NH_4Cl-P accounted for less than 0.35 % of total P and that of redox sensitive P species varied from 0.9 – 15.6 % of total P content.

Table 5.10.2. Concentration (mg/kg d.w.) of phosphorus speciation forms in L. Skirnas sediments in August 2021.

Sampling site	**TP, mg/kg**	**NH_4Cl-P, mg/kg**	**$NaHCO_3$/ Na_2S_2O4-P, mg/kg**	**NaOH-P, mg/kg**	**HCl-P, mg/kg**	**residual-P, mg/kg**
L. Galiņu/Salna, LT side	727	0.76	40	47	71	568
L. Galiņu/Salna, LT side	864	0.85	56	71	65	672
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

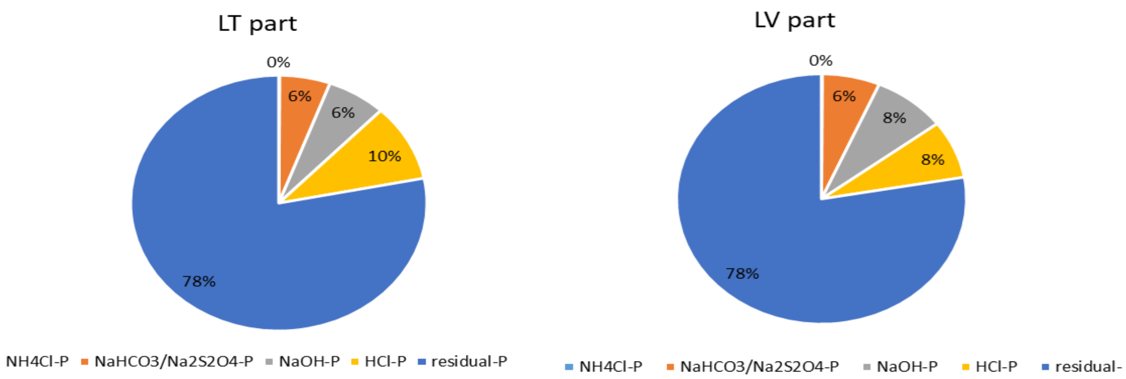

Figure 5.10.1. Proportion of phosphorus fractions in Lake Galiņu/Salna sediments.

5.11. Summary ecological quality according to the WFD criteria

The monitoring results obtained in this project coincide with the monitoring results of previous years and confirm that Lake Skirnas is in a good ecological status according to

Latvian assessment system. Nutrient concentrations continue to decrease. Oxygen concentration is sufficient in most of lake. Monitoring of all biological elements shows that this lake possibly can be chosen as one of lake type L5 reference lakes (Table 5.11.1).

Table 5.11.1. Total ecological status assessment of Lake Skirnas in Latvia, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	High	High	High	Good	0.55	0.011	5	Good	Good	Good

According to the ***Lithuanian*** ecological status classification system, the ecological quality of the lake is classified as good with medium confidence (at least two biological elements indicate the same ecological status that is one status class lower than that according to the physico-chemical elements).

Table 5.11.2. Total ecological status assessment of Lake Skirnas in Lithuania, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**Ntot, mg/L**	**Ptot, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Good	High	High	Good	0.55	0.011	5	High	Good	Good

Ecological status assessment shows that the Lake Skirnas is in good ecological status in both countries.

6. ECOLOGICAL QUALITY OF LAKE LAUCESAS/LAUKESAS

6.1. Lake waterbody type

According to the lake typology in Latvia, Lake Laucesas/Laukesas belongs to the type L5. That is a shallow clearwater lake with high water hardness. Average depth of the type L5 lakes is in the range 2 – 9 m, water colour is <80 mg Pt/L and electric conductivity (indicator of water hardness) is >165 µS/cm.

Monitoring results confirm the lake belongs to lake type L5. Average depth of the lake is 5.4 m. According to measurements done in 2021, yearly average colour is 30 mg Pt/L (varies from 27.4 mg Pt/L to 34.8 mg Pt/L), and conductivity is 406 µS/cm (varies from 356 µS/cm to 463 µS/cm).

According to the lake typology in Lithuania, the lake belongs to type 2, that is a stratified lake.

6.2. Major pressures in the lake catchment

According to ***Latvian*** 3rd cycle River basin management plans 2022-2027, the most significant pressure on the lake is diffuse pollution from agriculture and transboundary pollution from Lithuania. Diffuse pressure from forests is considered insignificant.

Lake Laucesas/Laukesas can be characterized as a natural lake without significant water level alterations. Drainage (amelioration systems) occupy about 1.5 % of the whole lake catchment. There are no hydropower plants, dams or other obstacles on inflowing and outflowing rivers and ditches. Forests cover up to 45 % and agricultural lands 43 % of total transboundary catchment area. Urban areas and non-natural land-use occupy 4 % and wetlands 1 % of catchment.

Modelling results show that the greatest share of nitrogen loads within the catchment originate from agricultural lands and forests – 46 % and 35 % respectively. Most important sources of phosphorus load are agricultural lands and forests as well, runoff from agricultural lands accounts for 46 % of P loads and runoff from forests for 33 % of the total load in the catchment.

Figures 6.2.1, and 6.2.2. show nitrogen (N) and phosphorus (P) load distribution by sectors in Laucesas/Laukesas Lake catchment for 2021.

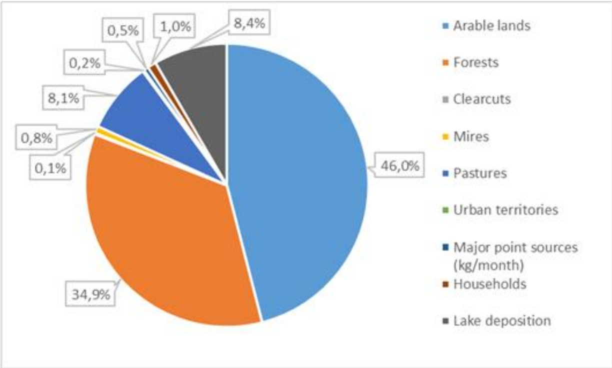

Figure 6.2.1. N source apportionment in Laucesas/Laukesas Lake catchment

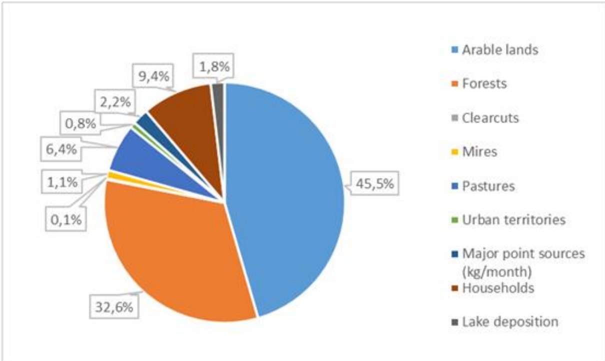

Figure 6.2.2. P source apportionment in Laucesas/Laukesas Lake catchment

According to ***Lithuania***'s 3rd cycle River basin management plans, there are currently no major sources of pollution that could negatively affect the ecological status of the lake. The lake previously has suffered from poorly treated wastewaters, coming from Zarasai wastewater treatment plant via Laukesa River. The reconstruction of the Zarasai wastewater treatment plant was carried out in 2009. During the reconstruction, chemical phosphorus removal, sludge dewatering equipment and a new sand trap were installed. After the reconstruction, the removal efficiency for ammonia nitrogen, suspended solids and BOD reached 99%, for total phosphorus and orthophosphate 96 – 98 % and for total nitrogen 91 %. Therefore, the Zarasai WWTP is no longer considered as significant pressure. Modelling of nutrient loads from diffuse sources has also shown that the impact of diffuse pollution is not significant. According to the 2017 monitoring data, all monitored quality elements met the criteria for good status. Therefore, the status of the lake was assessed as good in the third cycle of the Lithuanian river basin management plans. However, some biological elements were not monitored.

6.3. Overview of previous monitoring results

In Latvian side, there is one surface water quality monitoring station in Lake Laucesas – *Lauces ezers, vidusdaļa*. It is located in the middle part of the lake in Latvian side and monitoring has been carried out by the Latvian Environment, Geology and Meteorology Centre. Lake was monitored once in the first monitoring cycle, two times in the second monitoring cycle and once in the third monitoring cycle. The ecological status of the lake water body is very stable – moderate (Table 6.3.1). Biological quality, except phytoplankton, has not changed significantly during the 7-year period. Nitrogen and phosphorus concentrations show decreasing trend, also water transparency has improved and is now close to a good quality class boundary.

Table 6.3.1. Long-term changes in lake ecological quality (LEGMC data).

Year	Macro-invertebrates	Macro-phytes	Phyto-plankton	Biology, total	TN, mg/L	TP, mg/L	Secchi, m	Physico-chemical, total	Total status
2008	Good		Moderate	Moderate	1.10	0.047	0.9	Poor	Moderate
2011	Good		Moderate	Moderate	1.10	0.050	1.0	Moderate	Moderate
2012	Good		Moderate	Moderate	0.90	0.039	1.3	Moderate	Moderate
2015	Good	Moderate	High	Moderate	0.94	0.040	1.7	Moderate	Moderate

6.4. Phytoplankton indicators

Phytoplankton samples were collected twice during vegetation season - in May and August. Minor seasonal variations were observed, and Latvian phytoplankton EQR index value varied from 0.65 to 0.75 indicating a good quality. Annual average quality is good. Chl-a concentrations varied from 6.3 µg/L (good quality class) to 17.4 µg/L (moderate quality).

According to the Lithuanian phytoplankton method, the ecological quality of the Lake Laucesas is moderate. Although the phytoplankton methods of the two countries are intercalibrated, the EQR values still belongs different quality classes (Table 6.4.1), although chl-a concentration indicates possibly moderate ecological quality in summer.

Table 6.4.1. Lake ecological quality according to phytoplankton.

Latvia		Lithuania	
Quality assessment	EQR	Quality assessment	EQR
Good	0.70	Moderate	0.52

6.5. Macrophytes indicators

In the Lake Laucesas, macrophyte species composition is characteristic for eutrophic lakes. Ecological quality of the lake is assessed as moderate (Table 6.5.1.). Diversity of macrophyte species in the most part of the lake is moderate and submerged species occur rare due to low water transparency (Figs. 6.5.1. and 6.5.2.). Dominating species in the whole lake are *Phragmites australis, Nuphar lutea, Ceratophyllum demersum,* as well as *Typha latifolia*. Two last species are typical for eutrophic and polluted waters.

Higher species diversity is found only in the bay where River Ilgas flows in the lake and water transparency is higher. Only in this part of lake charophyte species – *Chara globularis*, *Nitella mucronata* and *Nitellopsis obtusa* are found.

Figure 6.5.1. Low water transparency in Lake Laucesas.

Figure 6.5.2. Blue green algae blooming in the western part of the lake.

Table 6.5.1. Ecological quality assessment according to macrophytes.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Moderate	0.6	Poor	0.18

6.6. Benthic invertebrates' indicators

Macroinvertebrates were sampled in May and October 2021 at two sampling points in the littoral zone. The littoral zone of the lake is mostly covered by mineral substrate – gravel, pebbles and rocks. Lake Laucesas is at good status (Table 6.6.1.) according to both the Latvian LLMMI (Skuja and Ozoliņš, 2016) and Lithuanian LLMI (Šidagytė et al. 2013) assessment methods.

Table 6.6.1. Ecological quality of Lake Laucesas according to benthic invertebrates.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.88	Good	0.59

The abundance of macroinvertebrates varied from 561 to 2369 specimens. The most abundant taxa were larvae of Chironomidae, aquatic worms Oligochaeta and mayflies *Caenis horaria*. Invasive zebra mussel *Dreissena polimorpha* is also common in Lake Laucesas. A nationally protected species river nerite *Theodoxus fluviatilis* was also common in the lake (Regulations of the Cabinet of Ministers No. 396). In spring, altogether 48 benthic invertebrate taxa were found while in autumn 60 taxa were found in the littoral samples.

6.7. Fish indicators

Fish sampling in Lithuanian part of the lake was carried out in August 2021. During the fish survey, seven species of fish were recorded. The most numerous species in the catch per unit of effort (CPUE) are the roach, white bream and perch, which together account for 77.3 % (20.9 – 29.9 %) of the total number of individuals in the catch. However, roach dominates in terms of relative biomass, accounting for 52.7 % of total CPUE. Two obligatory species were missing from the catch. In addition, no fish were present in the nets set in the deeper layers of the lake. However, in the upper layers the density of fish is high. According to Lithuanian lake fish index, the status of the lake is moderate.

Fish sampling in Latvian part of the lake was carried out at the beginning of September 2021. In total, 7 (14 in all gears) fish species were recorded. Catches were dominated by roach, accounting for 41.9 % of the total number of fish and 52.0 % of the total biomass. The relative abundance of piscivorous perch was moderate (26.4 % and 27.9 %). According to the Latvian lake fish index, the ecological status of the lake is good.

Table 6.7.1. Ecological quality of Lake Laucesas according to fish.

Latvia		**Lithuania**	
Quality assessment	EQR	Quality assessment	EQR
Good	0.70	Moderate	0.54

6.8. Physico-chemical indicators

In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

In Latvia, according to TP and TN concentrations, ecological quality of the Lake Laucesas/ Laukesas is good, but the Secchi depth value indicates moderate ecological quality. Lithuanian methodology indicates a high status by TN and TP concentration, and good status by transparency. Based on the WFD principle “one-out, all-out”, the overall physico-chemical quality of the lake is estimated as moderate in Latvia and as good in Lithuania (Table 6.8.1).

Table 6.8.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (color scheme as for the EU WFD: blue – high, green – good, yellow – moderate, orange – poor, and red – bad ecological quality).

Latvia		**Lithuania**	
parameter	average value	parameter	average value
TP, mg/L	0.029	TP, mg/L	0.029
TN, mg/L	0.94	TN, mg/L	0.94
Secchi depth, m	1.30	Secchi depth, m	2.10
TOTAL	**moderate**	**TOTAL**	**good**

Oxygen concentration is one of the most important indicators to describe lake ecosystem health. According to commonly used water quality standards, including those for priority fish waters, healthy oxygen concentration must exceed 5 mg/L. In Lake Laucesas/Laukesas O_2 concentration exceeds 5 mg/L in depth which is shallower than 4 m and about 49 % of lake is suitable for aquatic organisms. If depth exceeds 6 m, anoxia can be observed and in 37 % of lake area O_2 concentration is less than 0.5 mg/L (Fig. 6.8.1.).

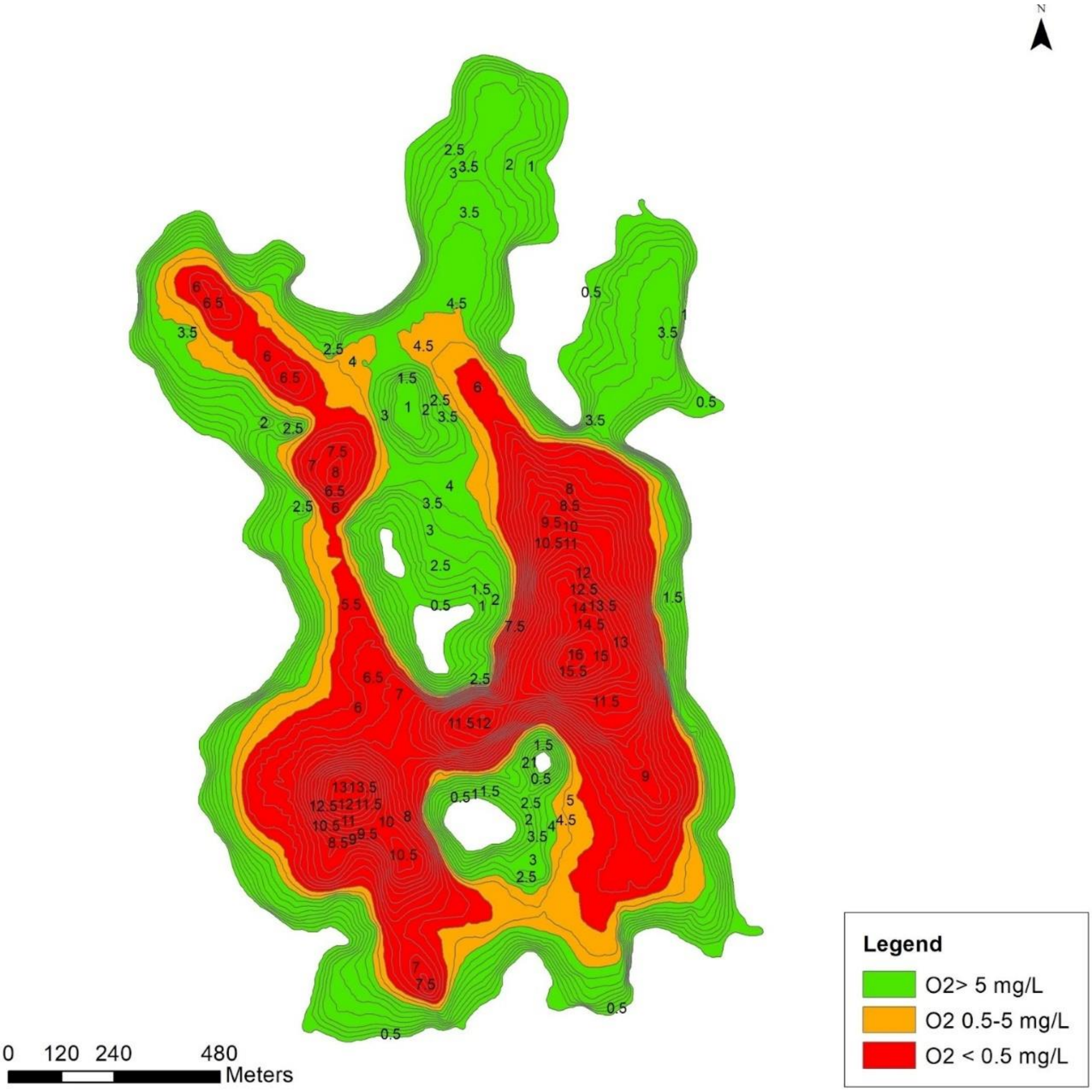

Figure 6.8.1. Changes in oxygen concentration depending on the depth of the Lake Laucesas/Laukesas.

6.9. Hydromorphological indicators

The WFD requires physical features of surface waters to be considered when assessing ‘ecological status’ and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history. The Lake Habitat Survey (LHS), as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs, was adopted in Latvia in 2014.

Lake Laucesas/Laukesas can be characterized as a natural lake without significant water level alterations. Amelioration systems are constructed in the north-eastern (Latvian) part of the lake catchment, in the Ilga River sub-basin and occupy about 1.5 % of the whole lake catchment. However, there are no hydropower plants and dams on the main Laucesa River as well as the river flow is not regulated at least for 4.6 km upstream and 18 km downstream of the Lake Laucesas/Laukesas. The absence of large hydrological structures and the natural water level regime allows to classify Lake Laucesas/Laukesas as a waterbody in high hydrological status.

LHS for the Lake Laucesas/Laukesas was carried out on foot on July 29th, 2021 (in Latvian part). Four sampling plots or Hab-Plots were selected in order to record detailed habitat characteristics in the shore, riparian and littoral zones. However, field surveying results cannot fully replace available digital data and maps because collected data on habitat characteristics and pressures cover only 59 % of the whole lake shoreline length (instead of the minimum 75 %).

During the field survey boat docks and footbridges were recorded only within one of four Hab-Plots. However, this pressure regarding lake shore modification is not permanent and may be built in one place and disappear – in another. Artificial structures like 'hard engineering' and 'soft engineering' were not recorded along Laucesas/Laukesas Lake shore. Anthropogenic impact and pressures, like commercial activities, residential areas, roads and railways, parks and gardens as well as large areas of pastures and tilled land, were recorded and estimated within 15 and 50 m reaching 68.7 % of total lake shoreline length.

Less than 50 % of Lake Laucesas/Laukesas area could be affected by deposition (excluding vegetated islands). Lake sediments are composed of silt in the deeper areas. However, the bottom consists mainly of pebble, gravel and sand in shallows.

The Lake Laucesas/Laukesas is used mostly for recreational purposes: non-motor boat activities, angling from boat and angling from shore.

Data on the physico-chemical character of the Lake Laucesas/Laukesas was collected at a relatively deep point. On July 29th, 2021 lake's maximum depth at Index Site was 13 m. Dissolved oxygen levels ranged from 9.2 mg/L to 9.7 mg/L up to a depth of 3 m. Dissolved oxygen was almost not present at the deeper layers (0.1 – 0.3 mg/L). It should be noted that the Lake Laucesas is a stratified lake where the temperature changes at rates from 1.6 to even 5.7 ^{o}C per meter of lake depth during the summer season. The metalimnion is indicated at depths of 4 – 6 m and also at a depth of 8 m. Measured Secchi depth was only 0.95 m.

According to the CORINE Land Cover data of 2018, urban areas make up 1.6 % and total non-natural land-use – 2.2 % of the total catchment area. Forest lands comprise 45.2 %, wetlands – 1.0 % and water bodies (also including Laucesas/Laukesas Lake) – 8.1 % of the catchment area. Agricultural areas occupy 43.4 % and separately arable land – 5.7 % of the area.

Table 6.9.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Laucesas/Laukesas according to Latvian methodology.

Hydromorphological Indicator	Scores	Characteristics of the Impact
Shore zone modification	2	Low risk of impact
Shore zone intensive use	6	High risk of impact
Hydrological regime	0	Un-impacted condition
Sediment regime	2	Low risk of impact
In-lake use	4	Moderate risk of impact
Index Site condition	4	Moderate risk of impact
Catchment pressures	0	Un-impacted condition
Total	*18*	
Hydromorphological status	***Moderate***	

Developed scoring system for hydromorphological alterations and pressures in the frame of the LHS method illustrates that the difference of relevant scores for the Lake Laucesas/ Laukesas and for a lake in reference conditions reaches 36 %, i.e. 18 out of possible 50 scores when assuming the worst-case scenario (Table 6.9.1.). Thus, the Lake Laucesas/ Laukesas corresponds to a lake waterbody in moderate hydromorphological status (class 3).

The hydromorphological quality elements and their scores according to the Lithuanian methodology are presented in Table 6.9.2. An increase in the sum of the scores indicates a deterioration of the hydromorphological conditions. The EQR value of the Hydromorphological Index of Lithuanian Lakes (EHMI) is 0.75 indicating less than good status.

Table 6.9.2. Scoring of hydromorphological quality elements for the Lake Laucesas/Laukesas according to Lithuanian methodology.

Hydromorphological Quality Element		**Score**
Water level and water exchange		1
Shore structure	Length of natural riparian vegetation (forest) belt	2
	Shoreline alterations	1
	Shore erosion	0
Predominant substrate in the littoral zone		3
Total		*7*
Hydromorphological status		***Less than good***

6.10. Indicators not covered by the WFD

6.10.1. Zooplankton organisms

The zooplankton description below refers to figures in description of zooplankton in Lake Ilzu (Garais)/ Ilge.

Lake Laucesas was more eutrophic considering its total phosphorus concentration, Secchi depth and chlorophyll-a values.

All together in plankton and littoral biotopes there were 43 species found, of those in plankton particularly 22 species (11 rotifera, 7 cladocerans and 4 copepods).

Crustacean (Copepoda + Cladocera) species richness (11 species) versus total phosphorus was lowest among all studied lakes and closer to lake with moderate ecological status (Lake Ilzu (Garais)/Ilge) than to those with good ecological status (Lake Lielais Kumpinišku, Lake Skirnas, Lake Galinu), see Fig. 2.10.2.

The division among *Daphnia* spp., small cladocerans, calanoid copepods and cyclopoid copepods in the sample versus total phosphorus showed decreased share of calanoid copepods ratio compared to dominating cyclopoid copepods, which is typical for eutrophic lakes. This lake however had the greatest share of small cladocerans among all studied lakes that could indicate for instance the impact of cyanobacteria since the small-bodied cladocerans are less affected by blue-green algae (Fig. 2.10.3.).

Ratio of Cladocera:Copepoda abundance did not provide any clear information, while Cyclopoida:Calanoida ratio reflected total phosphorus, Secchi depth and chl-a values distribution among studied lakes (Fig. 2.10.4.) showing clear relation between Lake Laucesas Cyclopoida:Calanoida abundance ratio and total phosphorus amount.

Species such as *Keratella cochlearis, Chydorus sphaericus* and *Bosmina (B.) longirostris* were dominating, this indicates a positive response to eutrophication development (Urtāne, 1998; Čeirāns, 2007).

Cladoceran *Acroperus angustatus* was frequently found in littoral samples. So far this species is found in Latvia only once, and its distribution is not clear since it is often confused with similar species *A. harpae*.

6.10.2. Composition of lake sediments

Content of organic matter, carbon and mineral matter in Lake Laucesas varies (Table 6.10.1.). In central parts of the lake, the content of organic matter, carbonates as well as nitrogen is lower than in average in all studied transboundary lakes. In a bay in Latvian side, the sediments however are richer in organic matter, carbon and nutrients compared to other sampling stations. In general, the results are in range to those of a previous study done by Jankevica et al. (2012).

Table 6.10.1. Sediment composition of Lake Laucesas (data from sampling in 2021).

Sampling site	organic matter, %	carbonates, %	mineral matter, %	N, %	C, %
L. Laucesas, LT side	19.10	11.14	69.75	0.85	12.35
L. Laucesas, LV side, deepest point	20.28	11.48	68.24	0.87	12.62
L. Laucesas, LV side, bay	29.52	6.75	63.73	1.27	18.15
AVERAGE in 5 transboundary lakes	28.57	5.04	66.39	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hardwater lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 6.10.2., and proportion of P forms is shown in Figure 6.10.1. Concentration of total P in sediments from deeper parts of the Lake Laucesas is considerably higher than in other studied transboundary lakes. However, in a bay the total phosphorus content is as the average in the studied lakes. The largest fraction is the residual P, which comprises about 72 - 81 % of total P content in sediments. Considering the high content of organic matter in the lake sediments (Table 6.10.1), a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is higher if compared to that in other Latvian lakes (40 – 72 %; Jankēvica et al. 2012). The share of easily available mineral P fractions (NH_4Cl-P and $NaHCO_3$/ Na_2S_2O4-P) is small (Figure 6.10.1). Study of sediment quality in Latvian salmonid lakes by Jankēvica et al. (2012) showed that the share of NH_4Cl-P accounted for less than 0.35 % of total P and that of redox sensitive P species varied from 0.9 – 15.6 % of total P content.

Table 6.10.2. Concentration (mg/kg d.w.) of phosphorus speciation forms in Lake Laucesas sediments in August 2021.

Sampling site	**TP, mg/kg**	**NH_4Cl-P, mg/kg**	**$NaHCO_3$/ Na_2S_2O4-P, mg/kg**	**NaOH-P, mg/kg**	**HCl-P, mg/kg**	**residual-P, mg/kg**
L. Laucesas, LT side	1476	1.27	68	227	99	1080
L. Laucesas, LV side, deepest point	1470	1.36	81	223	101	1064
L. Laucesas, LV side, bay	1063	1.75	69	41	88	864
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

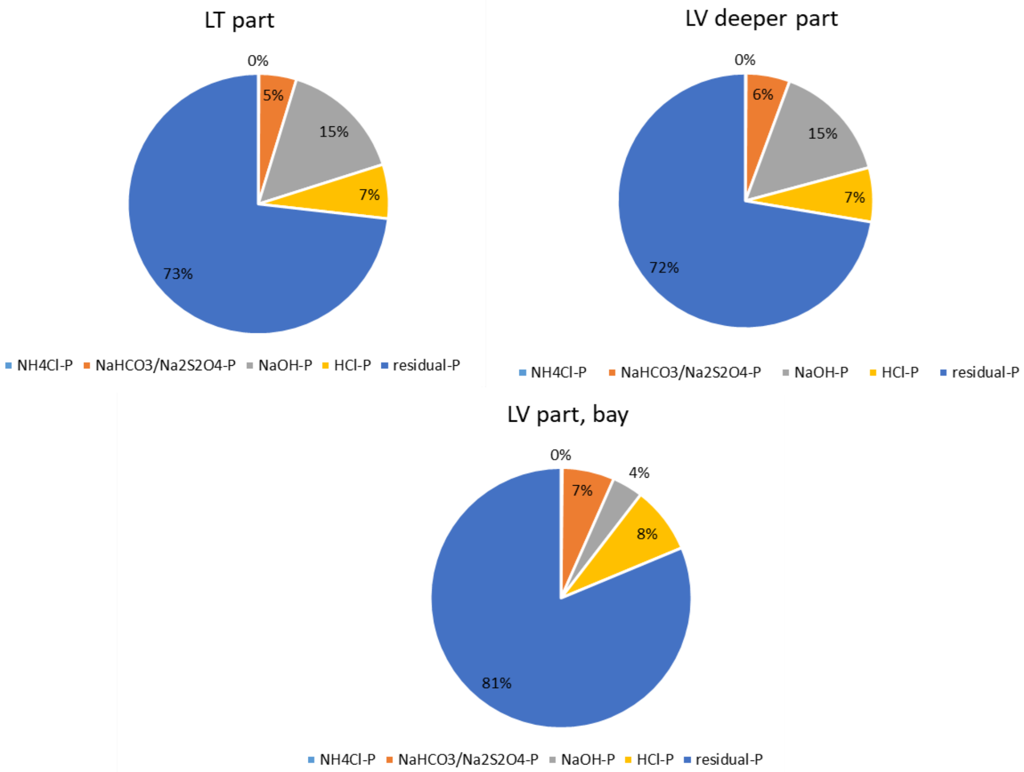

Figure 6.10.1. Proportion of phosphorus fractions in Lake Laucesas sediments.

6.11. Summary ecological quality according to the WFD criteria

The results of this project confirm that the lake is still in moderate ecological status (Table 6.11.1) and no changes have occurred during the 6-year period since last monitoring. The lake is not in a good status because of moderate quality of macrophytes and water transparency. Also, oxygen conditions are not good in most of lake.

Table 6.11.1. Total ecological status assessment of Lake Laucesas/Laukesas in Latvia, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**HyMo**	**Physico-chemical, total**	**Total status**
Good	Moderate	Good	Good	Moderate	0.94	0.029	1.3	Moderate	Moderate	Moderate

According to the Lithuanian ecological status classification system, the ecological quality of the lake is classified as poor with low confidence because according to one biological element the ecological status is more than one status class lower than that according to the physico-chemical elements (Table 6.11.2).

Table 6.11.2. Total ecological status assessment of Lake Laucesas/Laukesas in Lithuania, 2021.

Macro-invertebrates	**Macro-phytes**	**Fish**	**Phyto-plankton**	**Biology, total**	**TN, mg/L**	**TP, mg/L**	**Secchi, m**	**Physico-chemical, total**	**HyMo**	**Total status**
Good	Poor	Moderate	Moderate	Poor	0.94	0.029	2.10	Good	Less than good	Poor

Ecological status assessment in both countries shows that the Lake Laucesas/Laukesas is not in a good status and additional measures must be implemented to improve the ecological quality of this lake.

7. COMPARISON OF ECOLOGICAL QUALITY IN THE STUDIED TRANSBOUNDARY LAKES

Latvia and Lithuania have successfully intercalibrated all biological quality elements and, theoretically, the assessment of biological quality should be comparable. In practice, it was concluded that the biological quality element that causes the most discussions is macrophytes, whose ecological quality assessment significantly differed (mismatch between good/moderate boundary) in two lakes. Physico-chemical assessment completely coincides in two lakes and in another two lakes the differences are not significant (differences between high and good quality class). The biggest disagreement is about the physico-chemical quality of Lake Laucesas/Laukesas (Table 7.1), mismatch is caused by water transparency which is assessed as good in Lithuania but only moderate in Latvia. According to lake bathymetry maps, the deepest part of this lake is in Latvian side and therefore it can be concluded that the inconsistency between the results can be caused by the fact that in Latvia the summer average value is used in the transparency calculation, and in Lithuania the annual average value is used.

According to the WFD guidelines, biological quality elements are of greatest importance in determining the ecological quality of surface water bodies, and therefore special attention should be paid to the intercalibration and updating of biological methods.

Table 7.1. Overview of ecological status of the studied transboundary lakes according to Latvian and Lithuanian assessment methods.

Lake	Country	Biology	Hydromorphology	Physico-chemistry	Total status
Ilzu (Garais)/Ilge	LV	Poor	Moderate	Moderate	Poor
	LT	Moderate	Less than good	Moderate	Moderate
Lielais Kumpinišku/Kampiniskiai	LV	Good	Good	Good	Good
	LT	Good	Good	Good	Good
Galiņu/Salna	LV	Good	Good	Good	Good
	LT	Good	Good	High	Good
Lake Skirnas	LV	Good	Good	Good	Good
	LT	Good	Good	High	Good
Laucesas/Laukesas	LV	Moderate	Moderate	Moderate	Moderate
	LT	Poor	Less than good	Good	Poor

According to the WFD B system typology used in Latvia, lake water body is a lake with a surface area of 50 ha or more. During implementation of 2rd cycle River basin management plans, it was stressed out that there are several lakes with surface area > 50 ha which are not recognised as separate water bodies in Latvia. New delineation was done in 2017 – 2019 and the total number of lake water bodies increased from 263 to 277. In total, in Latvia there were four transboundary lakes with part of their water surface in Lithuania and after the new delineation number of transboundary lakes with Lithuania increased to 5(6) lake water bodies. Lake Lielais Subates consists of two parts (Lakes Lielais and Mazais Subates) and only Lake Mazais Subates borders with Lithuania. One of the new lake water bodies is Lake Lielais Kumpinišku/Kampiniskiai. In Lithuania, before the TRANSWAT project, only one transboundary lake water body with Latvia had been delineated. It was Lake Laucesas/Laukesas. During this project, other transboundary lakes were also delineated as water bodies in Lithuania, to fulfil requirements of WFD.

Zooplankton data supports information provided above reflecting lakes' ecological status, i.e., lakes Laucesas/Laukesas and Ilzu (Garais)/Ilge are of lower ecological quality compared to other studied lakes. Of all indicators examined in this survey, especially relevant turned out to be: crustacean species richness versus total phosphorus, the percentage share of calanoid copepods and cyclopoid copepods and a ratio of those two groups. As to particular indicator groups both in plankton and littoral, a more detailed studies in lakes across wider trophy gradient is needed, although some species showed promising potential to serve as an indicator. Present zooplankton absence in the monitoring recommended by EU WFD has resulted as absence of information on important trophic web elements. Therefore, it is recommended to develop metrics including threshold values at the regional level as already suggested by Jeppesen et al (2011) and to include zooplankton at least as a part of national monitoring in some lakes for long term data collection.

8. COMPARISON OF THE RESULTS OF TRANSBOUNDARY LAKE STATUS ASSESSMENT USING LATVIAN AND LITHUANIAN FISH SAMPLING DATA AND FISH-BASED METHODS

Where data on the quality element indicators used to determine the ecological status of lakes are collected using the same methodology, data collected in one country can be used to calculate biological indices used in another country. In this project, Lithuanian indices for phytoplankton, macrophytes and benthic invertebrates were calculated based on Latvian data, as the requirements for the data collection methodology and the level of taxonomic characterisation in general are the same. However, the fish sampling methodology differs between Latvia and Lithuania. The multi-mesh gillnets used in Latvia for fish sampling consist of 20, 25, 27, 30, 33 and 35 mm mesh size segments, while those used in Lithuania consist of 14, 18, 22, 25, 30, 40, 50 and 60 mm mesh size segments. Thus, only two mesh sizes (25 and 30 mm) overlap. Nevertheless, the 18 – 40 mm mesh size segment range in the Lithuanian multi-mesh gillnets covers the segment range of the Latvian gillnets. Therefore, an attempt was made to assess whether the Latvian fish data can be used for the calculation of the Lithuanian method and, conversely, whether the Lithuanian fish data from (18)22 – 30(40) mm mesh segments can be used for the Latvian method.

For the Latvian method, fish data from two different mesh size ranges in Lithuanian nets were used, which are closest to the mesh size range used by Latvia: 22 – 30 mm (i.e., slightly narrower than the Latvian mesh size range of 20 – 35 mm) and 18 – 40 mm (slightly wider than the Latvian mesh size range of 20 – 35 mm). In order to calculate the values of the fish metrics, the abundance and biomass of fish were converted to the catch per unit of effort (CPUE) using a net of 15 m length and 1.5 m height.

For the calculation of the Lithuanian method using Latvian data, total catch with Latvian gillnets was used (no absolute abundance metrics are used to calculate the Lithuanian fish index). The results are presented in Table 8.1.

Table 8.1. Ecological status of lakes by Latvian and Lithuanian methods using Latvian (LV) fish sampling data and Lithuanian (LT) data of fish catches with 22-30 mm and 18-40 mm mesh size net segments.

Lake	Latvian method			Lithuanian method	
	LV data	LT 22-30 mm mesh data	LT 18-40 mm mesh data	LV data	LT data
Galiņu/Salna	0.49	0.48	0.42	0.867	0.667
Ilzu (Garais)/Ilge	0.40	0.40	0.32	0.050	0.387
Lielais Kumpinišku/Kampiniskiai	0.84	1	1	0.824	0.763
Laucesas/Laukesas	0.69	0.61	0.54	0.666	0.537
Lake Skirnas	0.78	0.44	0.44	0.776	0.877

The results of the comparison show that the estimation of the ecological status of the four lakes using Lithuanian catches with 22 – 30 mm mesh size net segments for the Latvian method is in agreement with the estimation obtained using Latvian fish data. However, the exception is the Lake Skirnas, whose status using Lithuanian fish sampling data differs by as many as two status classes from the status estimated using Latvian fish sampling data.

Using the Lithuanian method and LV and LT fish sampling data, the ecological status classes are the same for only 2 lakes – Galiņu/Salna and Lielais Kumpinišku/Kampiniskiai. In lakes Laucesas/Laukesas and Skirnas the status assessment differs by one status class, and in Lake Ilzu (Garais)/Ilge by two status classes.

Using the Lithuanian method, the different estimation of status classes from LT and LV fish sampling data is due to different fish sampling methodologies (differences in the range of the mesh sizes of the multi-mesh gillnets) and, consequently, to different reference values for those fish metrics used in both the Latvian and Lithuanian fish indices, i.e. the metric of average weight of roach individuals (all lakes), and relative biomass of perch (the lakes that are classified as stratified lakes according to the typology of Lithuanian lakes). The reference values of the indicators are calculated for a given set of mesh size grids and cannot be extrapolated to another set. Accordingly, the Latvian fish sampling data cannot be used for the calculation of the Lithuanian lake fish index.

Using the Latvian method and LT fish sampling data with 22 – 30 mm mesh nets yields very similar status assessment results to the LV fish sampling data, as the fish data used to calculate the index are from a similar range of mesh sizes. Nevertheless, in one lake (Lake Skirnas) the status assessment using LV and LT data is still significantly different. This was due to significantly lower relative biomass of perch and average weight of roach in catches with LT 22 – 30 mm nets. This difference could be due to difference in the time and place of fish sampling, but it is more likely that differences in the mesh sizes had a greater influence. The Lithuanian sampling method includes a smaller range of mesh sizes within the range of 20-35 mm which is used in Latvian method, and therefore estimates with a larger margin of error the structure and composition of the part of fish stock, which is targeted by the sampling using the latter range of nets.

The results of the comparison of the assessment of the status of lakes based on the Latvian and Lithuanian fish methods and the fish data collected in the different countries show that the differences in sampling methods do not allow the use of one country's fish data to calculate the fish indices of both countries. Therefore, fish in transboundary lakes should be monitored separately for each country.

9. REFERENCES

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02000L0060-20141120

WFD CIS Guidance document No.13. Overall approach to the classification of ecological status and ecological potential. https://circabc.europa.eu/sd/a/06480e87-27a6-41e6-b165-0581c2b046ad/Guidance%20No%2013%20-%20Classification%20of%20Ecological%20Status%20(WG%20A).pdf

Skuja, A., Ozoliņš, D. 2016. *Fitting New Method—Latvian Lake Macroinvertebrate Multimetric Index (LLMMI) to Results of Central—Baltic Geographical Intercalibration Group (CB—GIG) Lake Benthic Macroinvertebrate Intercalibration*, Report, Institute of Biology, University of Latvia: Salaspils, Latvia, p. 12.

Šidagytė E., Višinskienė G., Arbačiauskas K. 2013. Macroinvertebrate metrics and their integration for assessing the ecological status and biocontamination of Lithuanian lakes. *Limnologica*. 43(4), 308-318. https://doi.org/10.1016/j.limno.2013.01.003

Urtāne, L. 1998. Cladocera kā Latvijas ezeru tipu un trofiskā stāvokļa indikatori. *Manuscript. Latvian University, Rīga (in Latvian)*.

Čeirāns, A. 2007. Zooplankton indicators of trophy in Latvian Lakes. Acta Universitas Latviensis, 723: 61-69.

Jeppesen, E., Noges, P., Davidson, T. A., Haberman, J., Noges, T., Blank, K., ... & Amsinck, S. L. 2011. Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia*, *676*(1), 279-297.

Psenner R., Pucsko R., Sager M. 1984. Die Fraktionierung organischer und anorganischer Phosphorverbindungen von Sedimenten – Versuch einer Definition ökologisch wichtiger Fraktionen. Arch.Hydrobiol.Suppl., 70: 111-155

Rydin, E. 2000. Potentially mobile phosphorus in Lake Erken sediment. *Water Research*, *34*(7), 2037-2042.

Ahlgren, J., Reitzel, K., De Brabandere, H., Gogoll, A., Rydin, E. 2011. Release of organic P forms from lake sediments. *Water research*, *45*(2), 565-572.

Jankēvica, M., Šīre, J., Kokorīte, I., Kļaviņš, M. 2012. Assessment of the sediment chemical quality in salmonid lakes in Latvia. *Acta Biologica Universitatis Daugavpiliensis Supplement*, *3*, 36-49.

Bledzki, L. A., Rybak, J. I. 2016. *Freshwater Crustacean Zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida) Key to species identification, with notes on ecology, distribution, methods and introduction to data analysis*. Springer.

CEN. 2011. EN 16039:2011 Water quality – Guidance standard on assessing the hydromorphological features of lakes.

Virbickas, T., Stakėnas, S. 2016. Composition of fish communities and fish-based method for assessment of ecological status of lakes in Lithuania. Fisheries Research 173: 70-79. http://dx.doi.org/10.1016/j.fishres.2015.08.015