«Environmental Value, Landscape and Biological Diversity of the Lori Plateau Lakes and Watershed (Lori Region, Republic of Armenia)»

Final Report

Project No. 31363-1
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The Rufford Foundation
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Yerevan, Armenia
January 2022

Reporting period: May 2020 – May 2021

Organization: «Nature Heritage» environmental, agricultural NGO

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INTRODUCTION

For many reasons lakes of the Lori plateau were in the focus of several research and conservation projects over time. The Lori lakes were listed in the State Program on Conservation and Management of the Protected Areas of Armenia (2014-2020) as requiring special status of protection [30], though the Strategy have not been updated after the expiration date. The lakes are included into the Emerald Network List in frames of the Bern Convention, as an Area of Specific Conservation Interest (ASCI). Moreover, the Lori plateau is designated as one of 14 Freshwater Key Biodiversity Areas (FKBAs) of Armenia [9] and as an Important Bird Area (IBA) (No. AM007) [14].

The Lori plain historically has been a remarkable natural complex. The site renders highly favorable conditions for biota, due to a habitat-forming function of freshwater ecosystems. The Lori plateau itself is a lowland, which contributes into the connectivity of the Caucasus large landscapes, being a part of the so-called Javakheti ecological corridor and “South Caucasus Uplands” Conservation Landscape [40].

In frames of the Emerald Network inventory 36 species from the Resolution 6 of the Bern Converntion [26] were registered in the site (species groups: 28 birds, 4 mammals, 3 invertebrates, 1 plant specimen), with some are also of the national importance, and at least 15 natural habitats of the Resolution 4 of the Convention were outlined [8, 25].

A number of ecological projects aimed at inventory of certain groups of species of flora and fauna have been performed during the last decade [28, 29, 37, 38], where all the authors summarize a necessity of the special protection regime to be established. In the current Project supported by the Rufford Foundation (Project 2020-2021 here and after) we aim to emphasize the value of biological and landscape (habitat) diversity in terms of the conservational perspective. Apart from the purely monitoring objectives, certain attention was paid to threats human activities pose to the environment of the lacustrine systems, which became a highly relevant issue considering internationally affirmed status of the site. Much of the Report is dedicated to the current state of the ecosystems, and a brief review of the possible ways of restoration for some heavily transformed landscapes.

Synopsis of the Project Report containing conclusions and recommendations on the ecosystems protection will be addressed the Lori province authorities and to the Ministry of Environment of the Republic of Armenia for discussion. Next stage of the work is planned to perform in 2023, and is supposed to include target research and inventory actions, and administrative practice on establishment a new protected area.

MATERIALS AND METHODS

Main part of the fieldwork was performed jointly by Russian and Armenian team members in September 2020. Armenian colleagues repeatedly carried out field observations in May 2021 for several days, and also several brief route inventories were previously made singly by project participants from Armenian side in July and August 2020.

All field studies were previously planned using satellite images from free sources. All routes and points were marked using GPS navigator Garmin 78s and then saved in *gpx data format. An inflatable boat was used for moving across the water area.

Landscape and habitat structure survey was conducted via visual route description method through several transects and key points picked beforehand. Drone footage via DJI Mavic Mini was conducted for the landscape survey correction and true altitude delineation. Supplementary photography was conducted using Canon EOS 1200D (lens Tamron 18-400 mm).

Depth of the basins was tracked manually with a measuring gauge by 5-6 profile transects across the basins of 5 lakes. Measurements were made with a 5-meter step. Daily water level was monitored in 7 lakes during the whole expedition term, using stationed measuring scales. In lake Novoseltsovo-1 3 gauge-scales had to be used due to significant level oscillations.

All spatial data were processed and mapped using Quantum GIS 3.16 software. IDW and Nearest Neighbor interpolation tools were used for creating contour lines on the maps.

Flora species were described in the field and photographed using a camera Canon EOS 2000D with a macro extension tube Fotorox for Canon. Some plant specimen herborized and stored in the Institute of Botany NAS RA. Species were determined by Dr. Ivan Gabrielyan.

Ichthyological survey was performed using crayfish traps (8 holes, diameter 80 cm, mesh 3 mm, with smelly bait inside). The traps were set at 0.5-1.5 meter depth, distanced by 1-5 meters from lakeshore. Round traps (diameter 70 cm, mesh 5 mm), fishing net (diameter 50 cm, mesh 8 mm, 1.5 m long) and fishing rod were used in some cases. Species of the caught fish were determined [20], complemented with genderand size variations of the fish fauna in some lakes.

Amphibia and reptiles species were determined visually and photographed. Snakes were captured with a snake tong. Amphibian species were studied considering their spatial distribution and morphometric features (body length, head length, head width, nose length, rostrum – nostril distance, palbebral fissure maximum length, eyelid maximum width, nose width distance between nostrils, maximum length of tympanic membrane, femur length, tibia length, tarsus length, length of the first finger of a hind leg, inner nuptial pad length, limbs length asymmetry, fingers length asymmetry, color morph, color patterns, assymetry) and released immediately after the measurements. Newt inventory was conducted using rectangular refuge traps with a plastic bags on top of them. Traps were placed 1-2 meters from lake shores in shallow water.

Birds inventory was performed during circular walking routes by the lakes shorelines. Photography was conducted using Canon EOS 77D with lens Sigma 150-600 mm 5-6.3 and Canon PowerShot SX60 HS. Birds species were determined by Vasil Ananian.

Water and sediments were sampled from lakes Horse Liman, Long Liman and Clear Liman in mid-September 2020 from central parts of the lakes; water samples were taken from the depth 0.5 m. Sediments were taken with the use of the measuring gauge. Sampling, conservation and processing of water samples for phytoplankton diversity study was performed according to the standard hydrobiological technique [19], using a Nazhott chamber. Saprobity level was calculated in accordance with the indicative system of Barinova [4]. The Shannon-Weaver diversity index was calculated on the basis of the methodology elaborated for communities [27].

Chemical composition for 25 elements in sediments and 26 elements in water samples was determined in “Hydrometeorology and monitoring center”, SNGO using inductively coupled plasma mass spectrometry (ICP-MS) (ISO 17294-2-2016).

During the whole term of the Project 2020-2021 the work was obstructed by insurmountable circumstances and emergencies. As the COVID-19 pandemic was announced in early 2020, a number of activities and trips were restricted, also for some of the participants of the Project from the Russian side who initially had been supposed to be involved in the work. The work was conducted only in September 2020 due to temporary international transport restrictions in summer 2020.

A military conflict broke out between Armenia and Azerbaijan in late September 2020 (so-called 2020 Nagorno-Karabakh war), just few days after the autumn expedition. National crisis after the war lasted almost until early spring 2021 and limited execution of the Project significantly, coupled by the COVID-19 “third wave”.

RESULTS

All studied lakes (Fig. 1, Table 1) were grouped depending on their geographical position and hydrological conditions into 4 groups:

(1) Stepanavan lakes (-1, -2, -3, -4)
(2) Central-Plateau lakes (Clear Liman, Long Liman, Horse Liman)
(3) Saratovka-Novoseltsovo lakes (Novoseltsovo-1, -2, Saratovka, Peatbog)
(4) Hillside lakes (Urasar, Khatnghbyur)

Also a so-called "Right bank lakes" group of 6 basins can be delineated along the right bank of the Dzoraget river canyon, still they were not embraced during the Project 2020-2021.

The grouping was also reasoned to correspond to the boundaries of the suggested specially protected area (see Appendiix 14), where Hillside and Central-Plateau groups wield sites of somewhat higher conservation value. Apart from the lakes listed in the report, at least 10 flooded or partially flooded pools exist in the area, which have not been visited during the Project 2020-2021, yet their study remains relevant for a future research.

Table 1. General information on the studied Lori lakes.
* - IUCN status other than LC is accounted (i.e. NT, VU, CR or DD)

Group name	Lake name	Center coordinates		Total area / clear water area, hectares	Max. depth, m	Number of IUCN [15] species found at the site*	Number of the Red Book of Armenia [1, 33] species found at the site
		N, °	E, °				
Stepa-navan	Stepanavan-1	41,03288	44,36199	2,66 / 0,85	Not measured	3	7
	Stepanavan-2	41,03391	44,35939	3,64 / 1,39			
	Stepanavan-3	41,03566	44,36244	2,21 / 2,21			
	Stepanavan-4	41,03787	44,35809	3,85 / 1,82			
Central - Plateau	Clear Liman	41,05232	44,31049	10,66 / 2,76	5,4	3	5
	Long Liman	41,05297	44,32323	12,22 / 0,5 (seaso-nally)	0,7	1	2
	Horse Liman	41,04127	44,32692	2,41 / 0,92	4,7	1	3
Saratovka - Novo-seltsovo	Peatbog	41,06413	44,30375	34,98 / 6,22	3,6	-	-
	Novoseltsovo -1	41,06814	44,28032	14,81 / 6,02	2,5	3	10
	Novoseltsovo -2	41,05675	44,28341	13,59 / 11,76	Not measured	1	3
	Saratovka	41,07639	44,28993	29,11 / 0,8 (seaso-nally)		2	9
Hill-side	Urasar	41,02329	44,30447	7,94 / 1,62		1	4
	Katnaghbyur	41,03459	44,24199	2,66 / 0,41		-	-

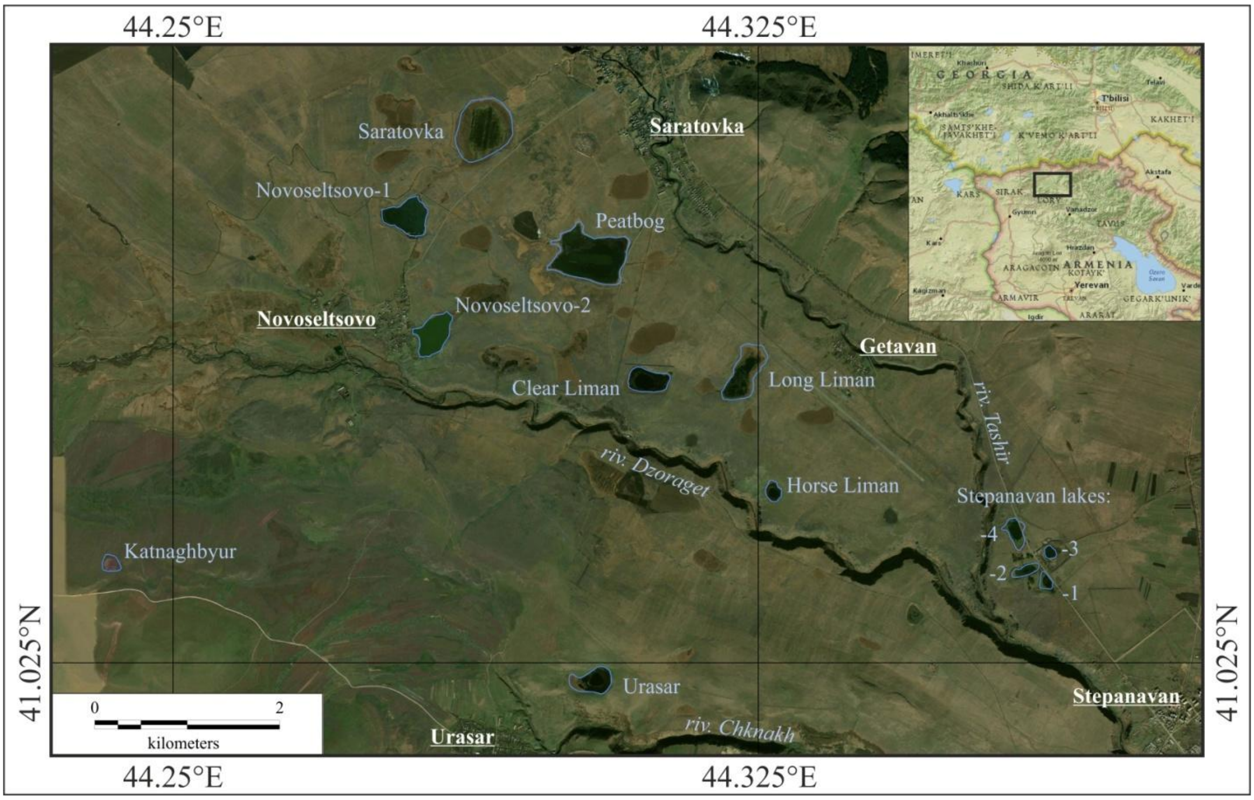

Figure 1. Geographical position of the studied Lori lakes

STEPANAVAN LAKES

Stepanavan lakes lie at the true altitude level of 1451 m above sea level (a.s.l.), in the eastern Lori plateau, near the rivers Tashir and Dzoraget confluence. 4 lakes of this group are situated just by the roadway «Stepanavan – Tashir», which virtually crosses the lacustrine basins. We assume that the road had rearranged the water balance and runoff network due to exerted damming effect. Major anthropogenic factor for this group are roadway and city of Stepanavan proximity, excessive livestock grazing, littering of the lakes and shores.

Stepanavan lakes are distanced only 50-200 meters from each other, therefore results of the ornithological survey are presented for the whole group (see Appendix 1). Among the rare and threatened birds at Stepanavan lakes the following were observed: *Aythya ferina* (IUCN – VU), *Clanga pomarina* (Red Book of Armenia, RBA – VU D1), *Circaetus gallicus* (RBA – VU D1), *Circus macrourus* (RBA – EN B1ab(iii)+2ab(iii); D, IUCN – NT), *Motacilla citreola* (RBA – VU D1), *Larus armenicus* (RBA – VU B1ab(iii)+2ab(iii), IUCN – NT) [1, 15].

Frogs populations were not studied specifically at Stepanavan lakes, still *Hyla orientalis* calls were detected at night in the vicinity of the lakes in May 2021. *Pelophylax ridibundus* is omnipresent in all the lakes of the group. See data on the observed amphibia and reptiles distribution in Appendix 2.

STEPANAVAN-1

Center coordinates: N 41,03288° E 44,36199°
Total area: 2,66 hectares
Clear water area: 0,85 hectares
Work conducted: brief air survey, avifauna inventory, brief flora inventory

Figure 2. Air footage of lake Stepanavan-1 (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020

An old drainage channel was noticed at the lake from the south (Fig. 2). The flow is densely overgrown with macrophytes and silted. Drying spots of silty ground 2-10 meters wide were noticed all around the lakeshore (Fig. 3), mostly in the part of the channel approaching the lake. During spring and early summer lake water drains down the channel until the level reaches the point below the drainage threshold by the end of summer, and the shores gradually dry off.

Figure 3. Lake Stepanavan-1.
Photo by Andrei Ostashov, 13.09.2020.

Most of the lake surface is densely grown by pondweed: *Potamogeton lucens*, *Potamogeton natans* and *Nymphaea alba* (RBA – EN B) [33]. Ichthyological studies were not conducted at lake Stepanavan-1, though by the information from local fishermen, only *Carassius gibelio* inhabits the lake.

STEPANAVAN-2

Center coordinates: N 41,03391° E 44,35939°
Total area: 3,64 hectares
Clear water area: 1,39 hectares
Work conducted: brief air survey, avifauna, flora, fish, amphibian inventory

Lake Stepanavan-2 is adjacent to lake Stepanavan-1 in the south-eastern border, separated only by a 40-meters wide rock mound. The lakes are connected by an overgrown artificial channel (Fig. 1, 4). The roadway lies just through the shore of the lake from the east

Figure 4. Air footage of lake Stepanavan-2. (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020.

Figure 5. Lake Stepanavan-2.
Photo by Andrei Ostashov, 13.09.2020.

Water macrophytes and hydrophytes (*Potamogeton natans*, *Polygonum hydropiper*, *Alisma plantago-aquatica*, Lemnaceae) create mats over the most of the water area. Semi-submerged plants and hygrophytes groups appear sporadically and do not form large thickets along the shore (Fig. 5). Of nationally protected species *Nymphaea alba* (RBA – EN B) is observed in the water area and *Acorus calamus* (RBA – EN B) was registered on the northern shore (Fig. 6) [33]. Plant species occurring at lake Stepanavan-2 are listed in Appendix 3.

Figure 6. *Acorus calamus* found at lake Stepanavan-2.
Photo by Vasil Ananian, 13.09.2020.
Identified by Ivan Gabrielyan.

Figure 7. *Pseudorasbora parva* specimen captured in lake Stepanavan-2 (male above, female below)

Fish populations inventory was carried in May 2021 and showed Stone moroko (*Pseudorasbora parva*) and Prussian carp (*Carassius gibelio*) inhabiting the lake, with proportion of species in capture equaling respectively 97.4% (185 specimen) and 2.6% (5 specimen) [22]. Males constitute up to 80% of the observed Stone moroko specimen (Fig. 7).

Local fishermen reported Common carp (*Cyprinus carpio*) to inhabit the lake, still it was not registered during the inventory (see Appendix 4 for the list of fish species inhabiting the studied lakes). *Cybister lateralimarginalis* (Coleoptera) beetles were observed massively in crayfish traps during the ichtyhyological survey in May 2021 (Fig. 8).

Figure 8. *Cybister lateralimarginalis* specimen captured on lake Stepanavan-2.

Newts inventory was carried out at the site in May 2021. According to the literature reports, Northern Banded Newt (*Ommatotriton ophryticus*) (IUCN – NT; RBA – CR B2ab (iii, v)) is expected to inhabit lake Stepanavan-2 [1, 2, 29]. Unfortunately, newts were not discovered during our work, nevertheless efforts were made to capture the newts in traps (Fig. 9). Still the expectations about occurrence of the newts at the Stepanavan-2 remain relevant for the next stage of the project.

Figure 9. Installation of the newt refuge traps on lake Stepanavan-2. Photo by Ilona Stepanyan, 22.05.2021

STEPANAVAN-3

Center coordinates: N 41,03566° E 44,36244°
Total area: 2,21 hectares
Clear water area: 2,21 hectares
Work conducted: brief air survey

The lake is bounded by a fencing and used for commercial fishery. Water surface is slightly covered with free-floating vegetation, and reed complexes occupy its eastern shoreline (Fig, 10, 11). Works were not carried out at the lake due to a restricted access.

Figure 10. Air footage of lake Stepanavan-3. (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020.

Figure 11. Lake Stepanavan-3. Photo by Dmitrii Sadokov, 13.09.2020

STEPANAVAN-4

Center coordinates: N 41,03787° E 44,35809°
Total area: 3,85 hectares

The basin of lake Stepanavan-4 (Fig. 1) was not studied during the project. Air survey reveals a continuous 15-meters wide belt of reed and bulrush by the western lake shore, which increases up to 70 meters in depth in the southern angle of the lake. The road transects the basin in its eastern part, cutting away a separate minor moist depression overgrown by reed. The western side of the lake is just 90 meters away from the steep river Tashir canyon (Fig. 12).

Figure 12. Air footage of lake Stepanavan-4. (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020

CENTRAL-PLATEAU LAKES

The group includes relict lakes Clear Liman, Long Liman and Horse Liman (Fig. 1), which were studied in September 2020 and May 2021. The lakes are situated at the true altitude level around 1470-1480 m a.s.l., correspondingly in the central part of the Lori plateau, between the canyons of rivers Tashir and Dzoraget (Fig. 13). Also several unstudied minor basins located in the same area can be included into this group.

At least 8 other lacustrine basins, altogether covering an area of 24 hectares, are dried at the moment (Fig. 13, 28), apparently as a consequence of the intensive drainage regulation through the system of channels designed for the Dzoraget Hydropower Plant (DHP) located in the village of Novoseltsovo.

Central-Plateau lakes differ in morphometry from those of Stepanavan and Saratovka-Novoseltsovo groups, having more rounded contours of the lake basins and symmetrical bathymetry of the depressions (see Fig. 16, 33, 34 and Appendices 7, 9).

Figure 13. Air footage of the Central-Plateau lakes (DJI Mavic Mini). Photo by Andrei Ostashov, 15.09.2020

Phytoplankton species diversity, abundance and biomass were assessed in water of the three Central-Plateau Lakes as proxies of the aquatic systems ecological status. It was shown that major algae groups from the lakes' phytoplankton communities are: diatoms (Bacillariophyta) (15 species, 31% from all recorded species), green algae (Chlorophyta) (17 species, 35%), blue-green algae (Cyanophyta) (12 species, 24%) and euglenoids (Euglenophyta) 5 species, 10%) (see Appendix 5). Chlorophyta algae amount to 71% of total population and 68% of biomass, thus being the dominant group in the Clear Liman, the Horse Liman and the Long Liman. Toxic blue-green algae *Aphanizomenon flos-aquae* were increasingly abundant in September 2020, which can affect water quality during bloom. Average values of Shannon diversity index and saprobity of phytoplankton equal to 2.07 and 1.78. This indicates an average level of community adaptability and apparent persistent organic pollution. The lakes can generally be characterized as **mesotrophic** by the studied phytoplankton biomass values.

Trace and major elements content of the Central-Plateau lakes water and of the uppermost sediment layer of lake Horse Liman are included into Appendix 6. Iron and manganese show enhanced concentration values in water in all three studied lakes, in particular in the Horse Liman, which probably is due to elevated regional background values of Fe and Mn in soils and rocks [34] and thus was not considered to be induced by anthropogenous pollution.

Figure 14. *Melolontha pectoralis* specimen collected at lake Clear Liman

Ornithological survey was conducted at the central part of the Lori plateau on the whole, but not separately for the lakes of this group. The following protected bird species were recognized during the pilot survey: *Circaetus gallicus* (lake Clear Liman) (RBA – VU), *Circus macrourus* (lakes Clear Liman, Horse Liman) (RBA – EN; IUCN – NT) [1, 15] (Appendix 1).

During the inventory in May 2021 nuptial flights of beetles *Melolontha pectoralis* was registered in the vicinity of Central-Plateau lakes (Fig. 14).

Recreational fishery, intended and unintended introduction of new fish species, littering of the terrain and water area, livestock pasture are major anthropogenic factors influencing Central-Plateau lacustrine ecosystems. Haymaking and grazing are basic agricultural activities of the local population. Drainage and shallowing of the numerous eutrophic water bodies (Fig. 15) occurred likely due to unwise runoff regulation as a result of unsustainable agriculture and water supply for the DHP.

Figure 15. Air footage of one dried overgrown basin between lakes Clear Liman and Long Liman (DJI Mavic Mini). Photo by Andrei Ostashov, 20.09.2020

CLEAR LIMAN

Center coordinates: N 41,05232° E 44,31049°
Total area: 10,66 hectares
Clear water area: 2,76 hectares
Work conducted: air and visual landscape survey, flora, fish, amphibia inventory, bathymetry and water level fluctuation measurements, phytoplankton and hydrochemical research

The shape of lake Clear Liman basin is close to oval, it stretches from East to West by 400 meters and is 190-260 meters wide (Fig. 16). Maximal depth (5 m) was measured in the center of the lake (Appendix 7). The eastern slope of the basin is smoother compared with the other shores. Lake's bathymetry is characterized by an isometric shape of the basin, with depth marks equally decrease in all directions from the central oval depression. Lake level remained stable in September 2020 with only a slight drop by 2 cm in 10 days. The level was higher by some 30 cm in May 2021.

The Clear Liman water shows high saprobity index (2.00) and the lowest level of phytoplankton species diversity (Appendix 5). According to slightly elevated values of manganese (0,159 ppm) and bulk iron (0,803 ppm) content in the lake water (Appendix 6), the Clear Liman can be labeled with III class of water quality (average) according to the Decree of the Government No. 75-n [23]; the rest of the parameters allow to classify the water quality as 'excellent' or 'good' (I and II classes). The marked rise in iron and manganese content is not as critical as it could be in case of any sort of notable contamination, and can be explained by natural reasons, because origins in water of these elements are perceived to possibly be linked with the weathered rocks of the research area, so their concentrations may be considered to be close to background level [34]. Considering all mentioned above, lake Clear Liman is estimated as 'almost uncontaminated', thus as well corresponding to the targeted water objects management on the basis of water quality, specifically for purposes of water objects preservation and/or fish industry, as suggested in the Decree of the Government No. 75-n [23].

Figure 16. Air footage of lake Clear Liman (DJI Mavic Mini). Photo by Andrei Ostashov, 15.09.2020

Vegetation distribution over terrestrial and aquatic parts of the lake basin is influenced by its almost symmetrical shape and drainless regime (Fig. 16). Monodominant *Nymphaea alba* mats form a dense 50-150 meter-wide belt along the lake periphery (Fig. 17), leaving an open-water spot in the center with an area of less than 3 hectares. The belt width is strictly limited to the lake center with depths more than 3 m (Appendix 7), and communities of floating hydrophytes (*Nymphaea alba*, *Utricularia minor*, Potamogetonaceae, Lemnaceae) occur within the belt. Groups of tall reedbeds (*Phragmites australis* and/or *Typha latifolia* with *Schoenoplectus tabernaemontani*) are frequent along the shore, expanding to shallow water down to depth of 40 cm (Fig. 18). Communities of *Carex acuta* and *Carex acutiformis* tussocks continuously stretch around the water

Figure 17. Belt of *Nymphaea alba* on lake Clear Liman.

edge and over the drying muddy shores, with the presence of various groups of helophytes, presented by semi-submerged (*Alismataveae*, *Polygonaceae*) and terrestrial forms (*Juncaceae*, *Ranunculaceae*) (Fig. 19). Upshore sequence of the plants associations ("Hydrophytes with *Nymphaea*" – "reedbeds of *Phragmites* or *Typha*" – "sedges with helophytes") is the most typical order of vegetation grouping at the spots of flat relief or gentle slopes (Fig. 20). At the north-eastern and western shores sedge tussocks contour can be subdivided into smaller units depending on the predominance of plant communities growing over the moist muddy substrate (typically aquatic helophytes) or on the dried ground.

Figure 18. Reedbeds of *Phragmites australis* at lake Clear Liman render shelter for migrating birds

Figure 19. Large tussocks of sedges on the shores of lake Clear Liman

Figure 20. Vegetation groups distribution on lake Clear Liman shores: hydrophytes – reedbeds – sedge with helophytes.

Carex bohemica Schreb. (Fig. 22) (RBA – EN B), *Nymphaea alba* (RBA – EN B) [35] and *Psephellus manakyanii* (Fig. 21) (endemic of Northern Armenia, IUCN - EN) [10, 15, 32] are the endangered flora species discovered on lake Clear Liman during the Project 2020-2021 (see Appendix 3).

Figure 21. *Psephellus manakyanii* found at lake Clear Liman (22.05.2021). Photo and identification by Ivan Gabrielyan

Figure 22. *Carex bohemica* found at lake Clear Liman (19.09.2020). Photo by Dmitrii Sadokov, identified by Ivan Gabrielyan.

Thus, at least two habitat types outlined in the international Conventions and Documents assigned for preservation [8, 25, 33] are present at the Clear Liman:

(1) Semi-submerged *Nymphaea alba* colonies (as a subdivision of the EUNIS class «Floating broad-leaved carpets» C1.241, listed in the Annex I of Resolution 4 of the Bern Convention, and as a community of the nationally protected species) [25, 33, 39]

(2) Beds of large *Carex* species, as a subdivision of the class «Beds of large sedges normally without free-standing water» D5.2 listed in the Bern Convention [7, 25]

Fish fauna of lake Clear Liman was studied in September 2020 and May 2021. Three fish species inhabit the lake, namely Stone moroko (*Pseudorasbora parva*), North Caucasian bleak (*Alburnus hohenackeri*) and Prussian carp (*Carassius gibelio*), which equal to 50.7%, 48.5% and 0.8% of the whole fish species diversity of the lake respectively (Fig. 23). Ratio of females to males for studied part of Stone moroko population was estimated as 9:1 respectively. *Ligula intestinalis* metacercariae were found in 5% of the caught Stone moroko and North Caucasian bleak specimen (Fig. 24). Dominance of the invasive species (*Pseudorasbora parva* and *Alburnus hohenackeri*) can be explained by their wider ecological tolerance and adaptability limits, while they have been regularly unintentionally introduced into the lake with other species of fish fauna for fishery purposes [21, 22].

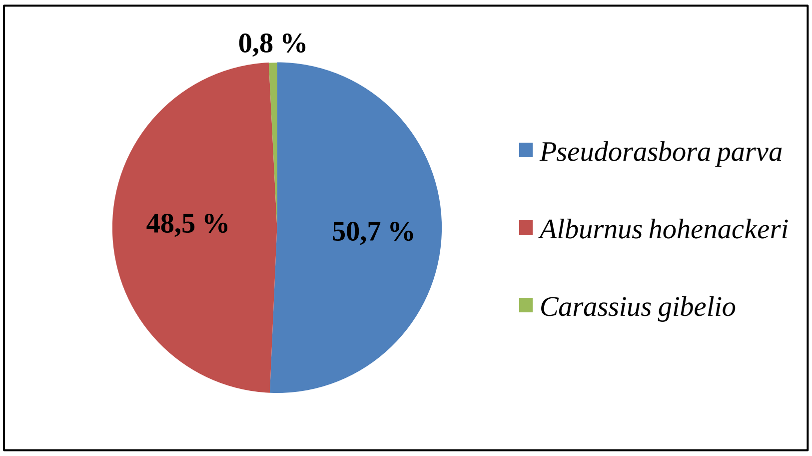

Figure 23. Ratio of ichthyofauna species inhabiting lake Clear Liman by the results of the autumn and spring captures

Figure 24. Metacercariae of *Ligula intestinalis* found in *Pseudorasbora parva* specimen in lake Clear Liman. Photo and identification by Samvel Pipoyan, 20.09.2020.

Rana macrocnemis, *Pelophylax ridibundus* (Fig. 25) and *Hyla orientalis* were observed to inhabit the Clear Liman shores and water (see Appendix 2). Morphometry of 26 *Pelophylax ridibundus* and 2 *Rana macrocnemis* adults was measured in order to gain statistics for spatial distribution of interpopulation frogs morphs (described in the paragraph «Materials and methods»). Obtained morphometry data will be used in complex assessments in the future scientific work.

During the May 2021 works the newt traps were placed close to the stone blocks which were meant to serve as winter shelters for newts. Similarly as at the Stepanavan-2, Northern Banded Newt (*Ommatotriton ophryticus*) was not observed during the inventory, despite the capture attempts (Fig. 9).

Figure 25. *Pelophylax ridibundus* (Maculata morpha) captured on lake Clear Liman for the measurements.

Figure 26. *Darevskia dahli* registered at lake Clear Liman. Photo by Dmitrii Sadokov, 15.09.2020, identified by Ilona Stepanyan.

Observations on reptile species diversity obtained during the route surveys at lake Clear Liman are included into the Appendix 2. *Darevskia dahli* (RBA – EN B1a+2a; IUCN – NT; endemic of the Caucasus) (Fig. 26) [1, 2, 15] was the only endangered reptile species discovered during the Project 2020-2021 and found only at the Clear Liman. For *Lacerta agilis* 6 different color and pattern variations (morphs) were recorded at the Clear Liman (Appendix 8).

Lake Clear Liman is the only lake of all studied basins where conservation status is assigned to natural objects. At the Clear Liman *Nymphaea alba* mats are determined as a protected natural complex (Fig. 27), although similar prominent communities are as well found on lakes Urasar and Horse Liman, and therefore also can be dedicated there for special protection. Lake Clear Liman is commonly used by local population as a fishing site, both from the shore and on boats. Fishing does not seem to damage *Nymphaea alba* communities, but more importantly, it seriously affects ichthyofauna population due to re-introducing dominating invasive species (see paragraphs Conclusion and Recommendations).

Figure 27. Placard at the shore of lake Clear Liman: «White water lilies of lake Clear Liman of the village of Saratovka have the status ´ ´ endangered species´ ´ and are listed in the Red Book. Any activity that contributes to the destruction of water lilies is subject to administrative punishment. /Article 93 of the RA Codex VIV/»

LONG LIMAN

Center coordinates: N 41,05297° E 44,32323°
Total area: 12,22 hectares
Clear water area: 0,50 hectares (seasonally)
Work conducted: brief air survey, flora, fish and amphibian inventory, general bathymetry characterization, phytoplankton study, chemical composition of water and sediments measurements.

Lake Long Liman stretches by 600 m from north-east to south-west and is 170-240 m wide in different parts. The Long Liman is connected with a neighboring grassy basin in its southwestern corner, in the direction of the Clear Liman (Fig. 28). Another least obvious linkage with the similar overgrown basin to the south from the Long Liman had not been flooded for even longer period of time than the first channel. Both channels remained absolutely dried in both autumn and spring. The vegetation structure traces high-level and low-level water standing, as shown by the shoreline configuration (Fig. 28). The northern slope of the lacustrine basin is smoother than the others, which is indicated by thick vegetation (Fig. 29). The basin in general is more flat and shallow than those of lakes Clear Liman and Horse Liman. Average depth in the central part in September was 0,8-1,0 m, without any distinctive spatial changes. In May the lake level was lifted by some 30 cm.


Figure 28. Air footage of lake Long Liman. (DJI Mavic Mini). Photo by Andrei Ostashov, 20.09.2020

Small depth of the lake favors semi-submerged *Potamogeton natans*, *Polygonum hydropiper* and sometimes *Nymphaea alba* colonies (Fig. 30) to cover almost the whole water area. Free-floating vegetation is not present in the lake. Tall reedbeds (*Phragmites australis, Schoenoplectus tabernaemontani* and *Typha latifolia*) (Fig. 29) and wider belt of sedges is attributed to the northern part of the smooth slope, and to the southwestern side, where the former channel attaches to the lake.

Figure 29. Air footage of the lake Long Liman northern shore (DJI Mavic Mini). Wide beds of reeds and sedges indicate smooth relief of the basin and create favorable habitats for riparian fauna. Photo by Andrei Ostashov, 20.09.2020

Figure 30. Semi-submerged and floating communities of hydrophytes and shoreline reedbeds on lake Long Liman. Photo by Samvel Pipoyan, 20.09.2020.

Figure 31. *Iris pumila* found at lake Long Liman (23.05.2021). Photo and identification by Ivan Gabrielyan

Of protected flora species at the Long Liman *Carex bohemica* (RBA – EN B) and *Nymphaea alba* (RBA – EN B) (see Appendix 3) were found in September 2020. Also *Iris pumila* was found in May 2021 (Fig. 31), which is notable for having IUCN status DD [15].

Fish die-off (*Pseudorasbora parva* and *Carassius gibelio*) was registered in September, probably due to hypoxia, caused by the lake level drop by the end of the summer and increased eutrophication. Fish fauna catch and determination was complicated due to the low water level.

Figure 32. A tadpole of *Pelophylax ridibundus* from lake Long Liman. Photo and identification by Valentina Digalova, 20.09.2020

Amphibian species diversity at the Long Liman is presented only with marsh frog (*Pelophylax ridibundus*) and European tree frog (*Hyla orientalis*) (calls) (see Appendix 2). Morphometrical observations of the total of 31 *Pelophylax ridibundus* yearlings were conducted. Second reproduction cycle of *P. ridibundus* was observed at the Long Liman (see tadpole at Fig. 32).

Bulk iron and manganese water concentration show significantly higher values (5,87 ppm and 0,99 ppm respectively) than those of lakes Clear Liman and Horse Liman (see Appendix 6). Enhanced level of Fe and Mn may be probably linked with their accumulation in terms of the lake level drop by the end of the summer with the involvement of the excessive organic compounds or sediment exposure of the elements. Special research needs to be carried out to disclose sources and factors of Fe and Mn inflow.

The major way of human impact that can be named for the Long Liman is overexploitation of the lake as a livestock watering place. Regular lake level drops occur by the end of the summer, and organic pollutants derived from livestock excrement can lead to even more enhanced eutrophication, when concentrated in conditions of the low water level.

HORSE LIMAN

Center coordinates: N 41,041273° E 44,326917°
Total area: 2,41 hectares
Clear water area: 0,92 hectares
Work conducted: air and visual landscape survey, flora, fish, amphibian inventory, bathymetry measurements, chemical composition of water measurements

The Horse Liman is a round-shaped lake up to 200 m in cross, which takes the easternmost position in the group of Central-Plateau lakes (Fig. 1, 13). The lake is 100 m away from the Dzoraget river canyon (Fig. 33). The shoreline configuration is close to circular, and is slightly more extended from north to south (Fig. 34, Appendix 9). True altitude values do not change considerably around the lake, showing only a slight growth from 1469 to 1471 m a.s.l. in the north-eastern part of the basin. The surface of the basin in the Horse Liman vicinity is covered with rocks plentifully, more than around any of the lakes studied in the Project 2020-2021. The stone fields are most abundant from the south-western side of the lake, where they are grouped into lines stretching in the direction of the Dzoraget river canyon (Fig. 33).

Figure 33. Air footage of lake Horse Liman (DJI Mavic Mini). Photo by Andrei Ostashov, 17.09.2020

Figure 34. Air footage of lake Horse Liman (DJI Mavic Mini). A floating island of Typhaceae beds is seen at the left side of the clear water. Photo by Andrei Ostashov, 17.09.2020

As it can be seen on the map (Appendix 9), the lake depth changes equally from edge to center correspondingly from average 1 m to maximal 4,7 m. A 2-3-meter wide zone of periodic inundation stretches along the shoreline, overgrown mainly by sedges with amphibious vegetation, which distribution is dependent on the water level position and duration of the current and previous year inundation (Fig. 35, 36). Dense beds of *Typha latifolia* and *Phragmites australis* are abundant by the brink of water from the western side. *Nymphaea alba* monodominant mats create a belt up to 50 meters wide in the lake periphery, with the spatial distribution limited by sharply increasing depth up to 3 meters (Fig 37). Groups and mats of floating hydrophytes (mostly Polygonaceae communities) adhere to the inner side of the *Nymphaea alba* ring.

Figure 35. Sparsely vegetated lower level of the zone of periodic inundation with moist muddy substrate. Lake Horse Liman, photo by Dmitrii Sadokov, 17.09.2020

Figure 36. Sedge and reeds in the upper level of the zone of periodic inundation. Lake Horse Liman, photo by Dmitrii Sadokov, 17.09.2020

Reedmace (*Typha latifolia*) with sedges occasionally form floating mats, some of which were noticed to migrate seasonally between the shores (contour 8 on the map in Appendix 9). An island observed during September 2020 (Fig. 34, 37) was not found during a field trip held in May 2021, presumably decayed by the ice during winter. This prominent phenomenon deserves special research, since functions of supply of valuable habitats, enhanced biodiversity and water purification are commonly attributed to floating mats and islands of macrophytes [13, 36], and that is particularly significant for small and stable localities [3]. Such complexes were corresponded with a habitat type D2.3 «Transition mires and quaking bogs» of EUNIS

Figure 37. *Nymphaea alba* floating mats and *Typha latifolia* carpets on lake Horse Liman. Photo by Dmitrii Sadokov, 17.09.2020

classification [6, 7]. Geobotanical structure of the water-fringing macrophyte beds and of the floating mats is provides biomass of living *Typha* components, which are known to contribute into the buoyancy of the substrate [12], so perspective fragmentation of the reedmace and reed is expected by the western shore of the lake. Similar processes were observed on lake Urasar.

To summarize, a total of 4 habitat types included into the Annex I of Resolution 4 of the Bern Convention [25] were specified around the Horse Liman, according to EUNIS terminology [6]:

- C1.224 – Floating *Utricularia* colonies
- C1.24 – Rooted floating vegetation of mesotrophic waterbodies
- C3.5 – Periodically inundated shores with pioneer and ephemeral vegetation
- D2.3 – Transition mires and quaking bogs

Additionally, semi-submerged *Nymphaea alba* colonies need to be put in priority for protection, similarly to lake Clear Liman (Fig. 27), due to high conservation status of *Nymphaea alba* in the Red Book of Armenia (EN) [33]. One more protected flora species detected in the Horse Liman is *Utricularia intermedia* (RBA – EN) [33], and this finding is in agreement with A. Tumanyan data [38].

Figure 38. The largest found specimen of *Pelophylax ridibundus* (length 86 mm). Photo made at lake Horse Liman by Valentina Digalova, 17.09.2020

Fish population of the Horse Liman includes Stone moroko (*Pseudorasbora parva*) and Prussian carp (*Carassius gibelio*), which were discovered both in September 2020 and May 2021, and confirmed also by local fishermen in personal communication.

Herpetological survey revealed *Pelophylax ridibundus*, *Lacerta agilis*, *Natrix tessellata* and *Natrix natrix* inhabiting the Horse Liman basin and surroundings (Appendix 2). A total of 29 marsh frogs were caught and measured at the Horse Liman (4 adults and 25 juveniles). The largest marsh frog observed during the Project 2020-2021 expeditions was registered on the Horse Liman shore, equaling 86 mm (Fig. 38) A specimen of *Pelophylax ridibundus* with an eye injury (or cyclopia) was found at the lake (Fig. 39). Snakes were observed much more abundantly at the Horse Liman than at any other studied site; most of which were presented by *Natrix tessellata* (Fig. 40) found along the shore, and 2 more trapped themselves into the crayfish traps trying to catch a fish or a frog.

Figure 39. *Pelophylax ridibundus* with cyclopia found in lake Horse Liman. Photo by Valentina Digalova, 17.09.2020

Figure 40. *Natrix tessellata* found at lake Horse Liman. Photo by Dmitrii Sadokov, 17.09.2020

Apart from slightly enhanced values of iron and manganese content in water of the Horse Liman, which was mentioned before, potassium concentration (16,6 ppm) exceeds that of lakes Clear Liman and Long Liman water by 10 or more times (Appendix 6), so that the lake corresponds to class V of water objects accepted in Armenia (unfavorable) [23]. It is unclear what the source of K inflow was, still one of the versions refers to uncontrolled use of potash chemicals in agricultural activities in the watershed. The issue needs to be elaborated in the future.

Trace elements composition in sediments was examined specifically in lake Long Liman, and contamination assessment was carried out briefly in accordance with the background concentrations of chemical elements in soils accounted for Yerevan district [35], clark concentration values for the upper continental crust [11, 17] and maximum acceptable concentrations (MAC) for topsoil ratified in Armenia [24]. Concentration values of 23 elements are included into the table in Appendix 6. There is no evidence for any element to exceed MAC. Concentration values of most of the studied elements are well in accordance and of the same order as background geochemical composition of Yerevan soils, and also below the clark values. Arsenic and lead concentrations notably exceed geochemical background level (which is possible due to the differences of the weathering rocks composition between Yerevan and Lori regions), but still are within the limits of the national MAC. Generally no signs of enhanced pollution of the lacustrine sediments top layer in the Long Liman were observed. The research needs to be broadened to the neighboring basins for more statistically reliable assessments; particular attention needs to be addressed to lake Urasar, as the most proximal reservoir to the former Armanis mining plant as a possible source of pollution.

Figure 41. Garbage at the shores of lake Horse Liman. Photo by Dmitrii Sadokov, 17.09.2020.

Many garbage and litter pieces of different size are distributed along the lakeshore of the site (Fig. 41). Considering the fact that the Horse Liman is more distanced from the roadway compared with other lakes, and that no tourists or fishermen were met at the site during the expeditions, the shores were assumed to have been littered by people of only certain groups or professions, and not by the resting people, so this matter needs to be specially monitored and prevented.

SARATOVKA-NOVOSELTSOVO LAKES

The group of 4 lakes and up to 10 drained basins grown over with sedges, reeds and grasses are located between villages Saratovka and Novoseltsovo (correspondingly rivers Tashir and Dzoraget) (Fig. 1, 42). The lakes are situated at true altitude of 1476-1480 m a.s.l. Many lakes are mutually connected with channels, most of which are malfunctioning and overgrown with water macrophytes. Comprehensive studies held at lakes Peabog, Novoseltsovo-1, Novoseltsovo-2 and brief works on lake Saratovka are reviewed in this section. Names of some lakes were corrected after the Interim Report (2020) was uploaded, so that they would be in agreement with the previous works held at the Lori Plateau [37, 38]. Thus, **lake Novoseltsovo-1 here corresponds to lake Novoseltsovo-2 in the Interim Report, lake Novoseltsovo-2 – to lake Novoseltsovo-1 and lake Saratovka – to lake Cellular.**

Figure 42. Air footage of the Saratovka-Novoseltsovo lakes (DJI Mavic Mini). Photo by Andrei Ostashov, 15.09.2020.

Saratovka-Novoseltsovo cluster varies from other lake groups by the range and character of anthropogenic influence. As seen from the satellite images (Fig. 1), most lakes here had been drainless, with only few of them had been interconnected with permanent or seasonal flows, while today most lakes are linked into a network to maintain the DHP facilities. In some basins peat had been extracted for years, which influenced hydrological regime strongly, so that many lacustrine ecosystems lost their initial structure and have been transforming into sedge mires and moist grasslands with sparse eutrophic ponds. No official data on the peat extractive industries in the surroundings have yet been found or studied, partially because of numerous unregistered or illegal activities had been carried out in this field. These activities have proven to be a disastrous damage to the lacustrine systems: large areas of clear water remain only in lakes Novoseltsovo-1, -2 and Peatbog. Environments of lake Saratovka and numerous dried basins undoubtedly deserve particular attention, but unfortunately they were not embraced during the Project 2020-2021.

Thus, the condition of majority of the basins here can be described as significantly (or eventually) transformed due to artificial water regulation. Some lakes (Peatbog, Saratovka and Novoseltsovo-1) seem to steer to perform basic ecosystem functions as habitats for certain flora and fauna populations, in spite of the violated hydrology and sediments structure. The rest of the lakes (Novoseltsovo-2 and numerous overgrown basins) actually can be taken to assess the ultimate stage or course of ecosystems transformation under mentioned continuous impact, in contrast to the Central-Plateau lakes.

Figure 43. *Hyla orientalis* found at the bank of river Dzoraget near village Novoseltsevo. Photo and identification by Samvel Pipoyan, 27.05.2017

Special inventory of amphibian was performed at lakes Saratovka and Novoseltsovo-1. Noteworthy, apart from the lakes of the group, *Hyla orientalis* was registered also at the Dzoraget river bank in 2017 (reported by Samvel Pipoyan, Fig. 43), the site that can also be ascribed to the Saratovka-Novoseltsovo lakes area.

PEATBOG

Center coordinates: N 41,064129° E 44,303752°
Total area: 34,98 hectares
Clear water area: 6,22 hectares
Work conducted: air survey, bathymetry measurements, amphibian inventory,

Lake Peatbog is the largest lake of all reservoirs studied in the Project 2020-2021. The lake wields near-rectangular shape with gentle slopes inclining equally from all sides.

Hydrological peculiarities are mostly related to the system of drainage channels and harmful consequences of peat extraction performed in the past. Old channels inflow from the west and outflow to the east, still the drainage system of the lake is not functioning properly nowadays, as indicated by large thickets of the macrophytes in the channels (Fig. 46). The lake level remains nearly stable, with slight oscillations observed around 1-3 cm during the September 2020 expedition. The traced surface of the lake bottom shows irregularity of depth across the basin (Appendix 10), which may probably be due to sediments structure transformation during peat extraction. Open water occupies much of the lake basin, vegetation is mostly distributed along the shores. Floating vegetation is poorly developed, compared with Central-Plateau lakes.

Pastures typical for the Lori plateau extend northward and westward from the lake (Fig. 40, 42). Overgrown grassy basins are located from the west and east and linked with lake Peatbog with the channels (Fig. 42, 45).

A country road is adjacent to the eastern shore of the lake (Fig. 42), which is the only available passage to water, since the lake is fenced all along the shores close to the brink (Fig. 46). Private land with fruit orchards extends southward from the lake, which help to prevent extreme pasture pressure on the lacustrine shores. We perceive an experience of the similar land ownership to be potentially a good practice in terms of lakes restoration, remediation and monitoring, if agreed with owner. In this view we propose to establish communication with local landowners and authorities in order to implement new sustainable management practices on lakes Peabog and Stepanavan-3.

Figure 44. Air footage of lake Peatbog from the east (DJI Mavic Mini). Photo by Andrei Ostashov, 16.09.2020.

Figure 45. Air footage of the dried basin and the overgrown channel approaching lake Peatbog from the east (DJI Mavic Mini). Photo by Andrei Ostashov, 16.09.2020.

Figure 46. Large reed thickets and beds on the north-western shore of lake Petabog. Air footage (DJI Mavic Mini). Photo by Andrei Ostashov, 16.09.2020

No special ichthyological survey was carried out at lake Saratovka, still a Prussian carp (*Carassius gibelio*) specimen was found at the shore. Also stone moroko (*Pseudorasbora parva*) presence is expected in the lake, likewise in all studied lakes.

Inventory of amphibian was performed both in daytime and at night, in order to investigate species diversity in different activity phases (Appendix 2). Only marsh frog (*Pelophylax ridibundus*) was observed visually (morphometry measured for 9 adults and 10 juveniles). Two marsh frogs with their legs torn off were found at the Saratovka lake (Fig. 47). *Hyla orientalis* calls were registered at single-standing trees by the eastern shore of the lake in late-September 2020.

Figure 47. One of two marsh frogs lacking a leg found at lake Peatbog in September 2020. Photo by Valentina Digalova, 19.09.2020

NOVOSELTSOVO-1

Center coordinates: N 41,068141° E 44,280320 °
Total area: 14,81 hectares
Clear water area: 6,02 hectares
Work conducted: air and visual survey of habitats, bathymetry measurements, brief ornithological inventory, flora, fish, amphibian inventory
Lake Novoseltsovo-1 was mentioned as Novoseltsovo-2 in the Interim Report

The Novoseltsovo-1 is the second largest lake among the studied basins, if not to account lake Saratovka, which was visited briefly. Lake Novoseltsovo-1 site is significant for lacustrine ecosystems transformation research and monitoring in terms of both natural processes and human activities in the region. The basin is equally elongated in three directions, with round-shaped curves of the shoreline (Fig. 48, Appendix 11).

Figure 48. Air footage of lake Novoseltsovo-1 (DJI Mavic Mini). Photo by Andrei Ostashov, 18.09.2020

The Novoseltsovo-1 is one of the few lakes where channels system is fully operating. Rapid stream inflows through the 5-meter wide channel from the north (Fig. 49, 50). The northern channel is interconnected with an artificial drainage ditch between rivers Tashir and Dzoraget, which traces the limit of the Lori lakes location from the north-west (Fig. 1). Another narrow drain leads from the northern channel to lake Saratovka, still it remains unclear whether its discharge capacity contributes into the water volume flowing into the Novoseltsovo-1 due to thick beds of vegetation developed in the drain (Fig. 51). A channel with gentle current and sometimes standing water, regulated by a hatch, flows out southward (Fig. 52). The southern channel flows into with a natural stream leading to river Dzoraget in the Novoseltsovo village.

Figure 49. Northern drainage channel flowing into lake Novoseltsovo-1. Photo during high water spring period by Ilona Stepanyan, 23.05.2021

Figure 50. Northern drainage channel at its influx into lake Novoseltsovo-1. Large reed beds on the water brink. Photo by Samvel Pipoyan, 12.09.2020

Bathymetry measurements were performed on lake Novoseltsovo-1 on 3 profiles, but the work was not finished due to unfavorable weather conditions. Thus, although the depth measurements are not adequate to build a bathymetry model, still it is possible to estimate general patterns of bottom relief. The bathymetry shows irregularity of depth distribution across the lake (Appendices 11, 12), in particular along the profile "C-A". It is seen that there is no symmetric depression in the centre of the basin, as it was observed in lakes Urasar, Clear Liman and Horse Liman, but mounded relief of the bottom was traced. Muddy sediments compose more than 1 meter of the upper part of the deposits. Depth differences in course of the profile may be explained due to secondary redistribution of the peat sediments as a result of their extraction and/or hydro-technical utilities construction.

Figure 51. Reed thickets filling the drain between lakes Novoseltsovo-1 and Saratovka. Photo by Dmitrii Sadokov, 12.09.2020

As most of the lake basin is shallow, large area is covered with floating and submerged rooted vegetation (Appendix 11). Carpets and mats of hydrophytes occupy 3/4 of the watered area. Unvegetated spots of clear water were observed only in the sectors where the channels approach the lake, as a consequence of the dynamic current that prevents these parts of the lake from eutrophication.

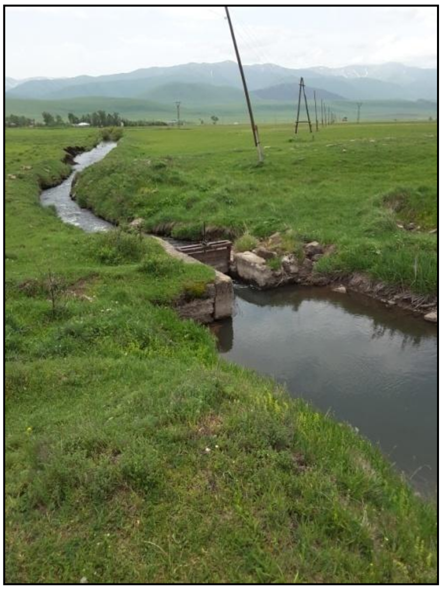

Figure 52. Southern channel flowing out of lake Novoseltsovo-1. Photo during high water spring period by Ilona Stepanyan, 23.05.2021

Water level oscillated significantly during the September 2020 expedition. Diurnal variation up to 43 cm were registered (Fig. 53), so that dynamic position of the shoreline caused the existence of regularly inundated zone with muddy sediments and sparse ephemeral amphibious vegetation. Shores adjacent to the channels and north-western gentle slope are overgrown by tall beds of reeds and sedge tussocks, which are generally attributed to the places of stagnant water of minor slope inclination or to shallow bays (Fig. 54).

The basin slopes are slightly terraced, which is best observed from the northern and southern sides of the lake, where the belt of water-fringing helophyte grasses, sedges and reeds broadens in correspondence to the smooth flat relief of the lower shelf of the lacustrine terrace (Fig. 55, Appendix 11). The inclining slope of the terrace is well represented around the lake, with the vegetation type markedly switching to hygrophyte

Figure 53. Stationary measuring scales at lake Novoseltsovo-1 after another level drop. Photo by Andrei Ostashov, 15.09.2020

and mesophyte pastures, which are being regularly mowed and overgrazed.

At least 2 habitat types can be certainly determined in and around lake Novoseltsovo-1, according to the EUNIS classification [6], included into the Resolution 4 of the Bern Convention [25], namely «Beds of large sedges normally without free-standing water» (D5.2) and «Periodically inundated shores with pioneer and ephemeral vegetation» (C3.5).

Figure 54. Large thickets of reeds and sedges in the littoral part of lake Novoseltsovo-1, marking drying shore. Photo by Vasil Ananian, 12.09.2020

Figure 55. Flat lacustrine terrace from the south of lake Novoseltsevo-1. Photo by Dmitrii Sadokov, 14.09.2020.

Acorus calamus, *Nymphaea alba* and *Iris sibirica* (IUCN – NT) [15] (Fig. 56) are the plant species discovered at lake Novoseltsovo-1 listed in the Red Book of Armenia [33] (Appendix 3).

Figure 56. *Iris sibirica* found at lake Novoseltsovo-1. Photo and identification by Ivan Gabrielyan, 23.05.2021

Rich diversity of birds species was observed at lake Novoseltsovo-1 (Appendix 1), most probably due to the mosaic structure of habitats, which intrinsically render shelters, breeding spots and feeding area for certain groups of birds. Dynamically changing water level, which uncovers much of the lakeshore, creates increasingly favorable conditions for the birds linked with the water-fringing helophytes, reedbeds and sedges. Various groups of birds manage to find here a comfortable niche: floating vegetation communities and tussocks serve as a shelter and feeding site for various waterbirds (Fig. 57, 58); various passerines and other insectivorous birds concentrate on the hay meadows beside the lake as well as on floating and emergent vegetation; raptors often find rodents near the overgrown brink of water; herons and egrets stalk for fish and frogs in the shallow parts of the lake. A number of nationally protected and rare birds species were observed at the Novoseltsovo-1, namely Glossy Ibis (*Plegadis falcinellus*), Lesser Spotted Eagle (*Clanga pomarina*), Short-toed Eagle (*Circaetus gallicus*) (Fig. 59), Pallid Harrier (*Circus macrourus*) (IUCN Red List – NT) and Armenian Gull (*Larus armenicus*) (IUCN Red List – NT) [1, 15], all of which are considered passage migrants (Appendix 1). Great Cormorant (*Phalacrocorax carbo*) (RBA – VU) and Montagu's Harrier (*Circus pygargus*) (RBA – VU) [1] were observed at lake Saratovka (just 500 m to the North-East). The Saratovka ornithofauna was not studied specifically, so the mentioned species are presented in this section as they are expected to inhabit the Novoseltsovo-1 surroundings as well.

Figure 57. *Ardea cinerea* resting on sedge tussocks at lake Novoseltsovo-1. Photo and identification by Vasil Ananian, 12.09.2020

Figure 58. *Ciconia ciconia* over the Novoseltsovo-1 surroundings. Photo by Vasil Ananian, 12.09.2020

Figure 59 (above). *Circaetus gallicus* near lake Novoseltsovo-1. Photo and identification by Vasil Ananian, 12.09.2020

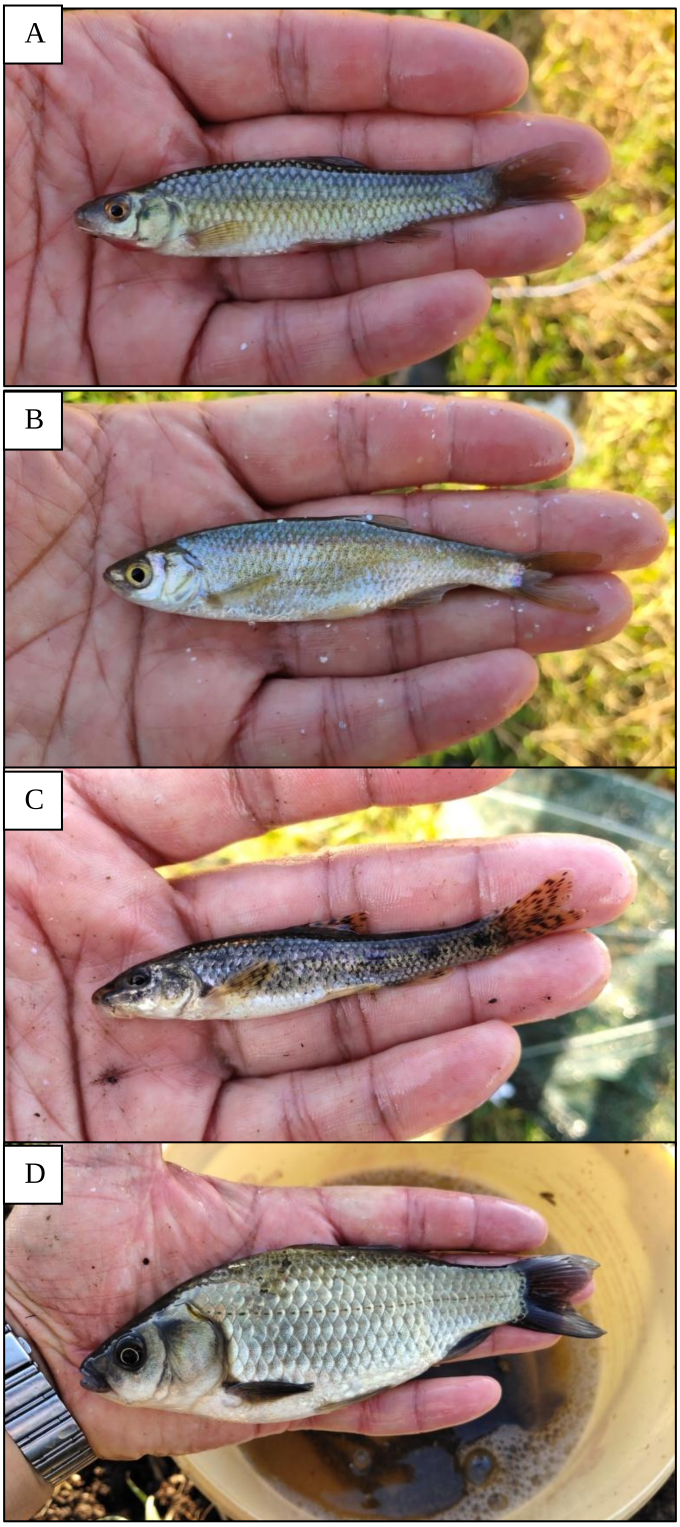

Figure 60 (right). Fish species found in lake Novoseltsovo-1. Caught and identified by Samvel Pipoyan. A: *Pseudorasbora parva*; B: *Alburnus hohenackeri*; C: *Gobio caucasicus*; D: *Carasius gibelio*

Figure 61 (below). *Rana macrocnemis* found at lake Novoseltsovo-1. Photo by Vasil Ananian, identification by Ilona Stepanyan, 12.09.2020.

4 fish species were determined in the lake: Prussian carp (*Carassius gibelio*), Gudgeon (*Gobio* cf. *artvinicus*), North Caucasian bleak (*Alburnus hohenackeri*) and Stone moroko (*Pseudorasbora parva*) (Appendix 4). *Alburnus hohenackeri* dominates among other species populations, of which only individual specimen were caught (Fig. 60). Up to 97% of local ichthhyofauna is presented by *Alburnus hohenackeri* (786 specimen caught), *Pseudorasbora parva*, *Gobio caucasicus* and *Carassius gibelio* do not exceed 1 % each (8, 10 and 9 specimen respectively).

Alburnus hohenackeri is presumed to suppress other fish species in lake Novoseltsovo-1 the same way as it was observed for *Pseudarasbora parva* in lakes Stepanavan-2, Novoseltsovo-

2 and Urasar due to higher adaptiveness and wider tolerance limits of both species, which enable them to successfully invade new ecosystems and to sustain dominance [21].

Inventory of amphibian revealed presence of *Pelophylax ridibundus* and *Rana macrocnemis* in lake Novoseltsovo-1. A total of 56 frogs were measured and photographed during the September 2020 research, where *Pelophylax ridibundus* composed 14 specimen (2 adults, 12 juveniles) and *Rana macrocnemis* (Fig. 61) composed 42 specimen (2 adults, 40 juveniles). The largest *Rana macrocnemis* indivual of all studied in the Project was registered at the Novoseltsovo-1 (56.5 mm).

NOVOSELTSOVO-2

Center coordinates: N 41,056751° E 44,283410 °
Total area: 13,59 hectares
Clear water area: 11,76 hectares
Work conducted: brief air survey, flora, fish inventory
Lake Novoseltsovo-2 was mentioned as Novoseltsovo-1 in the Interim Report

Lake Novoseltsovo-2 is 800 m away to the south from lake Novoseltsovo-1 (Fig. 62), and it is conceived to endure the largest human impact of all studied Lori lakes. The lake is currently employed as a reservoir to regulate the water supply for the DHP. A channel is directed towards the river through the village Novoseltsovo from the western side of the lake. From a semi-dried neighboring basin water flows into the Novoseltsovo-2 through the inlet at the northern shore (Fig. 63), which was totally dried and overgrown with sedges in September 2020. Buildings of the village stand close to the water brink from the west, where the shores are beached with stone barriers. Water level is strictly regulated and balanced; the lake is completely drained in some years, as locals report.

Figure 62. Air footage of lakes Novoseltsovo-1 (in the forefront) and Novoseltsovo-2 (in the background) (DJI Mavic Mini). Village Novoseltsovo lays to the right from lake Novoseltsovo-2. Photo by Andrei Ostashov, 18.09.2020

Water-fringing and helophyte vegetation is poorly developed, only several groups of reeds are found near the channel from the north (Fig. 63). The whole lake area is clear from floating vegetation, which is untypical for the Lori lakes, and may be a signal of some undetermined hydrological or hydrochemical effect that constrains growth of hydrophytes. Only a small island composed possibly of floating reed or sedges mats migrating across the water area (similar to the *Typha* island at lake Horse Liman) was observed while studying satellite images, still the case requires special research

Figure 63. Northern shore of lake Novoseltsovo-2 with the overgrown channel. Air footage (DJI Mavic Mini). Photo by Andrei Ostashov, 12.09.2020.

Among all the birds observed at lake Novoseltsovo-2 (Appendix 1), 3 species included into the Red Book of Armenia were recorded at the site, namely Lesser Spotted Eagle (*Clanga pomarina*), Armenian Gull (*Larus armenicus*) (IUCN List – NT) and Whiskered Tern (*Chlidonias hybrida*) (Fig. 64) [1, 15].

Figure 64. *Chlidonias hybrid* near lake Novoseltsovo-2. Photo and identification by Vasil Ananian, 12.09.2020

Fish population of the Novoseltsovo-2 includes Stone moroko (*Pseudorasbora parva*), North-Caucasian Bleak (*Alburnus hohenackeri*) and Prussian carp (*Carassius gibelio*). From the total 741 fish individuals, *Pseudorasbora parva* accounted for 690 specimen (93%), *Alburnus hohenackeri* – for 50 specimen (6.7%), *Carassius gibelio* – for 1 specimen (0.1%). Noteworthy, *Ctenopharyngodon idella* was found in the lake in 2019 (oral report by Samvel Pipoyan).

SARATOVKA

Center coordinates: N 41,076388° E 44,289926 °
Total area: 29,11 hectares
Clear water area: 0,8 hectares (seasonally)
Work conducted: brief air survey, water level measurements
Lake Saratovka was mentioned as Cellular in the Interim Report

Lake Saratovka ("Cellular") is a large reservoir (Fig. 65), which presumably endured heavy anthropogenic pressure in the past due to peat extraction and drainage channels constructing activities. The water area is almost completely covered with floating mats of hydrophytes, which create a polygonal or 'cellular' texture over the water surface, which the lake owes the trivial name to.

The Saratovka is connected with river Tashir with a channel laid through a neighboring totally drained basin. From the south-western side a trench leads to lake Novoseltsovo-1. The trench is densely overgrown with reed and reedmace beds (Fig. 51), so it is perceived to have been invalid for draining purposes for many years. Instead of this old trench a new channel is operating between rivers Tashir and Dzoraget, skirting lake Saratovka around just some 5-10 meters away from the north, and connecting further to the west with a duct from lake Novoseltsovo-1 (Fig. 48, 65). Water level remained constant during the expedition with only minor 2-cm oscillations registered weekly.

Figure 65. Air footage of lake Saratovka (DJI Mavic Mini). Photo by Andrei Ostashov, 18.09.2020

The Saratovka was not studied specifically during the Project 2020-2021, still some rare species were registered during a brief visit. A number of endangered species of birds were observed, namely *Phalacrocorax carbo* (RBA – VU), *Clanga pomarina*, *Circaetus gallicus*, *Circus pygargus*, all assigned with a status VU in the Red Book of Armenia [1], and *Circus macrourus* (RBA – EN, IUCN Red List – NT) and *Larus armenicus* (RBA – VU, IUCN Red List

– NT) [1, 15] (Appendix 1). Among the plants *Acorus calamus*, *Carex bohemica* and *Nymphaea alba* were noticed at lake Saratovka (Fig. 67) (listed in the RBA) [33] (Appendix 3).

Figure 66. Air footage of the cellular geobotanic structure of the water vegetation on lake Saratovka (DJI Mavic Mini). Photo by Andrei Osatshov, 18.09.2020

Figure 67. *Nymphaea alba* carpets on lake Saratovka. Photo by Vasil Ananian, 12.09.2020

HILLSIDE LAKES

Lakes Urasar, Katnaghbyur and a number of small reservoirs located on the elevated hillside by the Lori plateau southern periphery. The terrain of the studied hillside is represented by a slightly undulated surface of the plateau (Fig. 68), elevated over its central part by some 85 meters. Lakes are uncommon for this area, the only 7 moist or flooded basins are grouped on the pieces of flat relief near cities of Armanis, Urasar and Katnaghbyur (Fig. 1). Apart from the lakes, hydrographic network of the area includes rivers Chknakh (Fig. 69) and Metsaru (tributaries of the Dzoraget river), which flow from the Bazum ridge in the south, and form deep canyons in the research area.

Figure 68. Air footage of the terrain between the Hillside lakes (northern low slopes of the Bazum ridge to the right) (DJI Mavic Mini). Photo by Dmitrii Sadokov, 13.09.2020

Figure 69. Air footage of river Chknakh canyon from lake Urasar (DJI Mavic Mini). Photo by Dmitrii Sadokov, 13.09.2020

The Hillside lakes are prominent for several scientific and conservation reasons, listed below:

1) According to the EUNIS approach, a number of habitats corresponding to several mesotrophic and eutrophic vegetation groups can be basically outlined in the area. Generally group of habitats «Permanent mesotrophic lakes, ponds and pools» listed in the Resolution 4 of Bern Convention (C1.2) is referred to all Lori lakes [6, 7, 25], so the very presence of lakes on the Southern Hillside of the plateau makes them highly valuable. Hence, more definite habitat types are expected within the outlined lacustrine basins, including the endangered ones.

2) A number of threatened and nationally protected plant species were described around several Hillside lakes, in particular at lake Urasar, which was also highlighted for special conservation measures due to the botanical richness [37, 38].

URASAR

Center coordinates: N 41,023290° E 44,304473°
Total area: 7,94 hectares
Clear water area: 1,62 hectares
True altitude: 1559 m a.s.l.
Work conducted: air and visual landscape survey, ornithological inventory, flora, fish inventory

Lake Urasar is the largest among the Hillside lakes. It is located 1 km away from city Urasar and 200 m to the north from the Chknakh river canyon brink. Lake Urasar basin has an extended oval shape, narrowing to the west, of 500 m in length and from 150 to 300 m in width. Elevation contour lines mark the shape of the reservoir, with steeper slopes limiting the basin from the east, and more gentle slopes elongating it to the west .

Geomorphological patterns influence vegetation distribution in the lake, which thus creates a remarkable habitats structure (Appendix 13).

Figure 70. Lake Urasar. *Nymphaea alba* floating mats and carpets. Photo by Vasil Ananian, 13.09.2020

A spot of clear water in the center of the eastern part of the Urasar remains uncovered by floating vegetation. It is surrounded by wide monodominant carpets of *Nymphaea alba* (Fig. 70, 71, Appendix 13), similar to lakes Clear Liman and Horse Liman. Floating beds mainly of *Typha latifolia* with sedges and other macrophytes (mostly Polygonaceae and Poaceae) spread across the water area from the western periphery. The western lakeshore presents a wide mosaic of various groups of wetland vegetation (Fig. 72, Appendix 13), with floating mats of macrophytes

Figure 71. Air footage of lake Urasar central part (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020

appearing by the water edge. Communities of reeds, tall helophytes and water-fringing sedge tussocks, often on quaking watered buoyant ground, dynamically alternate on the western periphery, and some pieces break off the shore to turn into islands (Fig. 71, 73) [12]. Similar phenomenon was observed on lake Horse Liman. Wind and wave disturbance together with ice pressure are presumably the triggering factors influencing pieces of floating mats to decay.

A community of tall hygrophytes and grasses on the moist peaty substrate fringes the floating beds from the west (Fig. 72, 74) and serves as a broad barrier between aquatic and terrestrial ecosystems. Water sustains in several ponds overgrown by *Carex acutiformis* and Typhaceae in an isolated basin in the very western corner of the Urasar, separated from the major pool by the vegetation described above (Fig. 72, Appendix 13).

Figure 72. Western shore of lake Urasar with mosaic wetland vegetation cover. Air footage (DJI Mavic Mini). Photo by Andrei Ostashov, 13.09.2020

Heterogeneity of water-fringing and floating complexes of the western shore of the Urasar forms a prominent combination of habitats, most of which are determined to correspond to the endangered habitat types listed in the Resolution 4 of the Bern Convention [25], such as «Free-floating vegetation of mesotrophic waterbodies» (C1.22), «Floating broad-leaved carpets» (C1.241), «Transition mires and quaking bogs» (D2.3).

Nymphaea alba was the only protected flora species found at lake Urasar during the Project 2020-2021 (Fig. 70, 74), though more species listed in the national Red Book had been mentioned in previous works to occur at the Urasar [33, 38].

At least 3 endangered bird species use the environs of lake Urasar area during migrations or in breeding season, namely Lesser Spotted Eagle (*Clanga pomarina*) (RBA - VU), Pallid Harrier (*Circus macrourus*) (RBA - EN, IUCN Red List - NT), European Roller (*Coracias garrulous*) (RBA - VU) [1, 15] (Appendix 1).

Figure 73. Floating mats of wetland vegetation among *Nymphaea* mats in lake Urasar. Photo by Dmitrii Sadokov, 13.09.2020

Almost 99% of the fish population are presented by Stone moroko (*Pseudorasbora parva*) of different size (292 caught specimen) (Fig. 75) and Prussian carp (*Carassius gibelio*) (Fig. 76) constituted about 1%.

Mining industries are situated near city of Armanis, 1 km to the south from lake Urasar (see on Fig. 73 in the background), where auriferous and polymetallic ore was extracted until recent time. It is expected that Armanis quarries are the major source of contamination of the adjacent rivers and soils. However, it is an objective of a specific research

Figure 74. Hygrophyte grassland community on the moist substrate in the western part of lake Urasar. Photo by Dmitrii Sadokov, 13.09.2020

Figure 75. *Pseudorasbora parva* specimen of different size found in lake Urasar. Caught and identified by Samvel Pipoyan, 13.09.2020

Figure 76. *Carassius gibelio* found in lake Urasar. Photo and identification by Samvel Pipoyan, 13.09.2020

KATNAGHBYUR

Center coordinates: N 41,034592° E 44,241990°
Total area: 2,66 hectares
Clear water area: 0,41 hectares
Work conducted: brief ornithological, flora, fish inventory

The studied basin called lake Katnaghbyur is one of two minor pools near the village Katnaghbyur, which is situated 2 km to the west from them. Unfortunately, the lake was studied briefly, because of unfavorable technical and meteorological conditions. The basin is almost completely covered with permanent vegetation cover of macrophytes, mostly overgrowing the still-standing water (reeds, sedges and tall helophytes) (Fig. 77). Unvegetated water is limited to several small ponds (Fig. 78, 79), where beds of floating *Utricularia minor, U. vulgaris* (listed in Resolution 4 of the Bern Convention under code C1.224) (Fig 81) [8, 25] and *Potamogeton natans* were described (Fig. 80). Large tussocks of sedges stand by the water brink, indicating progressive mire formation (Fig. 79), similarly to lake Urasar in the western part (Fig. 72) and some dried lakes of the Central-Plateau and Saratovka-Novoseltsovo groups (Fig. 82, 84).

Figure 77 (above). Basin of lake Katnaghbyur. Photo by Samvel Pipoyan, 13.09.2020

Figure 78 (left). One of the few ponds with clear water in the basin of lake Katnaghbyur. Photo by Ivan Gabrielyan, 13.09.2020

Prussian carp (*Carassius gibelio*) species represents fish monoculture in lake Katnaghbyur. No other amphibian species but *Pelophylax ridibundus* were found at the Katnaghbyur.

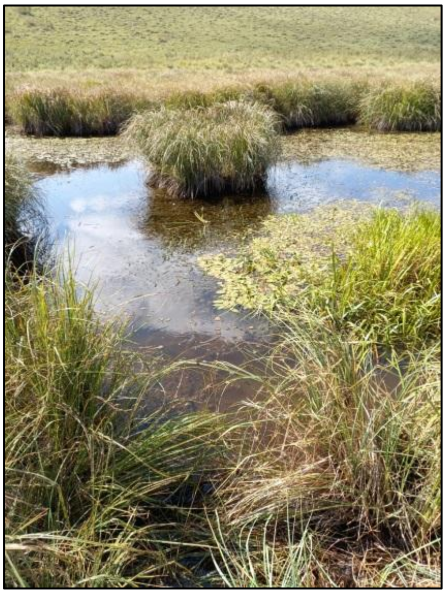

Figure 79. Large tussocks of sedges in ponds of lake Katnaghbyur. Photo by Samvel Pipoyan, 13.09.2020

Figure 80. *Potamogeton natans* and *Potamogeton alpines* in the pond in lake Katnaghbyur. Photo and identification by Ivan Gabrielyan, 13.09.2020

Figure 81. *Utricularia vulgaris* found in lake Katnaghbyur. Identified by Ivan Gabrielyan.

Lake Katnaghbyur is similar by its hydrological conditions and general geobotanic structure to the numerous dried overgrown basins of Central-Plateau and Saratovka-Novoseltsovo groups (Fig. 42, 45, 82), which are very specific in their habitats diversity and value. Comprehensive study of these pools was not planned in frames of the Project 2020-2021, but it is regarded as an essential objective for the future research.

CONCLUSION

1. For the first time an inventory of the Emerald Site «Lori Lakes» was performed at each lake individually in terms of EUNIS classification of habitats [6]. The following **habitat types included into the Resolution 4 of the Bern Convention** [25] were described in the area:

- Free-floating vegetation of mesotrophic waterbodies (C1.22)
    - Floating *Utricularia intermedia* and *U. vulgaris* colonies (C1.224)
- Rooted floating vegetation of mesotrophic waterbodies (C1.24)
    - Floating broad-leaved carpets (C1.241)
- Periodically inundated shores with pioneer and ephemeral vegetation (C3.5)
- Transition mires and quaking bogs (D2.3)
- Beds of large sedges normally without free-standing water (D5.2)

From the point of the Lori plateau landscape diversity, habitats value and conservation perspectives lakes Urasar, Clear Liman, Horse Liman and Novoseltsovo-1 were defined as most prominent. Lake Peatbog is considered to be a promising site to establish and develop community-based conservation or recreation initiatives, provided the private land-use management would create favorable conditions for joint actions. Numerous dried lacustrine basins in the area (Fig. 82, 83) are expected to maintain highly valuable habitats, particularly if natural hydrological regime be restored.

Figure 82. A dried overgrown basin near lake Peatbog. Air footage (DJI Mavic Mini). Photo by Andrei Ostashov, 15.09.2020

Figure 83. Hygrophyte grassland in the basin between lakes Novoseltsevo-1 and Saratovka. Photo by Dmitrii Sadokov, 14.09.2020

2. **16 threatened species** listed in the Red Book of Armenia [1, 33], **8 species** included into the IUCN Red List [15] and at least 2 endemic species of the Northern Caucasus [2, 10, 32] were observed at the Lori lakes in 2020-2021. *Iris sibirica*, *Psephellus manakyanii*, *Circus macrourus*, *Larus armenicus* and *Darevskia dahli* are the species of the highest observed value, attributed to more than one list of species dedicated for conservation (Appendices 1, 2, 3). *Hyla orientalis* distribution in Armenia is poorly investigated, which seems to be declining due to the loss of forest habitats and intense agriculture [2], that is why an emphasis was made on the new information about this frog at the Lori lakes.

Some species of special conservation and scientific interest expected to inhabit the area were not discovered via the Project 2020-2021, and will be kept highly on the agenda of future investigations. *Ommatotriton ophriticus* (RBA – CR; IUCN – NT) [1, 15] has been the object of numerous previous and current research works in Armenia, which is particularly relevant for the Lori plateau [27, 38]. *Chamaenerion dodonaei*, *Salvinia natans*, *Potentilla erecta*, *Sagitaria sagittifolia* and *Sagitaria trifolia* are listed in the Red Book of Armenia [33] and were repeatedly collected at the Lori plateau during XX and early XXI centrury [37], although were not discovered during the Project 2020-2021.

3. A range of **threats and effects from human activities on the wetland sites** of the Lori plateau were studied and ranked. Below are the major ways of the past and present anthropogenic impact highlighted for the Lori lakes, listed in descending order by their influence on nature systems.

(a) Drainage of the basins and peat extraction

A network of old trenches and channels interconnects many lakes of the Lori plateau (Fig. 42, 45, 48, 51, 52, 62, 65), and also the numerous drained basins (Fig. 15, 28, 45, 82). The latter are mostly overgrown with sedge and reed beds, some of them wield pools of open water covered with floating vegetation. The drainage of water from these basins was reasoned by the activity of uncontrolled peat extraction. Mechanical consequences of the latter can be seen in many drained basins as regularly shaped pits (Fig. 84), unnatural bottom relief (Appendices 10, 11, 12) and vegetation cover patterns (Fig. 66, 67). Ecological consequences are expressed in loss of species and habitats diversity.

Figure 84. One of many rectangular pits designed for peat extraction in the dried basin between lakes Novoseltsevo-1 and Saratovka. Photo by Dmitrii Sadokov, 14.09.2020

Thus, long-lasting effects on the lacustrine systems were caused by the local pronounced damage of the hydrological network. Many lakes literally disappeared, while the rest were subjected to complete reorganization of ecosystems, in conditions of the vegetation cover breakdown and violated hydrological regime, which is crucial in terms of freshwater systems preservation [9]

(b) Modern transformation of hydrological regime

Several renewed channels have been operating in the vicinity of the Novoseltsovo village, linking lakes Novoseltsovo-1 and Novoseltsovo-2 with the Dzoraget Hydropower Plant. The effect that the channels exert on the environment maintains lacustrine ecosystems in dynamic (or quasi-) sustainability, as new groups of species actively expand on the periodically inundated shores. Still, on the other hand, fish and amphibian fauna remains under pressure due to the intraseasonal water level drops. Apart from that, habitats of the lakes upstream endure steady degradation, the same way as in case of peat extraction drainage, since the water sinks down to the Dzoraget due to the regular level drops in the linked regulated basins.

(c) Agriculture

Intense livestock grazing and haymaking are major agricultural activities in the area. These obviously influence the steppe grass-forbs communities in the way of sustaining strongly modified geobotanic structure, so that basic consumers inhabiting the meadows and steppes (i.e. insects, rodents) suffer and their abundance remains lowered. Therefore, biodiversity of the plain natural complexes is limited by the agriculture, due to the decreased bioproductivity, which is perceived a predominant controller to re-establish healthier environment if enhanced.

Livestock may also exert damage to water objects when they are used as watering places. As a result, seasonally dried shoreline gets trampled, which implies a straight threat to amphibian juveniles inhabiting this zone. Moreover, helmint eggs may introduce the lakewater and then threaten mollusks and fish populations, as it was demonstrated for lake Clear Liman (Fig. 24).

(d) Leisure and recreation

Local residents use the Lori lakes as sites for recreation, which includes fishery, hunting, barbecue, travelling and other outdoor activities. Litter and garbage are the most obvious consequences of the human presence at lake shores. The biggest amount of solid waste and garbage was noticed during the fieldwork at lakes Horse Liman (Fig. 41), Stepanavan-1, Stepanavan-2 and Novoseltsovo-2.

As demonstrated by the study of the fish fauna in lakes Urasar, Novoseltsovo-2, Novoseltsovo-1, Clear Liman and Stepanavan-2, invasive species *Pseudorasbora parva* and *Alburnus hohenackeri* may constitute up to 99% of the fish population of a lake, singly or together. Having a great potential to increase its population with broader ecological tolerance limits, *Pseudorasbora parva* can significantly affect the number of other fish species by feeding on their fish egg and fingerlings [22]. Local fishermen are reported to introduce new fish specimen into the lakes (mostly *Cyprinus carpio, Ctenopharyngodon idella, Hypophthalmichthys molitrix* and *Carassius gibelio*) for their own interest, while the invasive species mentioned above are delivered into the lakes unintentionally and soon begin to dominate in their ecological niches and to displace native species. All this leads to establishment of monocultures and depauperization of fish fauna diversity. Moreover, dominating *Pseudorasbora parva* may influence epizootic status of fish populations in a way of disease or parasites transmission, which may be dangerous to superior vertebrates, but make no harm to host fish species.

Boat fishery may also violate the integrity of the floating *Nymphaea alba* mats on lake Clear Liman, which are already highlighted for protection on the local scale (Fig. 27).

Finally, certain harm to the lacustrine flora and fauna was noted because of visitors' ignorant behavior, such as intended collecting of the rare and protected plants, and killing of non-poisonous snakes for personal entertainment.

(e) Other

Chemical pollution of lake water, sediments and soils may appear in the area, mostly caused by the organic influx from livestock. Using of pesticides may cause enhanced accumulation of certain elements, for example potassium, which was found at high level in the water of lake Horse Liman (Appendix 6). Armanis mining plant is also a likely source of trace elements contamination, still a special research needs to be performed in this direction.

RECOMMENDATIONS ON THE MITIGATION OF THE MAJOR THREATS TO LANDSCAPE AND BIOLOGICAL DIVERSITY

A number of options that would help to resolve or mitigate major environmental risks and threats of the Lori Lakes ecosystems were elaborated on the basis of the Project 2020-2021 results. The following suggestions were outlined for public and expert use and addressed to the federal and local authorities in order to initiate a joint framework with certain conservation actions to be implemented in the nearest years.

(a) **Designation of special conservation status**

Most of the Lori lakes require special conservation status and measures to be approved on the national level, as it had been mentioned in the National Strategy [30]. A range of research projects provide comprehensive evidence on the necessity of establishing a protected area at the Lori plateau [28, 29, 37, 38]. The lakes also have been acknowledged as an area of special conservation interest (ASCI) as part of the Emerald Network [8]. More advanced, the territory was designated as a Freshwater Key Biodiversity Area by WWF Armenia (Dzoraget-Tashir) [9] and an Important Bird Area (AM007) [14].

From this point an action plan should be initiated in the Government in order to promote the launch of new preservation policy at the Lori plateau. Our 2020-2021 data well contribute to the datasets mentioned above, and specify spatial distribution and state of the endangered species and habitats. Zonation of a proposed protected area on the Lori plateau is drawn in Appendix 14, with consideration to the Project 2020-2021 results. Lakes Clear Liman, Horse Liman, Urasar and possibly Stepanavan lakes have been by now considered most valuable in terms of preserving rare species and habitats, so they were outlined as potentially most strictly preserved sanctuaries in order to legally sustain the lacustrine ecosystems completely undisturbed. A buffer zone is suggested to embrace the area around and between the proposed sanctuaries and also to cover the lakes which are most regularly and intensely exploited for agricultural and hydrotechnical purposes. Within this buffer limited use of natural resources under sustainable management is suggested, in order to maintain integrity of the plateau ecosystems and to mitigate negative impact from agriculture and livestock pasturing [31].

(b) **Restoration of water objects and hydrological network**

Almost all pools of the central Lori plateau and the hillside endured disorder of hydrological regime, one way or another. Many of these wetland sites require restoration in order to sustain natural water balance that would secure stability of ecosystems. Sustainable management should be employed for every basin taking into consideration definite hydrological conditions (channels network configuration, level oscillations, bottom relief) and landscape peculiarities (plant communities distribution, width of regularly inundated zone, basins geomorphology). Mostly it refers to lakes Novoseltsovo-1 and Novoseltsovo-2, but is also meaningful for lake Peatbog and Stepanavan lakes.

Overgrown dried basins with severely transformed habitats require specific risk assessment and elaboration of possible restoration strategies, such as, for example rewetting of peatlands and raising water table [31]. Special research needs to be carried out to address the issue of hydrological regime restoration, which would definitely support (or raise) value of the lakes in terms of the Freshwater Key Biodiversity Area preservation [9].

(c) **Ichthyological remediation**

A control on the fish fauna introduction needs to be carried out rigorously. First and foremost, invasive and native fish populations need to be balanced in the studied lakes, in order to avoid monodominance of the introduced and aggressive species (Stone moroko). A range of regulative methods are available for this purpose: introduction of predator species or genetic methods [16].

If new conservation measures will be implemented, fishery rules need to be established according to the zoning principles (Appendix 14). As such, recreational, sport and commercial fishing is suggested to be totally prohibited on the lakes outlined as strictly protected (Clear Liman, Horse Liman, Urasar). In the so-called buffer zone capture limitations and consistent standardization on the new species introduction, and regular monitoring are considered to be the key factors for the healthy state of ichthyofauna populations.

(d) **Scientific and educational initiatives**

Each step of preservation and restoration activities might be more effective if accompanied with scientific and educational work in the area. A number of special botanical, herpetological and ichthyological studies were performed in the area in recent years, all of which emphasized the role of fundamental science in species and habitats protection [21, 28, 29, 37, 38]. Determination of newt species diversity and distribution, threatened plant species inventory, better understanding of the area used by local and migratory birds, and comprehensive hydrological assessment of the lacustrine plain network are some of the most relevant research lines. Interdisciplinary fundamental scientific and educational practice is the key element for successful management of geodiversity and geoheritage protection [5]. Involvement of students in frames of their university practice in the monitoring activities as part of conservation initiatives might also attract more public attention to the work and demonstrate mutual interest to the issue from academic, educational and municipal communities.

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Appendix 1. Results of the ornithological inventory at the Lori lakes

Occurrence status legend: r – resident, sb – summer visitor – breeder, s – oversummer without breeding, w – winter visitor, pm – passage migrant, ? – relevant status uncertain.

Scientific Name	English Name	Red Book of Armenia (2010) [1]	IUCN Red List (as of December 2021) [15]	Lakes / Sites	Occurrence status in the study area
Anas crecca	Common Teal		LC	Saratovka, Stepanavan	pm, w
Anas platyrhynchos	Mallard		LC	Saratovka, Stepanavan	sb, pm, w
Aythya ferina	Common Pochard		VU	Stepanavan	sb?, pm, w
Tachybaptus ruficollis	Little Grebe		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	r
Phalacrocorax carbo	Great Cormorant	VU B1ab(iii)	LC	Saratovka	pm, w
Podiceps cristatus	Great Crested Grebe		LC	Saratovka, Novoseltsovo-1	r,w
Egretta garzetta	Little Egret		LC	Novoseltsovo-1	sb?, pm
Ardea cinerea	Grey Heron		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar, Clear Liman	s, pm, w
Ardea purpurea	Purple Heron		LC	Stepanavan	sb?, pm
Ciconia ciconia	White Stork		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Peatbog, Clear Liman, Long Liman	sb
Plegadis falcinellus	Glossy Ibis	VU D1	LC	Novoseltsovo-1	pm
Clanga pomarina	Lesser Spotted Eagle	VU D1	LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Peatbog, Urasar	pm
Milvus migrans	Black Kite		LC	Katnaghbyur*	pm
Circaetus gallicus	Short-toed Eagle	VU D1	LC	Stepanavan, Saratovka, Novoseltsovo-1,	pm

				Clear Liman, Peatbog	
Circus aeruginosus	Western Marsh Harrier		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	sb, pm, w
Circus macrourus	Pallid Harrier	EN B1ab(iii)+2ab (iii); D	NT	Stepanavan, Saratovka, Novoseltsovo-1, Urasar, Clear Liman, Horse Liman	pm
Circus pygargus	Montagu's Harrier	VU D1	LC	Saratovka	sb?, pm
Buteo buteo	Common Buzzard		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	pm
Buteo rufinus	Long-legged Buzzard		LC	Stepanavan, Saratovka, Novoseltsovo -1, Urasar, Peatbog	pm
Falco tinnunculus	Common Kestrel		LC	Novoseltsovo-1	r, pm, w?
Gallinula chloropus	Common Moorhen		LC	Stepanavan, Saratovka, Novoseltsovo-2, Urasar, Clear Liman	sb, pm, w
Fulica atra	Eurasian Coot		LC	Stepanavan, Saratovka, Novoseltsovo-1, Peatbog	sb, pm, w
Vanellus vanellus	Northern Lapwing		LC	Novoseltsovo-2, Long Liman	sb, pm
Philomachus pugnax	Ruff		LC	Saratovka	pm
Tringa glareola	Wood Sandpiper		LC	Novoseltsovo-1 (calls)	s, pm
Tringa ochropus	Green Sandpiper		LC	Novoseltsovo-1 (calls)	s, pm
Gallinago sp.				Novoseltsovo-2	
Larus armenicus	Armenian Gull	VU B1ab(iii)+2ab (iii)	NT	Stepanavan, Saratovka, Novoseltsovo-1, -2	s, pm
Sterna hirundo	Common Tern		LC	Novoseltsovo-2	sb? pm
Chlidonias hybrida	Whiskered Tern	VU D1	LC	Novoseltsovo-2	sb? pm
Columba livia	Rock Dove		LC	Stepanavan	r

Streptopelia decaocto	Eurasian Collared Dove		LC	Stepanavan town*	r
Apus apus	Common Swift		LC	Novoseltsovo-1	sb, pm
Upupa epops	Eurasian Hoopoe		LC	Stepanavan	sb, pm
Merops apiaster	European Bee-eater		LC	Stepanavan (calls), Saratovka, Novoseltsovo-2, -1 (calls), Urasar (calls)	sb, pm
Coracias garrulus	European Roller	VU B1ab(iii)	LC	Urasar	sb, pm
Alauda arvensis	Eurasian Skylark		LC	Novoseltsovo-1 (calls)	sb, pm, w?
Riparia riparia	Sand Martin		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	sb, pm
Hirundo rustica	Barn Swallow		LC	Omnipresent	sb, pm
Anthus trivialis	Tree Pipit		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar, Clear Liman	sb, pm
Anthus spinoletta	Water Pipit		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	pm, w
Motacilla flava	Yellow Wagtail		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	sb, pm
Motacilla citreola	Citrine Wagtail	VU D1	LC	Stepanavan	sb?, pm
Motacilla alba	White Wagtail		LC	Omnipresent	sb, pm, w
Phoenicurus phoenicurus	Common Redstart		LC	Stepanavan and Novoseltsovo towns*	pm
Saxicola rubetra	Whinchat		LC	Stepanavan, Saratovka	sb, pm
Saxicola rubicola	Common Stonechat		LC	Stepanavan	sb, pm
Oenanthe oenanthe	Northern Wheatear		LC	Stepanavan, Urasar	sb, pm
Acrocephalus schoenobaenus	Sedge Warbler		LC	Novoseltsovo-1	sb, pm
Phylloscopus	Mountain		LC	Stepanavan town*	pm

lorenzii	Chiffchaff				
Parus caeruleus	Blue Tit		LC	Stepanavan town*	r
Parus major	Great Tit		LC	Stepanavan town*	r
Sitta neumayer	Western Rock Nuthatch		LC	Dzoraget river gorges*	r
Lanius collurio	Red-backed Shrike		LC	Stepanavan, Saratovka, Novoseltsovo-1, -2, Urasar	sb, pm
Pica pica	Common Magpie		LC	Stepanavan, Novoseltsovo-2	r
Corvus monedula	Western Jackdaw		LC	Stepanavan	r
Corvus corone	Hooded Crow		LC	Novoseltsovo-1	R
Passer domesticus	House Sparrow		LC	Stepanavan town*	r
Fringilla coelebs	Common Chaffinch		LC	Stepanavan	pm
Carduelis chloris	European Greenfinch		LC	Stepanavan town*	sb, pm
Carduelis carduelis	European Goldfinch		LC	Stepanavan	sb, pm

Appendix 2. Results of the herpetological inventory at the Lori lakes

Latin name	**English name**	**Red Book of Armenia (2010) [1]**	**IUCN Red List (as of December 2021) [15]**	**Lakes / Sites**
Rana macrocnemis	Long-legged wood frog		LC	Clear Liman, Novoseltsovo-1
Pelophylax ridibundus	Marsh frog		LC	omnipresent
Hyla orientalis	European tree frog		LC	Long Lilman, Clear Liman, Peatbog, Stepanavan lakes
Lacerta agilis	Sand lizard		LC	Clear Liman, Horse Liman, Novoseltsovo-1
Darevskia dahli	Dahl's lizard	EN B1a+2a	NT	Clear Liman
Darevskia armeniaca	Armenian lizard		LC	Clear Liman, Horse Liman
Natrix tessellata	Dice snake		LC	Horse Liman
Natrix natrix	Grass snake		LC	Clear Liman, Horse Liman
Coronella austriaca	Smooth snake		LC	Clear Liman

Appendix 3. Results of the flora species inventory at the Lori lakes

TAXA (Scientific name)	Red book of Armenia status [33]	IUCN Red List status [15]	Long Liman	Horse Liman	Clear liman	Saratovka	Urasar	Katnaghbyur	Novoseltsovo -1	Novoseltsovo -2	Stepanavan-1	Stepanavan-2	Stepanavan-3
BRYOPHYTA Ricciaceae -													
Riccia sp.												+	
PTEROPHYTA Dryopteridaceae													
Dryopteris filix-mas (L.) Shott.								+					
Woodsiaceae													
Cystopteris fragilis (L.) Bernh.					+								
GYMNOSPERMAE Pinaceae													
Pinus sylvestris L.											+	+	
ANGIOSPERMAE Acoraceae													
Acorus calamus L.	**EN**					+			+	+		+	
Alismataceae													
Alisma plantago-aquatica L.			+		+				+			+	
Apiaceae													
Daucus carota L.							+						
Asclepiadaceae													
Vincetoxicum amplifolium K. Koch							+						
Asteraceae													
Achillea millefolium L.					+							+	
Artemisia absinthium L.												+	
Artemisia vulgaris L.											+	+	
Bidens tripartita L.			+	+						+	+		

Carduus nutans L.					+								
Centaurea salicifolia Bieb.									+				
Cichorium intybus L.												+	
Conyza canadensis (L.) Cronq. (ERE=Erigeron canadensis L.)					+								
Hieracium piloselloides Vill.										+			
Lactuca serriola L.												+	
Psephellus manakyanii (Gabr.) Gabr	**endemic**	**EN**			+								
Betulaceae													
Betula pubescens Ehrh.								+					
Brassicaceae													
Rorippa islandica (Oeder) Borbas			+										
Caprifoliaceae													
Lonicera caucasica Pall.								+					
Viburnum lantana L.								+					
Ceratophyllaceae													
Ceratophyllum demersum L.			+	+					+	+	+		
Crassulaceae													
Sedum album L.										+			
Sedum caucasicum (Grossh.) A. Bor.					+								
Sedum oppositifolium Sims.					+			+		+			
Cyperaceae													
Carex acuta L.					+								
Carex acutiformis Ehrh.					+								
Carex bohemica Schreb.	**EN**		+		+	+							
Eleocharis acicularis (L.) Roem. & Schult.									+				
Eleocharis palustris (L.) Roem. et Schult.											+	+	
Schoenoplectus tabernaemontani (C. C. Gmel.) Palla			+		+		+						
Dipsacaceae													

Scabiosa argentea L.					+								
Fabaceae													
Trifolium campestre Schreb.				+									
Trifolium pratense L. var geniculatum R. et F.				+									
Trifolium repens L.				+						+			
Hypericaceae													
Hypericum perforatum L.					+								
Iridaceae													
Iris sibirica L.	**VU**	**NT**							+				
Iris pumila L.			+										
Juncaceae													
Juncus articulatus L.				+		+							
Juncus bufonius L.									+				
Juncus effusus L.							+	+		+		+	
Juncus inflexus L.												+	
Lamiaceae													
Lycopus europaeus L.			+	+			+			+	+	+	
Mentha longifolia (L.) Huds.				+	+		+	+		+			
Nepeta mussinii Spreng.													+
Teucrium orientale L.					+								
Thymus rariflorus K. Koch					+			+		+		+	
Lemnaceae													
Lemna minor L.					+					+		+	
Lemna trisulca L.												+	
Lentibulariaceae													
Utricularia minor L.					+		+	+					
Utricularia vulgaris L.							+	+					
Utricularia intermedia Hayne	**EN**			+									
Lythraceae													
Lythrum salicaria L.			+	+			+			+		+	

Malvaceae													
Alcea rugosa Alef.												+	
Hibiscus trionum L.													+
Menyanthaceae													
Nymphoides peltatum (S. G. Gmel.) O. Kuntze						+					+		
Myriophyllaceae													
Myriophyllum spicatum L.						+		+		+	+		
Myriophyllum verticillatum L.						+							
Nymphaeaceae													
Nymphaea alba L.	**EN**		+	+	+		+		+	+	+	+	
Oleaceae													
Fraxinus excelsior L.							+						
Onagraceae													
Epilobium hirsutum L.			+	+			+			+			
Papaveraceae													
Papaver fugax Poir.												+	
Plantaginaceae													
Plantago major L.										+		+	
Poaceae													
Alopecurus aequalis Sobol.										+			
Catabrosa aquatica (L.) P. Beauv.										+		+	
Phalaroides arundinacea (L.) Rauschert							+						
Phleum pratense L.							+						
Phragmites australis (Cav.) Trin. ex Steud.			+		+					+			
Puccinellia sevangensis Grossh.							+						
Polygonaceae													
Polygonum aviculare L.				+			+			+			
Polygonum hydropiper L.			+	+			+				+	+	
Rumex crispus L.			+							+		+	

Potamogetonaceae													
Potamogeton alpinus Balb.						+		+					
Potamogeton crispus L.										+			
Potamogeton lucens L.					+						+		
Potamogeton natans L.			+		+	+		+		+	+	+	
Primulaceae													
Lysimachia verticillaris Spreng.							+						
Ranunculaceae													
Batrachium trichophyllum (Chaix) Bosch (ERE=Ranunculus divaricatus Schrank)						+							
Pulsatilla albana (Steven) Bercht. & J. Presl				+	+								
Ranunculus sceleratus L.				+		+	+			+			
Rhamnaceae													
Rhamnus cathartica L.								+					
Rosaceae													
Agrimonia eupatoria L.							+						
Aruncus vulgaris Raf.								+					
Cerasus avium (L.) Moench								+					
Filipendula ulmaria (L.) Maxim.								+					
Malus domestica Borkh.					+								+
Malus orientalis Uglitzk.						+							
Padus racemosa (Lam.) Gilib.								+					
Prunus divaricata Ldb.					+		+						
Pyrus caucasica Fed.					+		+	+					
Rosa spinosissima L.					+		+						
Rubus idaeus L.					+		+	+		+			
Sorbus aucuparia L.								+					
Salicaceae													
Populus alba L.													+
Populus balsamifera L.					+								

Populus nigra L.			+										
*Populus simonii Carr.													+
Salix armeno-rossica A.K.Skvortsov.				+									
Salix caprea L.			+		+		+	+					
Salix elbursensis Boiss.					+	+	+						
Salix excelsa S. G. Gmel.					+								
Salix pseudomedemii E. Wolf					+		+						
Salix triandra L.			+		+	+	+		+	+			
Scrophulariaceae													
Limosella aquatica L.									+				
Sparganiaceae													
Sparganium erectum L.											+	+	
Sparganium neglectum Beeby												+	
Thymelaeaceae													
Daphne mezereum L.								+					
Typhaceae													
Typha angustifolia L.			+					+					
Typha latifolia L.			+		+		+			+	+	+	
Typha laxmanii Lepech.			+				+		+				
Urticaceae													
Urtica dioica L.							+			+		+	
Violaceae													
Viola arvensis Murr.					+								

Appendix 4. Results of the ichthyologial inventory at the Lori lakes

Lake / Site	Species (latin name)	Species (English name)	Notes
Stepanavan-2	*Pseudorasbora parva*, *Carassius gibelio*	Stone moroko, Prussian carp	*Pseudorasbora parva* - 97,4 %, *Carassius gibelio* – 2,6 %. For *P.parva* males – 80 % of all captured
Novoseltsovo-2	*Pseudorasbora parva*, *Alburnus hohenackeri*, *Carassius gibelio*	Stone moroko, North Caucasian bleak, Prussian carp	*Pseudorasbora parva* - 93 %, *Alburnus hohenackeri* -6.7 % of fish population. One specimen of *Pontastacus leptodactylus* was found
Novoseltsovo-1	*Carassius gibelio*, *Gobio caucasicus*, *Alburnus hohenackeri*, *Pseudorasbora parva*	Prussian carp, Gudgeon, North Caucasian bleak, Stone moroko	Abundance of *Alburnus hohenackeri* amounts 96% of fish population
Katnaghbyur	*Carassius gibelio*	Prussian carp	Monoculture
Urasar	*Pseudorasbora parva*, *Carassius gibelio*	Stone moroko, Prussian carp	*Pseudorasbora parva* - 99% of fish population
Clear Liman	*Pseudorasbora parva*, *Alburnus hohenackeri*, *Carassius gibelio*	Stone moroko, North Caucasian bleak, Prussian carp	*Pseudorasbora parva* - 60%, *Alburnus hohenackeri* – 40% of fish population. *Ligula intestinalis* metacercariae were found in 5% of both fish species. *Carassius gibelio* is known to inhabit the lake from oral report of locals, and has more dark color
Horse Liman	*Carassius gibelio*, *Pseudorasbora parva*	Prussian carp, Stone moroko	Carp and grass carp are reported by local fishermen to have been introduced into the lake in the past
Long Liman	*Carassius gibelio*, *Pseudorasbora parva*	Prussian carp, Stone moroko	Many fish were found dead because of water level decrease
Peatbog	*Carassius gibelio*	Prussian carp	No special ichthyological study was performed. *Pseudorasbora parva* is likely to be found

Appendix 5. Results of the algological survey in lakes Clear Liman, Long Liman and Horse Liman

N	Taxon	Horse Liman	Long Liman	Clear Liman	Abundance, cells/l	Biomass, g/m^3
	Cyanophyta				20000 - 444000	0.04 – 1.45
1	*Aphanizomenonflos-aquae*		+			
2	*Aphanothececlathrata*	+	+	+		
3	*Chroococcusturgidus*	+				
4	*Coelosphaeriumkuetzingianum*		+	+		
5	*Microcystisaeruginosa*	+				
6	*M. wessenbergii*	+				
7	*Merismopediaelegans*	+				
8	*Phormidiumfoveolarum*	+	+			
9	*P. retzii*		+			
10	*Spirulinaabbreviata*	+				
11	*Oscillatorialacustris*			+		
12	*O. teniius*		+			
	Bacillariophyta				16000 - 88000	0.071 – 0.370
1	*Cyclotellacomta*	+	+			
2	*Naviculapupula*	+				
3	*N.cryptocephala*		+			
4	*N.radiosa*		+			
5	*Nitzschialinearis*		+			
6	*N.palea*		+			
7	*Eunotiaargus*	+				
8	*Synedraacus*	+				
9	*Melosiragranulata*	+				
10	*Surirellaovata*		+			
11	*Cymbella lanceolata*		+			
12	*C. ventricosa*		+			
13	*Stephanodiscusastrae*	+				
14	*Diatomahiemale*	+				
15	*D. vulgare*	+				
	Chlorophyta				772000 - 820000	3.367 – 6.00
1	*A.contorta*	+				
2	*Ankistrodesmusangustus*		+			
3	*Ankistrodesmusspiriliformis*			+		
4	*Botryococcusbraunii*	+	+			
5	*Chlorococcummultinucleatum*	+				
6	*Closteriumacutum*	+				
7	*Cosmariumreniforme*	+				
8	*Dictyosphaeriumpulchellum*		+			
9	*Elakototrix sp.*	+				
10	*Kirchneriellacontorta*	+	+			
11	*Oocystislacustris*	+				

12	*Scenedesmusacutus*	+				
13	*S.obliquus*	+	+			
14	*S.obtutus*	+				
15	*S .quadricauda*	+	+	+		
16	*Sphaerocystissphroeterii*	+				
17	*Staurastrumcuspidatum*		+			
	Euglenophyta				8000 - 132000	0.104 – 2.012
1	*E. pisciliformis*	+	+			
2	*Euglenaacus*	+				
3	*Phacusoscillans*	+				
4	*T. volvocina*	+				
5	*Trachelomonasoblonga*	+	+	+		
Saprobity		1.65	1.72	2.00		
Shannon diversity index		2.90	2.06	1.26		

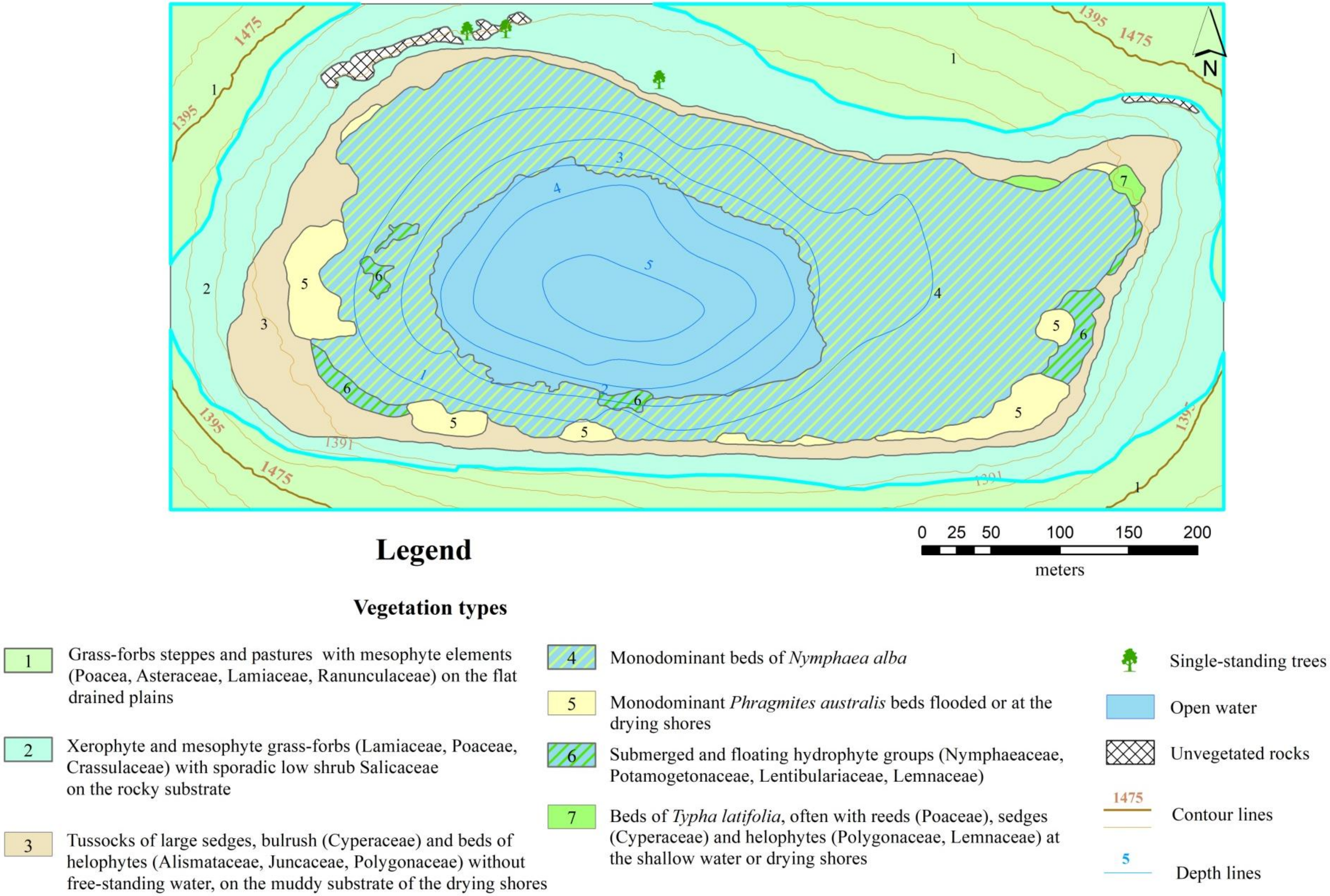
Appendix 6. Values of chemical elements concentration in water and sediments of lakes Clear Liman, Long Liman and Horse Liman

Bold are values exceeding maximum acceptable concentrations (MAC) [23, 24] or clark concentration values [11, 17]

Parameters	**Measured value**			
	Clear Liman (mg/l)	**Long Liman (mg/l)**	**Horse Liman (water) (mg/l)**	**Horse Liman (sediments) (g/kg)**
Lithium	0,00105	0,00128	0,000951	0,0101
Boron	0,0343	0,0610	0,0585	0,0165
Sodium	1,92	2,51	6,42	2,50
Magnesium	5,24	8,54	12,56	2,09
Aluminium	<0.01	0,0168	<0.01	Not measured
Total Phosphorus	0,0416	0,162	0,0507	0,782
Potassium	0,387	1,76	**16,61**	2,67
Calcium	18,14	23,85	28,27	4,95
Titan	0,000509	0,00312	0,000788	1,840
Vanadium	<0.0001	0,001	<0.0001	0,0486
Chromium	0,00449	0,00522	0,00549	0,0396
Iron	**0,803**	**5,87**	0,811	12,66
Manganese	**0,159**	**0,990**	**0,0910**	0,239
Cobalt	0,000132	0,00177	0,000120	0,0124
Nickel	0,000549	0,00152	0,000738	0,0358
Copper	<0.0001	0,000305	0,000119	0,0282

Zinc	0,00107	0,00104	0,000555	0,0728
Arsenic	0,000953	0,00479	0,000783	0,00660
Selenium	0,00374	0,00191	0,00222	0,00180
Strontium	0,0543	0,0865	0,135	0,0439
Molybdenum	<0.0001	0,00015	<0.0001	0,000796
Cadmium	<0.0001	<0.0001	<0.0001	0,000405
Tin	<0.0001	<0.0001	<0.0001	<0,0001
Antimony	<0.0001	<0.0001	<0.0001	0,000549
Barium	0,00979	0,0265	0,0292	0,103
Lead	<0.0001	0,000346	<0.0001	0,0295

Appendix 7. Map of vegetation types of lake Clear Liman basin



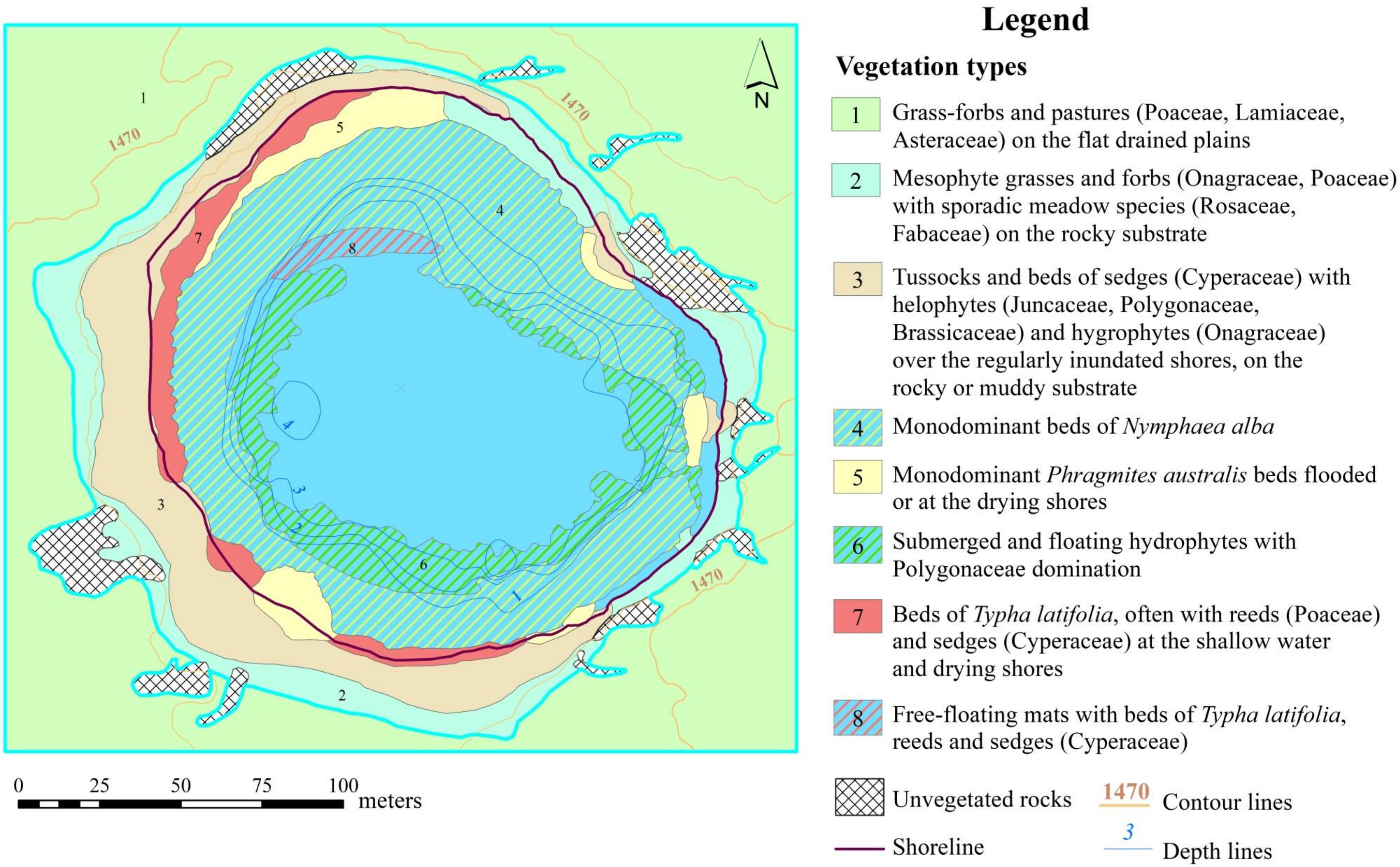
Appendix 8. *Lacerta agilis* color and pattern variations (morphs) recorded at lake Clear Liman

Photo by Dmitrii Sadokov, Ilona Stepamyan, Samvel Pipoyan, Knarik Hambardzumyan and identification by Ilona Stepanyan

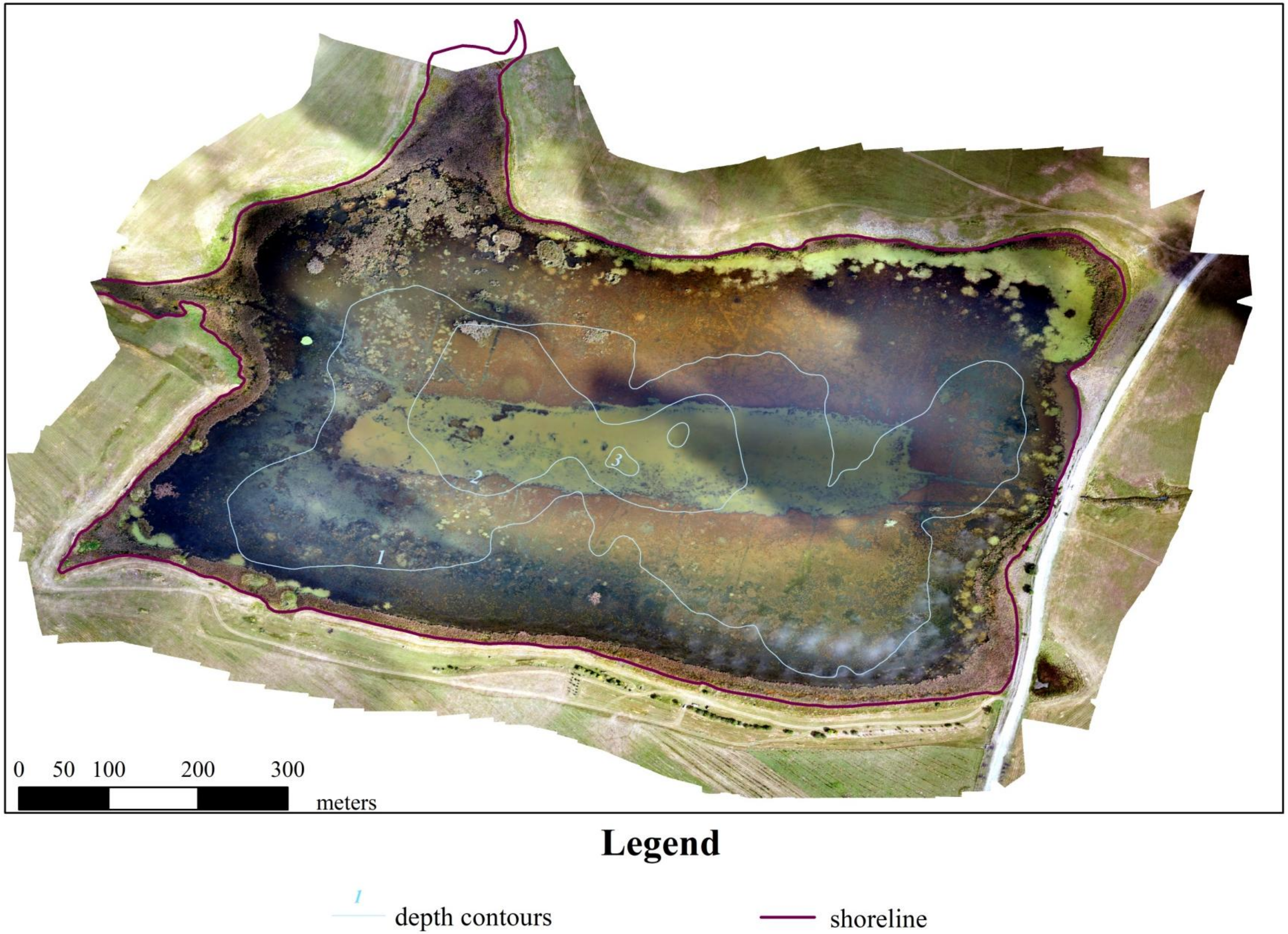




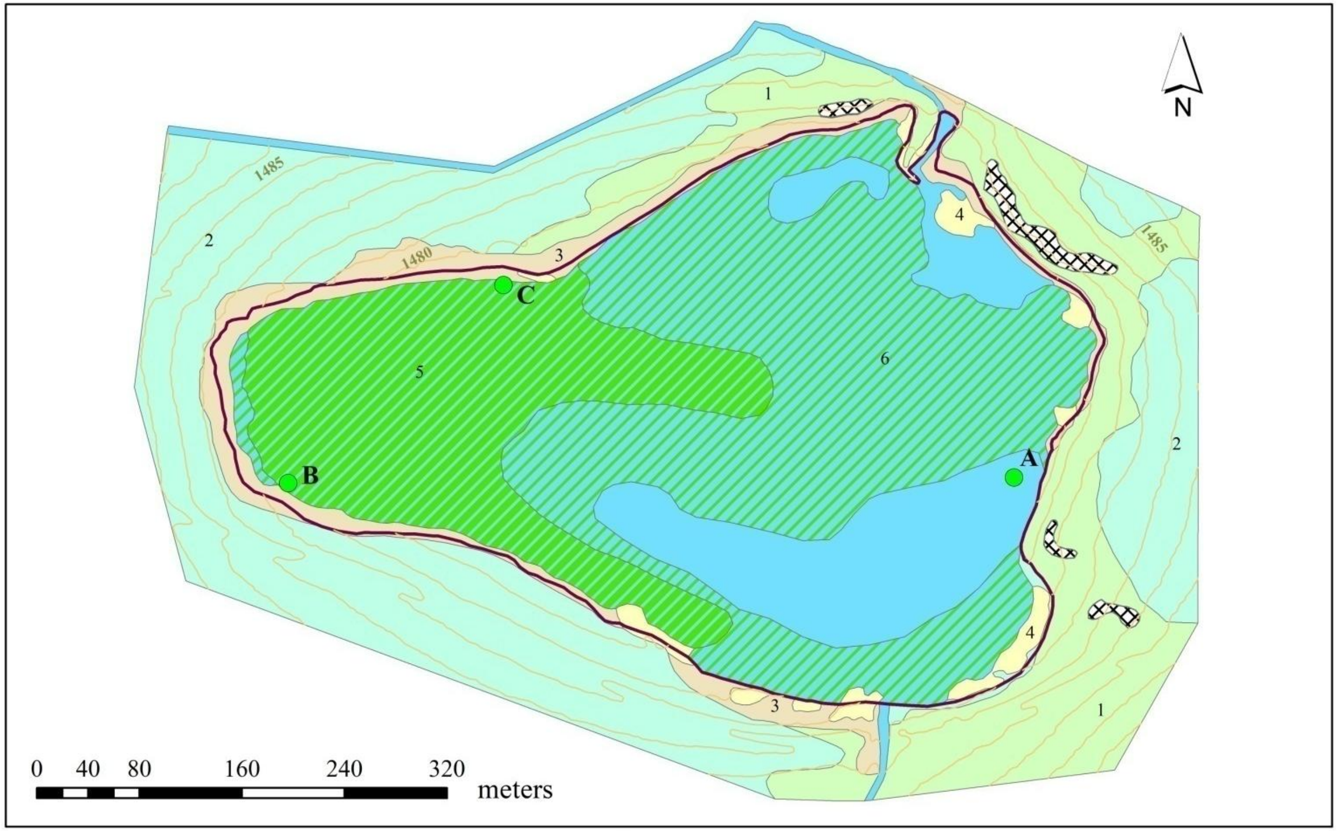

Appendix 9. Map of vegetation types of lake Horse Liman basin



Appendix 10. Drone footage of lake Peatbog basin with bathymetry contours



Appendix 11. Schematic map of habitats of lake Novoseltsovo-1 basin



Legend

Types of habitats

1 Dry grass-forbs steppes and overgrazed pastures commonly on the rocky substrate

2 Grass mesotrophic pastures, sometimes with single-standing trees or scrub

3 Water-fringing medium-tall grass beds, tussocks of sedges and pioneer vegetation on the periodically inundated shores

4 Water-fringing and amphibious tall beds of common reed and reedmace

5 Dense carpets and beds of floating and rooted hydrophyte vegetation

6 Water with sparse mats of floating and submerged vegetation

Open water

Unvegetated rocks

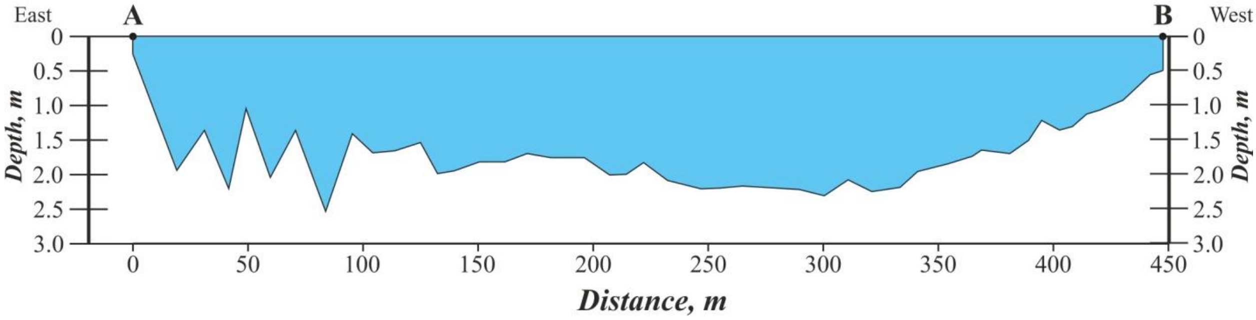
Shoreline

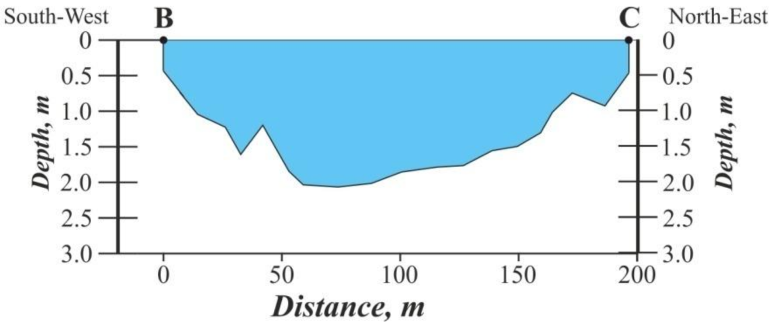
1480 Contour lines

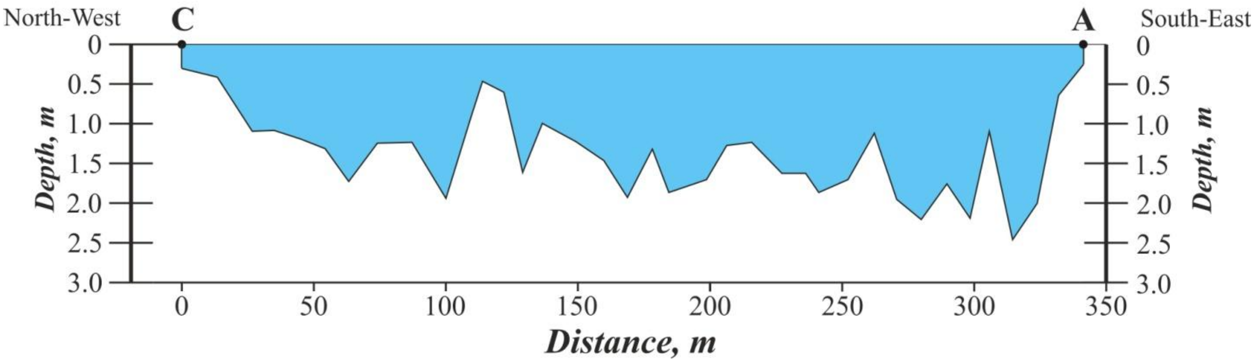
A Bathymetry profiles end/start points

Appendix 12. Profiles of bathymetry measurements on lake Novoseltsovo-1

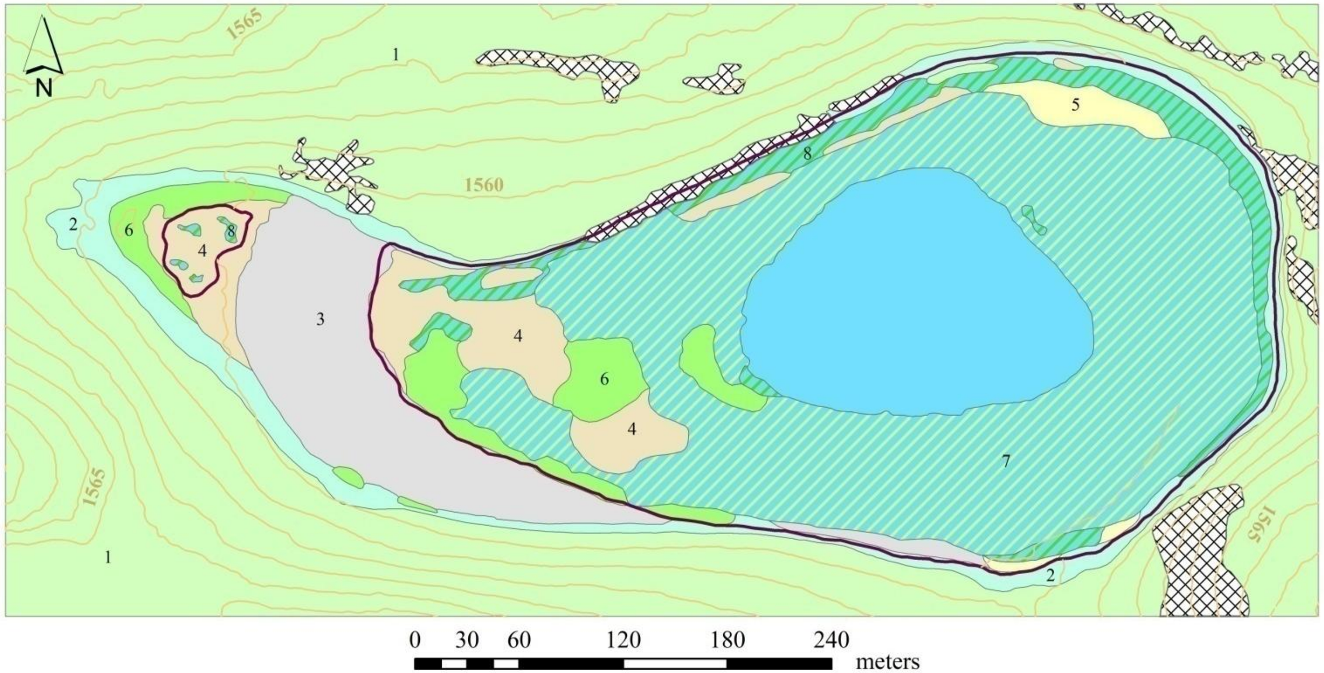
See points positions on the map in Appendix 11. Performed 18.09.2020







Appendix 13. Map of vegetation types of lake Urasar basin



Legend

Vegetation types

1 – Dry grass-forbs and overgrazed pastures (Poaceae, Lamiaceae, Asteraceae) on the undulating drained plains

2 – Tussocks of riparian hygrophyte sedges and spike sedges (Cyperaceae), mesophyte grasses and forbs (Lamiaceae, Primulaceae, Onagraceae) with sporadic Rosaceae scrub, at the base of the basin slope and on the moderately moist substrate by the shore line

3 – Heterogeneous grasslands with hygrophyte forbs (Cyperaceae, Onagraceae, Juncaceae, Polygonaceae) and sedges on the moist and muddy ground

4 – Beds of sedges (*Carex acutiformis*) and *Typha latifolia*, often floating or fragmented

5 – Beds of *Phragmites australis*, often with sedges (Cyperaceae), at the shallow water

6 – Floating mats of *Typha latifolia* with sedges, helophytes (Onagraceae, Polygonaceae, Cyperaceae, Poaceae) and sporadic Salicaceae bushes

7 – Monodominant beds of *Nymphaea alba*

8 – Submerged and floating hydrophyte mats (Nyphaeaceae, Lentibularicaceae, Potamogetonaceae)

Unvegetated rocks

Open water

1480 – Contour lines

Shoreline

Appendix 14. Scheme of the suggested zonation of the Lori lakes site considering its conservation value