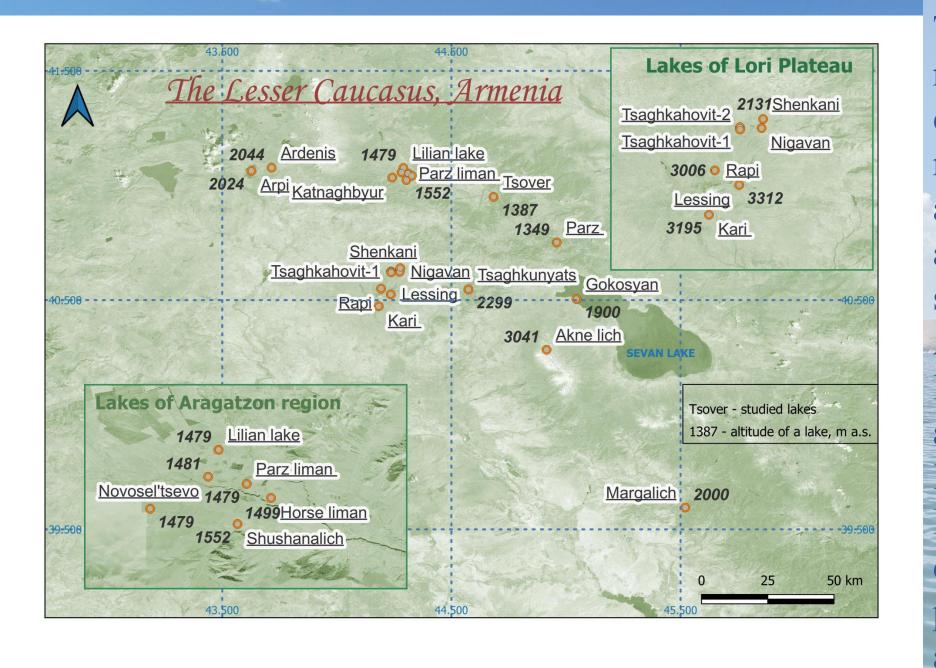
# Անցյալ և ներկա ժամանակաշրջանների շրջակա միջավայրի և կլիմայական փոփոխությունների ազդեցությունը Յայկական լեռնաշխարհի լճերի Էկոհամակարգերը

երկու տարվա հետազոտություն

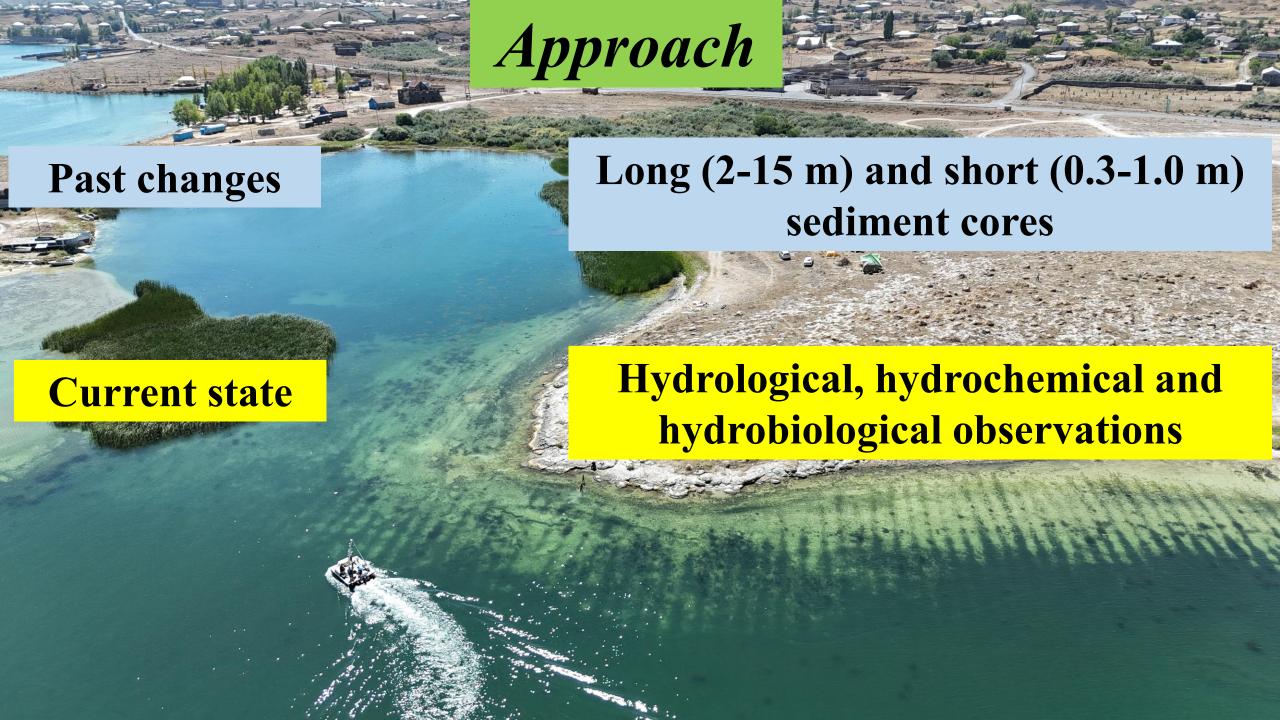
23IRF-1E02

Ֆեդորով Գ., Ֆեդորովա Ի., Գաբրիելյան Ի., Յայրապետյան Ն., Խումարյան Լ., Ալեքսանյան Ա., Գաբրիելյան Դ., Արաջյան Մ.

Ա.L. Թախտաջյանի անվան բուսաբանության ինստիտուտ



The goal of the research project is to evaluate the impact of recent climate change and other anthropogenic stressors on Armenian Highland lake ecosystems with a special focus on the largest Caucasus Lake Sevan by using data from present and past conditions to assess changes in ecosystem functions.



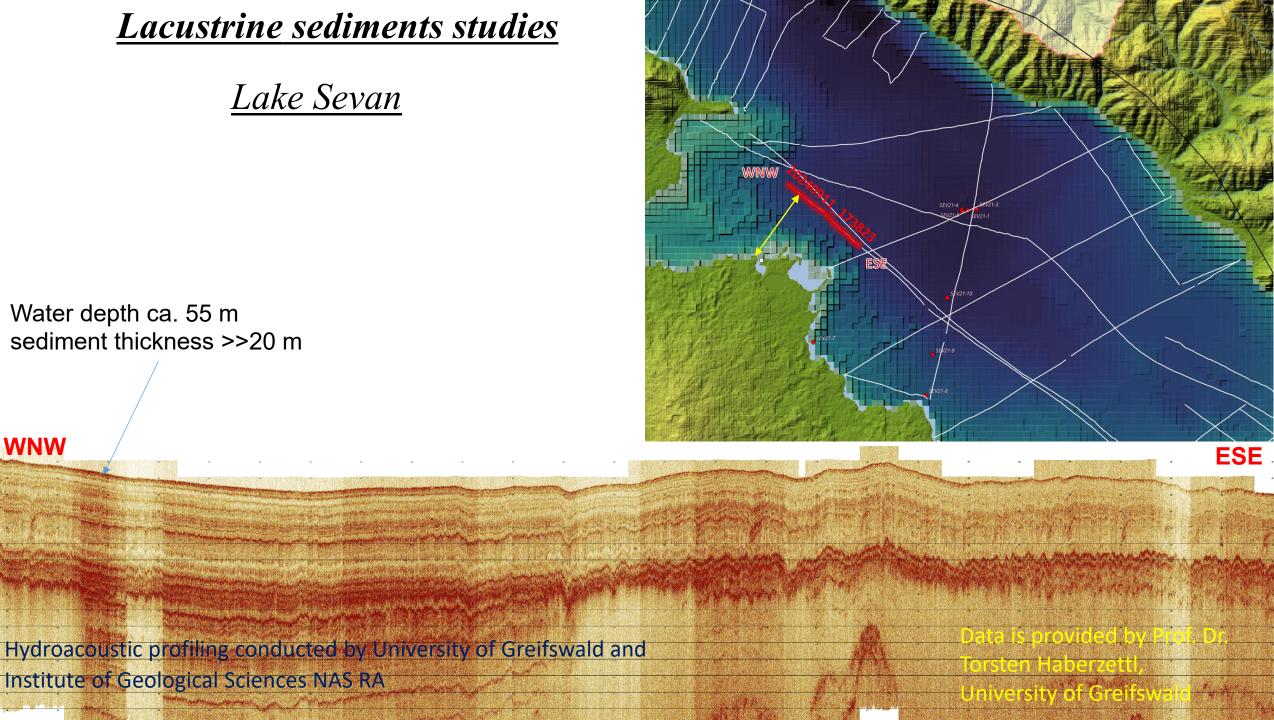
## Lacustrine sediments studies

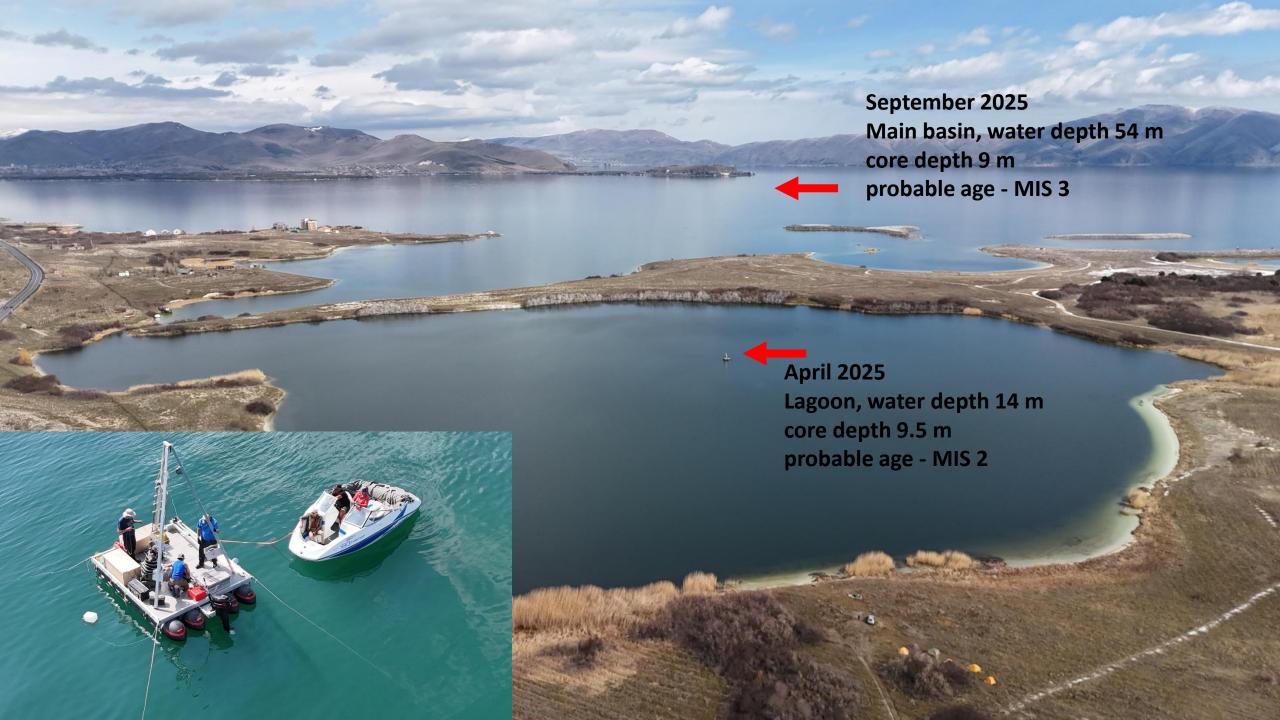
Lake Sevan

Water depth ca. 55 m sediment thickness >>20 m

Institute of Geological Sciences NAS RA

**WNW** 

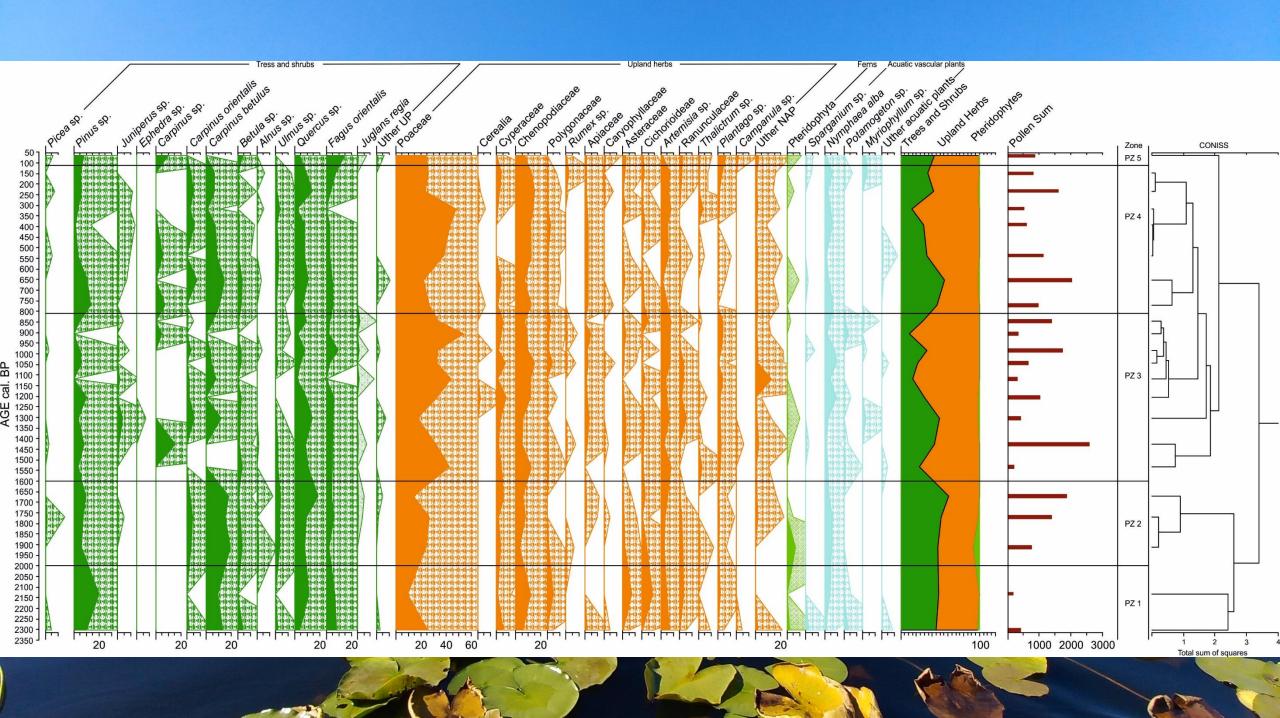


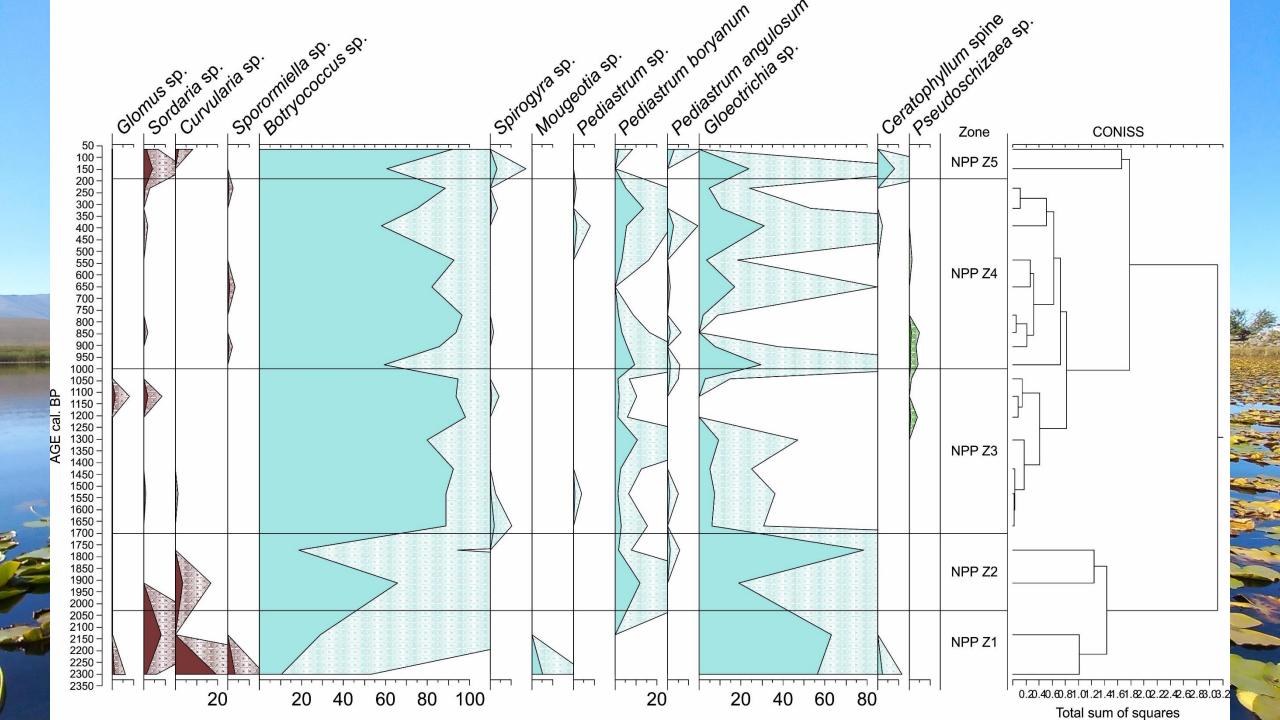


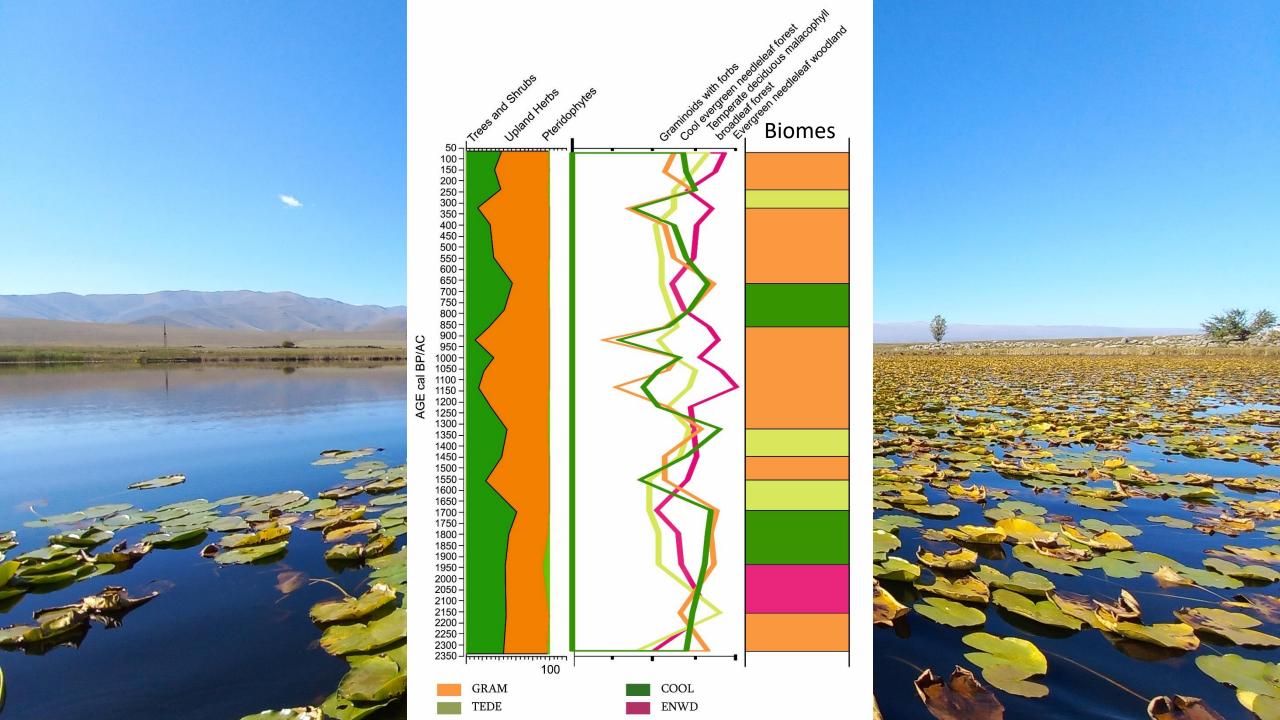


# Small lakes





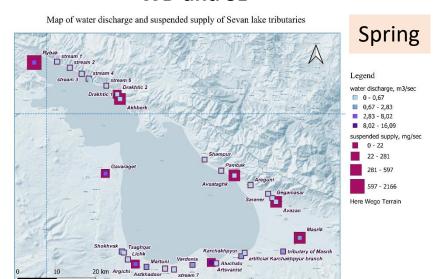






## Water discharges and suspended loads of Sevan inflow streams in different seasons

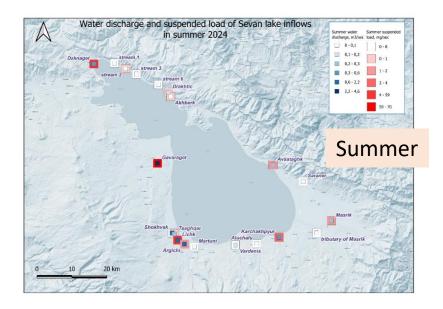
#### WD and SL



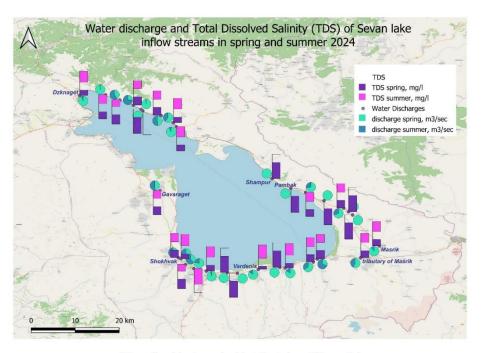
Hydrological parameters demonstrate high variability during the year.

During the flooding water discharges ranged from 0.7 l/sec to 16.1 m3/sec with the biggest value in an artificial channel Arpi-Sevan (Artsvanist). Natural largest tributaries are Argichi, Dzknaget, Gavaraget, and Masrik rivers with water discharges 8 m3/sec, 6.3 m3/sec, 4.5 m3/sec, 2.8 m3/sec correspondingly. During the rest of the year, except for flooding Gavaraget and Argichi rivers has significant flow as well.

The average turbidity values detected in inflows during spring, summer and winter were 224.2 mg/l, 20.7 mg/l, and 2.8 mg/l respectively that shows decrease of suspended load concentration during the year in hundred times.



period	Water	Suspended	Ionic load.	Riverbed	Solid and
	runoff.	supply. ton	ton and %	load. ton and	dissolved
	Mm <sup>3</sup> and %	and % per a	per a season	% per a	load. ton and
		season		season	% per a year
	per a year				
Flood period (III-V)	393 (52%)	40.7 (52%)	24.5 (31.3%)	13 (16.7%)	78.2 (94.7%)
Summer-Autumn (VI-	219 (29%)	3.1 (83%)	0.03 (0.7%)	0.6 (16.7%)	3.7 (4.6%)
XI)					
Winter low period	148 (19%)	0.5 (81%)	0.01 (2 %)	0.1 (16.7%)	0.6 (0.7%)
(XII-II)					
III.2024-II.2025	759 (100%)	44.3	24.54	13.7	82.5 (100%)
(year)					

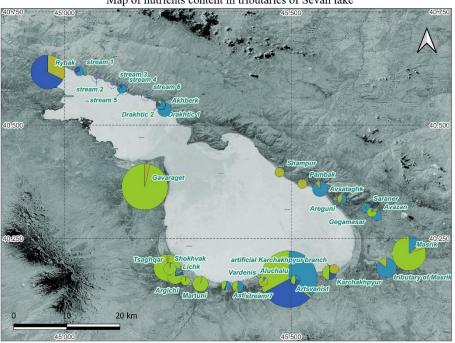




Legend

NO2, mg/l

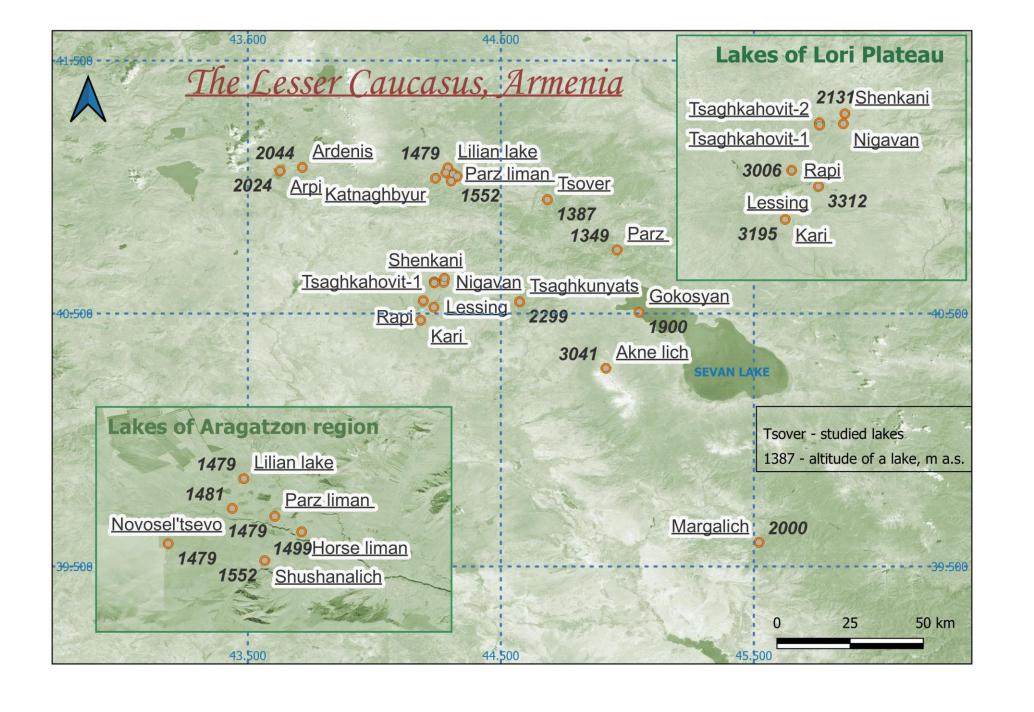
Si, mg/l



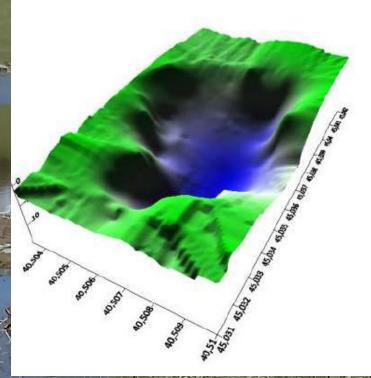
#### TDS and Nutrients during the hydrological year

- Throughout the year, mineralization in rivers is relatively low: TDS values are 0÷254 mg/l or 16÷492 μS/cm corresponds to low or medium water salinity. Ionic discharge is up to 917 mg/sec. The highest TDS values are typical for the eastern slope of Sevan Lake depression (Araguniyskiy and Sevanskiy ridge).
- Amplitude of ionic discharges in winter was 0.01-0.37 mg/sec. The highest values were detected in the rivers Gavaraget, Argichi, and Shokhvak in descending order. In summer-autumn period the main sources of ionic runoff were mostly due to groundwater income.
- Considerable differences between sources of nutrients for mountain ridges around Sevan Lake are noticed. Thus, Gegamskiy and Vardeniskiy ridges, including Artsvanist artificial channel provide huge volume of silicates (Si) in contrast to phosphates (PO<sub>4</sub>) and nitrites (NO<sub>2</sub>) from Pambaksiy, Areguniyskiy, and Sevanskiy ridges.
- Phosphates (PO<sub>4</sub>) have higher concentration during the flood period while the NO<sub>2</sub>+NO<sub>3</sub> volume increased during low water period. Silicates have quite similar distribution during a year.
- High concentration of ammonium (NH<sub>4</sub>) is marked in Dzknaget river in spring that flows into the Lake from the north. Significant volume of ammonium comes from Artsvanist (artificial Arpi-Sevan channel) and Karchaghbyur channel that transfer water from the Arpi and Vardenis rivers.
- It should be noted that there is intensive agriculture along the shore of Lake Sevan that is important source of nutrients.

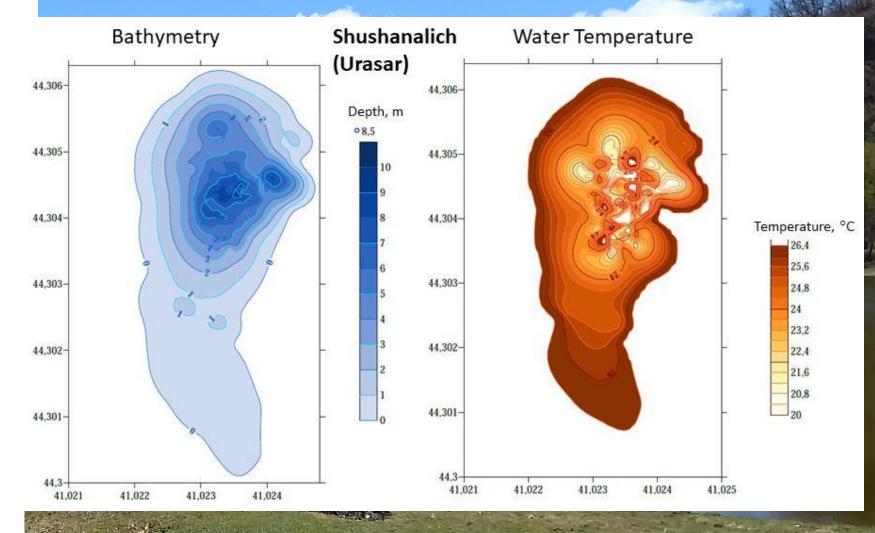




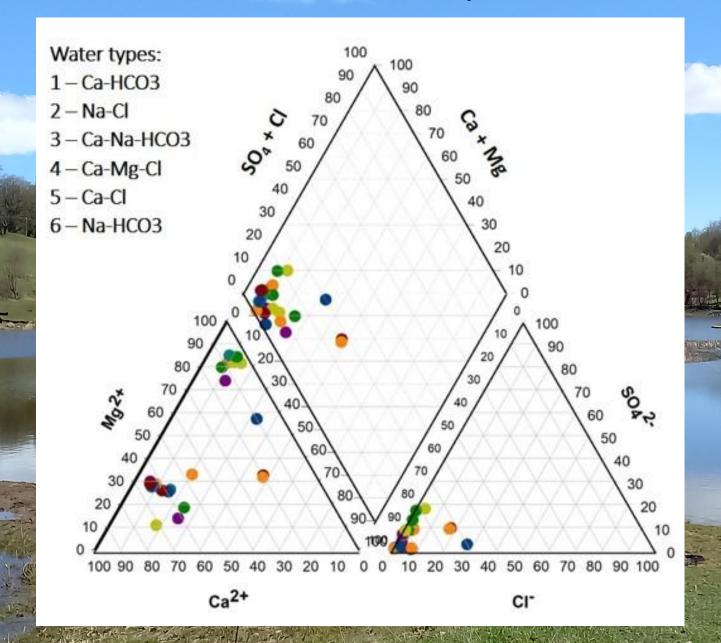
#### 40,512 40,511 40,509 40,508 40,506 40,506 40,506 40,506 40,506 40,506 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508 40,508



## Morphometric and hydro physical parameters



# Ion composition of lakes



- Calcium-bicarbonate and Magnesium-bicarbonate types of water composition.
- Magnesium cation is prevailed in high mountain lakes Kari and Rapi as well as in Tsover, Parz, Arpi, and Ardenis lakes.
- Lori Plateau lakes (Horse liman, Parz liman, Shushanalich) and Margalich, Akna lich, and Lessing Lake have calcium type of cations.
- For Gokosyan lagoon of Sevan
   Lake, that has a closed shape and
   slow water cycling, has non dominant cations type but there
   is a tendency for sodium
   concentration increasing.
- Weak acids (CO3+HCO3) exceed strong acids (SO4+CI) for all lakes.

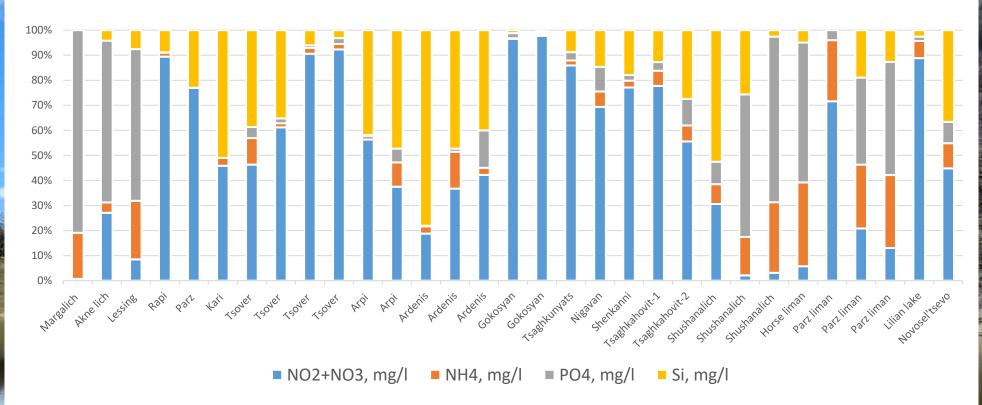
# Hydrochemical and physical parameters

	Statistical characteristics	water tempe rature, °C	condu ctivity, μS/cm	redox- potential Eh, mV	TDS, mg/l	рН	O2, mg/l	CO2 on surface	CDOM, αΟΡΟΒ (440), nm-1	BOC5 (biological oxygen consumption in 5 days), mg/l
	min	0,7	0	-219,2	0	6,3	3,8	0	0,15	1,6
	max	30,2	782	264,4	320	10,0	12,5	52,8	18,1	9,1
	average	17	184	151	70	8	8	9	2	6
3/10	σ (av. Sq. dev.)	3,8	6,8	180,5	100,8	73,4	0,9		4,2	
	Cv	0,9	0,4	1,0	0,7	1,1	0,1		1,8	
	Cs	1,4	-0,6	1,9	-2,2	1,9	0,6		3,9	
	Cv/Cs	0,7	-0,7	0,5	-0,3	0,5	0,2		0,5	

Conductivity range was 0-782  $\mu S$  cm-1, TDS - 0-320 mg l-1, pH - 6.3-10.0 for surfaces of the lakes. The redox potential of the lakes had mostly positive values, but negative Eh were observed in bottom layers for the Shushanalich in August 2023 and Tsover lakes in April 2025, which indicates the redox conditions of lake at the present time and generally marks its waterlogging.

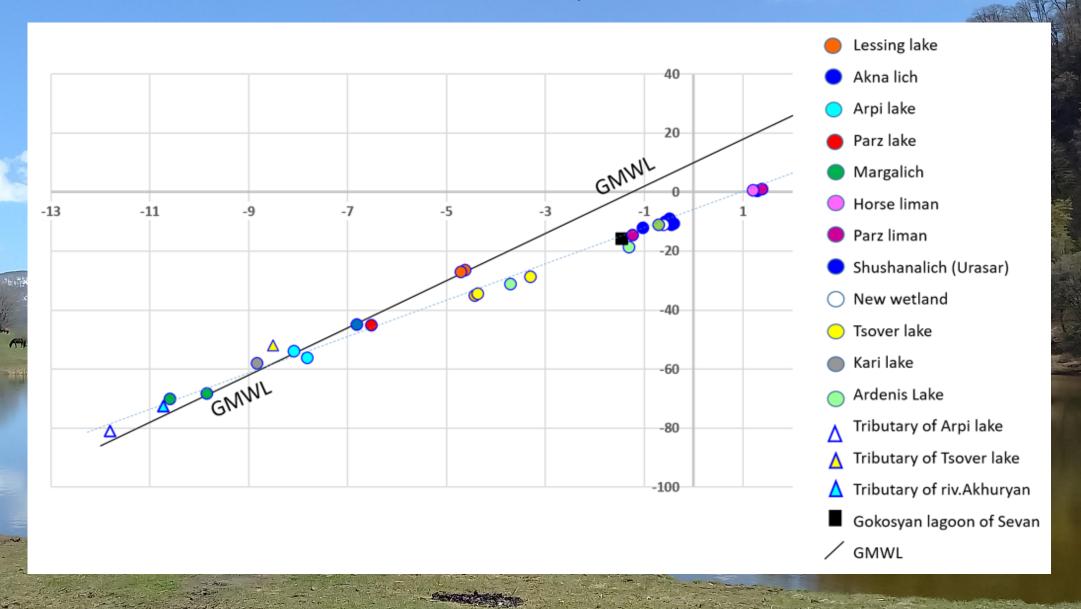




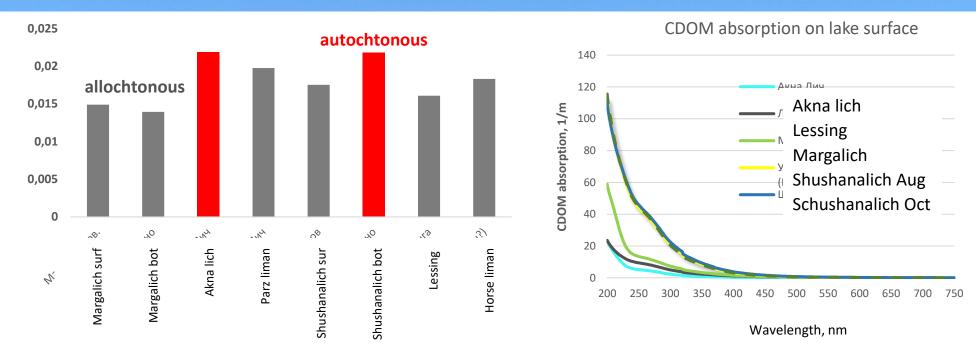


- Nutrients of studied lake had following concentrations: silicates Si (0.02-59.2 mg l<sup>-1</sup>), phosphates PO<sub>4</sub> (0.04-5.6 mg l<sup>-1</sup>), nitrites NO<sub>2</sub> (up to 22.8 mg l<sup>-1</sup>), nitrates NO<sub>3</sub> (up to 28.2 mg l<sup>-1</sup>), and ammonium NH<sub>4</sub> (0.02-1.6 mg l<sup>-1</sup>).
- The highest nutrients concentration observed in Margalich in summer 2023 and Arpi-Ardenis in 2024-2025, the most oligotrophic lake upland Akna lich and Rapi lake.
- NO<sub>2</sub>+NO<sub>3</sub> prevails in most part of the samples. Only in Shushanalich and Parz liman of Lori region PO<sub>4</sub> were significant.
- Silicates Si is important in Kari, Arpi, and Ardenis mountain lakes.

# Water isotope composition of lakes

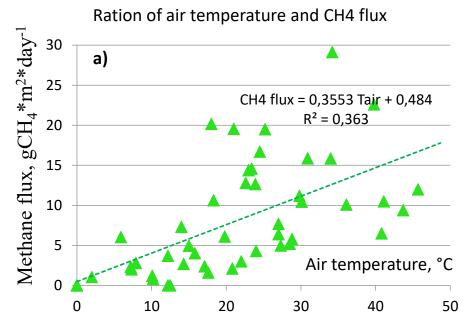


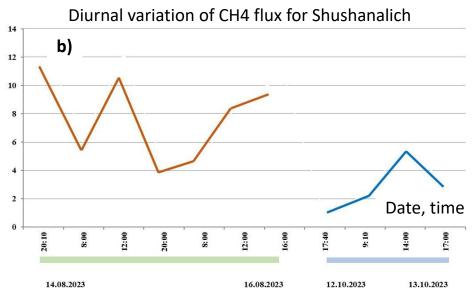
## CDOM in lakes



- CDOM and absorption illustrate an origin of organic matter, their age and ability of lakes to eutrophication.
- The largest number of CDOM at a wavelength of 440 nm, therefore, the largest number of DOC, was found in the Tsover lake (18.09 nm<sup>-1</sup>), and the lowest in oligotrophic and the least overgrowth Akna lich (0.15 nm<sup>-1</sup>). The DOC amount in these lakes varies significantly, by 12 times.
- According to the spectral slope *S* value, autochthonous origin of CDOM predominates in lakes Akna lich, Horse liman, Tsover and Shushanalich (in Autumn), Gokosyan lagoon rather allochthonous in Margalich, Lessing lake, Parz liman, Adenis, Arpi, and Shushanalich (in Summer).
- The angle of inclination S indicates also about predominate fulvic acids in the first group of lakes and humic acids in the second, on the contrary.
- No one lake has the specific process of photodegradation.

## Diffusion CH<sub>4</sub> emission from the lakes surface

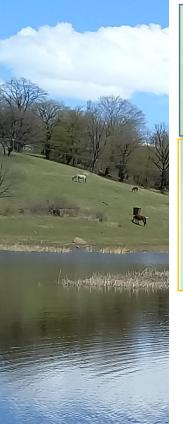


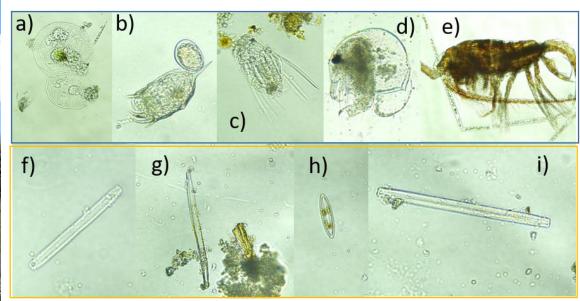


- The average diffusion **methane flux** for all studied small lakes was 10.5 gCH<sub>4</sub>\*m<sup>2</sup>\*day<sup>-1</sup> the highest volume that had been noticed before for the Caucasus region.
- The average values of CH4 flux were 29.1 gCH4\*m-2\*day-1 for the Shenkani lake on August 2025; 6.1 gCH4\*m-2\*day-1 for Akna lich on August 2023; 2.1-6.5 gCH4\*m-2\*day-1 for Parz liman on October 2023. For Shushanalich in August, the average flux at different hours per a day was 4.3-12.8 gCH<sub>4</sub>\*m<sup>-2</sup>\*day<sup>-1</sup>, in October it's ranged from 0.8 to 5.8 gCH<sub>4</sub>\*m<sup>-2</sup>\*day<sup>-1</sup>, i.e. decreased by more than 2 times.
- During the day CH<sub>4</sub> flux has a sinusoidal function (b). In Autumn the function attenuated.
- The most significant CH4 flux reached 81.3 gCH4 m-2 d-1 on 20 Aug 2025 at 16:00 on Shenkani lake surface.



# Lake ecosystems





#### (a-e) **Zooplankton**:

- (a) Rotifera Asplanchna sp.,
- (b) Rotifera Keratella cochlearis,
- (c) Rotifera *Polyarthra sp.,*
- (d) Daphnia Alonella excisa,
- (e) Calanoida Calanus sp.;

#### (f-i) Diatoms:

- (f) Nitzschia linearis,
- (g) Hantzschia amphioxys,
- (h) Achnanthes minutissima,
- (i) Synedra acus.

Ecosystems of studied lakes depends on altitudes and environment conditions of a lake catchment. Pelagic zooplankton of Shushanalich (1552 m a.s.) presented by Rotifera, Cladocera and Cyclopoida mostly, rather Lessing lake (3312 m a.s.) had only Copepoda (Calanus sp.). Rotifera largely contributed to the zooplankton abundance of Lori province lakes. Zooplankton of Lessing lake was poor, only *Calanus* sp. of Calanoida were found.

Research shows that among the modern diatoms of Shushanalich lake of Lori province, representatives of the genera *Navicula, Nitzschia, Cyclotella, Pinnularia, Gomphonema and Tabellaria* are the most common, bulk of which live in the sediments.

## Tsaghkahovit-2 lake

# Lacustrine ecosystems

**Aragatz mountain** 

Two nearest lakes (Tsaghkahovit 1 and 2, for example) can have different abundance of phyto- and zooplankton. There is Copepoda *Hemidiaptomus tarnogradskii* (Rylov, 1926) – relict of Tertiary period.

# Zooplankton: 9 species of Rotifera, 0 speceis of Cladocera, 3 species of Copepoda

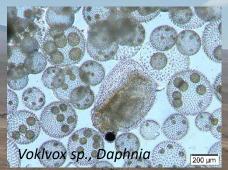
Filinia longisetta

Phytoplankton: a lot of small green algae, and there are diatomes





## Tsaghkahovit-1 lake



Zooplankton:
0 species of Rotifera,
3 species of Cladocera,
4 species of Copepoda

Phytoplankton: a lot of Volvox sp. (green algae) and there are Botryococcus brauna (Grape green algae)





During the year, members of our group took part in 6 conferences, where 8 reports on the results of the project were presented.

The largest conferences were the International Mountain Conference 2025 in September 2025 in Innsbruck (Austria) and the XXVth International Multidisciplinary Scientific GeoConference Surveying, Geology and Mining, Ecology and Management – SGEM 2015 in June-July 2025 in Albena (Bulgaria).



## **Publications**

During the reporting period, we published 5 articles in journals indexed in Scopus and Scimago Journal & Country Ranking.

Additionally, another article based on the SGEM conference proceedings (indexed in Scopus and Scimago Journal & Country Ranking) has been accepted for publication. Work is currently underway on two more articles for publication in international journals.

- 1. Grigory Fedorov; Dmitry Sadokov; Vsevolod Rudakov; Irina Fedorova; Larisa Ghazaryan // HOLOCENE LACUSTRINE SEDIMENTATION PATTERNS ON LORI PLATEAU (SOUTH CAUCASUS) / International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2024, 24, 91-97, Scopus, 10.5593/sgem2024/1.1/s01.13, 1314-2704.
- 2. Irina Fedorova; Larisa Ghazaryan; Vsevolod Rudakov; Elizaveta Chezhina; Grigorii Fedorov // HYDROECOLOGICAL STATE OF THE SMALL UPLAND ARMENIAN LAKES / International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2024, 24, 103-110, Scopus, 10.5593/sgem2024/3.1/s12.13, 1314-2704.
- 3. , Irina Fedorova, Ivan Gabrielyan, , Elizaveta Chezhina, , Grigory Fedorov, // Preliminary assessment of methane emissions from small Armenian lakes / Sustainable Development of Mountain Territories, 2024, 16 (3), 1302-1312, Scopus, 10.21177/1998-4502-2024-16-3-1302-1312, 19984502, 2499975X.
- 4. Galina Zdorovennova, Tatiana Efremova, Iuliia Novikova, exana Erina, Dmitry Sokolov, Dmitry Denisov, Irina Fedorova, Sergei Smirnov, Nikolay Palshin, Sergey Bogdanov // Contrasting Changes in Lake Ice Thickness and Quality Due to Global Warming in the Arctic, Temperate, and Arid Zones and Highlands of Eurasia / Water, 2025, 17 (3), 365, WOS-UQ (IF) 10.3390/w17030365, 2073-4441, 2073-4441.
- 5. Fedorov, G., Savelieva, L., Bobrov, N., Ludikova, A., Kostromina, N., Cherezova, A., Petrov, A., Bazhenova, E., Andreev, A., 2025. Late glacial and Holocene climate and landscape dynamics in the Valdai Highlands (East European Plain) inferred from lake sediment records. Quaternary Research, 1–17. https://doi.org/10.1017/qua.2025.10020

## Attracting international funding

## Grant received

Title: "Armenian (South Caucasus) small alpine lakes Geoportal"

Program: GEO Mountains Small Grants Programme 2024-2025

Funding agency: The Mountain Research Initiative (MRI)

Participants: Irina Fedorova (leader), Grigory Fedorov, Narine Hayrapetyan, Ivan Gabrielyan, Vsevolod Rudakov, Larisa

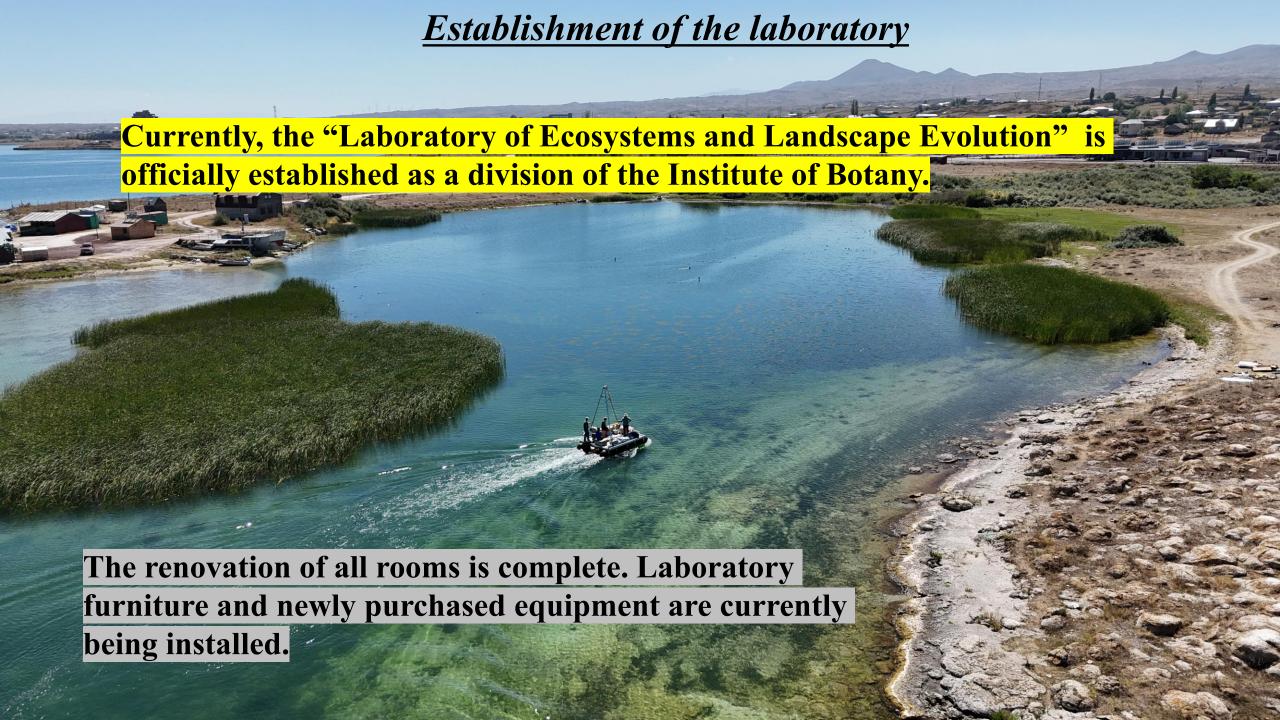
Kazaryan

Project budget: 10000 CHF

Geoportal: <a href="https://armenian-small-mountain-lakes.nextgis.com/resource/1/display?panel=layers">https://armenian-small-mountain-lakes.nextgis.com/resource/1/display?panel=layers</a>

## **Submitted Proposals**

- participation in proposal to BMBF (German Federal Ministry of Research, Technology and Space) to explore the mountain lakes of Armenia. Submitted by University of Greifswald. In collaboration with Institute of Geological Sciences NAS RA.
- participation in proposal to BMBF to explore Lake Zaysan. Submitted by University of Cologne. In collaboration with Institute of Geology (Kazakhstan).
- participation in proposal to DFG (German Research Foundation) for Lake Sevan investigation. Submitted by University of Greifswald. In collaboration with Institute of Geological Sciences NAS RA.
- participation in proposal to DFG for sediment core from Lake Sevan lagoon investigation. Submitted by University of Cologne. In collaboration with Institute of Geological Sciences NAS RA.
- participation in proposal to DFG for seismoacoustic survey on Lake Sevan. Submitted by Kiel University. In collaboration with University of Greifswald and Institute of Geological Sciences NAS RA.



Finance	

salary	26550000
services, equipment, materials	7784185
business trips	1104501
institute overhead	500000
total	35938686



