Small alpine Armenian lakes degradation under climate warming and anthropogenic impact

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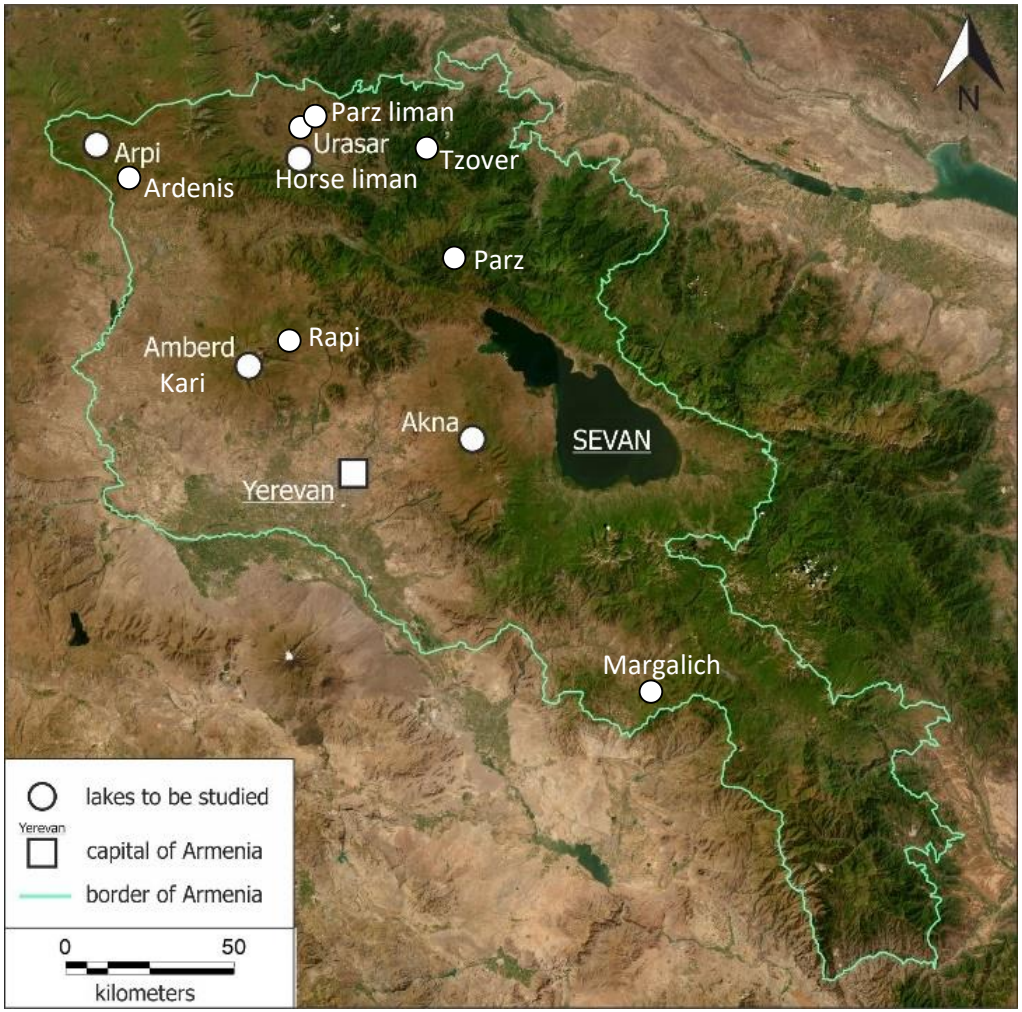
Milan, Italy, November 2024

Locations of studied lakes

Armenian Plateau,
Lesser Caucasus

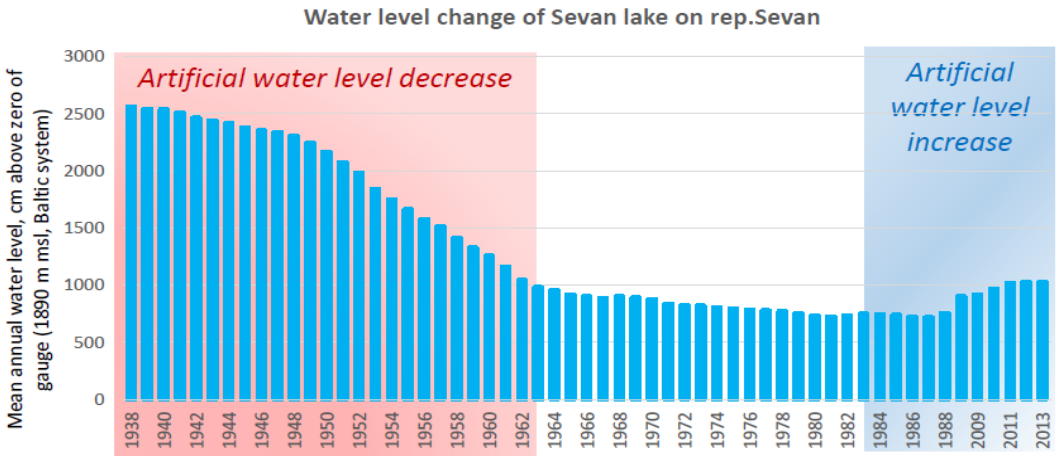
Mountain lakes:
Large lake Sevan and small alpine lakes

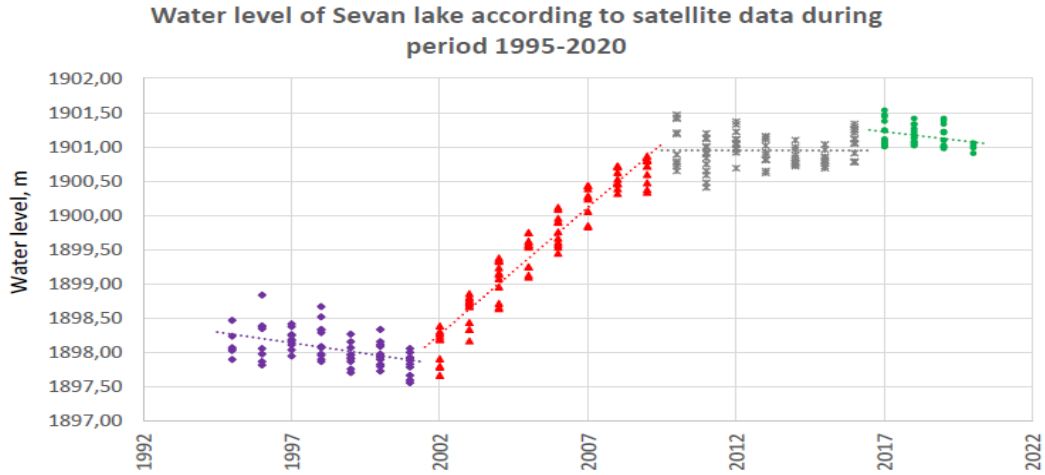


IMPACT project

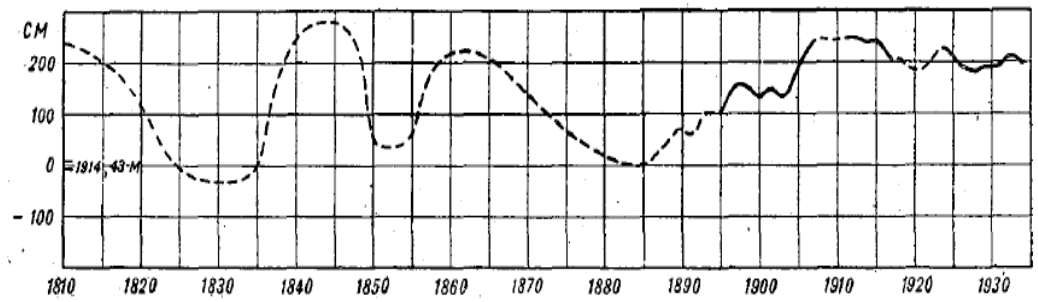
The **goal** of the research project **IMPACT** "Impact of Past and Current Trenchant climatic and environmental changes on Armenian Highland lake ecosystems" is to evaluate the impact of recent climate change and other anthropogenic stressors on Armenian Highland lake ecosystems with a special focus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

The project 23IRF-1E02 supported by Armenian Ministry





Long-term fluctuation of Sevan lake level (a.Lyaister, G.Chursin)



Approach and Methods

Research areas to trace current ecosystem changes in Armenian lakes:

- **Lake overgrowth**
  - Eutrophication (remote sensing to indicate overgrowth dynamic, geobotanical observations of aquatic and catchment vegetation)
- **Changes of hydrological, hydrochemical and hydrobiological regimes**
  - Statistical analyses of long-term meteorological and hydrological data. Difficulties relate to large data gap from 1980th to beginning of XXI century
  - Increasing of nutrients concentration, anoxic layers availability, change of ion composition and possible incline of salinity
  - Biodiversity change in aquatic ecosystems (phyto- and zooplankton, benthos etc.)
- **Aquatic ecosystem modeling**
  - Imitation modeling of ecosystems
  - Applying of climate scenarios
  - Receiving new parameters of small alpine aquatic ecosystems

Main stressors / triggers for aquatic ecosystems change in mountain:

- Earthquake
- Climate change
- Anthropogenic impact

The Earthquake in Spitak in 1988 (Armenia)

Chile Quake & Tsunami Dramatically Altered Ecosystems

News By Charles Q. Choi published May 7, 2012

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This uplifted rocky shore shows mortality of marine life after the 2010 Chile quake. (Image credit: Mario Manzano.)

The earthquake and tsunami that rocked Chile in 2010 unleashed substantial and surprising changes on ecosystems there, yielding insights on how these natural disasters can affect life and how sea level rise might affect the world, researchers say.

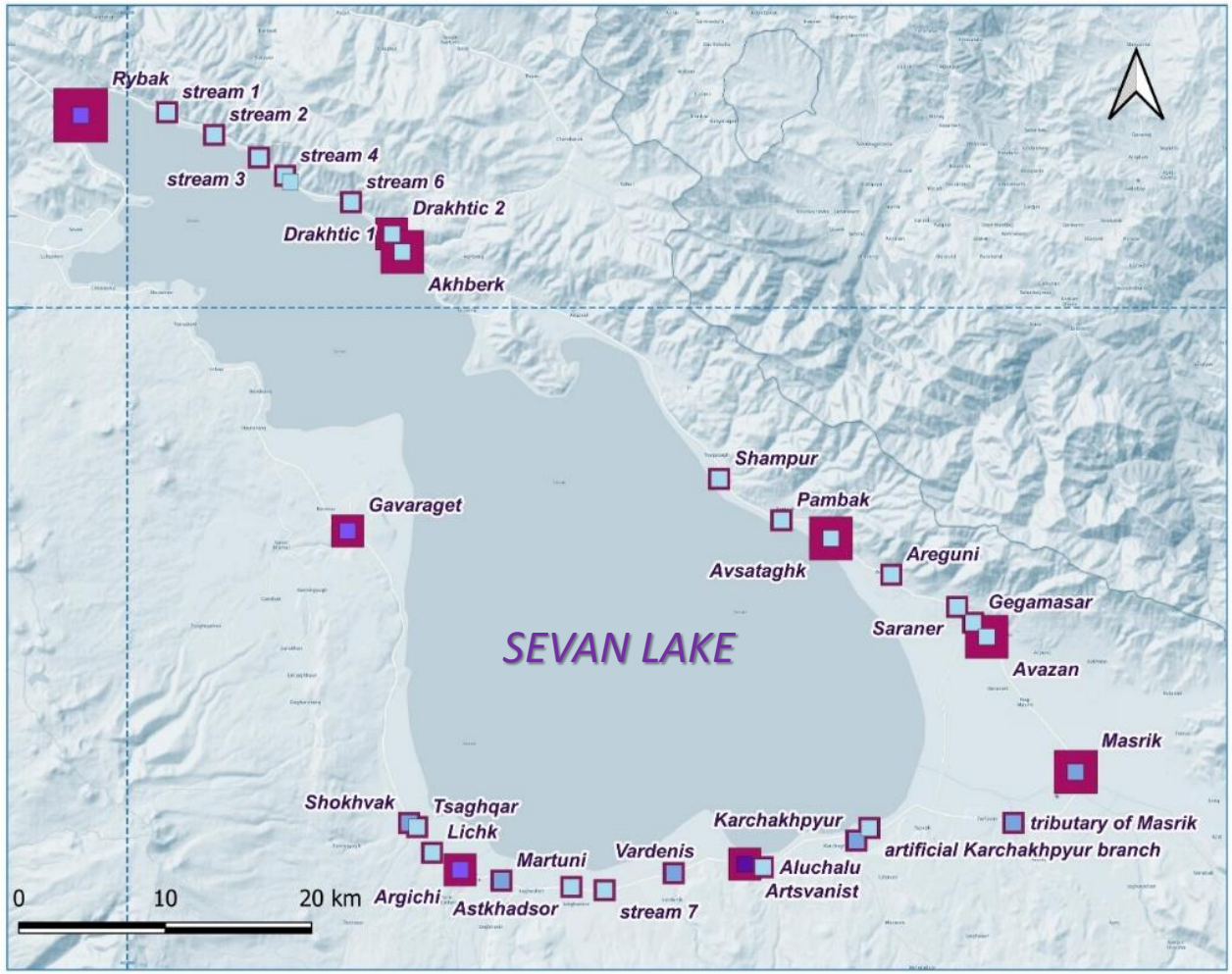
Rupture
Landslides
Aquifers change
Electromagnetic waves
Tephra, dust
Temperature change

⇩

Ecosystem change

Hydrological measurements on Sevan lake inflow streams

Map of water discharge and suspended supply of Sevan lake tributaries



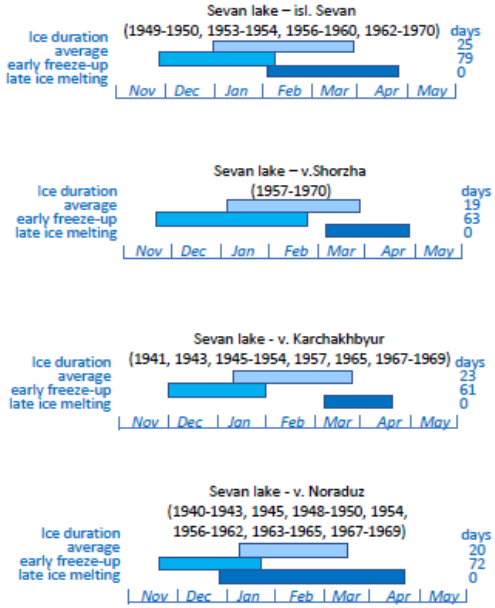
Statistical parameters of streams turbidity

Streams turbidity	spring 2024	summer 2024
average turbidity, mg/l	218	14
max, mg/l	3596	154
min, mg/l	2,4	0,0
Cv	3,1	2,5
Cs	4,7	3,5
Cs/Cv	1,5	1,4

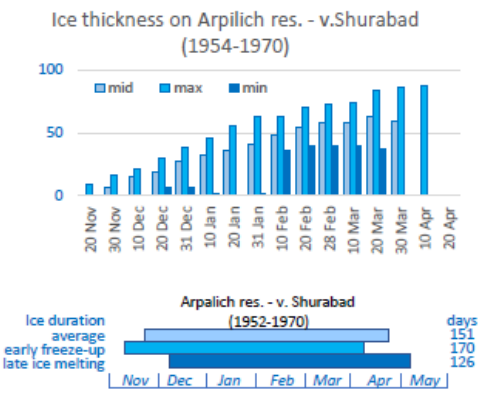
- Turbidity of streams in spring was in 3-200 times less than in summer but sometimes was smaller in 3 times
- Several streams were dry in summer
- In summer some streams, that had been dry in spring, were full by water – different regime of snow patch melting and ground water inflow in catchments
- Water discharge depends on season and (gold) mining activity
- Geochemical composition of suspended material has to be analysed during the year (and multiyear (?) – no data)

Sevan lake ice regime and nutrients income

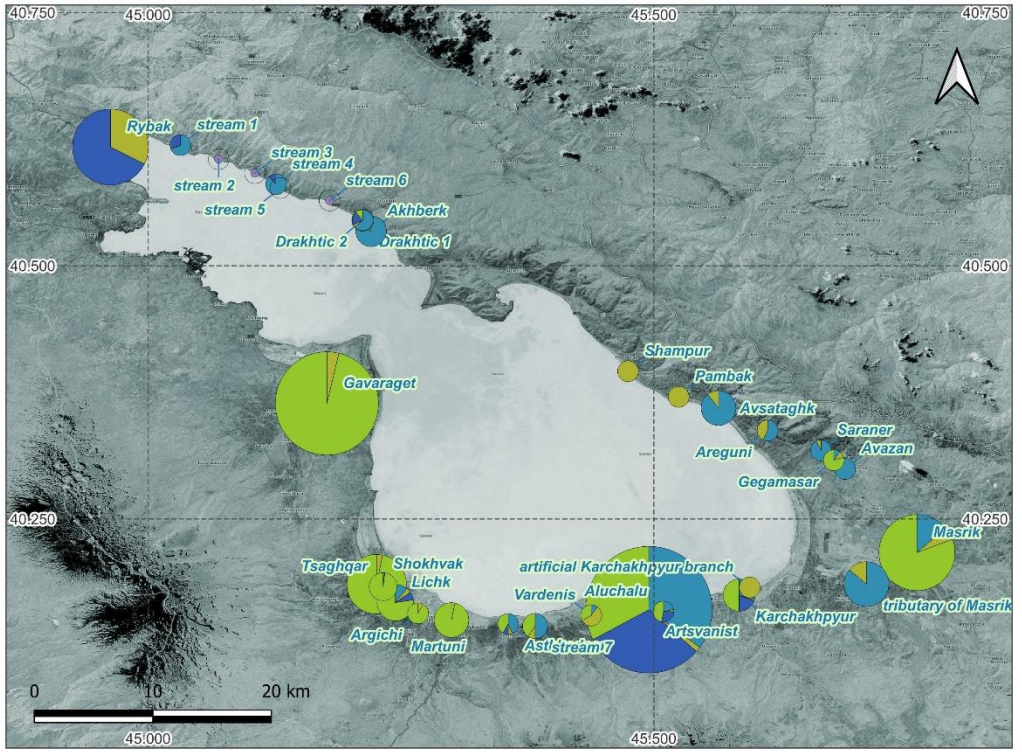
Sevan lake



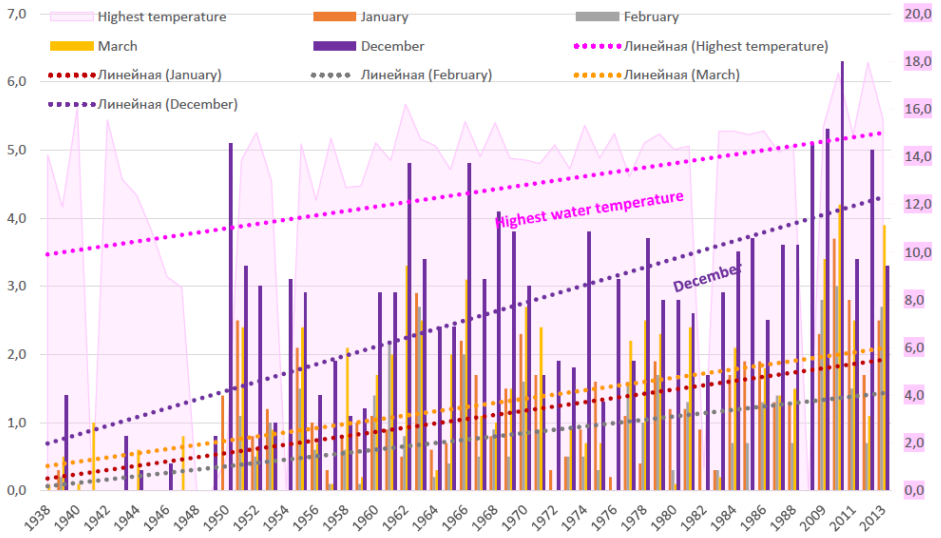
Arpilich res.



Map of nutrients content in tributaries of Sevan lake



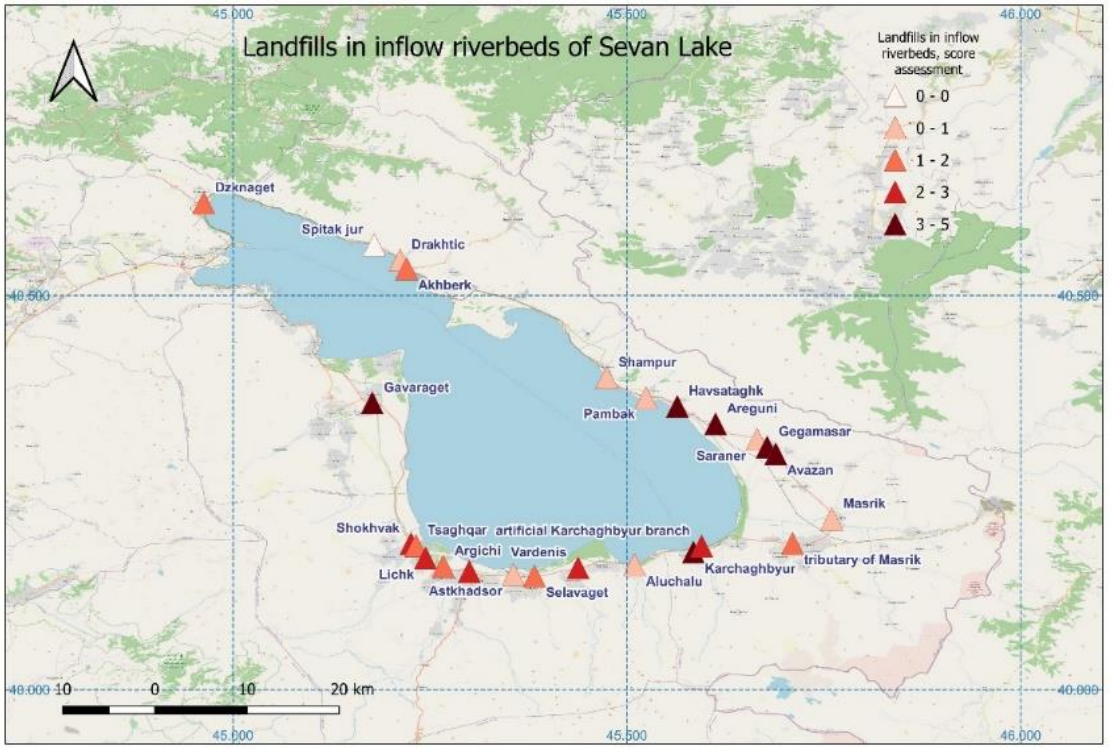
Water temperature (°C) of Sevan lake (rep.Sevan) during 1938-2013






Aside observations

Landfills in inflow riverbeds of Sevan Lake






Study of Sevan lake ecosystem and pollution

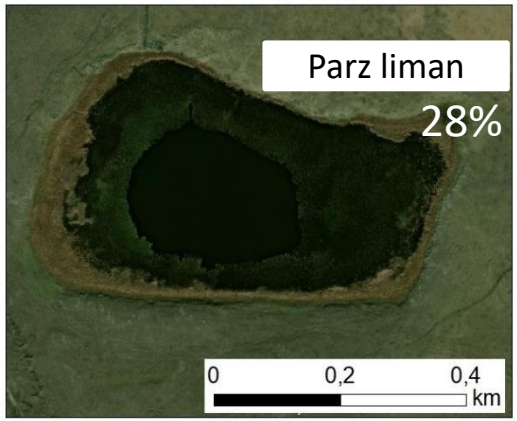
11 July 2019

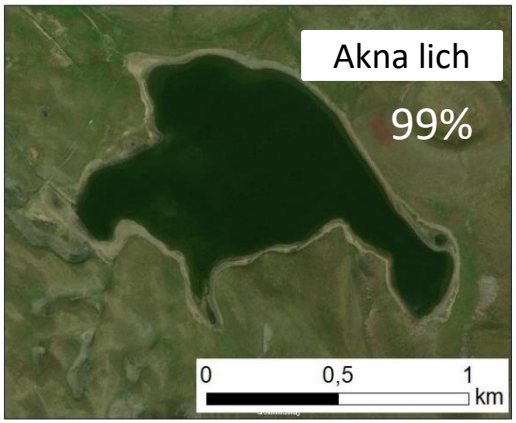
Our colleagues:
Laboratory of Applied Hydroecology at the Scientific Centre of Zoology and Hydroecology NAS RA; Center for Ecological-Noosphere Studies NAS RA

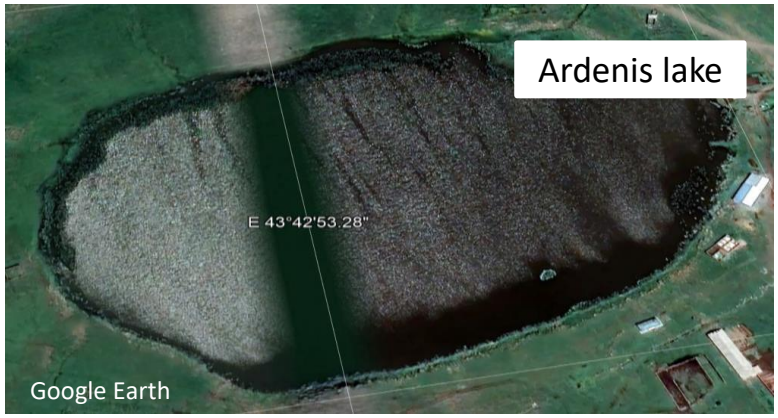
17 July 2022

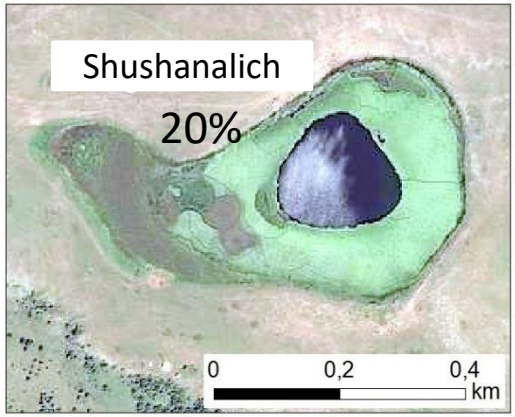
RGB representations of selected Sentinel-3 OLCI scenes showing algae bloom

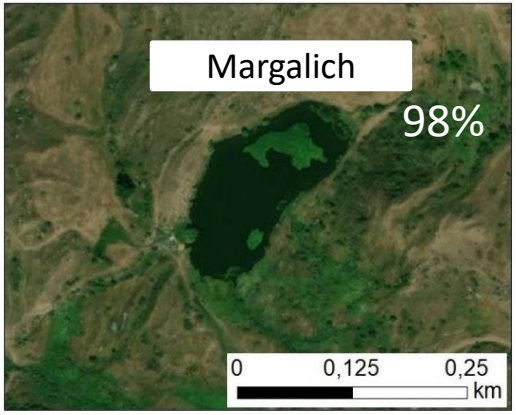
Small alpine Armenian lakes











Period of measurements July – Nov 2023, Sep-Nov 2024

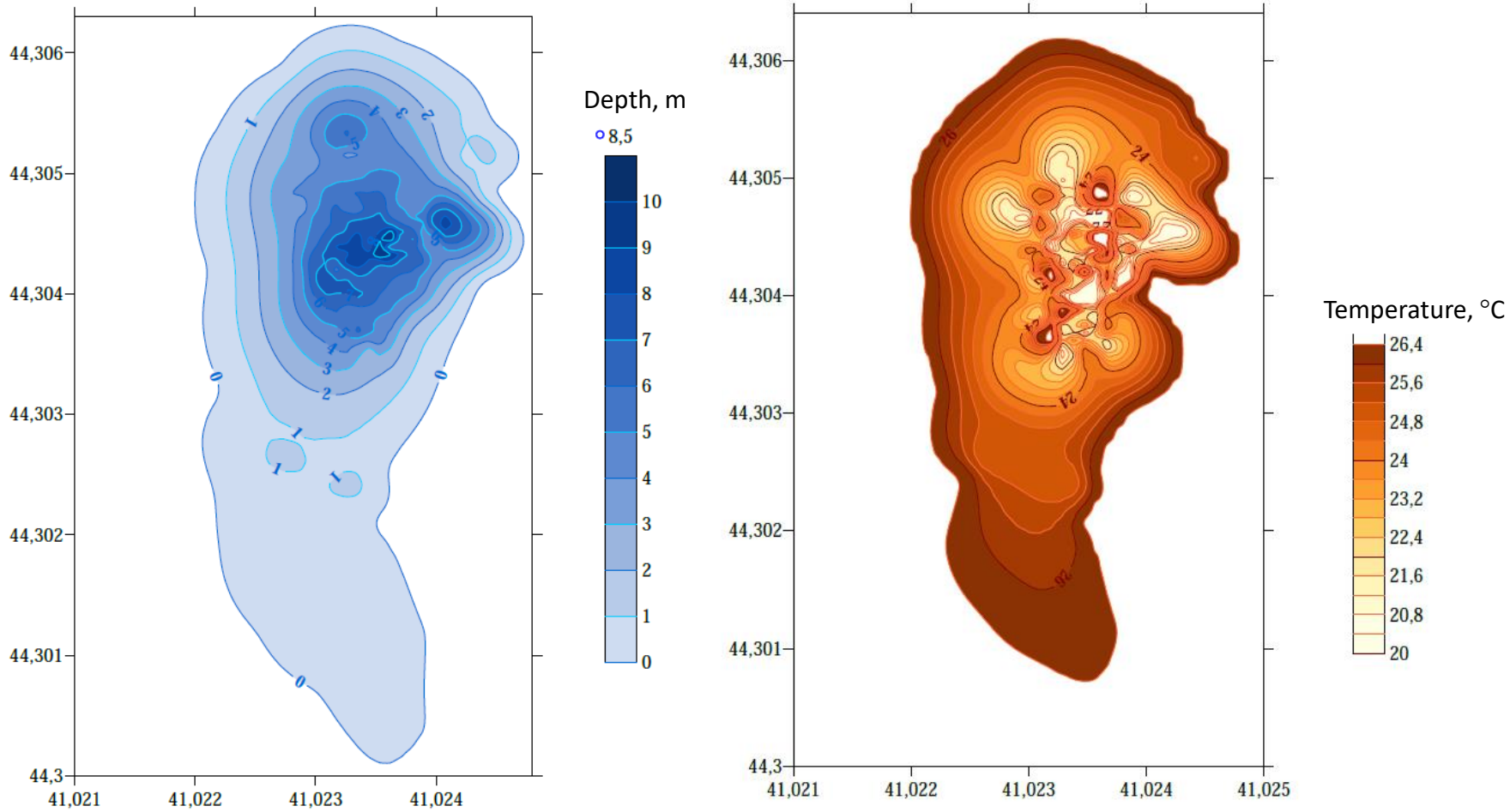
Lake names	Altitude, m a.s.	Maximal depth, m	Lake names	Altitude, m a.s.	Maximal depth, m
Margalich	2000	9	Rapi lake	3006	1,2
Akna lich	3041	12	Kari lake	3195	8
Shushanalich	1552	8,5	Parz lake	1349	8
Parz liman	1479	5,3	Tsover lake	1387	8
Lessing lake	3312	1,5	Arpi lake	2024	9,5
Horse liman	1499	6	Ardenis lake	2044	

Morphometric and hydro physical parameters

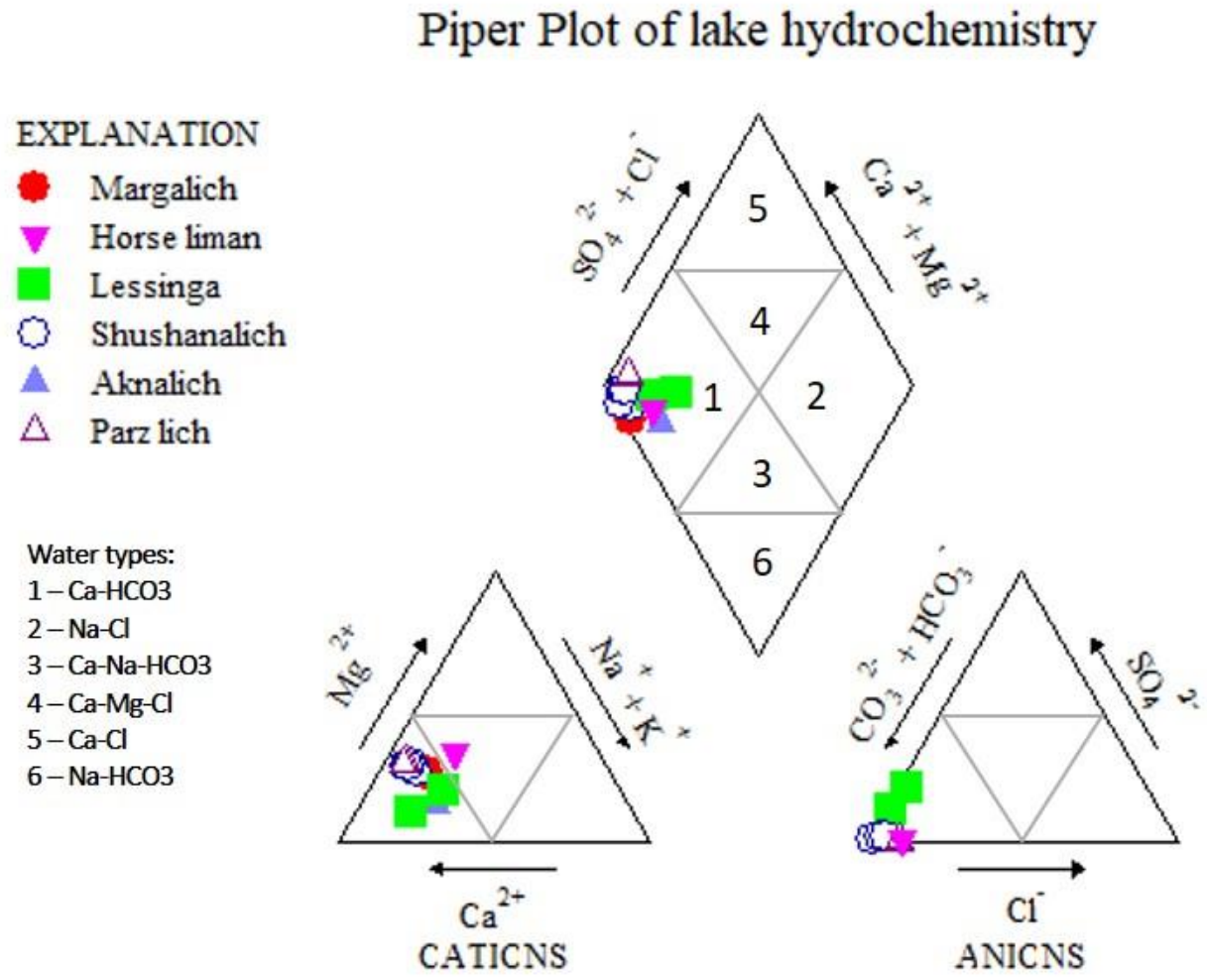
Bathymetry

Shushanalich

Water Temperature



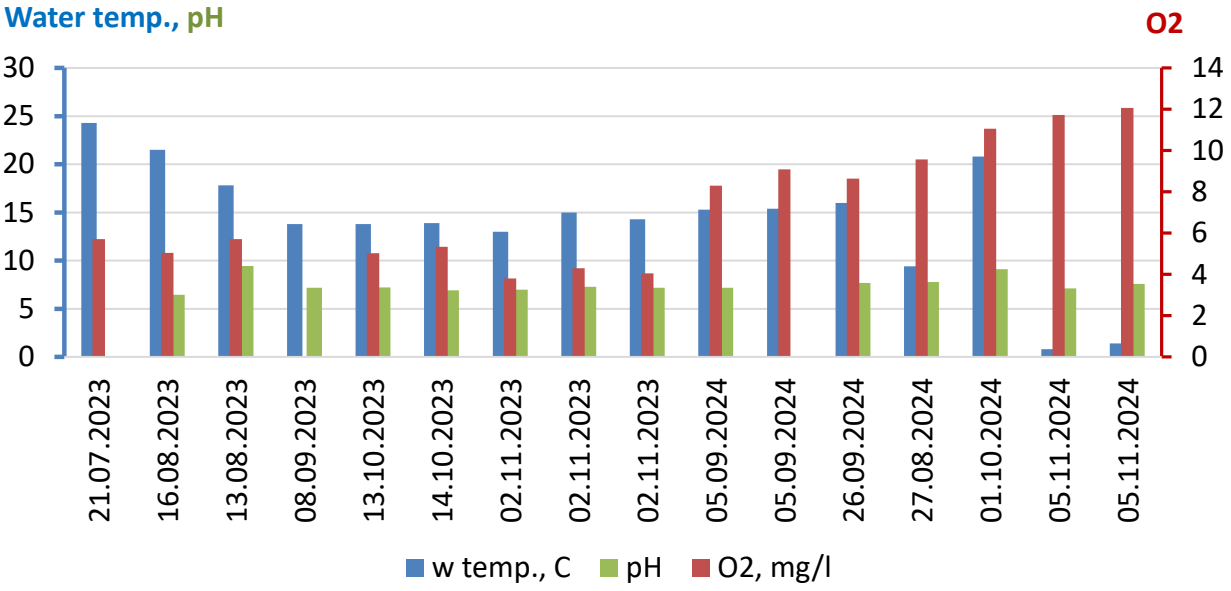
Ion composition of lakes

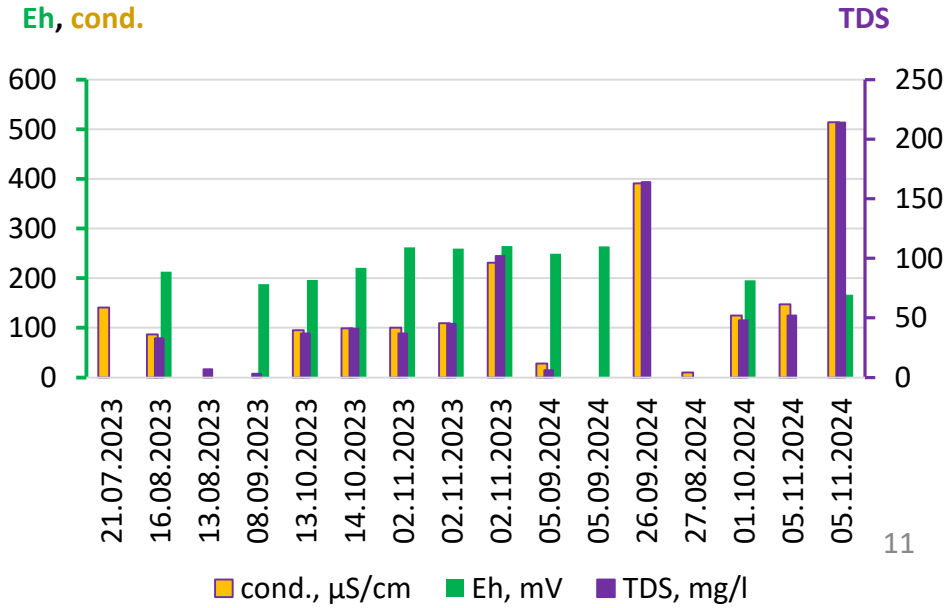


- Lakes have hydrocarbonate-calcium water type.
- Hydrochemic ratio of ions was similar for all lakes except Parz liman.
- Parz liman had ration of ions like (HCO_3^-+SO_4^{2-} <(Ca^{2+}+Mg^{2+}).
- Other lakes had more hydro carbonates than water hardness HCO_3^- > (Ca^{2+} + Mg^{2+}).

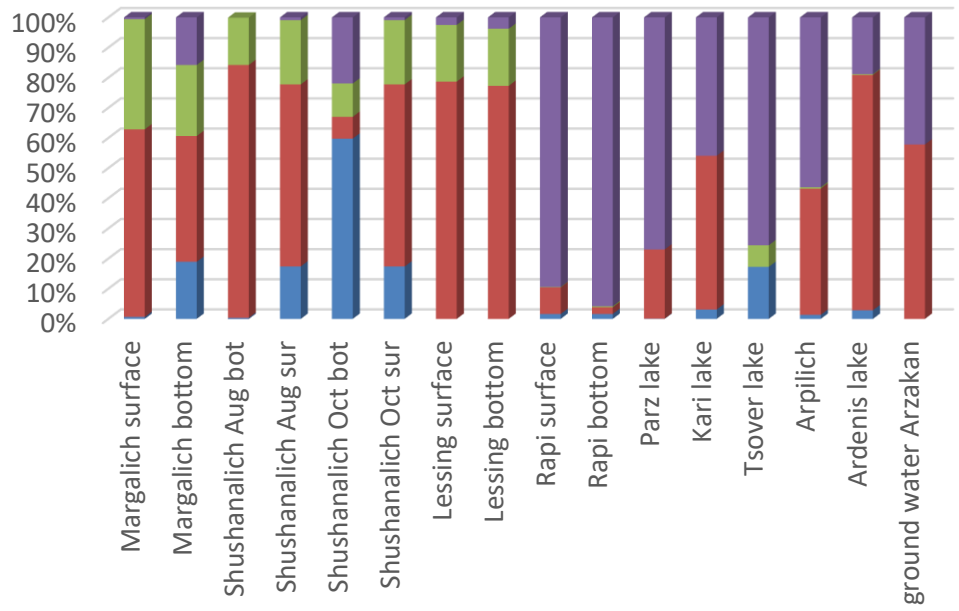
Hydrochemical parameters

Lake names	Dates of measurements
Margalich	21.07.2023
Shushanalich Aug	16.08.2023
Akne lich	13.08.2023
Lessing	08.09.2023
Shushanalich Oct	13.10.2023
Parz lich	14.10.2023
Shushanalich Nov	02.11.2023
Parz lich	02.11.2023
Horse liman	02.11.2023
Rapi surface	05.09.2024
Rapi bottom	05.09.2024
Parz lake	26.09.2024
Kari lake	27.08.2024
Tsover lake	01.10.2024
Arpilich	05.11.2024
Ardenis lake	05.11.2024

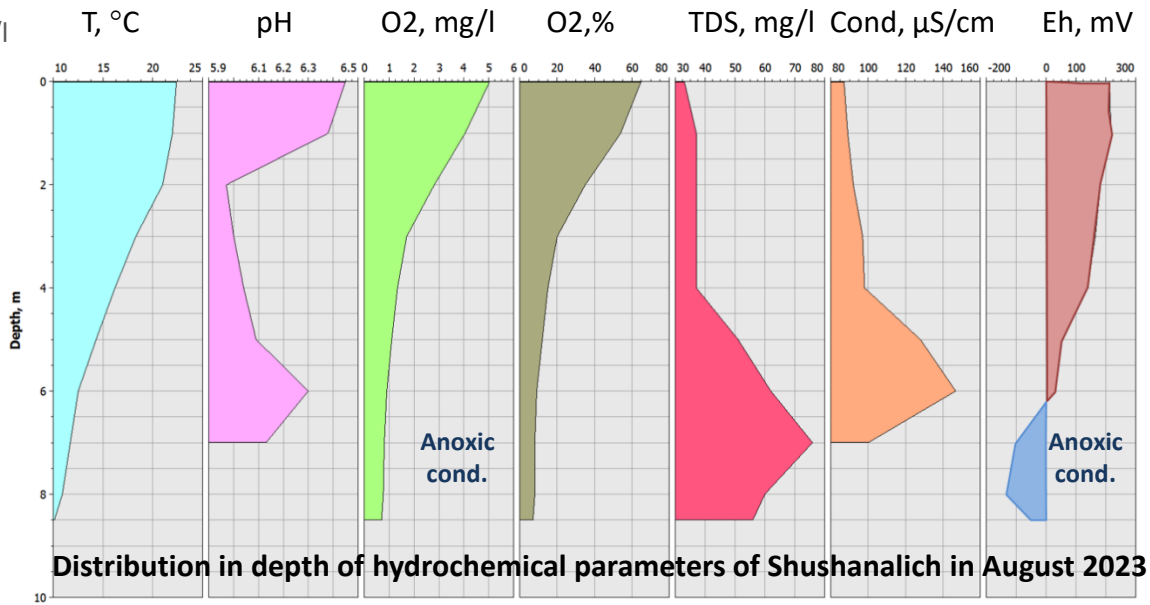




Nutrients in lakes

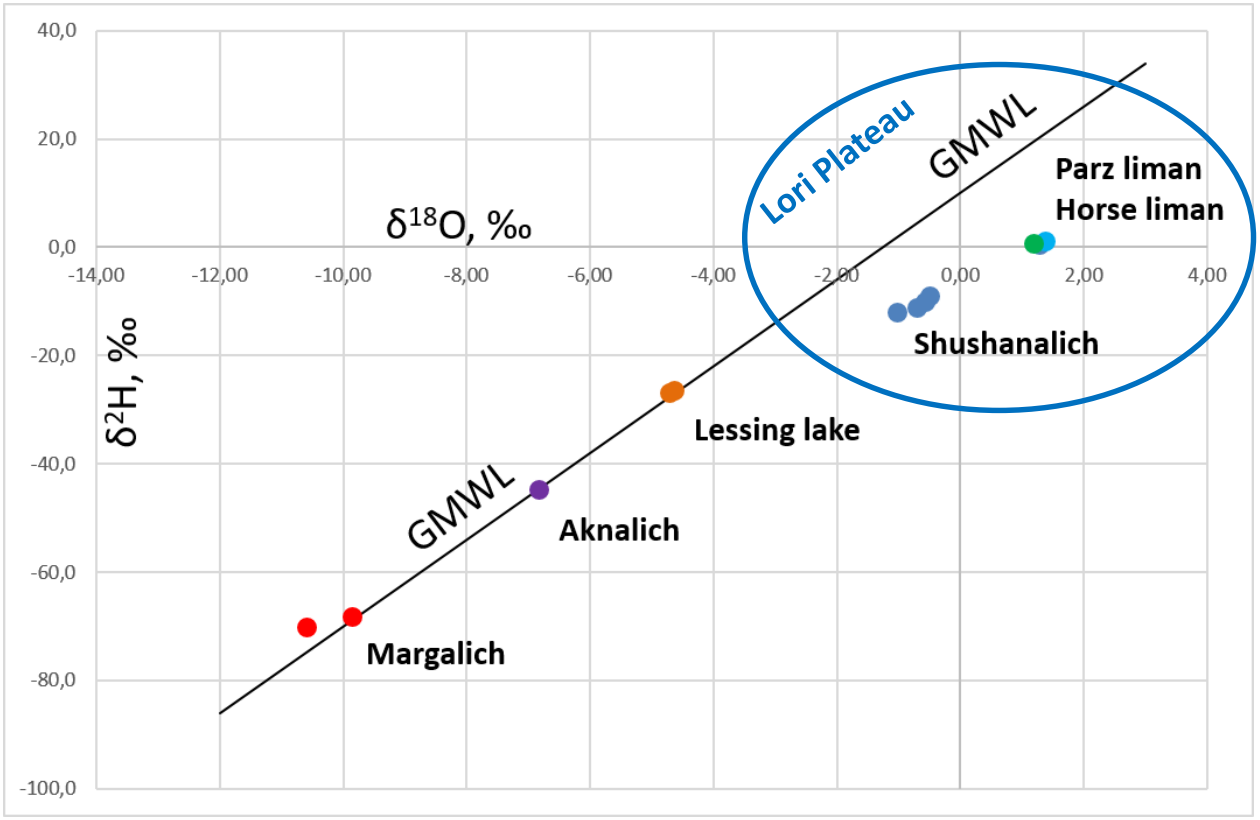


- Average content of oxygen ranged from 3.8 to 5.7 mg l^{-1} (36-86%) on the surface of all studied lake.
- Anoxic conditions was noticed on the bottom of Shushanalich in August (O_2 value was less 1 mg l^{-1}, Eh was -130 mV) but changed to oxygen regime in October.
- Main part of nutrients was silicates Si (0.02-59.2 mg l^{-1}) in 2023 and nitrate + nitrate – in 2024 (max 28,4 mg/l); phosphates PO_4 various 0.04-2.1 mg l^{-1} and ammonium NH_4 (0.02-2.2 mg l^{-1}).
- The highest nutrients concentration observed in Ardenis lake, the most oligotrophic lake – upland Akna lich and Lessing lake.



Distribution in depth of hydrochemical parameters of Shushanalich in August 2023

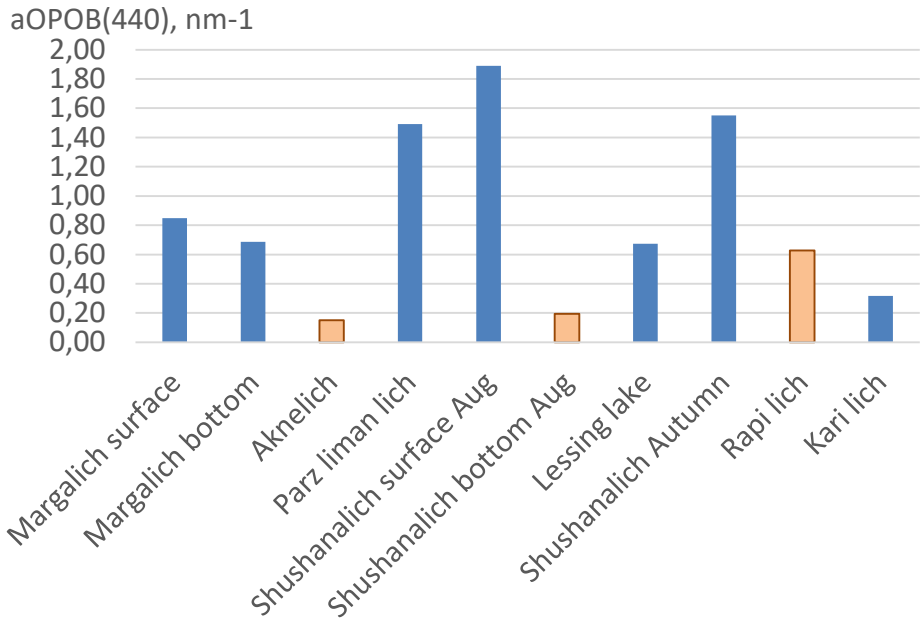
Water isotope composition of lakes



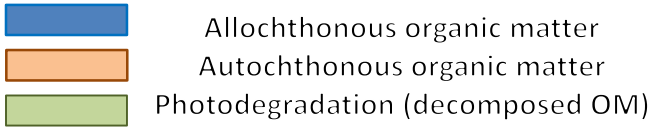
- The heaviest isotopic content has Margalich (-10.59‰ $\delta^{18}O$ and -68.52‰ $\delta^{2}H$), satiated on the 2000 m a.s.
- Meaning of Akna lich (3041 m a.s.) and Lessing (3312 m a.s.) lakes are between Sushanalich and Margalich lakes' values.
- Lori Plateau lakes has atmospheric water income
- Margalich has groundwater inflow mostly

Stable water isotopes has huge variation of value $\delta^{18}O$ from -10.59 to +1.39‰, range of $\delta^{2}H$ are - 70.2 ÷ +1.1‰.
GMWL- Global Meteoric Water Line

CDOM in lakes



Lake name	αCDOM (440) nm^{-1}	S (275-295) nm^{-1}	Sr (Suv/Svis)	E2:E3 (α250/α365)
Margalich surface	0,85	0,015	0,94	4,98
Margalich bottom	0,69	0,014	0,77	5,34
Aknelich	0,15	0,022	1,02	9,25
Parz liman lich	1,49	0,020	1,01	7,18
Shushanalich surface Aug	1,89	0,018	0,94	6,29
Shushanalich bottom Aug	0,19	0,022	1,12	8,49
Lessing lake	0,67	0,016	1,16	4,86
Shushanalich Autumn	1,55	0,018	0,93	6,73
Rapi lich	0,63	0,021	1,25	8,44
Kari lich	0,32	0,019	1,49	7,00



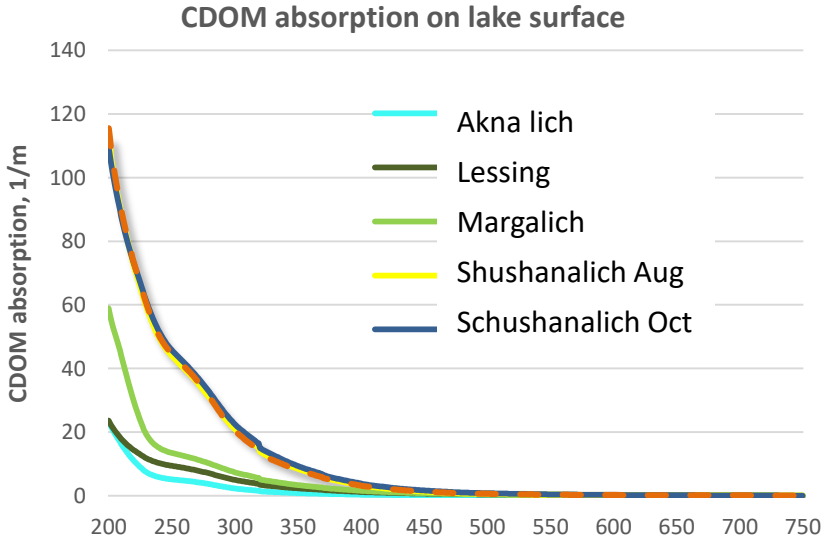
CDOM and absorption illustrate an origin of organic matter, it's decomposition degree and ability of lakes to eutrophication.

Ratio Sr<1.2 on the Margalich bottom reflect additional influx of groundwater and additional organic matter to the lake .

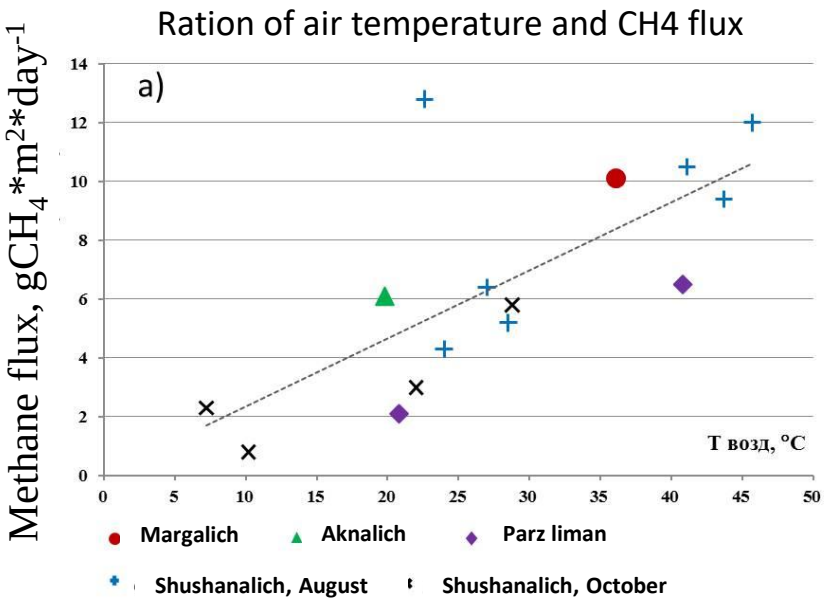
Autochthonous OM sedimentation in lakes Parz liman, Horse liman, Shushanalich and Rapi reflected by spectral slope S.

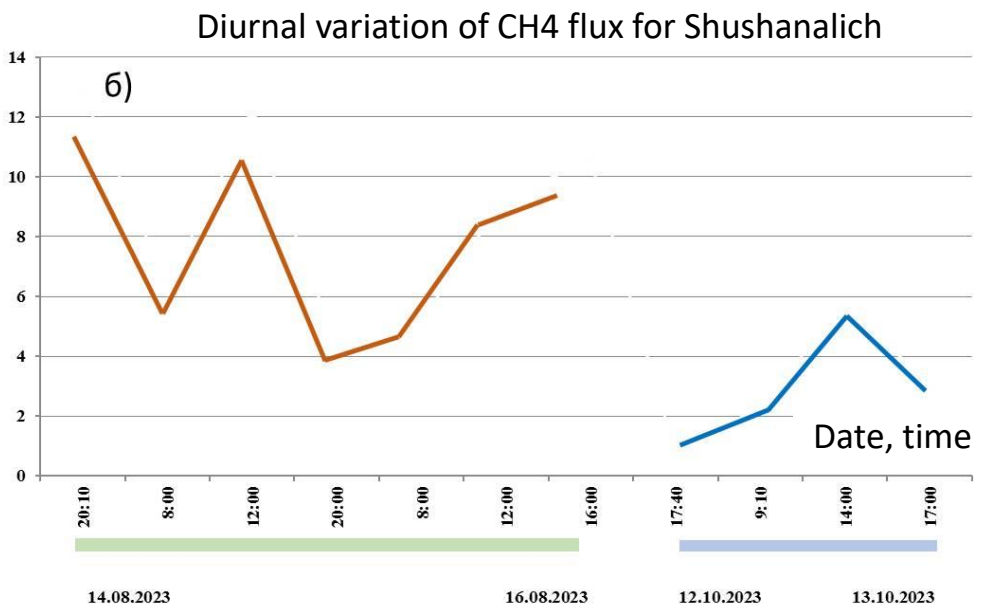
Lotic lakes Akhe lich, Margalich and Kari have predominant allochthonous organic.

Rapi and Kari lakes had phothodegradation process of decomposed OM in Autumn.



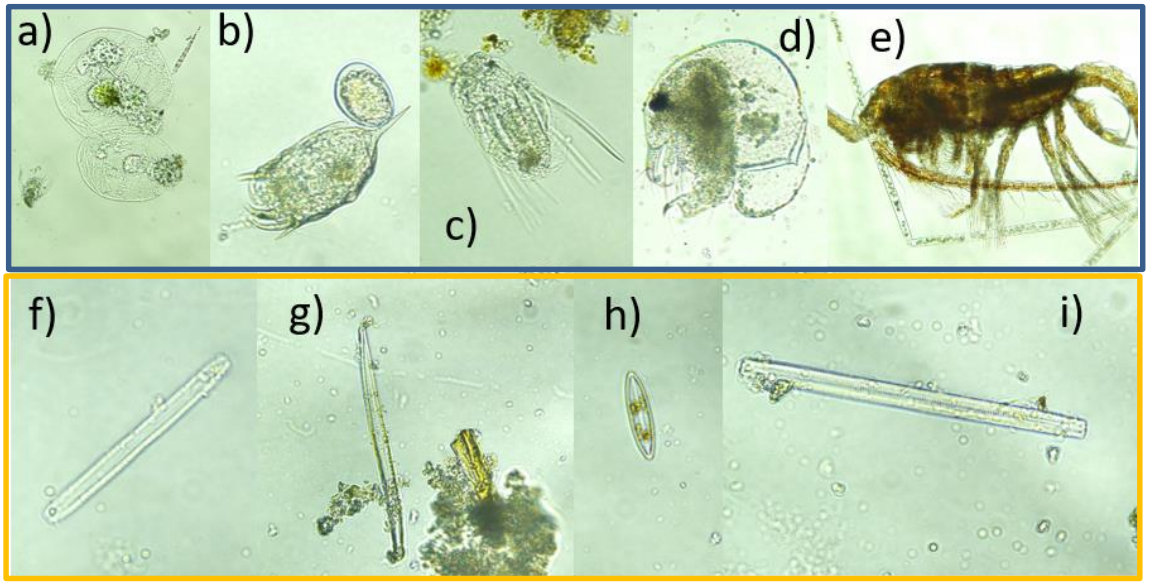
Diffusion CH_4 emission from the lakes surface





- The average diffusion **methane flux** for all studied small lakes was 6.5 $gCH_4*m^2*day^{-1}$ - the highest volume that had been noticed before for the Caucasus region.
- The average values of CH_4 flux were 10.1 $gCH_4*m^{-2}*day^{-1}$ for the Margalich on July 2023; 6.1 $gCH_4*m^2*day^{-1}$ for Akna lich on August; 2.1-6.5 $gCH_4*m^{-2}*day^{-1}$ for Parz liman on October.
- For Shushanalich in August, the average flux at different hours per a day was 4.3-12.8 $gCH_4*m^{-2}*day^{-1}$, in October it's ranged from 0.8 to 5.8 $gCH_4*m^{-2}*day^{-1}$, i.e. decreased by more than 2 times.
- During the day CH_4 flux has a sinusoidal function. In Autumn the function attenuated.
- The most significant CH_4 flux reached 13 $gCH_4\ m^{-2}\ d^{-1}$.

Lake ecosystems



Plankton monitoring of small lakes was in a middle of last century. Sevan lake is studied well up to now.

(a-e) **Zooplankton**:

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

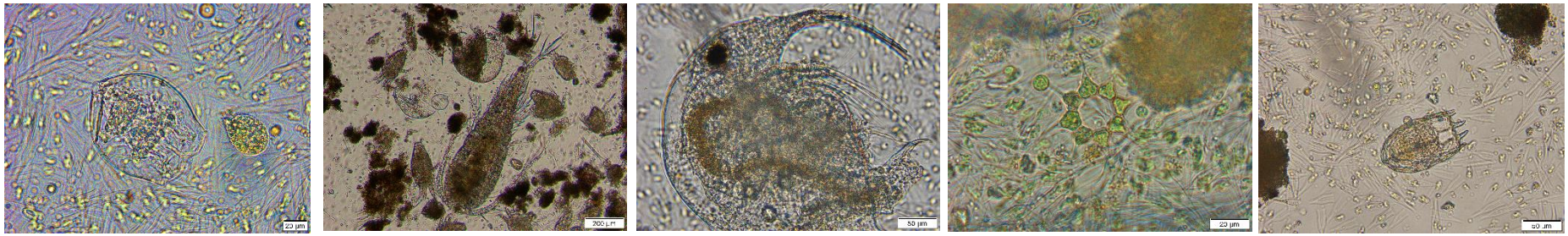
(f-i) Diatoms:

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

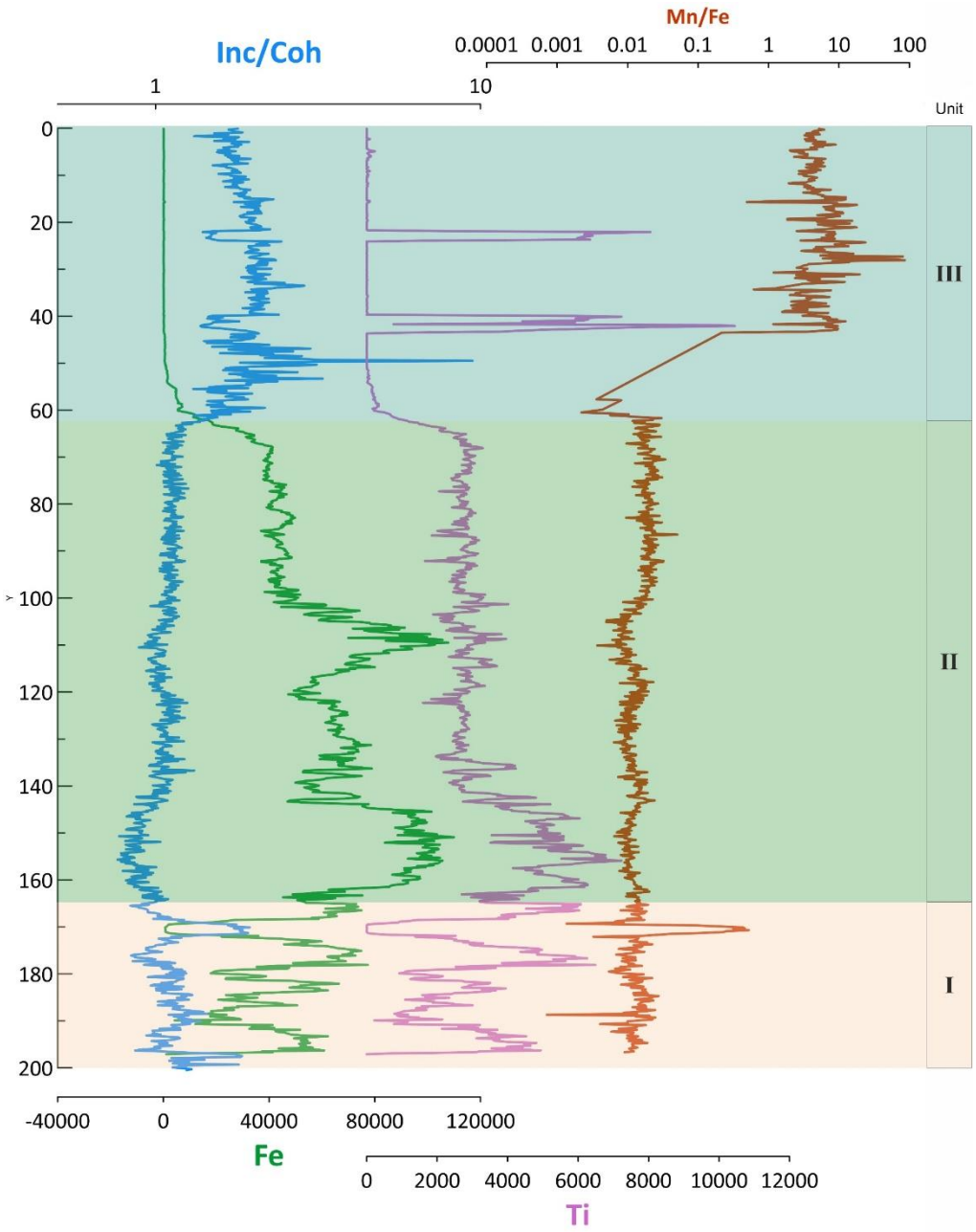
Ecosystems of studied in 2023 lakes depends on altitudes and environment conditions of a catchment. Pelagic zooplankton of Shushanalich (1552 m a.s.) presented by Rotifera, Cladocera and Cyclopoida mostly, rather Lessing lake (3312 m a.s.) had only Copepoda (Calanus sp.). Rotifera largely contributed 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.

Phyto- and Zooplankton in Parz lake in September 2024



Geochemistry of lacustrine sediment cores



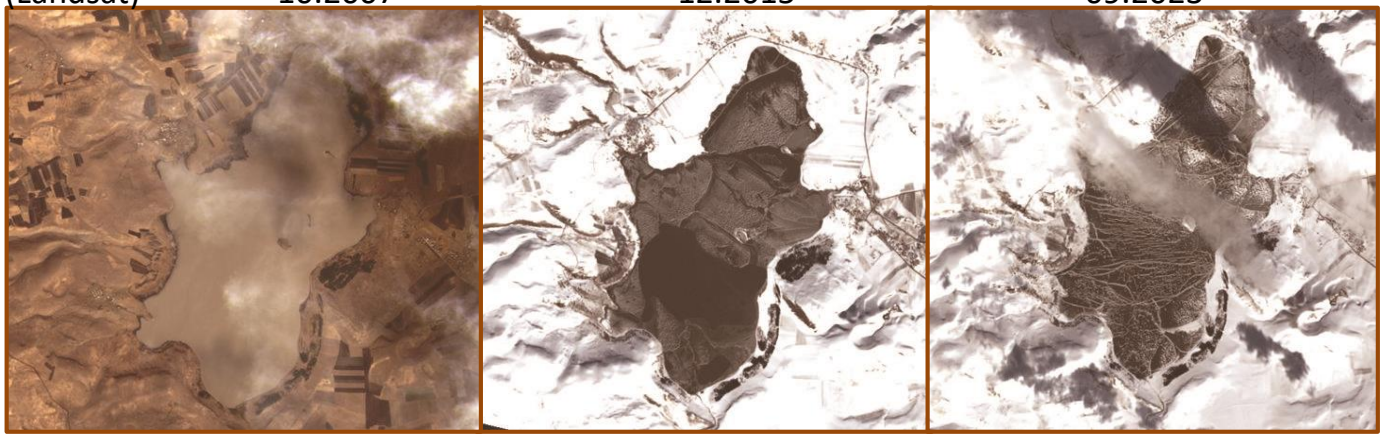
O2
OM

Use of remote sensing and GIS

Kari lake

(Landsat) 10.2007 12.2015 09.2023

Arpi lich



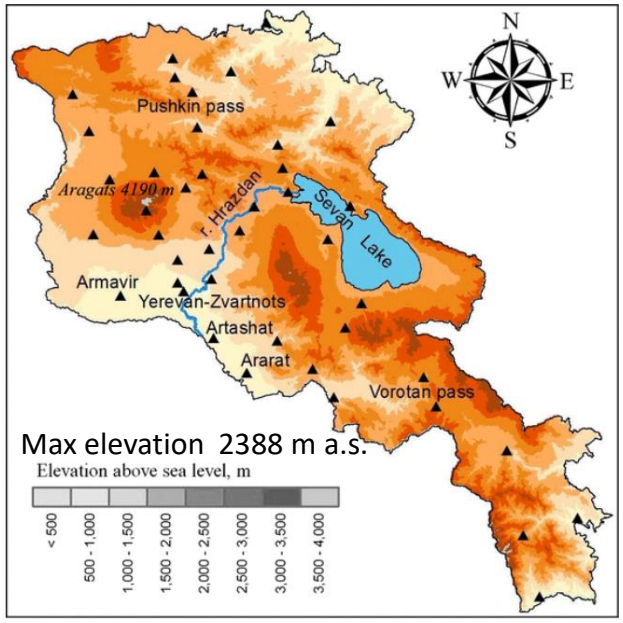
(Landsat) 16.11.2023 19.12.2023 27.12.2023

- Lack of satellite images especially for Caucasus region
- No historical images
- Absence of some parameters identification (ice phenomena, CDOM etc.)

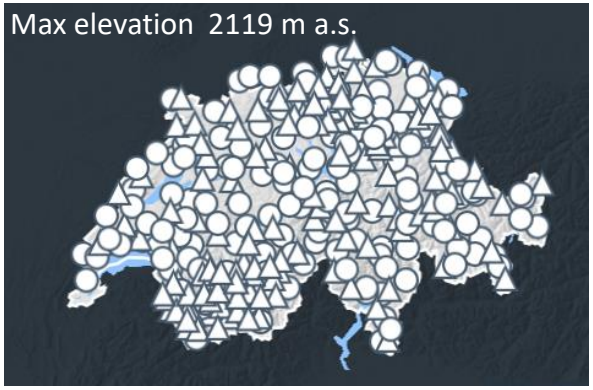
- Small artificial features detecting is important for hydrological and environmental forecasting
- Human impact can be a positive factor for small lakes surviving

Climate change and forecasting problems

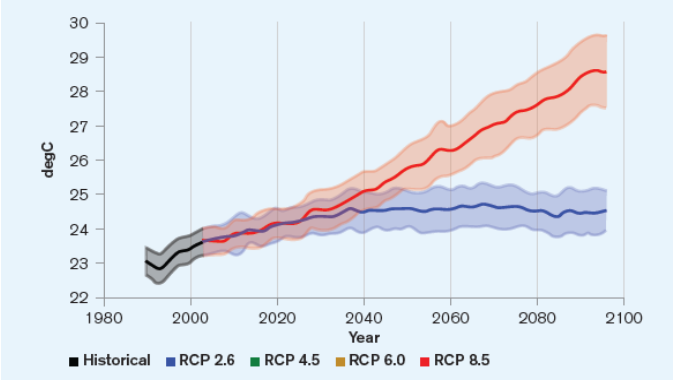
43 meteorological stations in Armenia



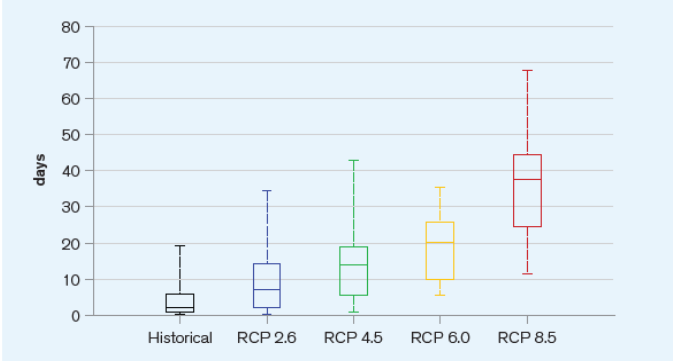
Meteorological stations in Switzerland



Historic and projected average annual temperature
in Armenia under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble.



Box plots showing historical (1986–2005) and projected (2080–2099) average annual frequency of very hot days >35°C

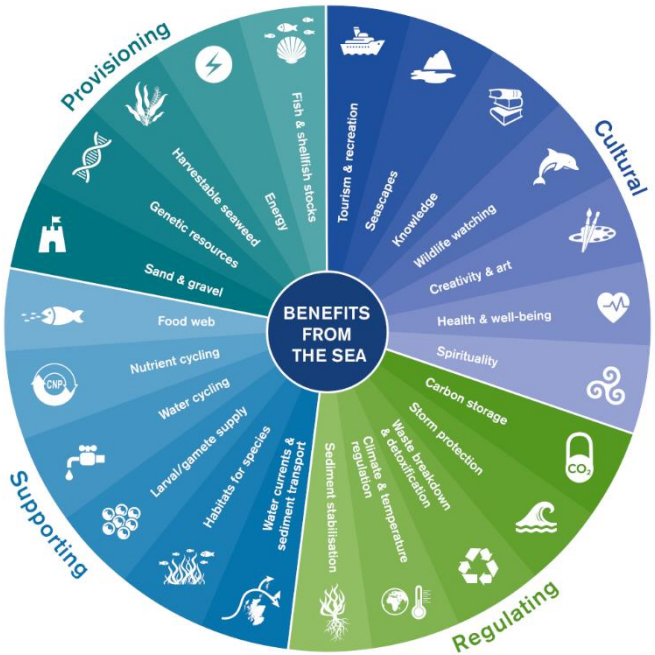


CLIMATE RISK COUNTRY PROFILE: ARMENIA

- Projections suggest Armenia could experience warming at levels significantly above the global average, with potential warming of 4.7°C by the 2090s, above the 1986–2005 baseline, under the highest emissions pathway (RCP8.5).
- Expected rise in maximum and minimum temperatures are even more significant and represent major threats to human health, livelihoods, and ecosystems.
- Warming is projected to be strongly biased towards the summer months of July, August, and September.
- Increased drought risk is a particular threat to poorer rural communities dependent on subsistence agriculture.
- **The increased risk of both flood and landslide hazards demand attention on disaster risk reduction, particularly in Armenia's poorer rural communities**

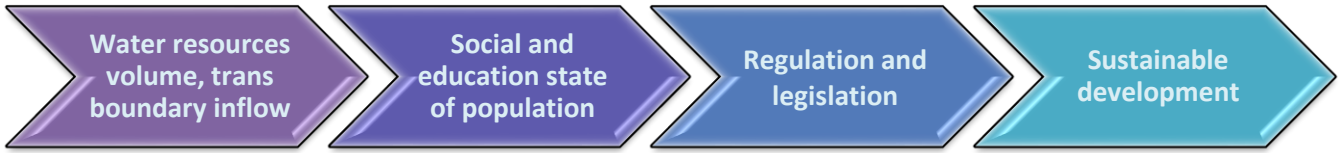
(Climate Risk Country Profiles that are jointly developed by the World Bank Group (WBG) and the Asian Development Bank (ADB)).

Sustainable water resources



- Surface water resource of Armenia is estimated at 7.7 billion m3, including 940 million m3 of additional transboundary waters. Only 2.3 billion are used, other volume flows into the Caspian Sea.
- Armenia currently has 9480 rivers and 90 reservoirs of various sizes. There were about 194 small lakes in 1963 and only 120 at the beginning of this century.
- Irrigation water losses in the republic, according to approximate estimates, reach 50-55%.
- Armenia has the transboundary waters with Georgia, Iran, Azerbaijan, and Turkey.
- In recent years, Turkey has been actively building new reservoirs on the Kars and Araks rivers, which affect the water resources formed in the Ararat Valley, thereby pursuing a systematic and consistent policy of water blockade of Armenia. However, Armenia speaks out about the waterways of the Zangezur range as a response to Azerbaijan's claims

Armenia is on 74 places according to Human development Index



Agriculture in Araks river valley

The biggest river of Armenia – the Araks river

https://s9.travelask.ru/system/images/files/001/459/146/wysiwyg_jpg/%D1%84%D0%BE%D1%82%D0%BE_1.jpg?1614330694

Waste on the river channels

Conclusions

- During 2023 several small alpine Armenian lakes were firstly studied in XXI century. Obtained data partly support previous studies (XX century) and partly widening the aquatic ecosystems parameters.
- Obtained new data could be used for modeling and forecasting. Thus, CDOM – for remote sensing, water isotopes – for source of water and water balance calculation.
- CH_4 emission from small Armenian lakes surface 2-3 times higher than predicted before for Caucasus region.
- Various of inflow runoff characteristic around the year, it's long-term changes as well as anthropogenic impact should be taken into account for Sevan lake ecosystem modeling
- Transboundary water (runoff, groundwater income etc.) should have special international regulation and legislation. So, Arpa-Sevan channel gives new addition phyto- and zooplankton species to Sevan lake, for example. Polluted water of Araks river flow to neighboring countries. Monetization of water resource is required.
- Social aspect vs. informing the local people about water resources problem, pollutions and about necessities of sustainable water development (in irrigation especially) are the first focus of media and (?) government.
- Continuation of monitoring, enlarging the number of study sites and lakes inventory, will allow to enrich our knowledge about all small alpine lakes of Lesser Caucasus.
- We are ready to share results of our monitoring for scientific collaboration.

Current project: The Mountain Research Initiative (MRI) project
"Armenian (South Caucasus) small alpine lakes Geoportal"
under the framework of the GEO Mountains Small Grants Programme 2024-2025

Thank you for your attention!
Welcome to Armenia!

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KARI Lake