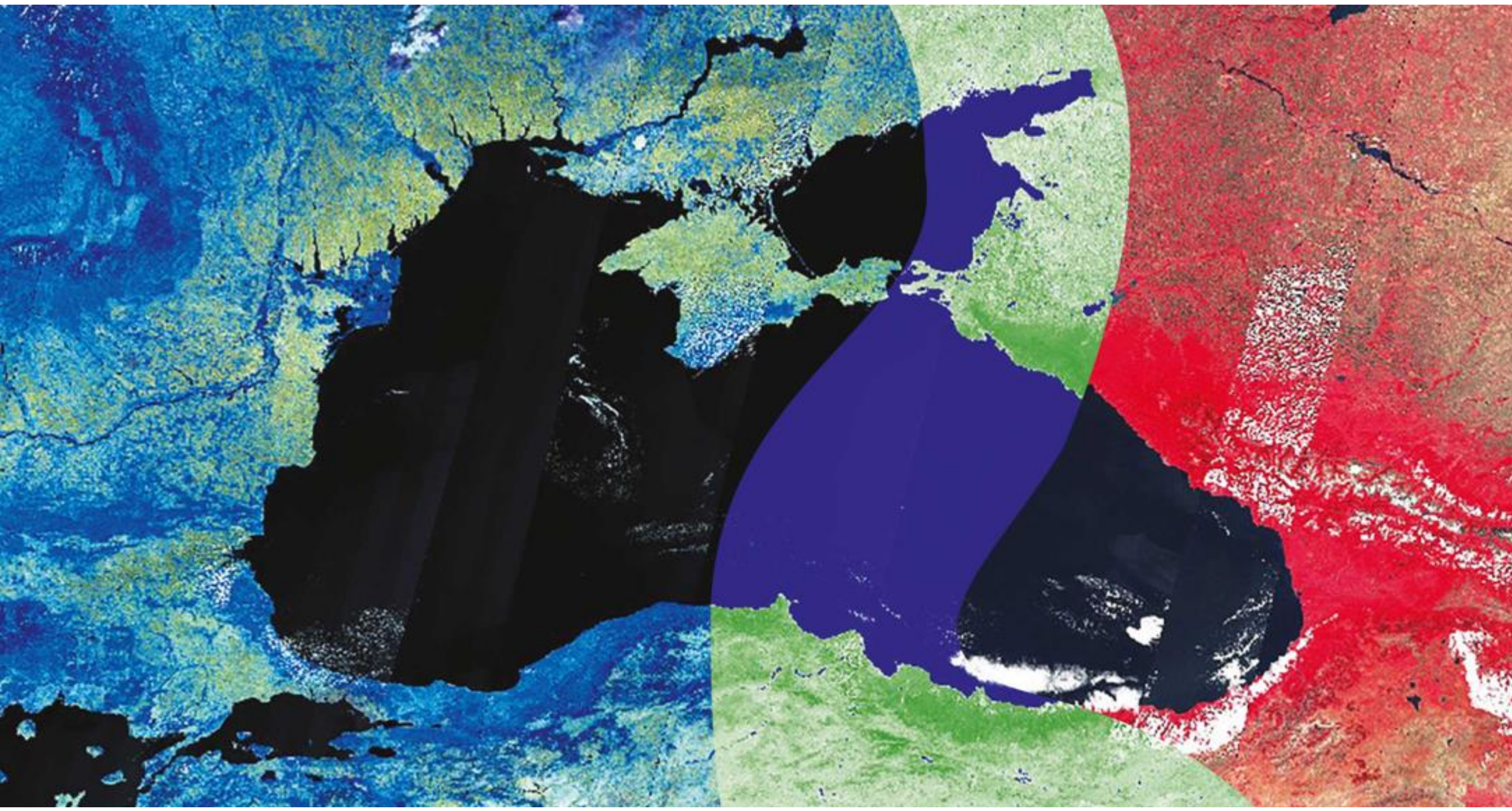
Project funded by EUROPEAN UNION

Copernicus assisted environmental monitoring across the Black Sea Basin – PONTOS



Assessment on changes in wetland and floating vegetation cover

Deliverable D.T1.2.4

Green Alternative

PONTOS-GE (Georgia) – The entire coastline of Georgia & Kolkheti lowland

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Green Alternative, 2022

Content

Introduction

Floating water vegetation biomass, species composition is an important attribute of almost all aquatic ecosystems, as floating vegetation is a key habitat, a source of food for other organisms, and an indicator of water quality (Findlay et al. 2014; Orth et al. 2006). Significant reduction or degradation of floating vegetation can affect water quality and lead to the destruction of fish and other animals associated with water bodies (Hughes et al. 2009). The area of wetlands in Georgia is approximately 51,500 ha, of which floating water vegetation occupy a small area, as the main area of wetlands is covered by peatland vegetation or swamp forest. Such scarcity of floating water plants is explained by hydrological features of Georgia, in particular, the lack of lakes and ponds. Nevertheless, on the Kolkheti plain, between Rioni and Khobi rivers, there is Lake Partotskali, which, despite its small size (21.6 ha), is a unique reservoir of floating water plants, where Georgia's endemic populations - the Colchian water chestnut (*Trapa colchica*) and other indicator species are widespread (see Annex 1 and Annex 2). In addition to the unique species composition, Lake Partotskali is singled out by its isolated location from anthropogenic influence, which further distinguishes it from other lakes and water bodies. It is precisely because of such unique features that Lake Partoskali and its ecosystem were selected as a candidate for a reference water body. Reference status describes the natural state of a water body that can be used as a benchmark and be compared to other water bodies (Bailey et al. 2004, Reynoldson and Wright 2000). There is no uniform approach for assigning and describing the reference status because levels of variation and factors affecting natural water bodies are very different (Herlihy et al. 2012). It is worth mentioning the EU Water Framework Directive that requires all EU member states to determine reference status of water ecosystems for environmental monitoring. In this regard, there are many methods of separation and classification of reference water bodies based on chemical or biological analyzes (Andersen et al. 2004; Schaumburg et al. 2004). In case chemical indicators are not available, geographic information system (GIS) and remote sensing approaches are used (Herlihy et al. 2012). Through GIS, it is possible to estimate the spatial location of water bodies and anthropogenic factors affecting them (Herlihy et al. 2012). Water quality in water bodies can be assessed by concentration of unnatural amounts of chlorophyll a (EPA 2021). Remote sensing technology is such a tool for detecting increased chlorophyll a in waters from fertilizers, septic systems, sewage, and urban runoff (EPA 2021).

In the given project, our task was to develop a methodology for conducting qualitative assessment of Lake Partotskali and its floating plant habitats through remote sensing and geoinformation technologies and assigning it a reference status.

Methodology

Study area

Lake Partotskali is located on the Kolkheti plain between Rioni and Khobi rivers, in the Kolkheti National Park. Hydrologically, Lake Partotskali is a part of the wetland area, which, apart from Partoskali itself, consists of two more nameless small ponds, which are located at a distance of

1 km from each other. To the west, the lake is bordered by alder swamp forest (*Alnus glutinosa*) and artificially planted maritime pines (*Pinus pinaster*) on acidic peat soils, and to the east it is surrounded by peat bogs dominated by Imeretian blue moor grass (*Molinia caerulea*). The lake is located at 0.3 m above sea level, and its area is 21.6 ha, where a maximum of 16 ha is covered with water floating plants (*Trapa natans, Nuphar lutea, Potamogeton natans, Egeria densa Planch and others)* during the summer months (see Appendix 1). Two small rivers - Tsivi and Tsia flow in the vicinity of the lake, which are partially channeled, so their natural hydrological regime is partially changed. According to the hydrological classification, Lake Partotskali is a humic water body. Such lakes are typically characterized by brownish water with low pH, low nutrient concentrations, and low light penetration (Weyhenmeyer 2009). The high level of humic substances in Lake Partotskali is caused by the high level of dissolved organic carbon, which is related to the influence of surrounding peatlands.

The lake is 2,500-3,000 meters away from the sea aquatory, and 3,000 meters from the river Rioni delta. The area around the lake is characterized by warm temperate sea climate. Summer is moderately warm (24-25 °C), and winter is cool (4-6 °C), average annual precipitation is high and amounts to 1800-2200 mm (Nakhutsrishvili et al. 2011).

Lake Partotskali is quite isolated, the nearest settlement is the Nabada area of Poti city, which is located on the opposite side of River Rioni, 3 km away. Near the lake, there are dirt motor roads and railways in about 200 meters, which connect to Kulevi village and Kulevi Oil Terminal in the north, 6 km away. (See Figure 1.)

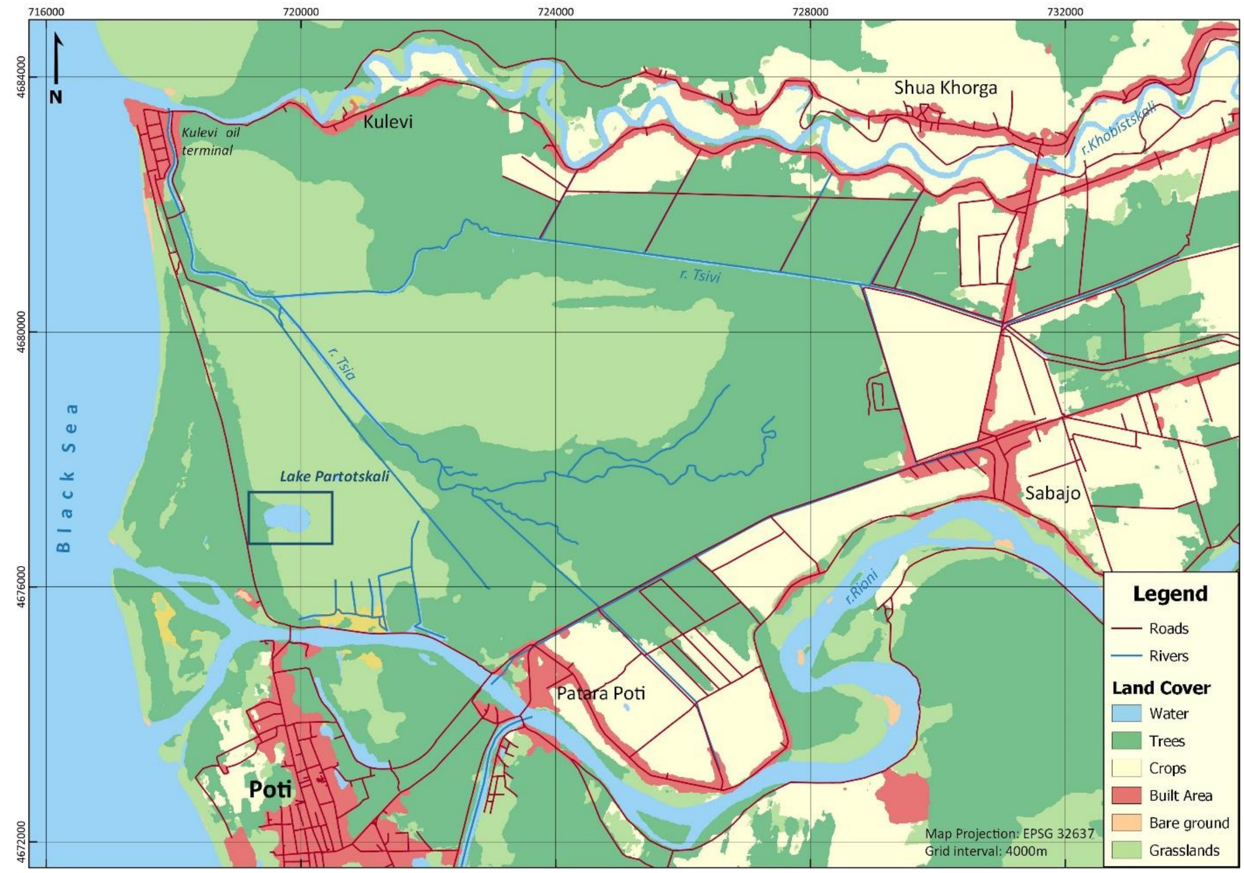


Fig. 1. Map of Lake Partotskali location and its surroundings.

Methodology development

A methodology to evaluate Lake Partotskali and substantiate the possibility of assigning it a reference status was developed based on two approaches: 1. GIS analysis, based on which the impact of types of Land use/land cover, transport and hydrological network on the lake was assessed, and 2. remote sensing, which determined the concentration of chlorophyll a in the lake, which is one of indicators of the lake status.

First, the unit has been defined within which the study was conducted and area around the lake was evaluated. Lake surroundings is a wetland area, the average height of which is only 1.29 m, the minimum is -0.3 m, and the maximum is 5.1 m. above sea level. The nearest rivers, Tsivi and Tsia, have been heavily altered and are interconnected with drainage channels. Determining the catchment area for such territory is extremely difficult, which is why we took the territory which is bounded by the sea from the west, the rivers Rioni and Khobistskali from the north and south, and the historical border of the wetland area from the east, as the unit of the study area. Thus, we have got a research area of 11689 ha, within which the analysis was carried out. To assess the potential impact of land use on Partotskali, we used ESRI land cover map (Karra et al. 2021), derived from ESA Sentinel-2 images at 10 m resolution. (See Figure 1.) Minor inaccuracies in the land cover data were corrected manually using the SCP Plugin. The land cover map included 10 land categories captured during 2020 and subsequently averaged: water bodies, trees, agricultural land, urban area, bare ground, grass cover (mostly swamp grass vegetation). To vectorize the hydrological (river and drainage channels) network, we used very high resolution images in Google Images and Soviet topographic maps in 1:25,000 scale, from which we also extracted terrain elevation markers to estimate the topography of the site. A road network was also vectorized from the very high resolution images, from which 100 m buffered polygonal layers were created and a road density map was created using the Line density tool of QGIS 3.22.6-Białowieża.

Human activity is usually greater and more visible around settlements, along roadsides and agricultural lands, thus in those places where anthropogenic activity is low, water ecosystems are less pressured, which is the basis for selection as a candidate reference object. Spatial and buffer analysis was carried out using the GIS layers, through which the sources of potential diffuse pollution and their possible impact on the water body were determined. For the buffer analysis, distances from potential pollutants were considered based on other studies (Herlihy et al. 2012); (Nielsen et al 2012).

Chlorophyll a (Chl-a) concentration was determined using Sentinel-2 satellite multispectral images. The images were available through the data portal (https://scihub.copernicus.eu/dhus/#/home). To determine the concentration of chlorophyll a, we selected cloud-free monthly images from 2017-2021 (59 in total), which were processed using the ESA SNAP 8.0 application C2RCC processor. C2RCC processor is based on Artificial Neural Networks (ANN) method, where neural networks are learned based on a database of modelling water reflectance coefficients and its associated TOA radiance (Asim et al. 2021). Finally, IOP generation of chlorophyll a and water optical properties was performed using the C2RCC processor. Chlorophyll a values were converted to mg/m^3 units, and the file was converted to GeoTIFF format for further analysis in QGIS workspace. Three reference points (coordinates) were selected for the assessment of chlorophyll concentration in the western, central and eastern parts of the lake. The obtained Chl-a concentrations were compared with reference lakes in Europe (Poikane et al 2010), where the ecological status was determined based on more extensive surveys and multi-year *in-situ* data.

Lake Partotskali is also notable for its water vegetation, the coverage and dynamics of which were assessed using Sentinel-2 satellite multispectral images. It is known that vegetation indices are used to evaluate vegetation, among which the most well-known is NDVI - Normalized Difference Vegetation Index. NDVI determines quantitatively vegetation by measuring the difference between near-infrared (which vegetation reflects well) and red light reflectance (which vegetation absorbs) (GIS Geography 2022). NDVI values range from -1 to +1, with positive values indicating vegetation and negative values indicating areas without vegetation. NDVI is calculated using the following formula:

$$NDVI=(NIR-RED)/(NIR+RED)$$

where NIR stands for near-infrared radiation and RED for red radiation.

Monthly NDVI images for 2017-2021 (59 images in total) were generated for the area of Lake Partotskali, which were further averaged by years and months. Images were averaged using QGIS Desktop 3.22.

Results and discussion

As we have mentioned, Lake Partotskali is surrounded by wetland area, which in its turn borders agricultural, urban and industrial lands. Our goal was to identify potential pollution sources that affect the water quality and ecosystem of Lake Partotskali. Based on the information that we have obtained and processed, we evaluated the possibility of existence of both point and diffuse pollution sources.

Unlike point pollution, which enters a lake at a specific location, such as a pipe discharge, diffuse pollution occurs when potentially polluting substances are washed into surface and groundwater through precipitation, soil infiltration, and surface runoff. (FWR Information Center) Typical examples of diffuse pollution are fertilizers and pesticides applied to agricultural lands, as well as pollutants washed off roads, etc. (FWR Information Center).

Point pollution is not observed in Lake Partotskali, because only one, a 300-meter long channel which has been filled with silt for many years and no longer functions, flows from the surrounding drainage channels. In addition, the channel is completely located in a peat bog and is not connected to any other type of land category and thus does not represent a source of pollution.

Diffuse pollution in Lake Partotskali is potentially possible if there is a large volume of pollutant wash-off from agricultural lands in the study area. In this regard, we have evaluated the land cover map (see Fig. 1). Out of its 11689 ha area, 47.7% is covered by forest, 28.3% by wetland grass cover, 17.0% by agricultural land, 5.19% by urban and industrial zones, and 1.815 % by other land categories. Thus the source of pollutants can be only 22 percent of the total study area. Hydrogeologically, agricultural and homestead lands are connected to drainage channels, which in turn are spatially connected either to the sea or to Rioni and Khobistskali rivers (see Figure 1). Accordingly, the pollutants (e.g. fertilizers) leaked into the ground must first enter the river or drainage canals, and then flow through them into the Black Sea.

The second, no less important source of diffusion can be the road network from which the internal products of vehicles combustion engines may enter the soil. It is worth noting that the density of the road network in the study area is very low, and only one dirt road passes through surroundings of Lake Partotskali at a distance of 200 m from the lake. This road connects city of Poti and Kulevi Oil Terminal and is not characterized by frequent traffic. In addition, based on the buffer analysis, we have found that pollutants from roads might not affect the lake, as their distance does not exceed 100 m and therefore is not in the risk zone.

There is only one large industrial zone in the study area - Kulevi Oil Terminal - which is located on the sea coast, at the mouth of Khobistskali, 6 km away from Lake Partotskali. The probability of potential pollutants getting diffused into the lake area is very low, because the terminal, as we have mentioned, is far away from the lake and at the same time it is surrounded by the sea on one side, and the rivers Tsivi and Khobistskali on the other. The second industrial facility is smaller and is located at 1170 m, on the edge of the Rioni river delta. The facility is hydrogeologically connected to the river, so the probability of possible pollutants entering the river is greater than the peatlands around Lake Partotskali.

Chlorophyll a concentration and comparative analysis

The second method used to evaluate the ecological status of Lake Partotskali was to determine the concentration of chlorophyll a (Chl-a) in the water and its values allowed us to assess the ecological status of the lake. The analysis was performed using Sentinel-2 multi-spectral satellite imaging. The amount of chlorophyll concentration was determined at 3 locations in units of mg/m^3 during the period 2016-2021 (see Figure 2).

Samples	Std	Min	Mean	Max	Water bodies
1 (Partotskali)	24.2	0.0007	5	34.2	Lowlands, shallow, humic
2 (Partotskali)	16.2	0.02	5.1	36.7	Lowlands, shallow, humic
3 (Partotskali)	17.3	0.0071	4.6	34.1	Lowlands, shallow, humic

Table 1. Concentration of chlorophyll a in mg/m^3 in Lake Partotskali.

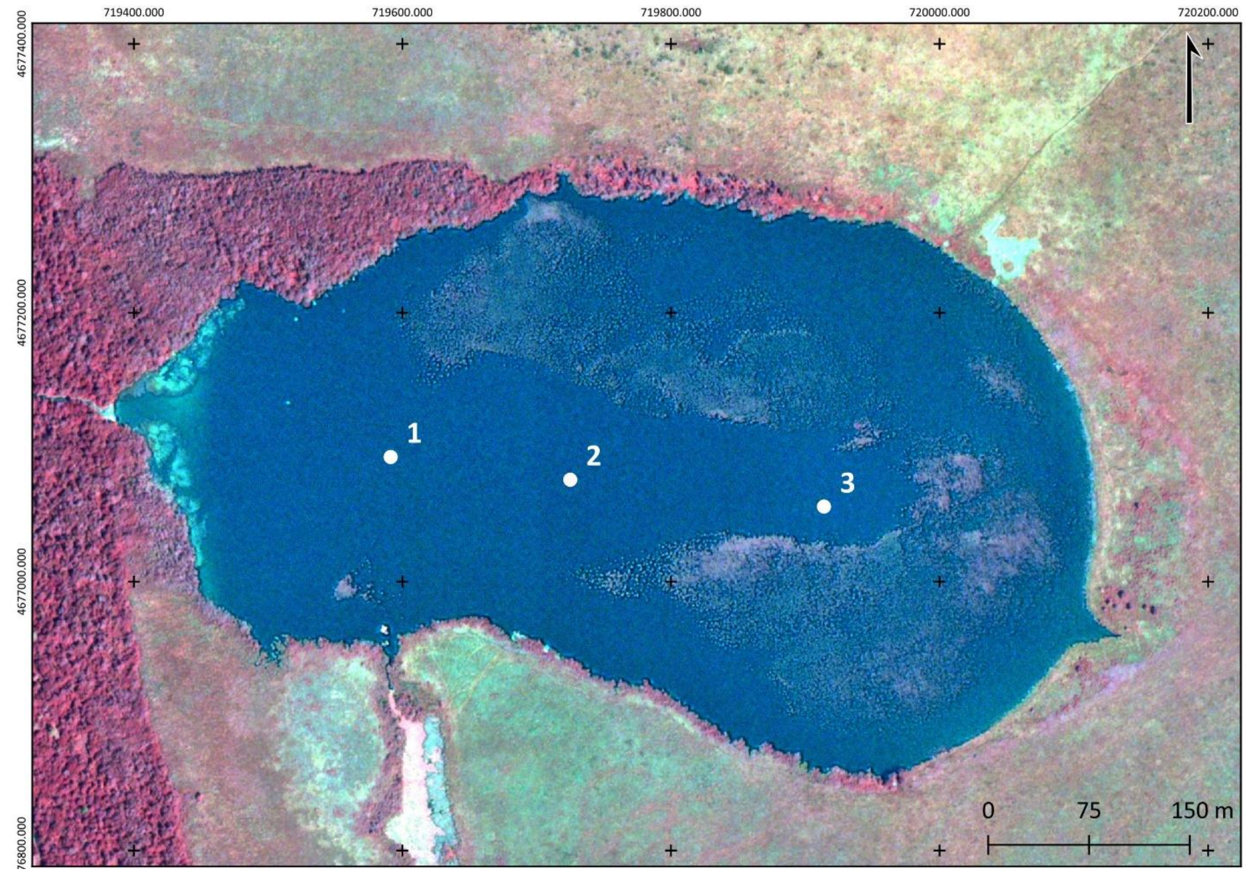


Fig. 2. A very high resolution image of Lake Partotskali in the infrared range VW-2 (22_08_2016). Sampling points are marked on the map.

The threshold values of quality for chlorophyll-a concentration were compared with the report (decision) published by the European Commission in 2008 "establishing the values of the Member State monitoring system classifications as a result of the intercalibration exercise" (EC 2008). According to this document, the average chlorophyll a concentration of the lake surface corresponds to the high ecological status. See Table 2.

Chlorophyll a concentration mg/m³		**Type of water body**
Best – Good threshold values	Good - average threshold values	Lowlands, shallow, humic (LN8a)
7.0 — 10.0	10.5 — 15.0	

Table 2. Ecological range of chlorophyll a concentration in lakes according to the 2008 European Commission Resolution (EC 2008).

Distribution of water vegetation

Lake Partotskali is represented by water plants, in particular by the population of water-chestnut, the coverage of which varies from year to year. We have analyzed monthly images of 5 years to determine the dynamics of the distribution of aquatic plants. During the last 5 years, the maximum area of water-chestnut was 9.8 hectares, which was recorded in 2017, and the minimum area was recorded in 2019 and was represented by 1.7 hectares. (see Fig. 3)

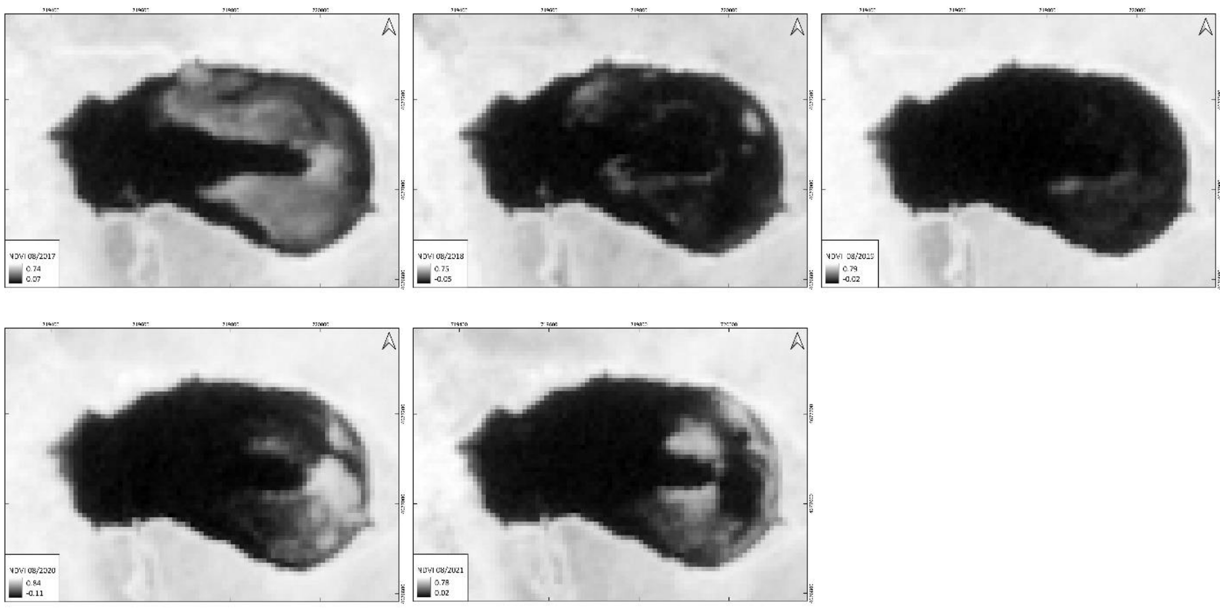


Fig. 3. The figure shows the variation of August (vegetation peak) NDVI values over time from 2017 to 2021. (Years change from left to right)

According to the multi-year series of NDVI-Normalized Difference Vegetation Index generated from satellite images and then averaged, the active phase of the water-chestnut vegetation period lasts for 4 months (June, July, August and September), with the peak of vegetation spread in the water body in August. (See Fig. 4 and 5)

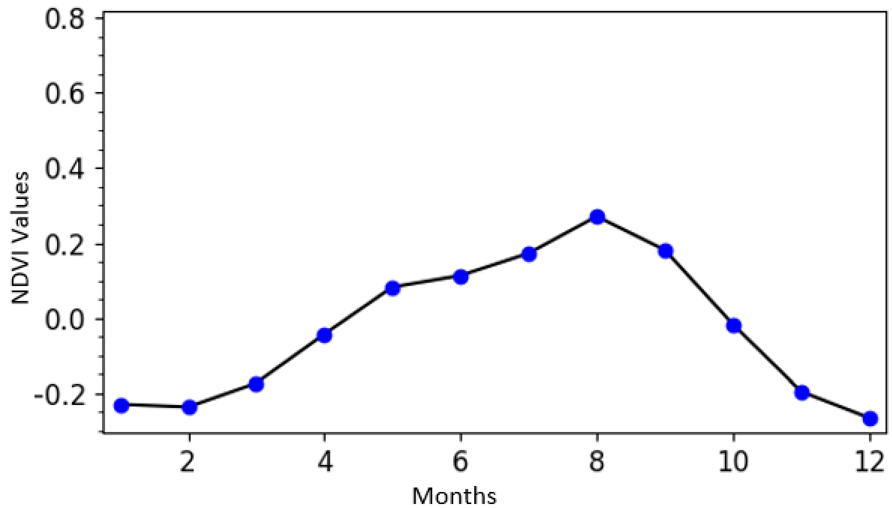


Fig. 4. Graph shows averaged NDVI values by month for 2017-2021. NDVI values above 0 indicate the intensity of water plant vegetation.

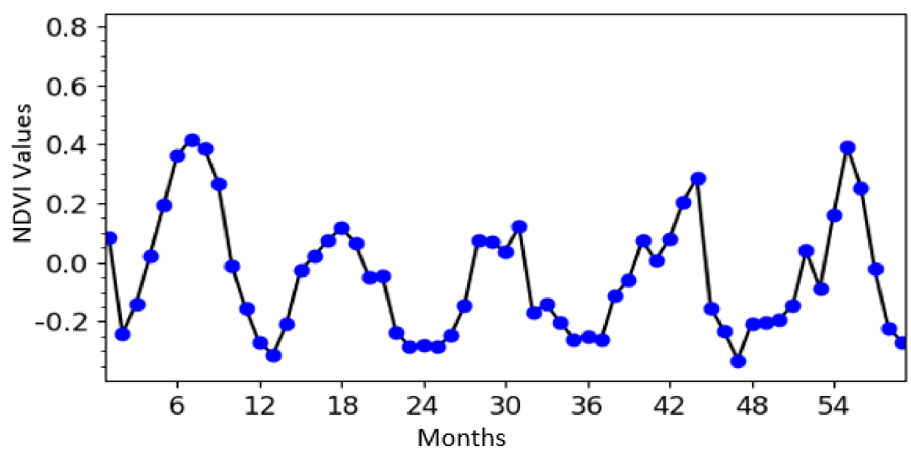


Fig. 5. Graph shows the changes in NDVI values by month in 2017-2021. NDVI values above 0 indicate the intensity of water plant vegetation. The values of the winter months are below 0, which indicates the absence of plants in the reservoir at that time.

Lake Partotskali is a complex ecosystem where the hydrological regime, nutrient cycling, and water plant dynamics are closely interrelated. For example, the concentration of chlorophyll a, which indirectly reflects the amount of nutrients, is variable in the lake, both from month to year and from year to year. For example, during the summer months, when the vegetative activity of floating plants is high, the concentration of chlorophyll a in the water decreases dramatically, which can be explained by the lack of nutrients and the competition between algae and aquatic vegetation. (See Fig. 6.)

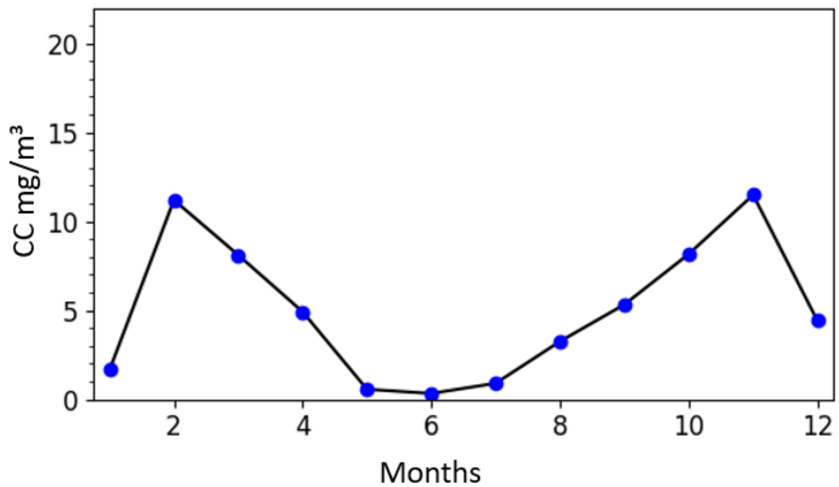


Fig. 6. Changes in the averaged chlorophyll a concentration by month in 2017-2021.

The amount of chlorophyll concentration varies from year to year, which must depend on climatic conditions, namely temperature and precipitation. During high temperatures, the decomposition process of the surrounding peatlands is intensified and this leads to the influx of additional nutrients into the lake, which promotes the spread of aquatic plants. Thus, Lake Partotskali is a complex ecosystem where aquatic organisms are highly dependent on the annual turnover of nutrients, which is a key factor in the healthy functioning of the lake ecosystem. Despite the complex dynamics of nutrients, the upper limit of the concentration of chlorophyll a depending on it does not deviate from the norms established by the European Union, which indicates only natural origin of nutrients.

Verification of field work and results

For the verification of the research conducted through remote sensing, field trips were conducted, during which the vegetation and water quality of the lake were evaluated. Among floating plants, only Nuphar lutea, *Egeria densa* and *Trapa natans* were described. The area of yellow water-lily *(Nuphar lutea*) has not changed compared to the area determined from the satellite images of previous years, and its habitat does not run over the area of the old (defunct) channel entering the lake. Egeria (*Egeria densa*) was observed in abundance in shallow areas, where the water level was up to several centimeters. In 2022, the population of water-chestnut has almost not developed. During field verification, only single specimens were observed, which is also confirmed by the Sentinel-2 image taken on the same day (see Fig. 7).

Water samples were also taken from Lake Partotskali, which were further processed in the laboratory to determine the concentration of chlorophyll a in it. Chlorophyll was determined using OCEAN INSIDE spectrophotometer at Ilia State University. The lake was sampled at 2 points, 20 meters from the bank and in the center of the lake (see Table 3).

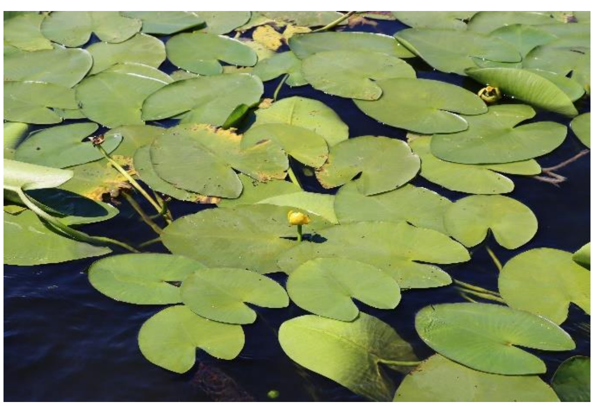
Chemical composition	***Near shore***	***Central part***
Crl a/580 nm ზე	*4.52 mg* $m^{\wedge-3}$	*2.37 mg* $m^{\wedge-3}$

Table 3. Concentration of chlorophyll a in Lake Partotskali

The chlorophyll concentration obtained from satellite images at the same time (11.09.22) is smaller than that measured in the laboratory and ranged from 0.3 to 7.6 mg/m^3 (see Figure 4).

Chlorophyll concentration in mg/m^3			
Minimum	*Maximum*	*Average*	*Standard deviation*
0.3	*7.6*	*1.7*	*1.4*

In our opinion, the difference in chlorophyll concentration between field measurements and satellite data is due to instrument calibration, which requires further research and increased sampling.



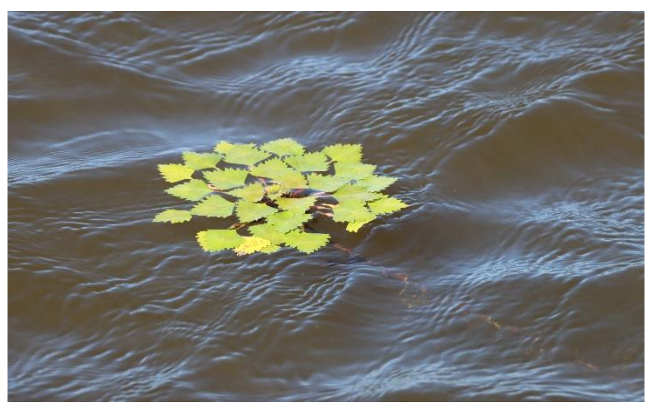


Fig. 7 Lake Partotskali and floating vegetation (Nuphar lutea and Trapa natans)

Conclusion

Assessing water ecosystems and assigning them reference status for ecological and environmental measures is an important issue because intact and untouched ecosystems are increasingly rare in our environment. The restoration and sustainable management of damaged ecosystems require reference ecosystems to be identified and described so that comparisons can be made with the damaged environment and restoration measures can be planned.

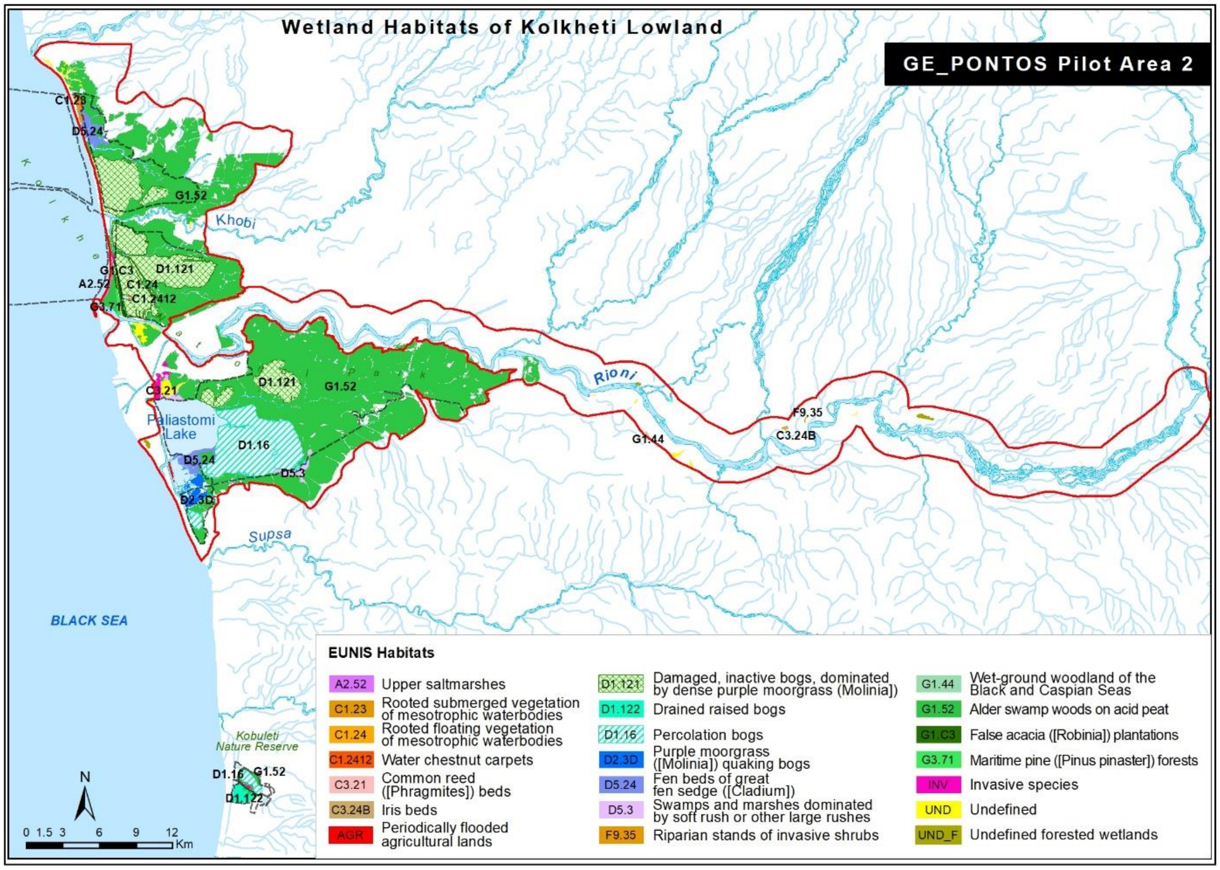
In our opinion, Lake Partotskali is one such system that has maintained a good ecological status. Multispectral Sentinel-2 monthly images from 2017 to 2021 were used to assess the lake and its vegetation. Using remote sensing technology, the concentration of chlorophyll a in water was estimated, which is an ecological indicator of the lake status. The average values of chlorophyll a concentration were compared to the standard established by the European Union for similar humic type water bodies, where the concentration of chlorophyll a was defined as "best - good" (7.0 - 10.0 mg/m^3).

As part of our study, we also determined the relationship between the intensity of water vegetation in the lake and the concentration of chlorophyll a. For five years, this interrelationship is stable, which proves the health of the given ecosystem and the absence of negative impacts. In the end, it can be said that Lake Partotskali is a natural water body without anthropogenic influences, with a healthy ecosystem, which can be assigned a reference status.

This report may be useful for those environmental organizations and government structures whose goal is to achieve good status and sustainable management for similar ecosystems.

The present study may be useful for those environmental organizations and government structures whose goal is to achieve good status and sustainable management for similar ecosystems. The study may also be used as a technical guide for hydrological facilities and basin management planners guided by EU Framework Directives or other environmental guidelines.

Annex 1. The map of wetland Habitats of Ge-PONTOS pilot area



Annex 2: List of Vegetation of Lake Partotskali

The highlighted species are recorded during the fieldwork carried out by the project. Other vegetation species described by (Machutadze 2022).

Emergent plants:

1. *Phragmites australis (Cav.) Trin. ex Steud.*
2. *Typha angustifolia L.*
3. *Juncus acutus L.*
4. *Lysimachia vulgaris L*
5. *Acorus calamus L*
6. *Scirpus tabernaemontani C.C.Gmel.*
7. *Sagittaria sagittifolia*

Submerged plants:

8. Egeria densa Planch.
9. Potamogeton pectinatus L.
10. Ceratophyllum demersum L.
11. Utricularia minor L.

Floating-leaved plants:

1. *Spirodela polyrrhiza (L.) Schleid.*
2. *Hydrocharis morsus-ranae L.*
3. *Trapa colchica Albov (Unresolved)*
4. *Trapa natans L.*
5. *Nuphar lutea (L.) Sm.*
6. *Nymphaea colchica (Woronow ex Grossh.) Kem. -Nath (Unresolved)*
7. *Potamogeton natans L.*

Trees:

1. *Alnus glutinosa (L.) Gaertn.*
2. *Hippophae rhamnoides L.*
3. *Ficus carica L.*
4. *Salix caprea L.*

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