

ECOSYSTEM SERVICES IN POMORIE LAGOON

Baseline survey



PROJECT LIFE19 NAT/BG/000804

CONSERVATION OF POMORIE LAKE COASTAL LAGOON

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БЪЛГАРСКА ФОНДАЦИЯ
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ЖИВОТ ЗА
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Introduction

An ecosystem is defined as an interacting system of biota and its associated physical environment. Ecosystem services can be defined as such if they produce benefits and values for human well-being. Ecosystem services are not hypothetical benefits associated with a given intervention; they are concrete benefits as perceived by the stakeholders.

The biota and physical structures of ecosystems provide a wide variety of marketable goods. These can be defined as provisioning services of the ecosystem and normally it is easy to assign a market value to them, since they are tradable. Additionally, society is increasingly recognizing the myriad life support functions that ecosystems provide and without which human civilizations could not thrive. These include water purification, recharging of groundwater, nutrient recycling, decomposition of wastes, regulation of climate, and maintenance of biodiversity. Derived from the physical, biological, and chemical processes in natural ecosystems, these functions are seldom experienced directly by users. These services are classified as regulating. Another type of service that ecosystems provide is the cultural services. These often include an intrinsic value - the value that exists independently, it reflects the value of something for its own sake. If people do not use the ecosystem, not even for recreation, study or contemplation, this value still remains. E.g. the very existence of cultural heritage, charismatic species and wild places contains value even if nobody uses them. These are very difficult to quantify economically. If we refer to the anthropocentric valuation, then it is rather the cost of protecting human right to know that these places/species exist. Because it is difficult to measure such values, they are often given zero in monetary terms and likely not accounted for in decision making.¹

While the structure of an ecosystem is relatively easy to describe, the adequate understanding of the link between the structure and function of natural systems and the goods and services derived by it, is sometimes difficult to prove. Ecosystem functions are often difficult to infer from observed structure in natural systems and we often lack comprehensive understanding of the behavior of aquatic systems. Therefore, sometimes decision on whether an ecosystem function exists or not cannot be taken without comprehensive research. For the purposes of the current report the data come from the lake monitoring. Collecting data to study particular functions of the ecosystem in depth is research and goes beyond the scope of the project. Therefore, the current assessment might be incomplete or lack the necessary robustness.

Method

Geographic scope of the assessment

Pomorie Lake covers an area of 850 ha and is located 2 km north of Pomorie. It runs parallel to the Black Sea coast, from which it is separated by low sandy stripe with a length of about 7 km and a width of 100-200 m. The level of Lake Pomorie is on average 0.6-0.7 m lower than the level of the sea. Evaporation from the lake exceeds 3-4 times the natural inflow of water. The inflow of water is regulated through an artificial canal with a sluice, connecting the southern part of the lake with the Black Sea. Additional sea water comes through infiltration underneath the sand stripe. The main part of Lake Pomorie is free of vegetation. Part of the lake has been turned into salt pans, where about 6,000 tons of sea salt are extracted annually.

Natura 2000 site "Pomorie" includes agricultural and marine areas, which make up around half of its territory. Only the ES services of the coastal lagoon habitat that will be affected by the project activities are the subject of the current study, meaning that marine and agricultural areas are excluded. Still, when we assess the coastal lagoon habitat, it is meant that this is the focus of the work but it is not possible,

¹ National Research Council 2005. Valuing Ecosystem Services: Toward Better Environmental Decision-Making. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11139>.

or appropriate to delineate clear spatial boundaries between aquatic and related terrestrial systems, especially in a dynamic system such as coastal lake. The fact that ecosystem services tend to be specific to locations and situations, also makes it difficult to develop generic principles or identify generic characteristics.

Purpose of the assessment

One of the policy objectives to be achieved by the LIFE projects is to improve the condition of ecosystems that are relevant to their area of intervention so as to increase their capacity to deliver ecosystem services. All LIFE Nature and Biodiversity projects financed since 2011 are requested to include assessment of the project's impact on ecosystems and their services. The purpose is to explain better to the public and stakeholders the multiple benefits of LIFE projects in connection to society and the economy. The current assessment uses the general framework of Mapping and Assessing Ecosystems and their Services (MAES) as proposed for LIFE projects. In MAES concept, ecosystems need to be in good condition to provide multiple ecosystem services. The term condition embraces e.g. conservation status under the Birds and Habitats Directives, ecological status under the Water Framework Directive. The purpose of the current report is to set a baseline for environmental conditions, and value the services they deliver to society. Another assessment shall be done shortly before the end of the project and thus establish trend and detect changes in the ecosystems delivered from the project activities. MAES uses the Common International Classification of Ecosystem Services (CICES). The latter builds on existing ecosystem services classifications and is based on a five-level hierarchical structure articulated around sections, divisions, groups, classes and class types. Additionally there is a distinction between biotic and abiotic services. Sections reflect the three broad groups of services: (i) provisioning, (ii) regulating & maintenance, and (iii) cultural. In the current study, due to lack of detailed data on the ecosystem functions it was difficult to separate biotic and abiotic factors, especially in case they provided the same service, e.g. nitrogen transformation and removal. We attempted to work on "class" scale of CICES but turned out to be difficult because of the lack of detail of the input information. Therefore, it was decided to work with the "group" level of CICES.

The project team and external experts started listing all the potential ES of the lake, taking into account the CICES classes. All classes were discussed as potential services provided by Pomorie lake. Then the following questions were asked:

- Is this ecosystem service relevant in the context of my project. Since similar valuation was not done before and the impact of the project could go beyond the assumed boundaries, we decided to include the maximum services relating to Pomorie coastal lagoon. Later in the report, the project impact will be separated from the additional external factors, not linked to the project activities but having influence on ecosystem conditions,
- Is there any indicator available to measure this ecosystem service and do I have the means/capacity/resources to measure it?

To select the indicators, a number of publications were reviewed for possible indicators to be used in the valuation, such as MAES 5th report, MAES cards on marine ecosystems, TESSA Toolkit, Valdez et. Al, 2013. When selecting indicators, the measurement/the quantification method had to be selected as well. There is no recommendation of quantification methods in the MAES, so they were selected based on the local conditions, and already used methods for collection of data. Interviews were conducted with stakeholders using the lake services in order to verify how and to what extent they were used. ²

1 Provisioning services

Provisioning services are tangible goods that can be extracted from nature. These are e.g. biomass for materials (plants and animals used for fibers, salt, water), nutrition (plants and animals used for food, fungi, bacteria salt, other minerals) and energy – wood, oil, water, solar energy, etc. Usually, provisioning ES have a non-linear relationship with the ecosystem status. A moderate use of ecosystem services is

² Camacho-Valdez, V., Ruiz-Luna, A., Ghermandi, A., Nunes, P. Valuation of ecosystem services provided by coastal wetlands in northwest Mexico. *Ocean and coastal management*, (2013), 1-11, 78

positively related to ecosystem condition but intensive use of provisioning ecosystem services has mostly negative impact and might cause ecosystem degradation. Such is the overuse of fish or any other native species. In the current case, as we work with already modified ecosystem, the extraction of salt does not have negative impact independent on the amount. Moreover, salt production cycle maintains the ecosystems as they function today.

1.1 Non-aqueous natural abiotic ecosystem outputs

1.1.1 Mineral substances used for nutrition, materials or energy

Production of table iodized salt and technical salt

The Pomorie Salinas use traditional salt production method - evaporation of sea water in an extensive basin system. The salt produced can be used for technical purposes or as table salt. To be used as table salt, the technical salt undergoes additional processing. In the last 5 years only technical salt was produced in Pomorie. The traditional way of salt production requires a lot of manual labour and therefore employment of more workers than would be necessary if the collection was fully mechanized.

Indicator	Data collection method	Information source	Economic valuation
Technical salt produced in t/year (average value for the last 5 years)	Inquiry	Pomorie Salinas	Market price of the salt, BGN/t
Number of people employed in the salt production sector (average value for the last 5 years)	Inquiry	Pomorie Salinas	The costs for the country budget for social compensations of unemployed people

The mean technical salt production for the period 2017 – 2020 is **5280.27 t** per year or **6.1 t/ha/year**. Year 2021 had no salt production due to the inflow of fresh water and low salt concentration of the lake. It is therefore not taken into account in the mean value. The mean price per year based on the cost for production is **59 BGN/t** or the total costs for the production of 21121.1 t of salt per year is 301850.32 BGN or 351 BGN/ha.

For the same period, the mean market price of the salt (mainly from Egypt), was 35 BGN, i.e., 24 BGN cheaper. This means that economically the salt production from Pomorie lake is non-profitable business and could not make economic sense without special arrangements, like preferential prices or subsidies.

The information about the employees is either missing or the workers are not employed within Pomorie Salinas.

Lye and mineral-organic deposits (mud)

In 2007 Pomorie was declared the capital of spa tourism. Mud therapy in Pomorie is unique because the mud used for the spa procedures is freshly extracted and with the most active healing properties. Pomorie is also preferred location for tourists and real estate investors due to the possibility to combine balneotherapy with a sea holiday. The healing mud has a complex effect on the peripheral nervous system. It has a positive effect on the pain, swelling, and scars vanishing by improving the exchange and regeneration processes. The skin health can also be improved due to supply of calcium, iodine and phosphorous.

The healing mud from Pomorie lake is used in three ways:

- 1) Free-access spots. There are 3 free-access spots in 3 different locations at the lake where people can use the resource unrestrictedly. This use is not regulated and is not supervised by

medical professionals. At one place wooden platforms are provided by the local municipality that can be used free of charge.

- 2) The second way to use the mud is in specialized sanatoriums and hotels. They collect mud and lye and use it for specialized procedures at their facilities. The accommodation capacity of these places is limited; therefore, some people use accommodations in the town and visit the facilities only for the procedures.
- 3) Due to their positive effect on human health and beauty, the mud is also used in cosmetics.

Indicator	Data collection method	Information source	Economic valuation
Nr of visitors to the free-access mud pans	Collected with cameras and on the site counting by volunteers;		The entrance fee applied at Atanasovsko lake (transferred value)
Number of procedures in the specialized facilities per year (5 years mean)	Inquiry	Healing facilities managers	Price per procedure.
M ³ of healing mud collected per year (5 years mean)	Inquiry	Healing facilities managers, Black sea Salinas and cosmetic companies. (Since all the mud collected is used for procedures and cosmetics, this indicator only supplements the other relevant indicators)	Price per kg and liter. Avoid double counting.
Number of people employed in the mud healing sector per year (5 years mean)	Inquiry	Healing facilities managers	
Labeled products (soap, toothpaste, cosmetics) nr produced /year	Inquiry	BAS https://seastarsshop.bg/ Anchialo healing cosmetics	Price per product and amount produced per year
Jobs created in the production of Pomorie labeled products	Inquiry	BAS https://seastarsshop.bg/ Anchialo healing cosmetics www.luga.bg	

Only the first two indicators from table 2 could be supplied with data. The visitors of the free mud access points were counted at one of the three points in a period of one month when the conditions of the mud are the best. The mean number of users per day, at weekends, is 117 people and during week days 110 people. The difference is small enough to assume that in this period there are no people coming to the area only for the weekends, they are either local people or tourists at longer holidays that use the mud during the whole week. The number is higher in the beginning of the period with trend going down towards the second half of September. If we extrapolate this number to the other two points of free access, the total number of visitors for a period of 30 days at the three points is **10 080**. If we use transfer value of 2 BGN, that is charged at the Atanasovsko lake, that equals **20160 BGN** worth services, having in mind that almost no costs are involved in providing the service.

In Pomorie town there are 48 hotels and 3669 private accommodations, which total number of overnights per season 234 392. Initially, in order to find out how much mud has been extracted and used by

specialized facilities, we inquired information, referring to National Act for Information Access, about the exploitation amounts in the lake, as well as the mud chemo-physical properties. The Ministry of Health issued a decision that this information is public and should be provided but the "Specialized Hospitals for Rehabilitation - National Complex" LTD refused to do so. Thus, we do not know how much mud has been extracted, except for one of the five specialized places.

Currently the following specialized facilities for healing procedures with products from Pomorie lake are operating:

- **Specialized Hospitals for Rehabilitation-Pomorie³**

The hospital has 150 beds, indoor pool, balneology, fitness center, sauna, doctor's offices, beauty center. The methods of treatment include: mud therapy - mud applications, mud baths, vaginal and rectal tampons, Egyptian method (mud mud treatment in the open); physiotherapy; compresses and inhalations with lye; kinesitherapy; massages (dry and underwater); acupuncture; laser therapy; dietary nutritionкапацитет.

Prices pp/per night is 67 BGN⁴. The price includes comprehensive health service - medical care prescribed by the rehabilitation team depending on the disease, medical nutrition, accommodation. This service can also be financed by the National Health Fund as financial aid for prevention and rehabilitation.

From statistical data of the Pomorie municipality, seasonal employment in the tourism sector is 45% and the bed occupancy rate 65%. Minimum tourist tax that the owners and managers pay to the municipality is 30% of the full yearly occupancy. The size of the tourist tax is defined by the municipality and for Pomorie it is 1 BGN. Thus, we can calculate the minimum and average income for the municipality from the tourist tax in the hotels.

30% of the full capacity of 150 bed * 365 = 54 750, 30% = **16 425 BGN**

65% of the full capacity = **35 587.5 BGN**

- **Grand Hotel Pomorie**

The hotel is located in the northeastern part of Pomorie between the shores of the Salt Lake Pomorie and the Black Sea. It is a combination of a hotel complex, a medical - rehabilitation and wellness center, a football stadium and a sports hall. It has 70 rooms with one bed, 80 rooms with two beds, 4 rooms adapted for people with disabilities, 19 apartments and 2 presidential apartments. According to the hotel administration, the rooms are occupied almost 100% throughout the year.

Mud is extracted every day and transported by pipes to a storage place. The mud volume per day is 2 m³ (water : mud=1:2), or 4 t. 4 т. This amount is enough for 70 mud procedures per day during summer months and half of this amount in winter season. The price per procedure is 25 BGN. Additionally, the price per double room is – 63.5 BGN per person.

70 procedures x 180 days x 25 BGN = 315 000 BGN

35 procedures – 157 500 BGN

The municipality income from tourist taxes is **113150 BGN**.

- **Hospital for balneology rehabilitation and prophylaxis "St. Georgi Pobedonosets (military sanatorium)**

Mud treatment of the following diseases is performed: musculoskeletal system, peripheral and central nervous system, urogenital system, of the skin, metabolic diseases, etc. The hospital provides

³ <http://nkrehabilitation.bg/filiali/pomorie/>

⁴ http://nkrehabilitation.bg/wp-content/uploads/2019/03/price_list_12_182.pdf

comprehensive treatment with Pomorie healing mud, alkali therapy, a wide range of physiotherapy procedures, kinesitherapy, bodybuilding and body treatment, inhalation therapy, laser therapy, underwater jet massage, manual massage, etc. The price per person per night is 30 BGN, additionally a health procedure costs 50 BGN⁵

With 140 beds, the municipality income from tourist taxes is at 30% and 65% occupancy **15 300 and 33216 BGN.**

- **St. George Spa Hotel (four stars)**

The hotel has 1 apartment, 3 studios, 16 deluxe, 70 double and 8 single rooms. The spa uses quality local products - Pomorie healing mud, lye, sea water, mud applications and mud bath. The price per person including accommodations and mud procedures is 75 BGN.

With 190 beds, the municipality income from tourist taxes is at 30% and 65% **20 805 and 45 077.5 BGN**

The above facilities are listed in the development plan of Pomorie municipality. Additionally, according to an internet search, one more hotel offers mud procedures and this is

- **Hotel St. Pavel and Peter⁶**

Package "HEALTH - MUD, LYE and SALT includes: 2 physiotherapy per day from the following: Partial mud application, Alkali treatment, Inhalation in a salt room. The prices for the health package are not listed on the site, the price pp/pn in a double room is 81 BGN.

With 75 beds, the municipality income from tourist taxes is at 30% and 65% **8 212.5 and 17 793.75 BGN.**

It is obvious that the healing mud from Pomorie lake attracts a number of tourists. None of these facilities uses lye from Pomorie lake, instead it comes from Atanasovsko lake. The reason for this in the last year was the null salt production season. Other reasons were not studied. Tourists using mud procedures are not only the guests of the mentioned facilities but also tourists that have their accommodations in private houses and other hotels. Therefore, the image of Pomorie as balneology center is highly important in order to maintain occupancy rate of the available accommodations. Proper functioning of the lake including the mud generation, only possible with salt production, is therefore the existence base of minimum the five specialized facilities and the image of the town. Moreover, the health effect on the people receiving procedures contributes to their well-being and reduces sick leaves, a benefit that we cannot calculate with the data available.

Regarding the third group of indicators, we interviewed the two companies, that produce cosmetics using mud and lye, namely Azimut 6000 and Institute of general and inorganic chemistry to the Bulgarian Academy of Sciences. Both do not use any products from the lake. The manager of Azimut 6000 claims that the mud contains heavy metals that are a result of flooding in a mine nearby that polluted the lake around 20 years ago. This information is currently being verified by the project team.

1.2 Biomass

1.2.1 Wild plants (terrestrial and aquatic) for nutrition, materials or energy

There is illegal reed collection from the lake in very small amounts. This indicator was not checked since no official way exists to collect reed and therefore it cannot be counted as a service.

1.2.2 Wild animals (terrestrial and aquatic) for nutrition, materials or energy

Food provision from the lake

Four fish species from fam. *Mugilidae* occur in the Black sea. *Mugil cephalus*, *Chelon auratus*, *Chelon salien* u *Liza haematocheilus*. These benthic fish species populations is decreasing according to the

⁵ <https://www.vita-pomorie.com/images/paketi1.pdf>

⁶ <https://www.hotelpetarpavel.com/tzeni-i-oferti/tzeni-lyato-paket-zdrave>

data of the catch size. Their catching is legal only in the canal but in the rest of the lake it is illegal. With the indicators below we can only estimate approximately the amount of illegal catch that was detected.

Indicator	Data collection method	Information source	Economic valuation
Proxy indicator - number of nets	Inquiry	Executive agency for fishing and aquaculture	Market price per kg, catch per year
Proxy indicator - number of signals for illegal fishing	Inquiry	Executive agency for fishing and aquaculture	

These indicators were not checked due to illegal nature of the activity.

Artemia salina, has no big value since the collection is very sporadic, collectors use it only for personal needs. Therefore, data about its use will not be of sufficient quality.

Polychaeta worms (*Nereis sp.*) used as fish baits

Indicator	Data collection method	Information source	Economic valuation
Worms sold in the local shops kg/year		Hunting and fishing shops in Pomorie	Price/kg

From interviews with Hunting and fishing shops, worms are not collected in Pomories lake. There is only one place in the country where the worm is collected and it is Varna Lake. Additionally, the shops sell worm baits imported from China.

2 Regulating services

2.1 Transformation of biochemical or physical inputs to ecosystems

2.1.1 Mediation of wastes or toxic substances of anthropogenic origin by living processes and non-living processes

Purification of the water coming from agricultural runoff in the canal

Agricultural fields in the watershed of Pomorie lake are likely pollution source with fertilizers and pesticides. The run-off water from the fields would enter the canal built to prevent freshwater flow into the lake. There are two reasons that can lead to run-off water entering the lake. Solid materials from the fields could sediment and accumulate at the bottom of the canal which reduces its conveying function with a potential to cause overflow. The second reason could be a compromised canal integrity. Along with bringing in pollutants to the lake, the freshwater reduces the salinity of the lake water and makes the salt production less efficient as well as reduces the quality and quantity of the mud and lye. That is why maintaining the canal is important for the salt production as well as for preventing contaminants entering the lake.

The two major types of contaminants are the fertilizers bringing N and P, as well as the pesticides. Pesticides are usually highly soluble in water. Their active chemical is accompanied by additives – wetting agents, solvents, adhesives, etc. During their degradation different chemical are formed each with specific toxicity. Organochlorine, organophosphates, carbamate pesticides are the most popular ones. In the current study there were no resources to analyze samples for pesticides.

Both abiotic and biotic processes take place in the water cleaning. The particulate contaminants might sediment if the flow velocity is low enough and they are of settleable size. Adsorption of P to soil and sediments particles as well as carbon decomposing bacteria will assimilate C and N as part of their metabolism functions. Denitrification is also likely to take place in a water that has anoxic conditions.

In the lake area water purification can be more intensive than in the canal due to the oxygen coming through the plant roots and the filtering role of the vegetation roots and stems. The vegetation can trap particles, sequestering toxicants in the sediment. Aerobic microbiological processes are faster than anaerobic one and can lead to better removal of nitrogen and carbon-containing compounds. The benefit from project activity regarding canal cleaning will prevent freshwater entering the lake thus increased efficiency of the salt production and increased amount of salt produced per ha, as well as improved quantity and quality of the mud and lye, the latter being dependent on the lake water salinity. On the other hand, purification of the water in the canal and the lake itself prevents eutrophication that would otherwise compromise the salt production and could endanger local flora and fauna. To study the removal efficiency of the pollutants arriving to the canal from outside we measured the concentration of P and N in a points in the canal and 4 points in different lake basins as shown on the figure below.



Figure 1. Monitoring points

Indicator	Data collection method	Information source	Economic valuation
Removal of N, P, mg/l	5 points, 4 times per season.	Self-collected samples and samples from the Regional environmental inspectorate regular monitoring	Replacement cost method (costs for the technical treatment of waters)

The flow of the water in 2021 was taking the following path PL Channel – PL3 – PL5- PL1 – PL2. The concentrations of ammonium, nitrate and orthophosphates were measured and efficiency of removal of these compounds calculated.

Table 1 Concentrations of nutrient elements at the monitoring points

Point	Points sequence along the water flow	NO ₃ – N, mg/l	NH ₄ -N, mg/l	PO ₄ -P, mg/l
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PL 1	4	0.21	0.03	0.10
PL 2	5	0.28	0.04	0.09
PL 5	3	<0.02	0.29	0.34
PL Channel	1	<0.02	0.40	0.46
PL 3	2	<0.02	0.58	<0.07

The results show that the first 3 points have high level of ammonium and low nitrates, while the two points at the end of the water path have very low concentrations of ammonium and increased concentrations of nitrates. That is a clear sign that the water in the channel receives pollution from the surrounding land, perhaps agriculture, in the form of ammonium from the fertilizer ammonium nitrate. On its way, the ammonium is oxidized to nitrites and nitrates. That is why at the two end points nitrates are higher. This is a sign that transformation of N species is going on and the lake acts as a water treatment facility. It still should be noted that ammonium and orthophosphates concentrations define the lagoon conditions as unsatisfactory and bad. To find if the process of denitrification takes place, we need to have denser network of points. With the current data is not possible to establish if this process takes place.

The same logic we see in PO₄-P concentrations. It is much higher in the beginning of the water path and gets reduced at the end. The only exception is PL3, which is too low and with the current data it cannot be explained.

The removal efficiency of the wetland was calculated by subtracting the outflow concentration of the parameter from its inflow concentration and dividing the result to the inflow concentration. To express it as a percentage it is multiplied by 100

$$R (\%) = (C_{in} - C_{out})/C_{in} * 100, \%$$

Between the first and the last point, PL Channel and PL2, the removal or rather transformation of the ammonium is 89.3% and the removal of PO₄-P is 81%.

2.2 Regulation of physical, chemical, biological conditions

2.2.1 Water conditions and maintenance of physical, chemical, abiotic conditions

The macrophyte *Rupia maritima* is widely distributed in the Pomorie lake basins. According to Ahmadi et al. (2017)⁷, the species efficiently removes organic matter, N and P from the water column. It improves the water quality and the conditions for other living creatures. The species also regulates the temperature, improves the oxygen concentration, and provides better nursery conditions for fish larvae.

Indicator	Data collection method	Information source	Economic valuation
Area of the <i>R. maritima</i> measured at the end of the growing season	Measured as area (ha) and BB scale	Self-collected	Replacement cost method (costs for technical treatment of waters)
Oxygen saturation, %	Samples	Self-collected samples	
Salinity, ‰	Samples	Self-collected samples	

⁷ Ahmadi, M., Sakib, H., Takdastana, A., Dinarvandc, M., Jorfia, S., Ramavandi, B. Advanced treatment of saline municipal wastewater by *Ruppia maritima*: A data set Data in Brief 13 (2017) 545–549

According to Braun-Blanquet method, *R. maritima* covers 0, 23 ha/ 4aBB.

In 2021, oxygen saturation was monitored on a monthly basis at all monitoring points. In L7 / L8, hypoxia (saturation below 50%) is observed periodically - in the bypass channel, due to anaerobic decay processes, and in the other points - due to algae blooms. In L9 and especially L10 in the summer levels above 200% saturation are observed during the day. Both values indicate unfavourable conditions regarding this parameter. This indicates increased eutrophication processes in the waters, caused by impaired circulation, as well as the load of sediment and inflowing waters with nitrogen and phosphorus pollutants. These factors cause massive algae blooms in these parts of the habitat, especially green microalgae, which produce high amounts of oxygen during the day, which is expended by breathing at night. Dissolved oxygen readings of greater than 100% air saturation can occur in environmental water because of the production of pure oxygen by photosynthetically-active organisms and/or because of non-ideal equilibration of dissolved oxygen between the water and the air above it. All this speaks of certain problems related to water circulation and pollution from inflowing surface water.

In 2021 the salts did not reach the critical technological crystallization concentration. The Crystallizers were left empty and the water from previous season was mixed in there with rain water which led to salinity lower than 70‰. In 2021 the precipitation was 44.4% higher than mean for the previous 6 years and additional fresh water was coming from the lake watershed. The lake technological infrastructure was not maintained; therefore, the water level of the different basins was more or less equal and this prevented the gravitational flow. Average salinity is this 30% lower than the one that allows proper functioning of the lake.

2.2.2 Regulation of baseline flows and extreme events

The town of Pomorie is the most affected tourist place by marine floods, as each of the registered sea floods has caused damage of over BGN 100 thousand. The city has an outdated concept for the protection of the sea coast. According to the assessment of floods risk by the Black Sea River Basin administration significant risk for Pomorie town comes only from the marine floods (Fig. 2). There were 5 sea floods in the last 20 years, the latest one from 2010 as each of them caused damages for more than 50 000 euros. The reason is the low coast from north and south and the high number of residential and resort houses located in the low area. The relief of the watershed with lack of steep slopes and high percentage of agricultural lands create conditions for slow run-off, retention and reduced wave height. Historically there was one significant river flood from Acheloy river in the northern part of the municipality but there is no future risk from river floods predicted in the analysis.

There are seasonal and inter-annual fluctuations of the lake level. They depend on the efficiency of the two drainage canals to convey fresh water from the lake watershed, the precipitation and other climate and management factors that define the water level of the lake. The flood storage capacity of a wetland is the difference between the potential maximum volume of water stored in the wetland and the average low water levels.

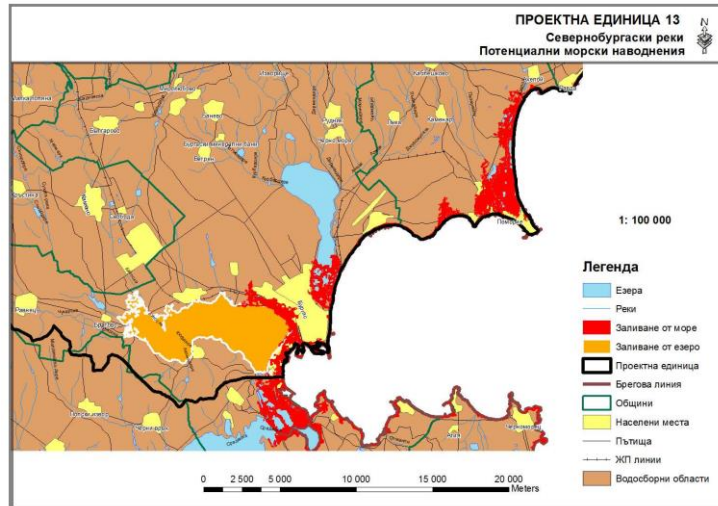


Figure 2. Areas flooded by marine floods, red colour

The canal linking the sea to the lake has a lower than the sea level of -0.4 m and 1.21 m height of the side walls. The slope is 1.4‰ in direction sea – canal. The canal sea – lake can potentially convey part of the high waves water into the lake. The floodwater storage depends on the maximum amount that the lake can store and the initial water level at the flood event. The maximum interannual sea level increase is 80 cm.

The rivers in the Black Sea River basin 50-70% of the rain precipitations fall in autumn and winter. This overlaps with the period of strongest winds that cause the marine floods. That means the level of the lake would be higher in winter due to precipitation levels and would be able to take less water. However, the technological process of salt production favours low winter lake levels for better salt production.

Indicator	Data collection method	Information source	Economic valuation
Amount of water that can be accumulated by the lake basins, m ³ /ha/year	Aerial images; Satellite images; Lake levels and conditions (wind speed, sea level) for potential flood risks	Google Earth Hydrology and hydraulic report. Flood reports.	Avoided damage costs, replacement costs

In 2021 the average water depth of the lake was 2/3 higher. It is not expected that the lake would have any flood attenuation effects as long as it is not properly managed and the water level is maintained lower. The disturbed hydrological regime affects negatively also the are available for birds breeding.

2.3 Lifecycle maintenance, habitat and gene pool protection

2.3.1 Maintaining nursery populations and habitats (Including gene pool protection)

Pomorie lake provides breeding habitat, migratory, and wintering habitat for waterfowl, reptiles, insects, etc. some of which are rare and endangered.

Indicator	Data collection method	Information source	Economic valuation
Habitat quality and habitat extent ha	The baseline data is taken from the Natura 2000 mapping project. Habitat types 1150, 1530, 1310	Mapping and determination of the favourable conservation status of natural habitats and species (past project)	-

Two of the habitats are in favourable status, 1310 Fv, 1530 Fv. The overall assessment of habitat coastal lagoon 1150* is bad (U2). The following parameters contribute to this value – minimum depth, oxygen saturation, pollution, changes in the hydrological regime.

3 Cultural services

3.1 Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting

3.1.1 Physical and experiential interactions with natural environment

Coastal and inland wetlands are areas of great diversity and beauty that provide open space for recreation and visual enjoyment.

Indicator	Data collection method	Information source	Economic valuation
Number of nuances of the basin colours; number of salt pyramids;	Satellite images, photos – aerial, on ground	Google Earth	
Number of photos posted		Photo fora	
Nr of joggers, walkers	Strava application	On the spot counting, applications like Strava	
Number of animal groups with aesthetic importance	Dragonflies, Charadrius sp, sterna, flamingo, pelicans, swans, harriers, pied avocet	Visitors questionnaire	

The number of people using the dyke for walking and cycling, The joggers registered is 193 and 243 in each direction. For the cyclists these numbers are 310 and 454. The period is however not defined, so it is since the application exists.

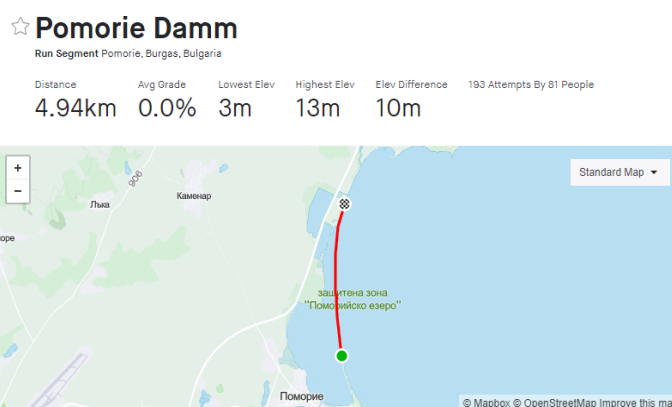


Figure 3. Section of the Pomorie SPA used most often by joggers and cyclists, Strava app

3.1.2 Intellectual and representative interactions with natural environment

Scientific investigations and creation of traditional knowledge, enable education and training

Indicator	Data collection method	Information source	Economic valuation
Nr of visitors of the museum and the visitor center per year	Inquiry	Salt museum, Visitors center	Ticket price
Scientific literature, lectures, classes etc. with research and education purposes	Research	Internet media, libraries	-
Videos, recordings, books, articles, reportages, social media inputs, stories, etc. with entertainment purposes	Research	Internet media, libraries	-

The museum in Pomorie is the only specialized museum in Bulgaria and in Eastern Europe for the production of salt by solar evaporation of sea water. The goals of the museum is to promote and preserve the intangible cultural heritage of ancient Anhialo. The museum presents the ancient Anhialo technology for sea salt production. It consists of an exhibition hall and 20 dka of operating salt pans. The Salt Museum is included in the 100 national tourist sites, souvenir brochures and more are offered.

For the last five years the average number of visitors 13525, excluding 2020, which is not representative, only half of the usual number of people visited dues to lockdowns and restrictions. The entrance fee is 3 BGN for adults and 2 for children or for one year the total amount collected from visitors' fee is **33 812.5 BGN**. The graph below shows the cumulative number of visitors within each year. The total visitors number is increasing every year until 2018 to 16 000 per year. There is discrepancy between the graph and the numbers provided by the project team for 2018, the latter being 2000 visitors fewer. For 2019 the number is close to the one in 2017 – almost 15 000, while the number in 2021 is still below the average, showing the effects of the pandemic fading away but not complete recovery.



Figure 4. Cumulative map of visitors to the Salt Museum

The visitor center is located on the south side of the lake, next to the Salt Museum. It has a rich exposition, comprehensively presenting its biodiversity. From the terrace, rare species of birds in their natural environment, how they feed, dance their wedding dances, nest and raise their young near the center building can be observe with optical devices. The average number of visitors is 2448, again excluding 2020. In 2021 this number is still lower than the average.

The average number of volunteers participating in annual camp with nature conservation activities is 21.4, as there is no particular trend.

Information about the other two indicators was not collected.

3.1.3 Spiritual, symbolic and other interactions with natural environment

Existence values

Indicator	Data collection method	Information source	Economic valuation
Number of endemic species, priority or species in the categories: VU, CE, EN	Research	IUCN Red list, scientific literature	-
Via Pontica – number of species using the place as stopover site			-

The lake hosts 91 species are of European conservation concern (SPEC) (BirdLife International, 2004). Rare and threatened **birds**, such as Pygmy Cormorant (*Microcarbo pygmeus*), White-headed Duck (*Oxyura leucocephala*), Red-breasted Goose (*Branta ruficollis*), Dalmatian Pelican (*Pelecanus crispus*), Ferruginous Duck (*Aythya nyroca*), Sandwich Tern (*Thalasseus sandvicensis*), Avocet (*Recurvirostra avosetta*), etc, White-headed Duck (*Oxyura leucocephala*), Red-breasted Goose (*Branta ruficollis*), Dalmatian Pelican (*Pelecanus crispus*), Ferruginous Duck (*Aythya nyroca*), Sandwich Tern (*Thalasseus sandvicensis*), Avocet (*Recurvirostra avosetta*), etc.

The area of the lake and the adjacent territories harbour a total of 17 **amphibian and reptile** species, many of which are rare and globally threatened, such as Spur-thighed Tortoise (*Testudo graeca*), Hermann's Tortoise (*Testudo hermanni*), European Pond Terrapin (*Emys orbicularis*), Fire-bellied Toad (*Bombina orientalis*), Balkan Green Lizard (*Lacerta trilineata*), Balkan Wall Lizard (*Podarcis taurica*), Southern Crested Newt (*Triturus karelinii*), etc.

Eleven **vascular plants** species are subject to protection under the Biological Diversity Act and seven are listed in the Red Data Book of Bulgaria as endangered and critically endangered species: Sea Bindweed (*Calystegia soldanella*) - EN, *Centaurea gracilentia* - EN, *Stachys maritima* - EN, *Eryngium maritimum* - EN, *Trachomitum venetum* - EN, *Petrosimonia brachiata* - CR, *Suaeda heterophylla* - CR. The sand strip separating the lake from the sea is notable for the sand dunes and the specific vegetation (*Euphorbia peplis*, *Eryngium maritimum*, *Ammophila arenaria*, *Trachomitum venetum*, etc.). The sand dunes around the lake hold Bulgaria's most significant population of the threatened *Trachomitum venetum* listed in Bulgarian Red Data book as endangered (EN).

Among **invertebrates** endemic invertebrates include midges *Chironomus anchialicus* Michailova, 1974 and *Chironomus valkanovi* Michailova, 1974; benthic nematode *Syringolaimus caspersi* Gerlach, 1951; hetroptera *Orthotylus (Melanotrichus) josifovi* Wagner, 1959; copepod *Nitokra fallaciosa* Klie, 1937. Dark Spreadwing (*Lestes macrostigma*) dragonfly is Critically Endangered in Bulgaria and Endangered in Europe being closely associated to saltmarsh bulrush (*Bolboschoenus maritimus*).

Mammals found at the site include 31 species. Among these are the smallest European mammal – the Pygmy White-toothed shrew (*Suncus etruscus*); IUCN listed (NT) Eurasian otter (*Lutra lutra*).

Via Pontica

During migration the lake is important staging and stopover site for many *Charadriiformes*: Dunlin (*Calidris alpina*) – around 500-800 ind., Black-tailed Godwit (*Limosa limosa*) – around 700 ind., Little Stint (*Calidris minuta*) – around 1500 ind., Curlew sandpiper (*Calidris ferruginea*) and *Laridae* – Little Gull (*Larus minutus*) more than 2000 ind., Slender-billed gull (*Larus genei*) around 100-200 ind. And Mediterranean gull (*Larus melanocapthalus*) around 1000-2000 ind and globally threatened species like Common Pochard (*Aythya ferina*) - IUCN listed as VU and White-headed duck (*Oxyura leucocephala*) - IUCN listed as EN, etc.

In recent years due to disrupted hydrological regime and increased freshwater inflow numbers of waders have gone down while wintering waterfowl has increased.