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# Rankings of Shorelines of Georgian Black Sea Sector According to the Ecological Sensitivity Index (ESI)

*By Nino Gelashvili*, Nino Machitadze±, Vakhtang Gvakharia°, Guram Maisuradze & Giorgi Beridze•*

*Georgia is concidered as one of the best alternative transit countries connecting Asia and Europe. The transportation of oil and oil products from the Caspian and Central Asian regions to European countries is especially significant. This boosts the country's economy, but it also increases the risk of marine environment pollution from oil hydrocarbons. In response to the risk of oil hydrocarbon pollution, it is necessary to intensify preventive monitoring efforts. This includes assessing the extent of oil hydrocarbon contamination on shores, in coastal waters, and in bottom sediments, as well as identifying and classifying areas along the coastline that are most sensitive to pollution. The division of shorelines into sensitive areas is carried out according to the ecological sensitivity index ESI, wich contains a numeric or alpha-numeric coded description of the shoreline characteristics for each shoreline segment. According to the 10 levels of sesitivity against oil pollution, the shoreline segments are classified from "low" sensitivity ESI 1 to "very high" sensitivity ESI 10, respectively 10 main classes and up to 30 sub-classes are identified. In Georgia coastal area, for the 113 km section from Ganmukhuri to Sarpi, we have identified shoreline segments with 7 main classes and 9 sub-classes of sensitivity.*

**Keywords:** *Black sea, Georgia, oil, sensitivity, rankings , pollution*

## Introduction

Geographical location and geopolitical situation of Georgia make it a crucial transit corridor between Asian and European countries. With the growing of volume of oil and oil products transportation from the Caspian and the Central Asian regions to Europe, there is significant international interest in the development of Georgia's transport infrastructure. Oil pipelines and transshipment terminals for oil and oil products are being built and are operational in Georgia. While this development strengthens the country's economy, it also increases the risk of pollution of marine environment with oil and oil hydrocarbons.

In response to the risks of petroleum hydrocarbon pollution, there is a need to intensify preventive monitoring studies. The monitoring activities includes assessing the pollution level of the alongshores, the coastal waters and the bottom sediments with petroleum hydrocarbons. Identifying and classifying pollution-sensitive areas

*Senior Scientist, Al. Janelidze Institute of Geology of I. Javakhishvili Tbilisi State University, Georgia.
±Senior Scientist, Al. Janelidze Institute of Geology of I. Javakhishvili Tbilisi State University, Georgia.
°Major Scientist, Al. Janelidze Institute of Geology of I. Javakhishvili Tbilisi State University, Georgia.
•Senior Scientist, Al. Janelidze Institute of Geology of I. Javakhishvili Tbilisi State University, Georgia.

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along the coastline permits to assess the potential impact of an oil spill on the coastal environment.

Improving the ecological conditions of the Black sea and effectively protecting the marine environment are national obligations (Association Agreement, 2014, Directive 2008/56/EC; Convention 1992). To prevent the oil pollution of the marine environment and ensure a timely and effective response to spills, Georgia, as a signatory to the international convention OPRC 1990 (International Convention 1990), has developed the "National Plan for Response to Oil Spills at Sea" {On the approval, 2014). The plan outlines the conditions and needs arising from an oil spill in Georgia's harbors or territorial waters. It includes priorities for environmental sensitivity, details the emergency preparedness system, defines the liability and competence of the responsible persons of different level, and discusses the readness measures and actions to be implemented in the event of an oil spill. In addition to the aforementioned issues, assessing the shoreline's vulnerability using the Ecological Sensitivity Index (ESI) is both relevant and practically important tool for environmental protection. The ESI is used to evaluate the potential impact of oil spills on the coastal environment, enabling early prediction of system stability and expected changes due to external impacts. The ESI contains a numeric or alpha-numeric coded description of the shoreline characteristics for each shoreline segment (Petersen et al. 2019).

It is known that oil spilled into the hydrosphere reaches the coastline through currents, wind, and sea waves, leading to pollution. The extent of the negative impact on the coastline depends significantly on the type of coast and the ecological sensitivity of the area (Response strategy 2015). In light of the above, and to refine the sensitivity scale of the shores outlined in the national oil spill response plan, we have conducted a ranking (classification) of the Georgian sector of the Black Sea coastline using the Ecological Sensitivity Index (ESI) scale.

## Study Area and Methodology

The purpose of the research was the ranking of the Georgian Black Sea coastline to assess its sensitivity against oil pollution. In case of an accidental oil spill, the sensitivity of the coastlines is determined by the many factors: relief, landscape category, beach substrate composition and grain size, geomorphological peculiarities of the shores, along-shore transport of the bottom sediments on the submarine slope, diversity and biological productivity of the coastal and marine ecosystems, recreational value of the shorelines, etc. During our research, we identified sensitive areas within the study region and assigned an index using the well used methods and the best practices (Gundlach and Hayes 1978, Petersen et al. 2019, Sensitivity mapping 2012).

According to these methods, the sensitive areas of the coastline are classified on a scale from "low" sensitivity (Class ESI 1) to "very high" sensitivity (Class ESI 10). A total of 10 main classes and up to 30 sub-classes have been identified.

The ranking is based on the shoreline sensitivity, determined by the several factors: shoreline topography, landscape category, beach substrate composition and grain size characteristics, geomorphological features, sediment transport along the

underwater slope, diversity and biological productivity of the coastal ecosystems, existing of the wetlands, the surface water bodies, and recreational value of the coastline.

The Black sea coast of Georgia, located in the eastern part of the sea, stretches for 320 km. The shores are characterized by the diversity of the landscapes and the geological features and have a high recreational value. We evaluated the sensitivity index for the central and southern section of the Georgia coastal zone from Ganmukhuri to Sarpi, which spans approximately 113 kilometers (Figure 1).

**Figure 1.** *The Study Area*

The Georgian coastal zone of the Black sea has an arcuate shape, convex to the east, and is comprised of three morphological units. The central unit is the Kolkheti Lowland, which is formed from the alluvium of the Rioni River and its tributaries (Kolkheti Lowland 1993). Geographically, the southern end of the Kolkheti Lowland is at the confluence of the Natanebi River, while the northern boundary is near Ochamchire. To the east, the plain is bordered by the crystalline massif of Dzhirula and to the west by the sea. It is flanked to the south by the Lesser Caucasus and Eastern Ponto mountain ranges, and to the north by the southern slopes of the Greater Caucasus (Maruashvili1971).

From a morphological perspective, the extreme southern part of the coastal zone, stretching from Cape Gonio to Kobuleti, is highly fragmented. The land relief exhibits significant variation in elevation within a small area, with deep valleys reaching heights of over 100 meters. The Adjara-Trialeti folded system in this region is predominantly composed of volcanic bedrocks, such as basalts, andesites, and tuffs, along with marine and lacustrine sedimentary formations (Kvinikadze et al. 2010).

The coastline has predominantly accumulative type, formed by sediments deposited by rivers over long geological periods. From an energetic perspective, modern lithodynamic processes - such as sediment distribution on the underwater slope and along the shores—are influenced by the sea's wave regime, currents, and gravitational forces (Gaphrindashvili et al. 2018, Zenkovich 1977). Of the total coastline, 96 kilometers (85%) are accumulative type beaches adjacent to dunes, while the ports of Batumi and Poti account for 4.5 kilometers of this length. The remaining 17 kilometers (15%) are characterized by naturally abrasive sections where beaches are absent or are limited to rocky, hard-to-erode intrusive rocks.

The sediment grain size on the beaches of the Georgian coastline ranges widely from 0.05 to 40 mm. The beaches of Kolkheti are predominantly sandy, with an average grain diameter ranging from 0.05 to 2.0 mm. In contrast, Adjara's beaches are pebbly, with an average grain diameter of 10 to 40 mm. Based on sediment grain size, the Georgian coastline is categorized into three main types: the first category includes beaches composed entirely of sandy sediments, with a total length of 43 km; the second category includes sand/shingle beaches, with a length of 30 km; and the third category comprises gravel-shingle beaches, with a length of 23 km. Additionally, in the extreme southern section of the coast near Sarpi, there is a 500-meter stretch of open rocky shores and slopes with boulders.

Among the land areas adjacent to the coastline that exhibit high ecological sensitivity and are vulnerable to pollution from oil spills, Kolkheti National Park stands out. This protected wetland area is hydrologically linked to the sea environment, including Paliastom Lake, Nabada, and Churia wetlands. Kolkheti National Park is recognized as one of the 36 biodiversity hotspots globally. The adjacent Black sea coastal aquifer features a shelf that extends an average of 6-8 km from the coastline, with wave heights ranging from 3 to 6 meters (Devidze et al. 2020). The relict swamps of Kolkheti host plant species that are now found only in the tundra and taiga wetland ecosystems of the Far North.

The territories of Kolkheti National Park are of great botanical interest. The park preserves phytocoenoses with rich assemblages of relict and endemic species, showcasing a diverse floristic composition across various plant groups, including those from swamps, marshy forests, and sandy dunes along the sea coast.

Kolkheti National Park is inhabited by 194 bird species, and many birds use the park as part of their annual migration routes: in autumn, they travel from north to south, and in spring, they move from warmer regions to their nesting sites. For some species, Kolkheti serves as a wintering area, eliminating the need for further southward migration. The park's ichthyofauna includes 88 fish species: 23 migratory, 21 freshwater, and 44 Black sea species [Assessment, 2019].

In the central part of the Kolkheti Lowlend's wetland area lies Paliastomi Lake, a unique reservoir with a surface area of 18.2 km². The lake has a maximum depth of 3.2 meters and an average depth of 2.6 meters. Located near the seashore, it is 0.3 meters below sea level. The Pichori River flows into the lake, while the Kaparchina River drains it. The Maltakva River connects the lake with the sea.

Until 1924, Paliastomi Lake was a freshwater body, sustained by atmospheric precipitation and supporting a diverse freshwater micro- and macrofauna and flora. However, after a channel was cut from the southwestern shore to the sea, the lake

became directly connected to the ocean. Over time, storm impacts widened the channel, allowing sea water to flow into the lake with little obstruction. This salinization led to significant changes in the species composition of the lake's unique fauna and flora. Despite these changes, the lake and its surroundings remain a unique ecosystem, serving as an important wintering site for migratory birds. It is also a key component of Kolkheti National Park and a notable tourist attraction.

The wetland area of Kolkheti National Park is of international significance and is protected under the Ramsar Convention (Convention on Wetlands, 1971). Its regulation and management are governed by Georgian legislation (Law of Georgia 1998/2023).

## Results and Discussion

On the study area, the division of shorelines into the segments with the different level of sensitivity against oil pollution is given according to the ecological sensitivity index classes and sub-classes.

## Class ESI 1

The Sub-class ESI 1A Exposed rocky shores and the Sub-class ESI 1C Exposed rocky cliffs with boulder talus base can be found in the extreme southern part of the coast of Georgia - in the vicinity of Sarpi. Taking into account wave and tidal effects, they belong to high-energy banks that directly follow the shoreline. Under the influence of prevailing winds, these shores are affected by wave action, resulting in reflected waves that carry pollution away from the shores. At the same time, the treated beach substrate is coarse-grained and easily freed from pollution. Therefore, the ecological sensitivity of these banks is low. In case of oil pollution, they will be discharged into the sea. The degree of degradation of oil and oil-contaminated waste is also high under the influence of wave disturbance (Figure 2).

**Figure 2.** *Sub-class ESI 1A, 1C*

| Sub-class **ESI 1A** Exposed rocky shores | Sub-class **ESI 1C** Exposed rocky cliffs with boulder talus base |
|---|---|
| | |
| The southernmost section of the coast of Georgia - rocky shores near Sarpi (E 712622.44; N 6600327.50) | |

The Sub-class ESI 1B Exposed, solid man-made structures are abundantly present in the coastal zone and can be found in the vicinity of Tsikhisdziri district, Mtsvane Kontskhi, Rion River, Shekvetili, Ureki, Tskaltsminda River. These areas are characterized by high energy and low sensitivity (Figure 3).

**Figure 3.** *Sub-class ESI 1B*

| Sub-class ESI 1B Exposed, solid man-made structures | |
|---|---|
| | |
| Coastal strip in the vicinity of the Chorokhi River mouth (E 715575.50; N 4610740.87) | Coastal strip in the vicinity of Tsikhisdziri district (E 728554.50; N 4627248.05) |
| | |
| Vicinity of Shekvetili water area (E 728966.15; N 4648338.32) | Ureki, at the Tskaltsminda river mouth (E 728004.82; N 4626630.15) |

## The Classes ESI 3 and ESI 4

The Sub-class ESI 3A Fine- to medium-grained sand beaches and the Sub-class ESI 4 Coarse-grained sand beaches are found north of the Supsa River mouth, including Kulevi and Anaklia. The slight sloping of the beache terrain helps to disperse the wave energy and scatter the waves. The mentioned factor and the relatively high dispersion of the beach-forming material lead to a long period of natural cleaning and, accordingly, an increased sensitivity to pollution (Figure 4).

**Figure 4.** *Sub-class ESI 3A, 4*

| Sub-class ESI 3A Fine- to medium-grained sand beaches | Sub-class ESI 4 Coarse-grained sand beaches |
|---|---|
| | |
| North of the Supsa river mouth, including Kulevi and Anaklia (E 727732.55; N 4655715.46 -E 710323.82; N 4696555.85) sections | |

## The Class ESI 5

The Sub-class ESI 5 Mixed sand and gravel beaches are present in Kobuleti-Shekvetili and Anaklia coastal strip. The shores are characterized by strong dynamism, medium slope, high degree of wave impact. Due to the large dimensions of the substrate, pollution penetrates deep into the sediment layer and fossilized, that is, they are covered with clean sediments. Fossilization is most rapid on pebbly beaches (Figure 5).

**Figure 5.** *Sub-class ESI 5*

| Class ESI 5 Mixed sand and gravel beaches | |
|---|---|
| | |
| Kobuleti-Shekvetili and Anaklia coastal strip (E 7303229.70; N 4633631.20 - E 729319.70; N 4644503.79) sections | |

**The Class ESI 6**

The Sub-class ESI 6A Gravel beaches (granules and pebbles) and ESI 6B Riprap Gravel Beaches (cobblesand boulder) - It can be found in the south and north of the Chorokhi River mouth , from Sarpi to Batumi. Taking into account the large size of the beach sediment grains, as well as the boulders present on the beaches, the probability of oil penetration and fossilization in the depth of the layer is high. Under conditions of moderate or low wave energy, oil can persist for years and hard asphalt can form. Considering this factor as well as the recreational value, the mentioned coastline is highly sensitive to pollution (Figure 6).

**Figure 6.** *Sub-class ESI 6A, 6B*

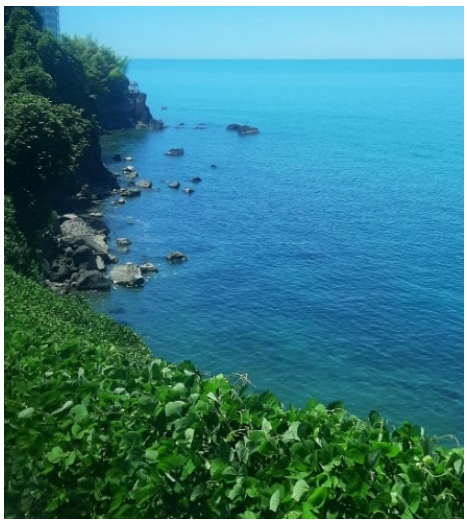
| Sub-class ESI 6 A Gravel beaches (granules and pebbles) | Sub-class ESI 6 B Riprap Gravel Beaches (cobblesand boulder |
|---|---|
| | |
| The southern and northern beaches of the Chorokhi River mouth, from Sarpi to Batumi (E 714477.64; N 4609270.40 - E 719889.43; N 4615146.50 and E 712598.80; N 4600684.55) | |

**The Class ESI 8**

The Sub-class ESI 8A Sheltered scarps in bedrock, mud, or clay Sheltered rocky shores (impermeable**)** can be found in Tsikhisdziri region and in the vicinity of Mtsvane Kontskhi. In these sections sheltered rocky shores occur. Here, due to attenuated wave action, the probability of long-term retention of spilled oil is high. These banks are also covered with dense vegetation. The ecological sensitivity of these areas is high considering the attenuated wave energy as well as the distinguished biodiversity (Figure 7).

**Figure 7.** *Sub-class ESI 8A*

Sub-class 8 A Sheltered scarps in bedrock, mud, or clay Sheltered rocky shores (impermeable)



Tsikhisdziri district and Mtsvane Kontskhi
(E 728801.56; N 4627852.33 და E 728004.82; N 4626630.15)

The Sub-class ESI 8B Sheltered, solid man-made structures, Sheltered rocky shores (permeable) the mentioned category of landscape is represented by port buildings and corresponding infrastructure, which leads to relatively high sensitivity in case of spillage, due to limited water exchange (Figure 8).

**Figure 8.** *Sub-class ESI 8b*

| Sub-class ESI 8B Sheltered, solid man-made structures Sheltered rocky shores (permeable) | |
|---|---|
| | |
| Poti sea port (E 718964.70; N 4670495.09) | Batumi sea port (E 720895.36; N 4614345.5) |
| | |
| Kulevi sea port (E 717337.82; N 4683293.49) | Batumi Coast Guard Marina (E 723088.49; N 4615874.76) |

**Class ESI 10**

The Sub-class ESI 10C Swamps - Swamps are present in the coastal strip of Poti-Anaklia. This section is distinguished by the highest sensitivity: it represents the wetland area of the Kolkheti plain, here there are coastal marshes characterized by a low rate of water exchange and a high indicator of ecological criteria of sensitivity - dense vegetation and a large number of habitats (Figure 9).

**Figure 9.** *Sub-class ESI 10C*

Sub-class ESI 10 C Swamps

Wetlands of Kolkheti plain Poti-Anakli - (E 717139.00; N 4684150.90 - E 713935.17; N 4693363.77) sections

The results of the study showed that taking into account the type of beach, beach substrate and ecological factors in case of the oil spills, the most sensitive area of the Georgian coastline of the Black sea is the wetlands of the Kolkheti plain with a sensitivity index of ESI 10 C (Figure 10). Paliastomi Lake, hydrologically connected to the sea environment, is located in the mentioned area. Carrying out pollution elimination works will be associated with significant difficulties, and it is problematic to predict the results. It should also be taken into account that the mentioned area belongs to the wetland territory of the Kolkheti National Park, which is of International importance and is protected by the Ramsar Convention, and its regulation and management is determined by the legislation of Georgia [17,18].

**Figure 10.** *Paliastomi Lake*

Paliastomi Lake (E 725461.07; N 4666822.81)

Tsikhisdziri district and Mtsvane Kontskhi are also highly sensitive to the impact of an accidental oil spill, with a sensitivity index of ESI 8A. Due to the covered rocky shores and the (attenuated) low rate of wave action in these sections, the

probability of long-term retention of spilled oil is high. These banks are also covered with dense vegetation.

Considering the type of substrate (gravel) and recreational purpose, the Adjara section is also highly sensitive with a sensitivity index of ESI 6A. It should be noted that the shores in this section are highly dynamic, characterized by a medium slope and significant wave impact. Due to the large size of the substrate (pebbles), pollution can penetrate deeply into the sediment layer and become buried, with clean sediments covering them from above. Fossilized oil layers we identified were described during the construction of the Batumi Coast Guard pier (Gelashvili et al. 2020). Our research, both completed and planned, is crucial as it introduces a new risk factor for oil pollution: oil exploration activities in both river basins that flow into the sea and the sea shelf area. Based on our research data, we will prepare Ecological Sensitivity Index (ESI) maps of the coastal zones of Black sea Georgia using geoinformation systems (GIS).

## Conclusions

The results of the study showed us that taking into account the type of beach, beach substrate and ecological factors in case of oil spills, the most sensitive area of the Georgian coastline of the Black sea is the wetlands of the Kolkheti plain with a sensitivity index of ESI 10 C. Paliastomi Lake, hydrologically connected to the sea environment, is located in the mentioned area. Carrying out pollution elimination works will be associated with significant difficulties, and it is problematic to predict the results.

The most sensitive area of the coastline is the wetlands of the Kolkheti Lowland, with a higher sensitivity index ESI 10C. These coastal wetlands are characterized by a low rate of water exchange procrsses and a high ecological sensitivity index due to dense vegetation and a large number of habitats. It should also be taken into account that the mentioned area belongs to the wetland territory of the Kolkheti National Park, which is of International importance and is protected by the Ramsar Convention, and its regulation and management is determined by the legislation of Georgia.

Tsikhisdziri district and Mtsvane Kontskhi are also highly sensitive to the impact of an accidental oil spill, with a sensitivity index of ESI 8A. Due to the covered rocky shores and the (attenuated) low rate of wave action in these sections, the probability of long-term retention of spilled oil is high. These banks are also covered with dense vegetation.

Considering the type of substrate (gravel) and recreational purpose, the Adjara section is also highly sensitive with a sensitivity index of ESI 6A, due to its gravel substrate and recreational use.

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