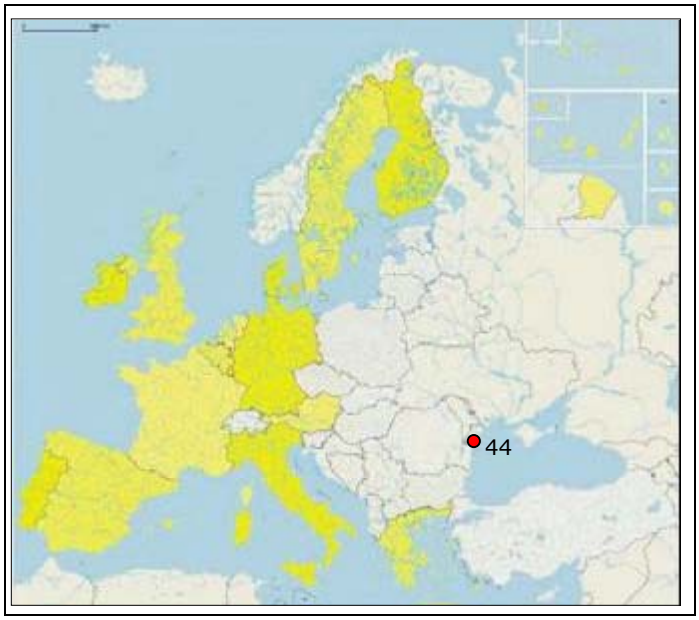
DANUBE DELTA (ROMANIA)



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1. GENERAL DESCRIPTION OF THE AREA

The Danube Delta is located the northern sector of Romania, just on the northwest limit of the Black Sea. Its coastline is almost 240km long, of which about 75km represents the coastline of Kilia Distributary Delta (Ukraine) and 165km comprising the Sulina section, the Sfântu Gheorghe distributary delta and lagoon complex Razim-Sinoie (Romanian territory).

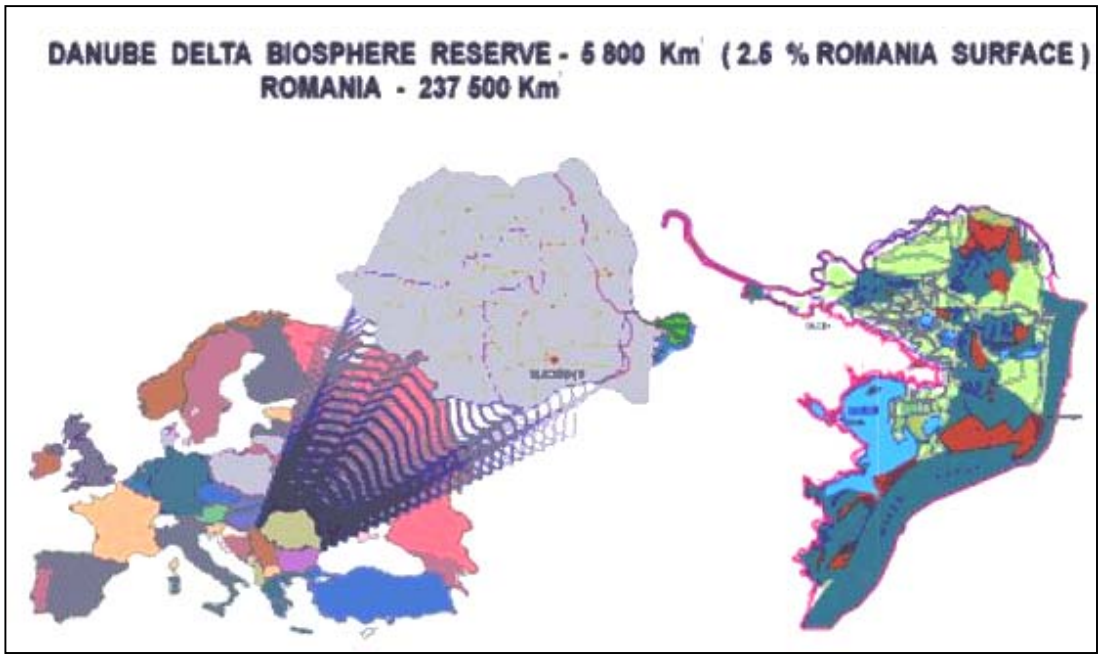


Fig. 1: Location map of the Danube Delta Biosphere Reserve, Tulcea County, Romania.

1.1. Physical process level

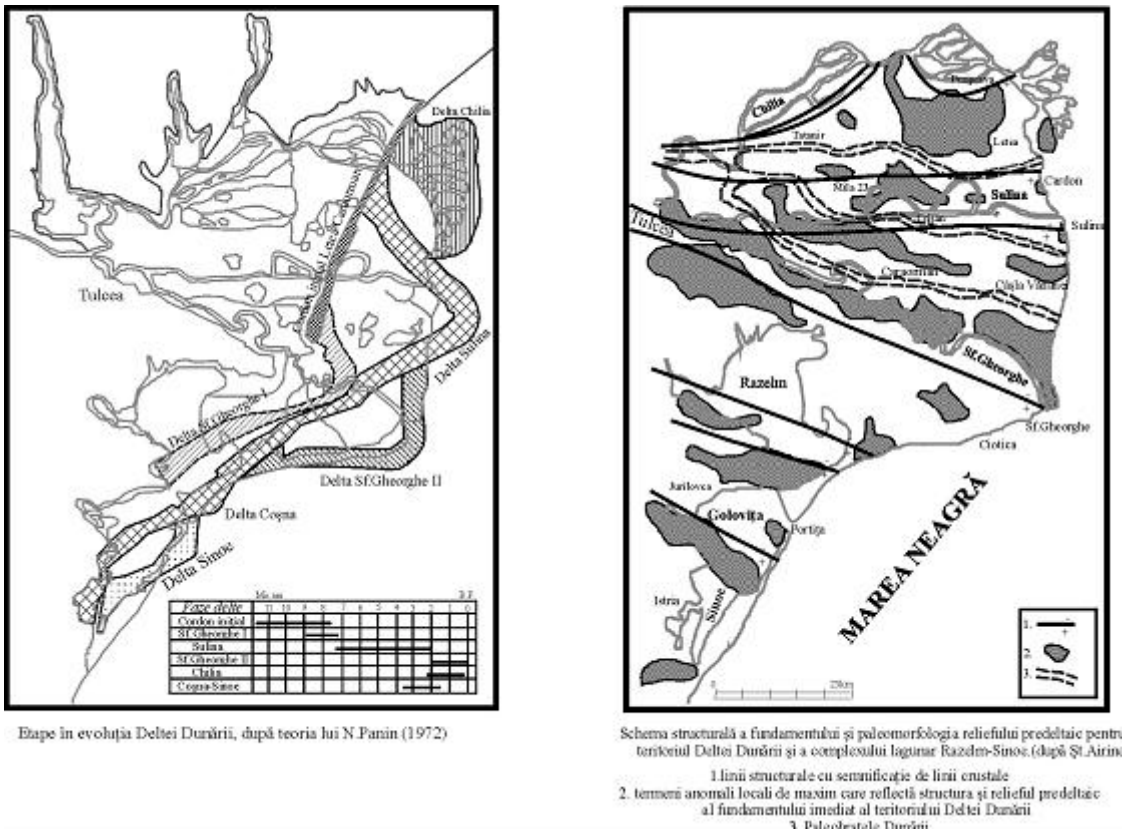
1.1.1 Classification

- General: sandy beach barriers, deltaic origin
- CORINE: beaches
- Coastal guide: delta plain

The Danube Delta consists of a fluvial zone characterised by sandy levees and densely vegetated lakes, a transitional zone, and a marine zone, dominated by dune and barrier beach complexes.

1.1.2 Geology

The deltaic conditions originate from the Quaternary. The oldest deposits in the area belong to Devonian and Silurian and due to their peculiarities belong mainly to the surface layer (see Figure 2). Surface layer deposits were constituted in four sedimentation cycles: Silurian-Carboniferous, Permian-Triassic, Jurassic-Cretaceous and Sarmatian-Romanian. The Quaternary depositions are characterised by red clay followed by a succession of gravels and argillaceous pellites. Deltaic deposits include several lithological complexes.



Etape în evoluţia Deltei Dunării, după teoria lui N.Panin (1972)

Schema structurală a fundamentului şi paleomorfologia reliefului predeltaic pentru teritoriul Deltei Dunării şi a complexului lagunar Razelm-Sinoe.(după Şt.Airin

1.linii structurale cu semnificaţie de linii enstale
2. termeni anomali locali de maxim care reflectă structura şi relieful predeltaic al fundamentului imediat al teritoriului Deltei Dunării

Fig. 2: Stages in the evolution of the Danube Delta.

The deltaic shelf basement is composed of metamorphic, magmatic and sedimentary rocks, belonging to the Northern-Dobrudja orogen. South Capidava-Ovidiu the basement is formed by the Moesian Platform, which consists of green schist, quartz sandstone, fine greywacke. Cretaceous and Palaeocene deposits compose the strata corresponding to the prolongation of the North-Dobrudja orogen. During the Quaternary, the sedimentation process continued, influenced by recurrent sea level oscillations, which emerged the shelf in different degrees.

1.1.3 Morphology

The shore between Sulina and Sfântu Gheorghe is part of the unique delta sector situated between two river branches, The interdistributary shore shows various different forms, generated by different processes. The shore between Ciotica and Periteasca consists of an alternation of dunes ridges (height 0.5-1.0 m) and flat sectors between them. Between Periteasca and Edighiol the shoreline presents more simplified profiles, dunes are absent but well developed washover fans are present. Orientation is given by the direction of the main surges ENE-WSW. Distribution of these processes resulted in a change of the shoreline configuration in the last 150 years, from a quasi-convex, through a longitudinal profile to a linear-concave one. The southern limit of the studied zone is Midia Cape (green schist formation), which is characterized by the presence of Buhaz swamps.

The foreshore has the form of a quasi-horizontal step, dipping slightly seaward, generally with a single ridge, at small depths -0.5 to -1.0m. Significant changes of the foreshore occur during storms, when, with no exception, volume variations are positive. Bars and through

systems are a highly variable, a system with two bars being distinct on the shores Sulina, South of Sfântu Gheorghe, Chituc and many bars, 3 to 5 bars, on the accumulative shore Periteasca and South of Sahalin island. The ridge of the first submerged bar could be found at -0.8 to-1.5m depth, and the secondary one (active during storms) up to -2.5 to - 3.0m (see Figure 3).

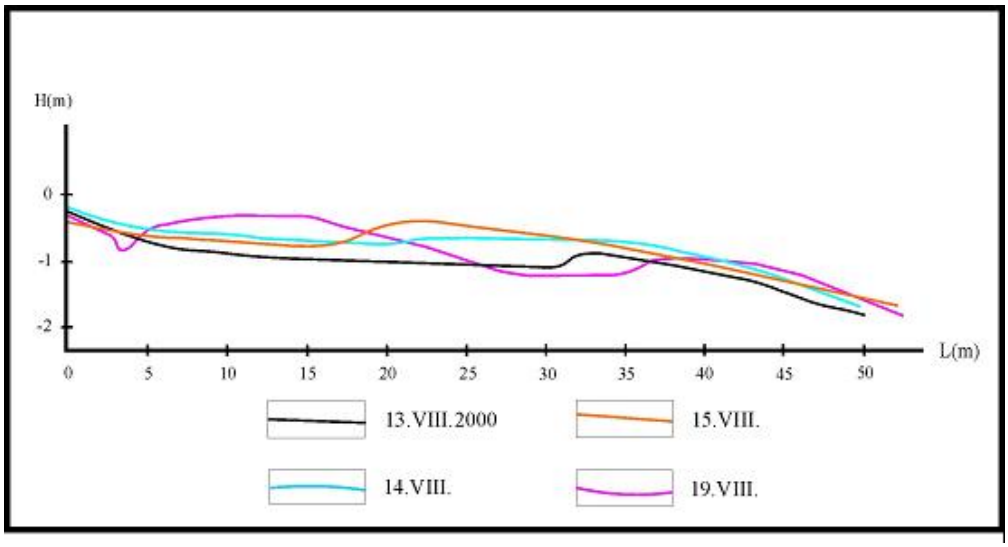


Fig. 3: Bathymetric profile of the Sf. Gheorghe sector.

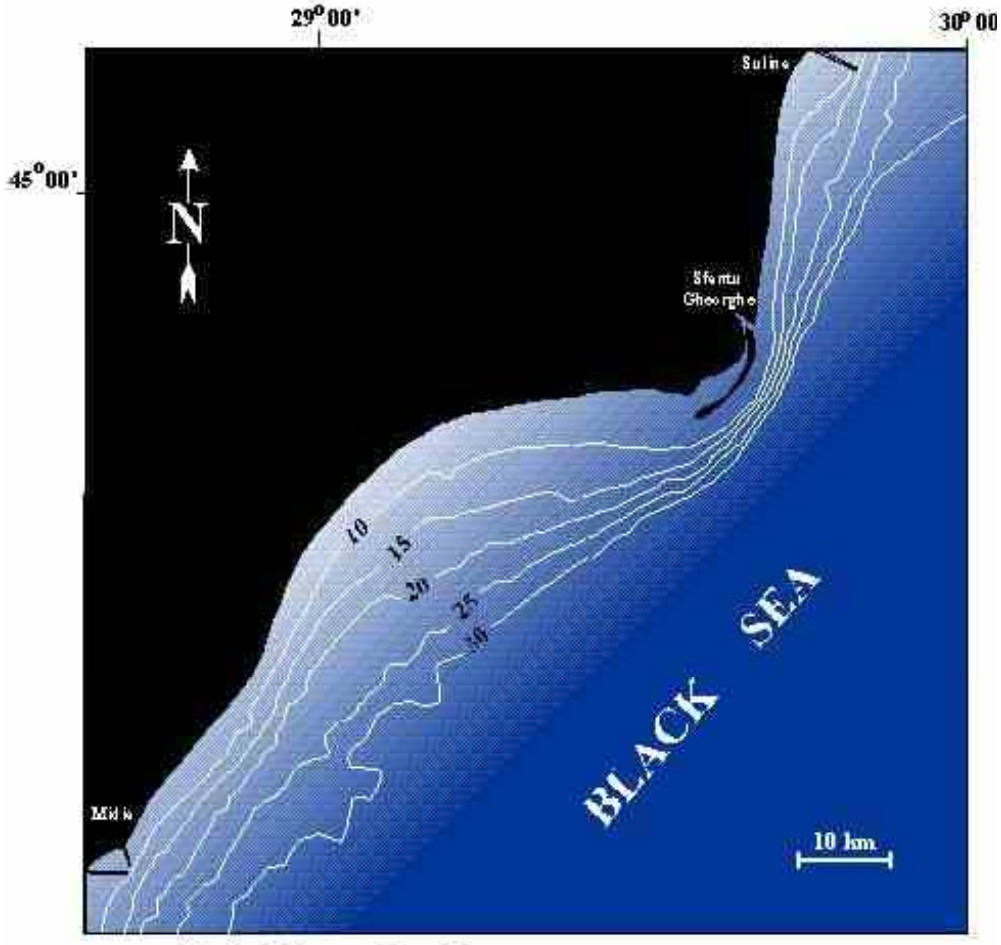


Fig. 4: Nearshore bathymetry of the Danube delta coast.

1.1.4 Physical processes

Wind

Northerly winds are strongly prevalent on the Delta's littoral. A general tendency of the wind to rotate clockwise is noticeable, which pushes western winds into the north sector. The intensity of eolian processes is higher during the warm season when, due to increased temperatures, decreased humidity and nebulosity, intensification of wind at noon, the sand is dried and displaced in significant quantities.

Sea level rise

Wind-induced deformations of the sea surface are important for the present evolution of the deltaic shore. These short-term variations have high amplitudes, are frequent and are generated by the air pressure on sea surface causing the superficial water to follow their direction (wind drift). As a direct consequence, the winds blowing from the sea will push the water masses to the shore leading to maximum sea levels and opposite, winds blowing from the land will push water masses seaward causing minimum sea levels at the shoreline. Sea surface deformations in different zones are influenced by coast orientation and morphology.

The sea level change over the last two centuries have been evaluated by various authors, leading to different interpretations. I. Gh. Miricã considers a 40cm rise in time interval 1880-1961. A. C. Banu points out a 29cm rise since 1856 until 1933. Archaeological data suggest a 20cm rise of the sea level in the last century and O. Selariu indicates +25.95cm/100 years at Constanta and 33.90cm/100 years for Sulina (see Figure 5).

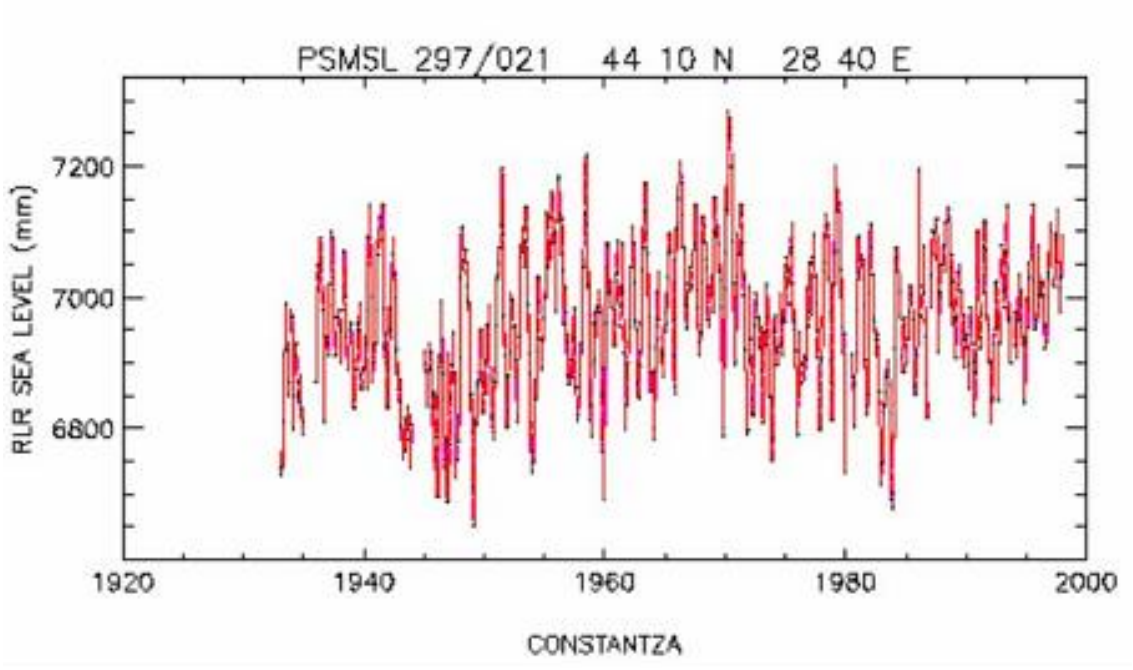


Fig. 5: Sea level oscillation at Constanta station (cf. PSMSL)

1.1.5 Erosion

Erosion type

Hydro-technical works built on the Danube and tributaries have resulted in serious decrease of Danube sediment load with negative consequences on the littoral sediment balance. Since 1858 until 1988 the flow volume increased from 178 to 203 km^3/yr, but the sediment load decreases from 65 millions to 38 millions tones/yr. Prevalent drift direction alongshore is north to south and the quantity of the transport is 1.2 million tones/yr. The longshore transport is controlled by the Sulina jetties (8km long) which are breaking the southward longshore drift (see Figure 6). The Sulina jetties deplete the southern littoral cell of sediment, because the sediment input is by carried offshore, away from the shoreline. Accelerated erosion was recorded between 1962 and 1985, followed by moderate erosion until 2000.

From the total length of Danube Delta Biosphere Reserve littoral, as much as 57% are eroded, 36% are under accretion and 7% shows a relatively constancy. Maximum shore retreating distance was 145m in the case of Sulina - Sf. Gheorghe sector and maximum accretion was of 101m distance near Sulina branch outlet.

Fig. 6: Longshore sediment transport model for Danube delta coast. Rates and sink volumes are given in 10^3 m^3/yr.

Erosion cause

Erosion is caused by the shortage in Danube sediment supply due to hydrotechnical works along the tributaries and the influence of the Sulina distributary jetties. Natural causes are represented by sea level rise (1.3mm/yr) and severe storms effect. Accretion around river mouths is accompanied by intensive erosion processes and accelerated regressive translocation of the deltaic, sandy barriers, was kept responsible for morphological profiles simplification.

1.2 Socio-economic aspects

1.2.1 Population rate

In 1966 a total of 20,421 inhabitants were registered in the zone. After 1966 (particularly after the years 1968–1970) the delta population decreases.

1.2.2 Major functions of the coastal zone

- **Agriculture and forestry**: are the most important land uses. The farmland covers an area of 61,453 ha, of arable land and natural meadows. Since 1975 these areas have been extended and have replaced the humid inundation zones through damming and draining. Forests cover a surface area of 18,800ha, 836.7ha in the Danube meadow, 11,613ha in the fluvial delta and 6,308.4ha in the fluvial maritime-delta. *Breeding* is favoured by the natural and climate conditions. The breeding is completely free during the entire year or protected by some precarious reed curtains during winter. The free stalling in semi-wilderness is still frequent for bovina and horses.
- **Nature conservation:** the Danube Delta was declared a *biosphere reserve* in 1990. It covers an area of 46,403ha. According to the provisions of the Law No. 82/1993 the Danube Delta Biosphere Reserve, as an important national and international ecological zone, consists of the Danube Delta, the Saraturile Murighiol-Plopu, the Razim-Sinoie lagoon complex area, the maritime Danube as far as Cotul Pisicii, the sector Isaccea-Tulcea with its inundation zone, and the Black Sea coast from the Chilia Branch to Cape Midia. The inland marine waters and the territorial sea as far as the -20m isobath are included in the biosphere reserve.
- **Fisheries and aquaculture:** the *fresh water fishing resources* are found in the 170,000-270,000ha of waters in the Danube Delta Biosphere Reserve. 112,000 ha are permanent waters, the remainder can be flooded with varying size and length. The *marine fishing resources* are spread over about 113,000ha of the Black Sea, which are part of the reserve. The level of the fishing resources depends on the intensity of fish migration towards the shore.
- **Industry and Harbours:** since ancient times, the harbours in the Danube are important for the economic activity of Romania. On the territory of the reserve and its conterminous zone are the fluvial-maritime harbours of Sulina and Tulcea .
- **Tourism and recreation:** the Danube Delta can meet various internal and international touristic demands from spring to autumn, owing to its favourable climate as well as to its rich fauna and flora. The touristic potential of the area is large.

1.2.3 Land use

Table 1: Land use In the DDBR.

Total DDBR	**580,000 ha**		**100 %**
I Strictly protected areas	50,600 ha		8.7 %
II Total Buffering zones of which marine buffering zones	223,300 ha	(103,000 ha)	38.5 % (46.1 %)
III Total Economic zones of which agricultural polders	306,100 ha		52.8 %
fish ponds		(43,391 ha)	(14.2 %)
silviculture		(39,567 ha)	(12.9 %)
built-up areas, private and official properties (Act 18/1991)		(6,442 ha)	(2.1 %)
zones proposed for ecological rehabilitation		(27,243 ha)	(8.9)
other uses in free hydrological conditions		(11,425 ha)	(3.7 %)
		(178,032 ha)	(58.2 %)

1.2.4 Assessment at capital at risk

Information on this topic is not available

2. PROBLEM DESCRIPTION

2.1 Eroding sites

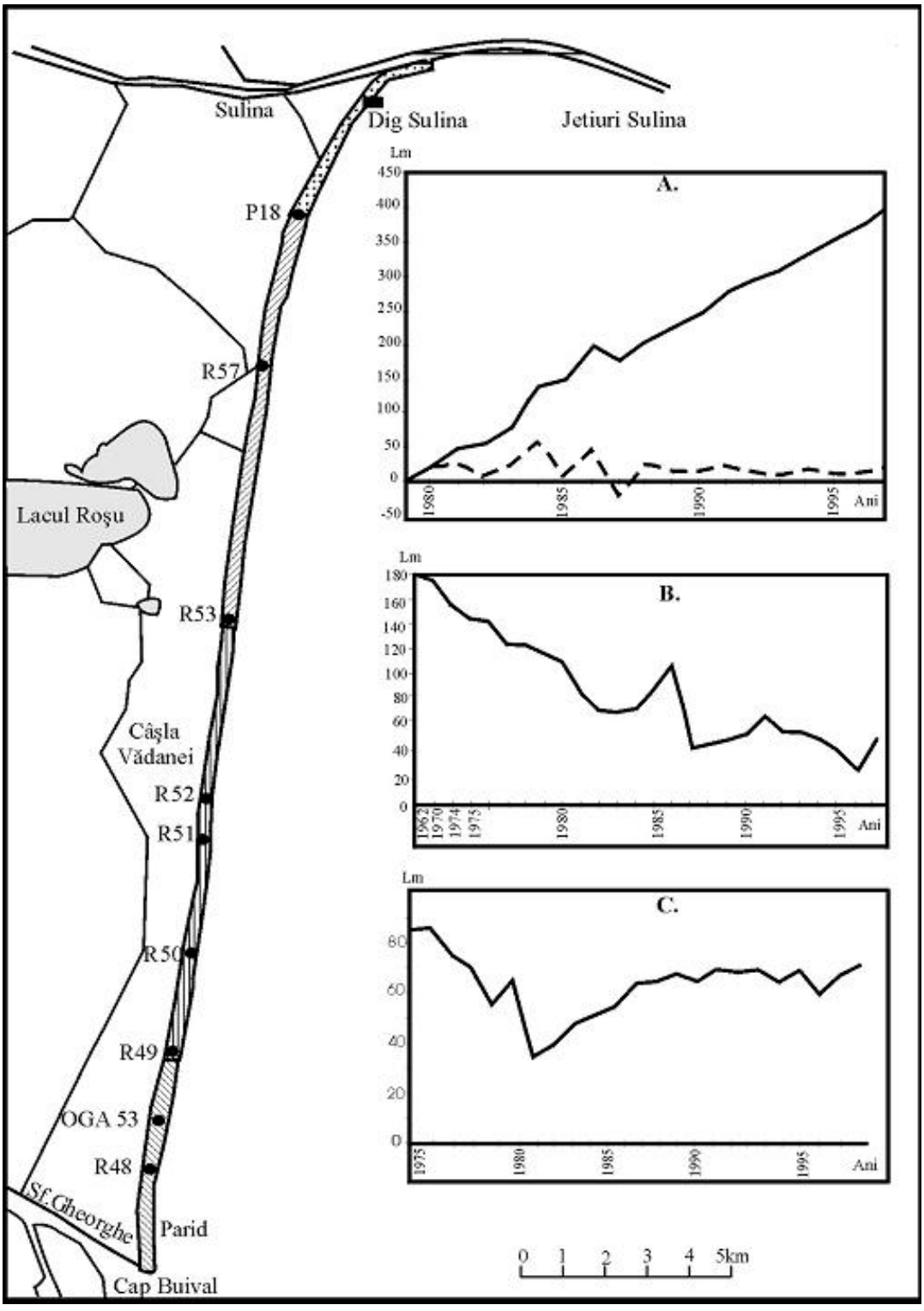


Fig. 7: Sulina – Sfantu Gheorghe coast afferent to Danube Delta.

Eroding sites from North to South of the studied area.

- **Sulina to Sf. Gheorghe**: see Figure 7 for locations.

- **Deltaic barrier** (R53-P18) is vulnerable to any marine energetic input. The mean height (0.5-1.0m) of the barrier allows mean and high waves to transport the sand over the dune's ridge and to deposit it, in the form of small overlapped wash-over fans on the deltaic muds and reed deposits. This mechanism pushes the deltaic barrier continuously westward. The structure of the deltaic barriers, with retreat rhythms 10m/yr, sometimes records total absence of sandy forms, so there is direct contact between the sea and reedy marsh (see Table 2).

Table 2: Erosion rates From Sulina to Sf. Gheorghe.

Location-distance from Sulina (km)	**1962-1979 (m/year)**	**1979-1997 (m/year)**
Ghiol Buival (6,5)	-4,4	-4,5
Gârla Împuţita (8,7)	-6	-6,6
Sud Gârla Împuţita (9,5)	-13,8	-11
Canal Sonda (10,2)	-18,8	-15,5
Nord Japşa lui Matei (12)	-9,5	-13
Japşa lui Matei (16)	-15,2	-9,5
Grindul Cerbului (17,5)	-15	-8

- **Sandy barrier** (R49-R53). Annual rates of shoreline withdrawal of 15-10-7 m/yr characterise the very simple morphological structure, where very large wash-over fans play a relevant role. The fans are periodically re- consolidated during storms and an impressive volume of sand is deposited here. The large, consolidate dunes occur after a period without sever storms, in the form of short belts prolonging the sand bank from Saraturile field (see Table 3).

Table 3: Erosion rates in the Grindul-Cerbului sector (R49-R53).

Landmark	1962-1972 (m/year)	1972-1979 (m/year)	1962-1979 (m/year)	1979-2000 (m/year)
R53	-18,2	-8	-14	-5,5
Câşla Vădanei	-16,7	-10	-14	-5,2
R51	-12,5	-4	-8	-4,7
R50	+6	-2	+2,7	?
2 km S R50	-1,2	+11,4	+4	?
R49	-6	+4,2	+3,6	-1,8

- **Sfântu Gheorghe**: see Figure 8 for locations.

- **Barrier Island Sakhalin** is a lateral curved bar, situated in front of the river mouth. The island is continuously increasing in length, and at the same time migrating onshore by overwashing.

- **Sfântu Gheorghe** is an equilibrium shore. The quiet conditions of this shore are due to the presence of the Sakhalin Island, which shadows Sf. Gheorghe's coast. Distance between landmark R-CSA 47 increased from 55m in 1962 to 460m in 1999.

From Sf. Gheorghe to Chituc:

- **Ciotica-Periteasca shore** represents a deltaic barrier, composed from alternative sand waves separated by direct contact sea-reed marsh areas. Evolution of the deltaic barriers is characterised by the unidirectional movement in the form of regressive translations imposed by the overwash processes during storms. This shore includes an erosion sector, deltaic barrier Ciotica-Perisor, and an accumulative one, Periteasca shore (see Table 4).

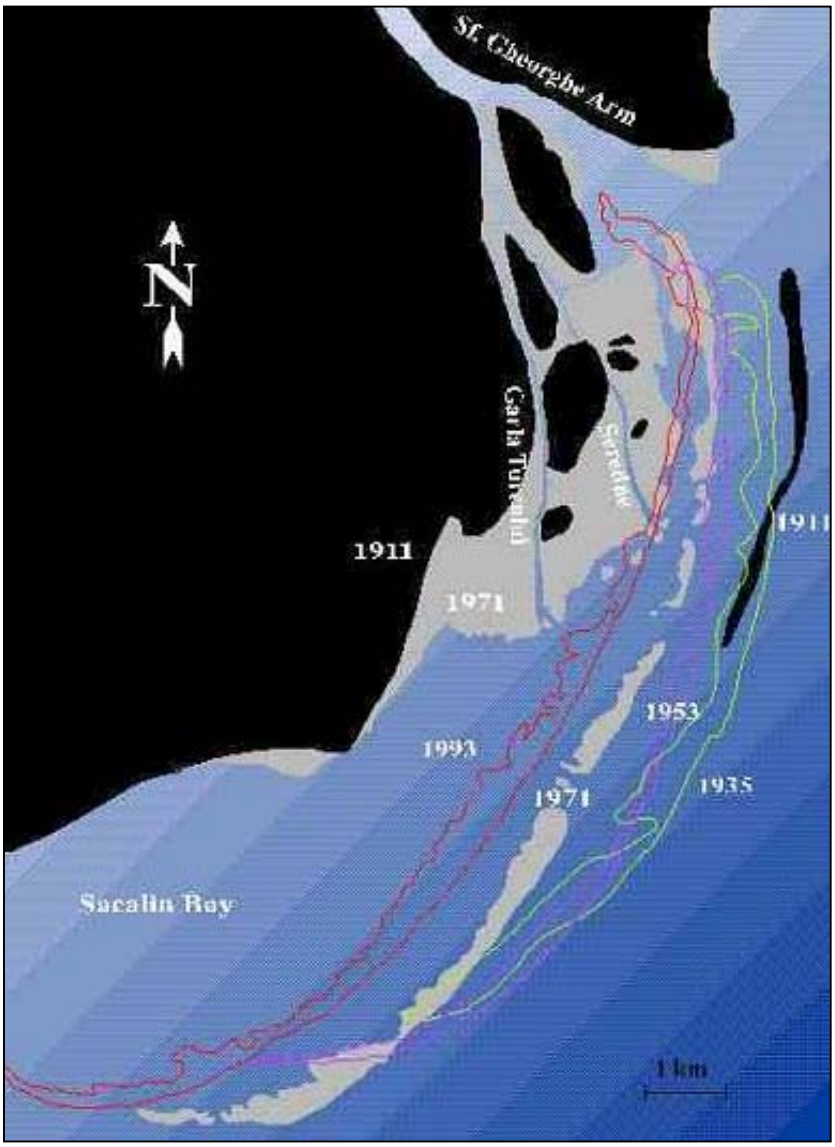


Fig. 8: Sahalin Island evolution for the period 1911-1993.

Table 4: Erosion rates for Periteasca-Portita sector.

Location – distance from R 30 (km)	1962-1979 (m/year)	1979-1997 (m/year)
R29 (2,8)	+8,6	+2,5
R28 (4,7)	+9,3	+4,4
R27 (6,7)	+5,4	+3,4
R26 (8,2)	+3,0	+1,6
R25 (9,5)	+1,5	+1,0

- **Portita-Periboina** is subject to strong erosion, due to intensive southward longshore sediment drift. Shore mean retreat rate was between 12 and 16 m/yr.

- **Chituc shore** is characterised by the presence of Buhaz swamps, which limit the active shore on the landward side. The southern half is the most complex, due to the border dunes. Beaches have considerable widths and lengths. This section is occasionally slightly eroded and characterised by strong longshore drift.

2.2 Impacts

In the coastal zone in the period 1962-1992 2,200ha of beaches from DDBR were registered lost and a lot of values were endangered. This has lead to partial losses of touristic beaches and degraded littoral lakes ecosystems.

3. SOLUTIONS/MEASURES

3.1 Policy options

The ruling policy option is 'Do nothing'. Under the communist regime, actions to protect the coast against erosion have been carried out in the Danube Delta littoral only at Portita, based on the 'Hold the line' option.

3.2 Strategy

3.2.1 Approach related to the problem

Until now there is no general strategy for Romanian Black Sea coastline protection. The local protection measures that have been undertaken had a "hold the line" option in view. Up to now almost all measures were of hard structures category. The Danube Delta coastal zone was and continues to be under state jurisdiction, under the management of the Danube Delta Biosphere Reserve Administration.

3.2.2 Issues concerning threat to life and property

There is no evacuation plan or measure for the Sf. Gheorghe locality, which is the one locality on the coast where the erosion process and flooding is threatening.

3.3 Technical measures

During 1980s a very large programme of Danube Delta transformation had been implemented. Fortunately, only a small part of it was performed. At present, under totally different political conditions and after the creation (in 1993) of the Danube Delta Biosphere Reserve with a specialised administration, measures have been taken for Danube Delta environmental recovery. Only few objectives of the former plan were continued. Among these, the project of cutting-off the meander belts of Sf. Gheorghe distributary has been completed by 1994, in order to activate the distributary water and reroute sediment fluxes for equilibrating the sedimentary budget of adjacent sections of the delta shore. The readjustment of water and sediment discharges after the rectification of the Sf. Gheorghe distributary is on the way to be realised. The preliminary results of the assessment after rectification suggest an sediment discharge augmentation by 5-10%. Such increasing of sediment supply into the littoral zone of Sakhalin Island and in the Sf. Gheorghe secondary delta has a very beneficial impact for the state of their sedimentary budget.

The protection structures at Portita have been undertaken in three stages: in the first stage three groins have been built and in the next two stages two protection dykes have been settled consisting of concrete tetrapods, stones and concrete platforms.

Fig. 9: Protection dyke using tetrapods and concrete platforms (Portita beach).

Other technical features are the jetties built in Sulina mouth. These jetties have not been designed for coastal erosion management, but were intended to facilitate the navigation at the mouth bar and protect the navigable canal of the Sulina arm from the Kilia-born sediments. The building of the jetties started in 1858. In 1861 the length of jetties was 1,412m, in 1925 - 3,180m, in 1939 - 4,150m, in 1956 - 5,773m, in 1980 - about 8Km (see figures 10 & 11). Reaching such a length the jetties are breaking the southward longshore drift of sediments, especially those brought into the littoral zone by the Kilia distributary. There is a natural tendency of sand accumulation in this section, which has been used for beach protection and development. The material dug from the drainage canal surrounding Sulina town was used for beach nourishment.

Fig. 10: Sulina jetties- landward view.

Fig. 11: Sulina jetties – seaward view.

In the southern part of the Danube delta the beach barrier was protected in the 1960-1980 period by a setback line of embankments for limiting losses of sand by overwashing. Locally, on the beach barrier different buildings and structures exist, for example at Portita there are a light house, a border police observing point, a tourist camp, a solar energy electric plant and a fishery. Two groins were designed and built to protect the structures. The coastline protection measures did not show the expected results

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

For the moment the "Portita" shoreline is stabilized. The existing coastal defense achieved almost 20 years ago should be maintained at optimum parameters. The effects of Sulina jetties are described previously.

4.2 Effects related to socio-economic aspects

As mentioned previously, no actions for coastal protection were carried out in the entire area, and no effects were recorded on users or the level of social acceptability. Except for Sulina which has 5,000 inhabitants, only the small locality of Sf. Gheorghe is located on the DDBR coast.

4.3 Effects in neighbouring regions

The hard protections adopted at Portita have stopped coastal erosion the moment. Further south, where no coastal protection exists, erosion process becomes stronger.

4.4 Relation with ICZM

ICZM is not practiced yet in Romania.

4.5 Conclusions

Effectiveness

Only 2% from the entire DDBR coast is protected against erosion with "hard" protection measure (Portita). The measure has resulted in stability of the shore, however it was only applicable for this part of the coast which was very vulnerable to erosion. The solution did not take into consideration the cost of the maintenance of this defence structure and its effect in the vicinity. The erosion phenomenon is now present on the southern part of Portita.

Possible undesirable effects

Effects of coastal protection measures are described previously. Undesirable effects regard Sulina jetties in relation with erosion worsening southwards.

Gaps in information

- Coastal erosion information/reports
- Geological maps
- Beach measurements data
- Topographic maps for beaches
- Information about hard coastal protection of Portita beach

- Aerial photographs
- Shoreline mapping
- GIS and remote sensing images for the Romanian Black Sea coast
- Beach user perception
- Bathing water quality

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