THE DANUBE RIVER AND ITS DELTA, HYDROGEOGRAPHYC CHARACTERISTICS – ACTUAL SYNTHESIS

PETRE GÂȘTESCU[1], ELENA ȚUCHIU[2]

Abstract. The Danube and its delta. Hydrogeographic characteristics. Actual synthesis. This paper provides an updated analysis of the Danube's hydrographic, hydrologic, and water quality features describing the characteristics of its entire course and focusing on the lower sector. The Danube is the second largest watercourse in Europe in terms of length (2860 km) and basin area (817,000 km^2). In Romania, the Danube is 1,075 km long and drains over 97% of the country's territory.. The Danube's *multiannual average discharge* increases downstream collecting the tributaries waters - 1,470 m^3/s at Passau, after the confluence with the river Inn; 1,920 m^3/s in Vienna; 2,350 m^3/s in Budapest and 5,300 m^3/s after the Drava, Tisa, and Sava confluences. The Danube enters Romania at Baziaş with 5,523 m^3/s (multiannual average flow during the 1931-2020 period). The *maximum discharge* is recorded by the high spring waters, but occasionally in summer, too: 15,800 m^3/s at Baziaș in April 2006; 15,300 m^3/s at Giurgiu, and 15,900 m^3/s at Ceatal Chilia. The *minimum discharge* occurs in autumn and occasionally in winter: 1,040 m^3/s at Baziaș in 1949; and 1,790 m^3/s at Ceatal Chilia in 1947. The *suspended sediments discharge* (1840-2000) was on average 53 million tons/ year at Isaccea, that is, 1,681 kg/s. Since 1996, *the qualitative monitoring of the water* has been implemented through the *Danube Transnational Monitoring Network (TNMN)* of the *International Commission for the Protection of the Danube River (ICPDR)*. The spatial and temporal variation in the Pontic sector of the physical-chemical quality indicators, reflects the general characteristics and the effect/impact of the main pressures identified at the basin level for the 1996-2020 period, in monitoring stations (from Baziaș to Reni and on its 3 arms). From a complete and integrative perspective and in line with the Water Framework Directive provisions, *the Danube water bodies*, their typology, ecological status/potential, and chemical status have been presented. The lower Danube-associated *natural protected areas* that are established under the international, European and national legal requirements have been reviewed.

Keywords: Danube, hydrogeographic characteristics, water bodies.

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1. GENERAL REGARDING ON THE DANUBE'S HYDROGEOGRAPHY

1.1. Hydrographic characteristics

The Danube river in Europe springs from the Black Forest Mountains (Schwarzwald) through the tributaries Breg and Brigach, that join at Donaueschingen (678 m altitude). The length of the Danube is approx. 2,860 km and has a river basin totalling about 817,000 km² including its 120 tributaries. The Danube is the only European river that flows latitudinal, from west to east, between 42° and 50° N latitude, making up 8.8% of Europe's surface (Fig. 1).

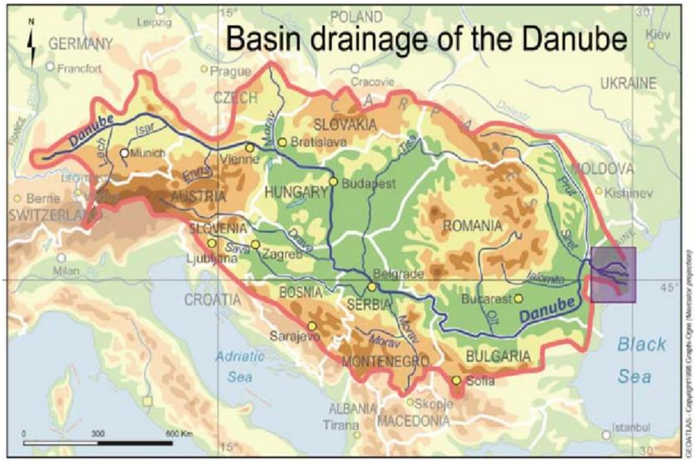

Fig. 1 – The Danube River Basin

Among the Danube countries, Romania takes up 28.4% of its river basin. It should be noted that Romania's territory is 97.8% drained by the Danube basin. From the source to the outflow, the Danube alternately crosses mountains through gorges/gates, depressions, and plains.

In terms of climate, the Danube basin is located at the interference of the oceanic type in the west, with the continental to moderate to excessive type in the east, the sub-Mediterranean in the south, and the Scandinavian-Baltic in the north. At the same time, there is an altitudinal climatic stratification, marked by the thermal gap and by precipitation: about 500-600 mm annually in the plains and over 1,200-1,400 mm on the mountain peaks, as there are glaciers in the Alps.

The gates or gorges(Devin, Iron Gates) delimit the ***three sectors of the Danube: upper-alpine, middle-panonic-lower-pontic*** (P. Gâştescu, 1998).

The upper sector(*alpine*) of the Danube River runs from its spring, to the Devin Gate (Bratislava) over 1,060 km, after the joining of the two tributaries of the source Brege with Brigach at Donaueschingen, to Passau where it forms a small gorge between the extension Alps and the Bohemian Massif. Downstream of the confluence of the two tributaries (Brege and Brigach), the Danube loses water to the underground through the Jurassic limestones of the Jura Swabian-Franconian mountains between Möhringen and Würtemberg. About 5 m³/s goes to the tributary Aach of the Neckar River, the Danube remaining dry 120 days on average in dry periods (in 1921, a particularly dry year, the Danube dried out in this segment for a period of 9 months) (Ujvari, I., 1972).

The middle sector (*pannonian*) extends to Baziaş over 725 km, between the Devin Gate that separates the Alps from the Lesser Carpathians (Male Karpati) downstream of the confluence with the Moravia and the Iron Gates, crossing the Pannonian Depression/Plain. In this sector, the Danube, between the Devin Gate and the Višegrád gorge, splits into two arms developing a 90-km-long island called the Inner Delta by the Slovaks. From Višegrád, further on, the Danube crosses from north to south the actual Pannonian Depression with the Tisza Plain (Nagy Alföld) on the left. Downstream of Budapest, due to the low slope (0.05 ‰), it splits into two arms defining the island of Csepel, then into numerous meanders, so that before Baziaş it receives the most important tributaries: the Drava, the Sava, and the Morava from Serbia, on the right, and the Tisza and the Timiş on the left.

The lower sector (*pontic*), 1,075 km long from Baziaş to the Black Sea forms Romania's natural border with Serbia, Bulgaria, Ukraine, and the Republic of Moldova. In this sector, the largest tributaries lie on the left bank on Romanian territory (Jiu, Olt, Argeș, Ialomița, Siret, Prut), while the right bank tributaries from Serbia and Bulgaria are much smaller (Timok, Ogosta, Iskar, Vit, Iantra, Lom). Here, the Danube forms the longest and most beautiful gorge area – the Iron Gates.

The slope of the riverbed, along the entire lower course, at an average level is 0.06 ‰ (at a level difference of 66.5 m between Baziaş and Sulina). When regarded separately, in the gorge, at a distance of 144 km, at an altitude difference of 30 m, the slope is 0.20 ‰, and in the plain region, at 941 km, with an altitude gap of 36.5 m, the slope is 0.04 ‰.

1.2. Hydrological characteristics

The Danube River water regime is characterised by significant level and flow variations during the year and over time. In spring, following the snow melting and the presence of heavy rains (the pluvial-snow supply), corresponding to the May-June interval, large spring waters are produced on the upper course, while in the middle and lower sectors, large waters occur in April-May as a result of pluvial-snow supply. From the confluence with the Inn River to Bratislava, the Danube, after receiving some tributaries that feed on the Alps' glaciers, records high flows in June. In autumn, low autumn waters occur, especially in September and October. In winter and summer, the water regime is characterised by moderate levels and flows.

Upstream of Baziaş, the Danube receives three important tributaries (the Drava with 670 m³/s, the Tisza with 814 m³/s, and the Sava with 1,460 m³/s, totalling an average flow of 2,944 m³/s). It enters Baziaş, in the Iron Gates Gorge, with an average flow of 5,523 m³/s (1931-2020).

On the lower course, from Baziaş to Ceatal Chilia, through the contribution of the tributaries from Romania, in particular, and from Bulgaria (Fig. 2) (P. Gâştescu, R.Știucă, 2005, Elena Țuchiu, 2018, b).

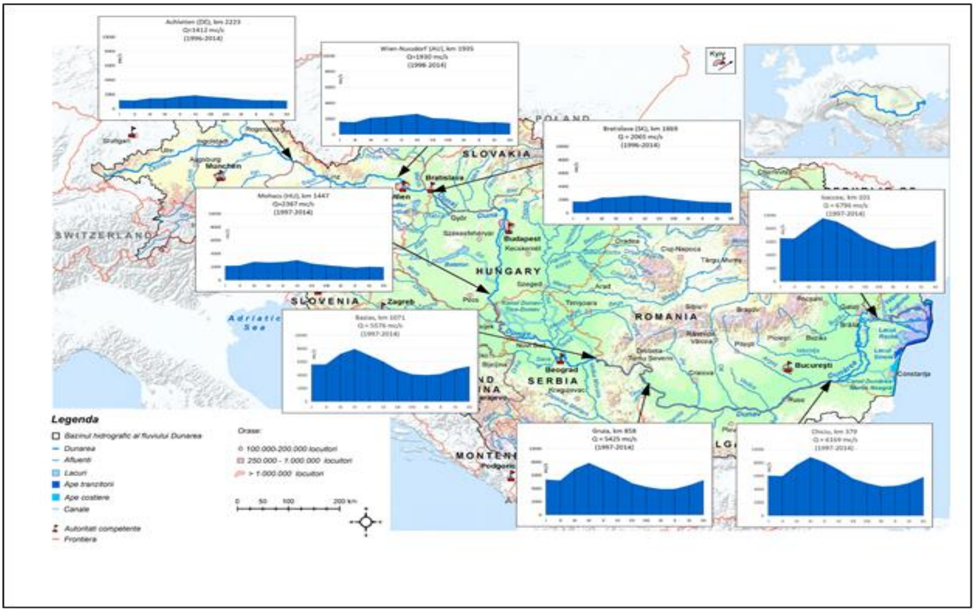

Fig. 2. The variation in multiannual monthly average discharges of the Danube River at main hydrometric stations (Elena Țuchiu, 2018, b).

Through the hydraulic works carried out for various purposes, those regarding the damming for flood protection, a 3.7 million ha surface of the floodplain was removed in the middle - pannonian sector of Slovakia, Hungary, Slovenia, Croatia, and Serbia, on the Danube and its tributaries. The territory of Bulgaria was dammed by about 88,000 ha of meadow on the right bank, works carried out in the 30s and 40s of the previous century. The Danube floodplain on the Romanian territory, between Gruia (downstream Ostrovul Mare) - 851st km and Isaccea - 108th km, 79% of the surface of about 550,000 ha was dammed.

1.3. Danube water quality

The Danube TransNational Monitoring Network (TNMN) of the International Commission for the Protection of the Danube River (ICPDR) has been implemented since 1996. Since 2000, the main objective of the TNMN has been developed to evaluate the water status (following the Water Framework Directive) and, for the long term, the water quality and pollutant loads for the Danube River and its main tributaries (Fig. 3).

Fig. 3 – The Danube TransNational Monitoring Network - TNMN stations (ICPDR).

For the spatial and temporal evaluation of the quality of the Danube River, the following quality elements were assessed: physical-chemical (general indicators, the oxygenation regime, and nutrients levels), chemical (heavy metals and metalloids, specific organic pollutants, organic micropollutants), and biological indicators (phytoplankton and benthic invertebrates) (Țuchiu, 2018 b, 2020).

The evaluation of spatial and temporal variations during a 10-year period (2006-2015) was conducted for 9 monitoring stations (Jochenstein, Hainburg, Bratislava, Szob, Hercegszántó, Borovo, Pristol, Chiciu and Reni), using annual average values for 6 physical-chemical parameters (suspended solids, chlorides, BOD_5, inorganic nitrogen, ortho-phosphates, and total phosphorus. From a spatial perspective, except for inorganic nitrogen which tended to decrease upstream to downstream, all other parameter concentrations increased from Jochenstein to Reni (Fig. 4, 5).

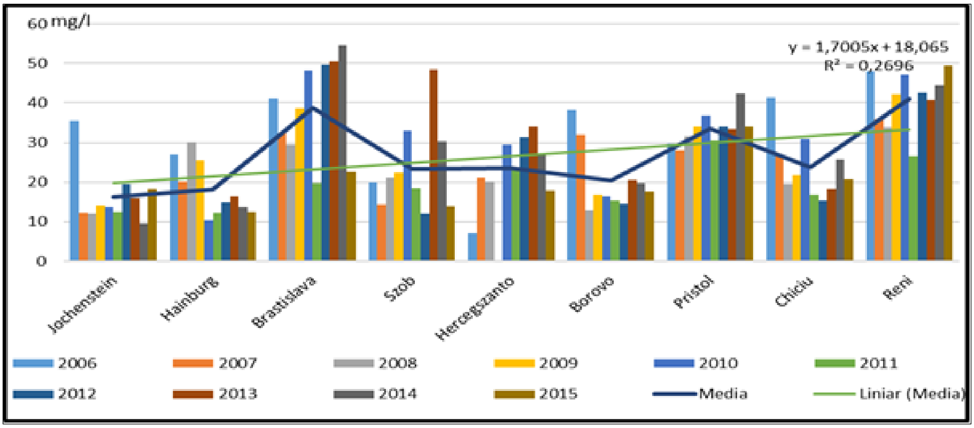

Fig. 4. The variation in the annual and multiannual average values (2006-2015) of suspended solids concentrations on the Danube River.

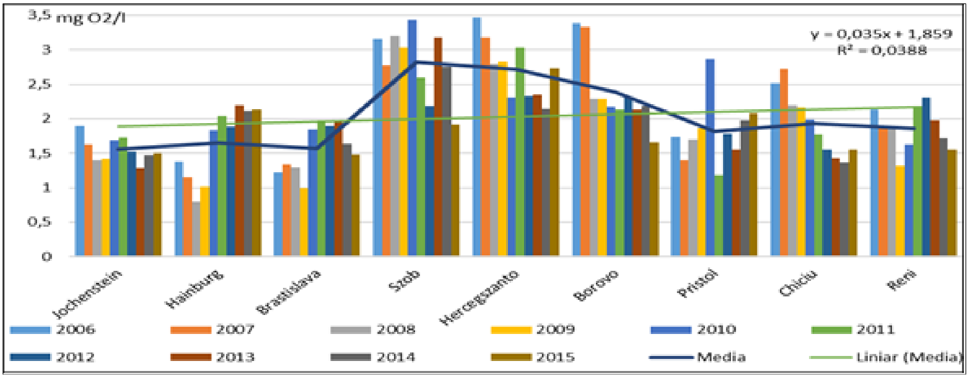

Fig. 5 – The annual and multi-annual variation in BOD_5 average concentrations (2006-2015) on the Danube River.

2. CHARACTERISTICS OF THE DANUBE'S LOWER PONTIC SECTOR

2.1. Hydrogeographic characteristics

According to the morpho-hydrographic configuration, the minor and major riverbed is subdivided into sub sectors: ***Baziaş - Gura Văii, Gura Văii - Călăraşi, Călăraşi - Ceatal Chilia (Pătlăgeanca)*** together with the Danube Delta and its special features.

The Baziaş - Gura Văii sub sector, 132 km long, known by the toponym ***The Iron Gates Gorge,*** is one of the most famous gorges in Europe, where the

Danube penetrates the Carpathians through the Cazanele Mari (3.5 km) and Cazanele Mici (5.5 km). Through the formation of the ***reservoir***, the morpho-hydrographic configuration was modified, alongside the hydrological regime of the Danube, of a semi-lacustrine (poli-dynamic) type. The hydropower and navigation system at the Iron Gates came into operation in 1971, while the dam at Gura Văii has a length of 1,278 m and a hydropower plant with a total installed capacity of 2,100 MW.

In the Gura Văii – Călăraşi sub sector, over a length of 566 km, the minor riverbed with widths between 500 and 1,500 m is characterized by a higher degree of meandering, having more islands. The Danube, in this sector, receives several tributaries, both from Bulgaria - Timok, Ogosta Iskar, Vit, Yantra, and from Romania - Drincea, Jiu, Olt, Vedea, and Argeş. In this sector, the second ***reservoir*** dam was built at Ostrovul Mare, which came into operation in 1986, having a hydropower plant with an installed capacity of 410 MW (Geography of Romania, vol. V, 2005).

In the Călăraşi–Ceatal Chilia sub sector (Pătlăgeanca) over a length of approx. 300 km, two subsectors are defined: ***Bălţile Ialomiţei - Brăilei*** and the ***maritime Danube (Brăila-Ceatal Chilia).*** Bălţile Brăilei and Ialomiţei/Borcei has a length of 195 km and is delineated by two of the main arms of the Danube. It has a special significance and importance as wetlands***(Balta Ialomiței and Balta Brăilei-original hydronyms)***.

The Danube Delta sub sector starts from the first Ceatal (bifurcation) where the Danube River splits into two arms (Chilia to the north and Tulcea to the south) to the second Ceatal, where it branches into the arms of Sfântu Gheorghe and Sulina. Within the boundaries between the Chilia branch to the north and the Tulcea and Sfântu Gheorghe arms to the south, and the Black Sea coastal-deltaic front, the actual surface of the ***Danube Delta*** is 4,152 km², 82% of which is located on Romanian territory (3,446 km²). The Chilia arm (with its many branches and islands) is the youngest and longest (120 km), and carries most of the water and alluvium/suspended solids (58%).

Following the studies done by the ***European Danube Commission (1856),*** the Sulina branch was preferred for maritime navigation, which led to the correction of meanders and deepening of the riverbed between 1862 and 1902. As a result, the length was reduced from 92 to 63.7 km and the volume of water and alluvia drained increased from 7-8% to 18.8% of the Danube flow. Sulina town, an important port for maritime ships, has had variations in its economic development.

Morpho-hydrographic changes evolved naturally until the second half of the 19th century, with the establishment of the European Danube Commission (1856) when the change was initiated, especially on the Sulina arm to make the maritime navigation channel. It was also hydrobiologist Grigore Antipa’s initiative to create canals in order to improve the fishing potential inside the delta, between 1900-1955, followed by the creation of agricultural and forestry land, some of them being currently abandoned. At present, in the configuration of deltaic land use, 30% of the Danube Delta's surface is removed from the natural weighing, respectively from the evolution of natural processes (Fig. 6).

The deltaic seashore in front of the Danube Delta and the Razim-Sinoie Lake Complex extends over about 180 km, between the Gulf of Jibrieni (Ukraine) and Midia Cape, at the southern end of the Chituc lagoon-spit. The shore of the delta consists of sandy beaches of low altitude (up to + 2.7 m), subject to floods during sea storms. The Danube arms' mouths are in the natural regime, except for the mouth of the Sulina canal, which is arranged and maintained for maritime navigation in the form of an extended canal with dikes extending into the sea for about 10 km from the southern shoreline.

The Danube floodplain, on the Romanian territory, the Danube floodplain covers an area of 5,500 km² (excluding the delta), through the damming action started modestly in 1904-1916 with the Chirnogi arrangement, continued with those from the Monastery, Luciu, Giurgeni and generalized in the period 1960-1990; it was dammed between Gruia and Isaccea over an area of 4,380 km² (79.6%) and compartmentalised into 53 modules (Ioaniţoaia *et al.* 2007, Mihailovici *et al.* 2006).

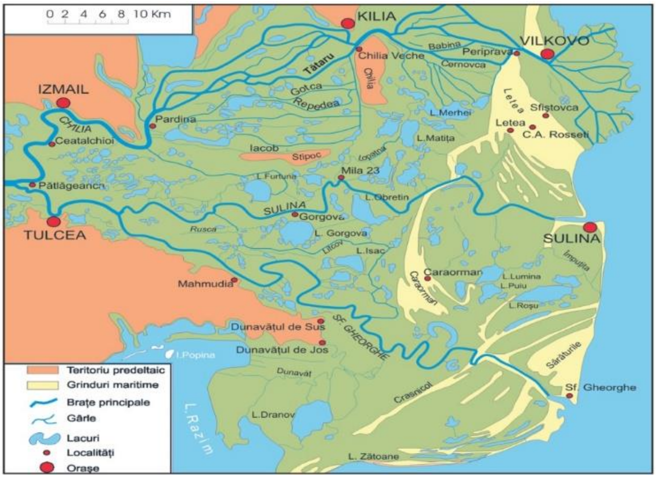

Fig.6. The morpho-hydrographic configuration of the Danube Delta prior to the development works (1860).

Until the early 1950s, the Danube floodplain was one of the most important wetlands in Europe, with natural and semi-natural ecosystems, about 45% of which were permanent aquatic ecosystems (lakes, ponds, swamps, backwaters), flooded 3-4 months/year during high waters. However, at present, most of the floodplains were reduced/modified. Thus, in natural conditions, the floodplain fulfilled important functions such as hydrological, biochemical (ecotonal), ecological, climatic, and socio-economic, and those services were largely lost by carrying out dam works (The Danube – A River with Green Floodplains, 2002) (Fig. 7).

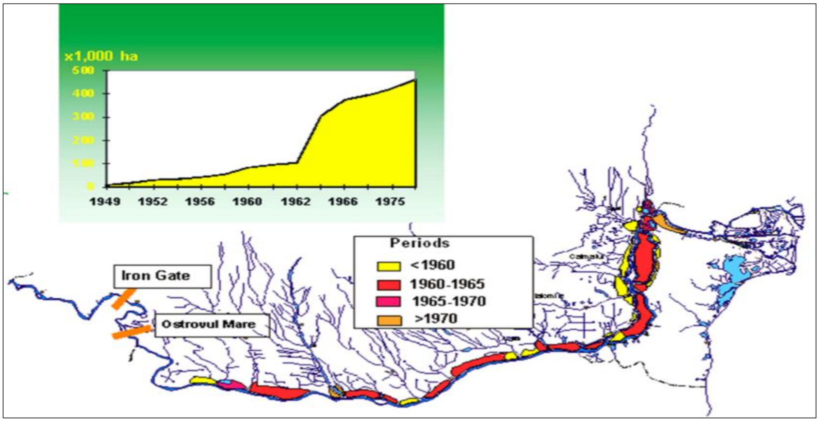

Fig. 7. The evolution of the Danube floodplain damming actions (NIRD Delta Dunării).

2.2. Hydrological characteristics

The hydrological regime of the lower Danube is considered relatively uniform due to the ratio between the minimum flow and the maximum flow of 1/10 determined by the alpine tributaries of the upper and middle Danube sectors, especially the Drava, Sava, and Tisa, before the Iron Gates Gorge, at Baziaș.

From the analysis of the flows from 1931-2020, on the 1,075 km of the lower Danube, there is an increase in the ***multiannual average flows*** from upstream - Baziaş (5,523 m^3/s) downstream - Ceatal Chilia (6,452 m^3/s), the ***minimum flo***w (1,040 m^3/s at Baziaş and 1,790 m^3/s at Ceatal Chilia) and ***maximum flow*** (15,800 m^3/s at Baziaş and 15,900 m^3/s at Ceatal Chilia).

The maximum flows are recorded during the high spring waters, but sometimes they also occur in summer. Thus, in April 2006, the highest flow (1931-2020) was registered at Baziaş - 15,800 m^3/s, at Giurgiu - 16,300 m^3/s, and at Ceatal Chilia - 15,900 m^3/s. The minimum flow registered during autumn and sometimes winter (1,040 m^3/s at Baziaş - 1949, 990 m^3/s at Gruia - 1985, and 1,790 m^3/s at Ceatal Chilia - 1947) (P. Gâştescu, Elena Ţuchiu, 2012).

For the 1931 - 2020 period, the hydrological parameters trends were determined by analysing the average, maximum, and minimum annual flow variation at the two extreme hydrometric/gauging stations, that is, Baziaş (upstream of the Iron Gates Gorge) and Ceatal Chilia (upstream of the Danube Delta).

The annual average flows at Baziaş registered a slightly decreasing trend, and the Ceatal Chilia hydrometric station – a very small decreasing trend (Figs. 8, 9, 10).

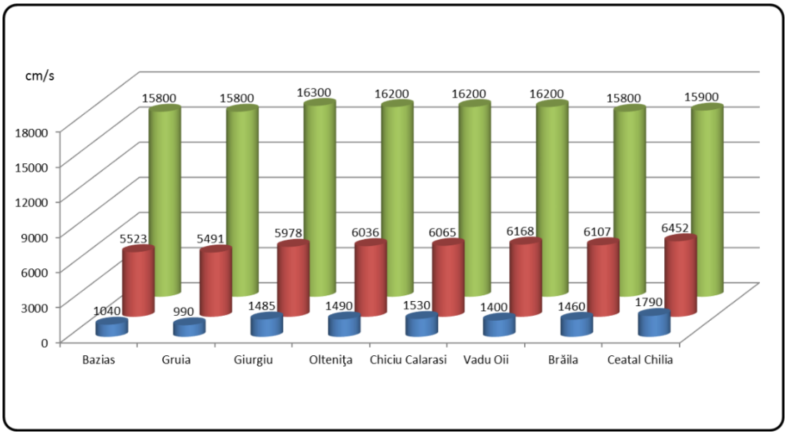

Fig. 8. The multiannual average, maximum and minimum flows at main hydrometric stations (1931 – 2020).

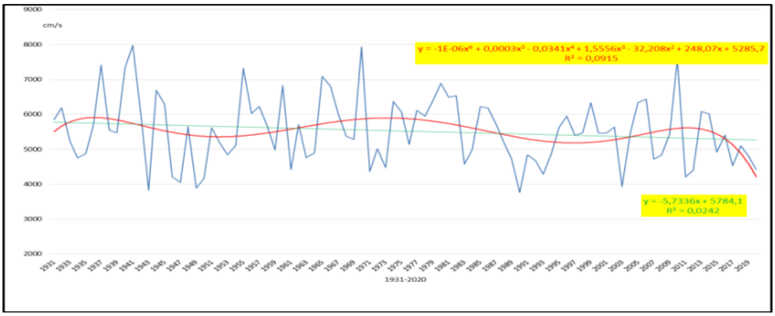

Fig. 9. The variation in the annual average flow at Baziaş (1931-2020).

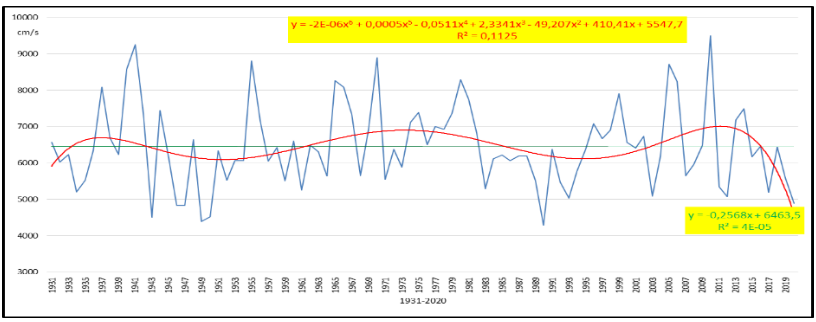

Fig.10. The variation in the annual average flow at Ceatal Chilia (1931-2020).

The minimum flows are usually recorded in autumn with a certainty rate of under 90% due to the reduction in precipitation amounts, and in winter with a certainty rate of over 90%, due to their being stored in the snow layer (Figs. 11, 12).

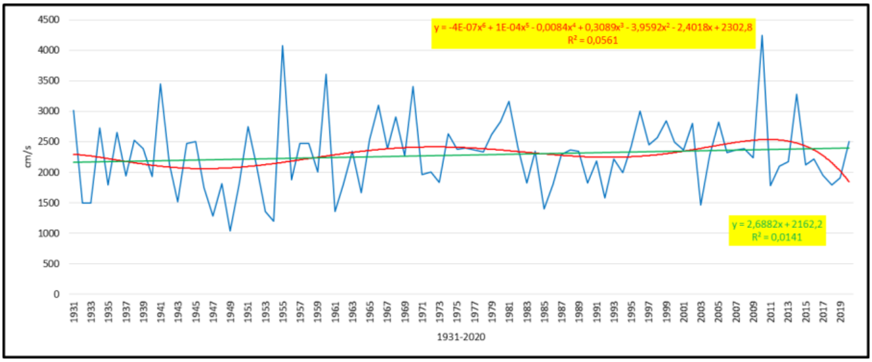

Fig. 11. The variation in the annual minimum flow at Baziaş (1931-2020).

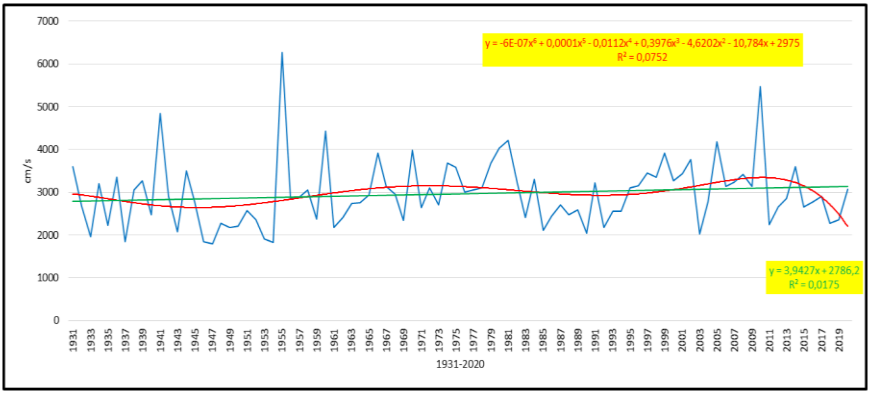

Fig. 12. The variation in the annual minimum flow at Ceatal Chilia (1931-2020).

The maximum flows usually occur in the spring-summer period, due to the overlapping effects melting snow and spring rains have on the entire basin and which generate large water flows. At the Orşova hydrometric station, the first to be established on the Danube, 52 floods were registered in the 1841-1965 period, with a flow > 10,000 m^3/s (The Danube between Baziaş and Ceatal Chilia - hydrological monograph, 1967).

To these are added another 23 flood-level events produced in the 1968-2010 period, reaching 75 floods (for this period, the flow at Baziaş was considered because the one at Orşova was no longer representative due to the Iron Gates reservoir). The annual maximum flows of 1931-2020, as resulted from the polynomial analysis, have a slight increase at the Baziaş hydrometric station and a significant upward trend at the Ceatal Chilia hydrometric station (Figs. 13, 14).

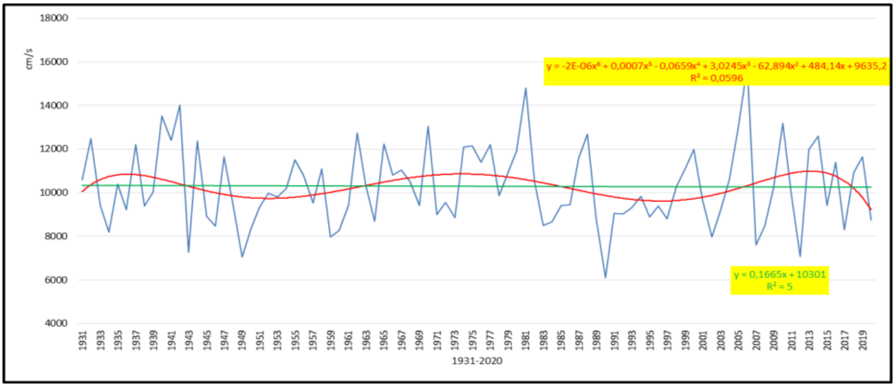

Fig. 13. The variation in the annual maximum flow at Baziaș (1931-2020).

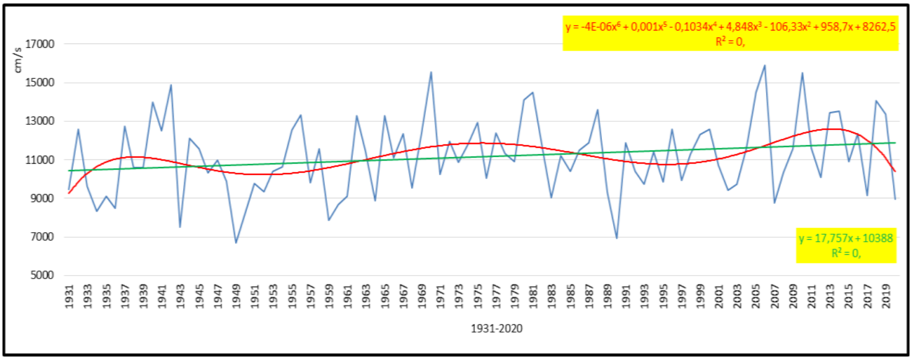

Fig.14. The variation in the annual maximum flow at Ceatal Chilia (1931-2020).

The floods in 2006 approximated within a 1% probability, such as flow, level, and duration over the flood level (CI), registered a maximum flow at the entrance to the gorge at the Iron Gates of 15,800 m^3/s, the highest in the monitoring 1840-2020 period (Fig.15).

The magnitude of the 2006 floods is compared to that of the 1970, 1981 and 1985 floods, which took place downstream of the reservoir/dam at the Iron Gates. The highest flows were recorded on the Turnu Măgurele – Oltenița Danube sector, and were gradually reduced downstream of this sector, as a result of flooding in the floodplain through breaches in dykes, including those disposed by the authorities to defend various important downstream localities (Brăila, Galați) as well as some even from the Danube Delta.

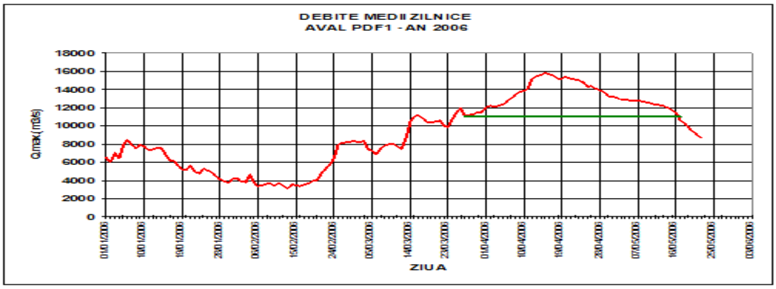

Fig. 15. The flow downstream of the Iron Gates during March-May 2006 (Şerban and colab, 2006).

With the exception of the floods of 2006, during the period of 180 years (1840-2020), floods with maximum flows > 15,000 m^3/s also occurred in: 1888 (Q = 15,500 m^3/s), 1895 (Q = 15,900 m^3/s), 1897 (Q = 15,400 m^3/s), 1940 (Q = 15,100 m^3/s in Olteniţa), 1942 (Q = 15,370 m^3/s in Giurgiu), 1970 (Q = 15,500 m^3/s in Ceatal Chilia), 2010 (Q = 15,500 m^3/s at Ceatal Chilia).

At Ceatal Chilia, in the ***Danube Delta,*** before branching out, the ***Danube multiannual average flow*** is estimated at 6,452 m^3/s (for the 1931-2020 period), the maximum value was registered in April 2006 (15,900 m^3/s), and the minimum in 1947 (1,790 m^3/s). For the 1931-2020 period, from the analysis of the average annual flows, there is an upward linear trend according to the relationship y = 17,757x + 10388, but for shorter periods there are positive/negative variations.

The Danube flow at Ceatal Chilia is differently distributed in time (over the monitored period) depending on the morphometric parameters of the riverbed and anthropogenic changes on the three arms – first on Chilia and Tulcea and then on Sulina and Sfântu Gheorghe. Selecting two representative years, such as 1910 and 1990, a flow reduction on the Chilia arm (from 72% to 58%) and an increase on the Sulina one (from 8% to 19.5%) were noted due to the works for ensuring maritime navigation (Fig. 16).

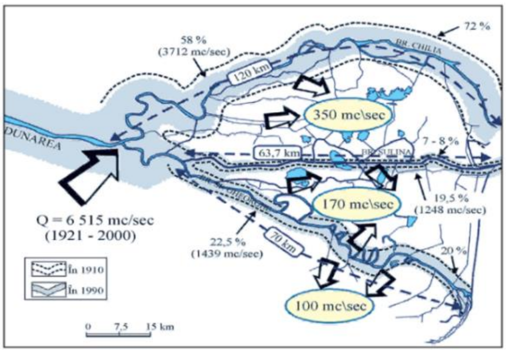

Fig.16. The distribution of water flows on the Chilia, Sulina and Sfântu Gheorghe arms.

An important role in the ecological status of deltaic ecosystems is played by the water flow entering the lakes and canals of the lake complexes and the stagnation period throughout the year (Table 1).

Table 1. The water flows of the Danube at the entrance and exit of the delta and the main arms

	2001-2010		2011-2020		2001-2020	
	Q (m^3/s)	%	Q (m^3/s)	%	Q (m^3/s)	%
Danube - Entrance (A)	6,896	100	5,985	100	6,441	100
Chilia	3,393	49.2	2,837	47.4	3,115	48.4
Sulina	1,164	16.9	994	16.6	1,079	16.8
Sf. Gheorghe	1,757	25.5	1,686	28.2	1,722	26.7
Danube - Exit (B)	6,314	91.6	5,517	92.2	5,916	91.9
Difference (A-B)	582	8.4	468	7.8	525	8.1

The overall water balance of the Danube Delta is:

$$(Y1 + X) - (Z + Y2) = \pm \Delta V$$

Y1 – the water volume transported by the Danube **(206 km³/year); X** – rainfall on the area of the Danube Delta **(1.3 km³/year); Z** – the evaporation and evapotranspiration on the area with swamp vegetation in the Danube Delta **(4.5 km³/year**); **Y2** – the outflow to Black Sea **(192.0 km³/year); +ΔV –** the volume difference **(10.8 km³/year).**

The Danube suspended solids flow is characterised by a decreasing trend due to the retention of sediments in the reservoirs at the river basin level. Between 1840-2010, the multiannual average value of 53 million t/year was registered, that is, 1,681 kg/s, of which 2.81 million t/year represents coarse alluvia (sands) with extreme values of 4,470 kg/s (141 million t/year) in 1871 and only 229 kg/s (7.2 million t/year) in 1990. During this period, a decreasing trend registered at an annual rate of 8.3 kg/year, but with oscillations corresponding to the water flow (Bondar *et al.*, 1991).

In the Isaccea hydrometric section, upstream of the Danube Delta, the following periods were identified: between 1900 - 1950 the annual flow of suspended solids flow decreased 1.3 times, that is, from 69.4 million t/year to 53 million t/year, the cause being the construction of reservoirs, especially in the upper Danube river basin; between 1950 - 1980 the annual suspended solid flows decreased about 1.8 times, that is, from 53 million t/year to 30 million t/year due to dams and reservoirs being continually built in the entire Danube river basin, including the Iron Gates dam and the reservoirs siltation, as well as the intensification of the erosion processes; between 2000-2010, an average value of suspended solids flow of 20 million t/year was registered (Fig. 17).

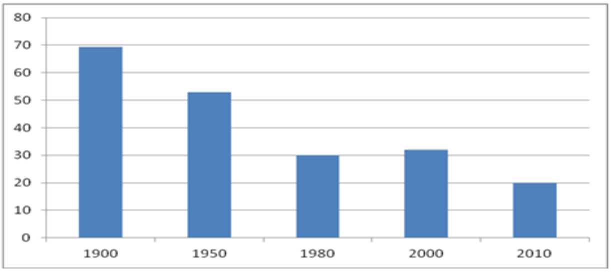

Fig. 17. The decrease in the annual flow of suspended sediments at the Isaccea hydrometric station (million t/year) (INHGA).

The evaluation of the variation in the suspended solids flows at the Ceatal Chilia hydrometric station displayed a significant downward trend (Fig. 18).

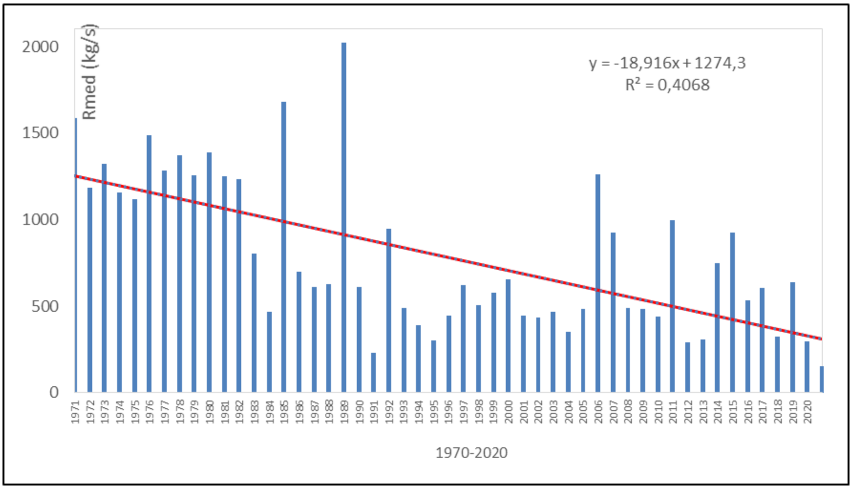

Fig.18. The variation in the suspended solids annual average flow at the Ceatal Chilia hydrometric station (1971-2020).

2.3. Lower Danube water quality

On the Romanian territory, 9 monitoring stations ensure the monitoring obligations as agreed in the TNMN, 6 being located on the Danube River, and 3 on its branches (Chilia, Sulina, Sf. Gheorghe).

The period analysed is between 1996 and 2020 (25 years) for all monitoring sites (except Gruia station, which has been monitored since 2007) for oxygenation conditions indicators (biochemical oxygen demand - BOD_5, chemical oxygen demand - COD-Cr), and nutrients regime (ammonium/NH4 – nitrogen/N, nitrates/NO_3 – N and total phosphorous – total P). The variation of multiannual average concentrations shows a spatial (from upstream to downstream) trend of significantly increasing for COD-Cr (almost by two times), a slightly increasing trend for NH_4 – N, NO_3 –N, and a slightly decreasing trend for BOD_5 and the total P (Table 2)(Fig.19,20).

Table 2. The multiannual average values of the concentrations of chemical indicators at the monitoring stations on the Danube (1996 – 2020).

Monitoring station / Parameter	Baziaș	Pris-tol	Olte-nița	Chiciu	Reni	Vâlcov / Chilia	Suli-na	Sf. Gheor-ghe
BOD_5 (mg/l O_2)	2.42	2.18	3.16	2.21	1.93	1.99	2.13	2.02
COD-Cr (mg/l O_2)	10.27	20.65	11.70	10.56	20.16	19.56	20.16	19.50
NH_4 – N (mg/l N)	0.18	0.21	0.16	0.13	0.19	0.20	0.20	0.21
NO_3 –N (mg/l N)	1.15	1.50	1.33	1.26	1.43	1.32	1.33	1.37
Total P (mg/l P)	0.109	0.091	0.117	0.135	0.101	0.091	0.091	0.091

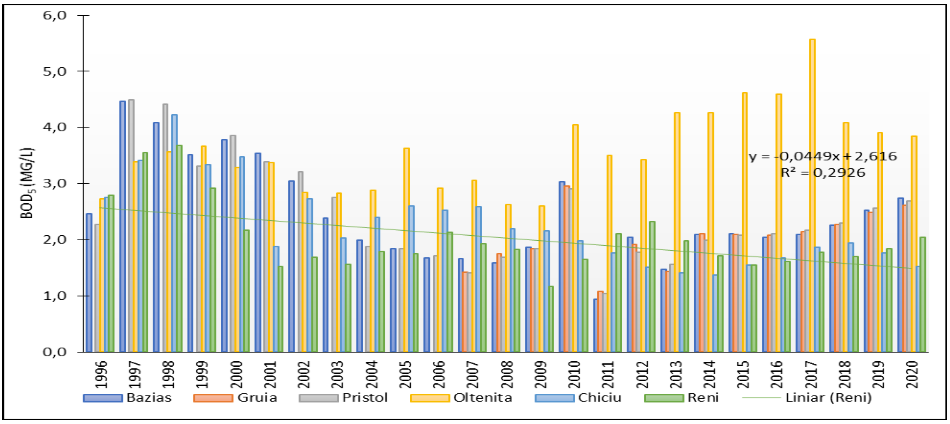

Fig. 19. The variation in annual average values of BOD_5 concentrations (1996-2020).

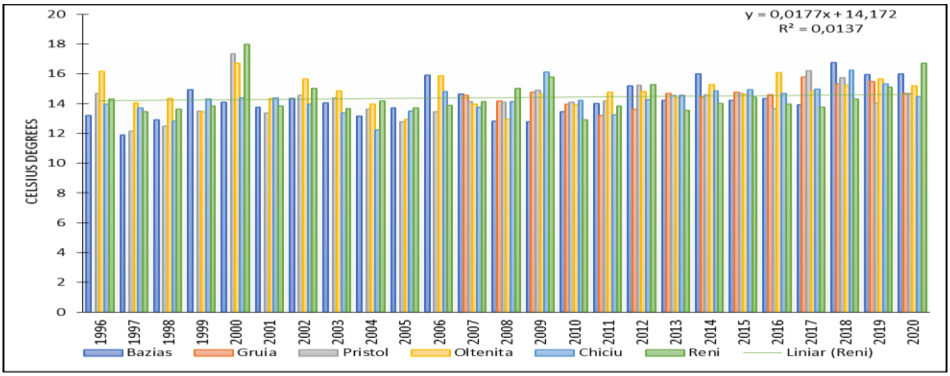

Fig. 20. The variation in annual average water temperature (1996-2020).

Furthermore, the variations in the annual average concentrations of suspended solids, BOD_5 concentrations water temperature (1996-2020 for 6 monitoring stations from Baziaș to Reni) are illustrated in the following figures, showing at Reni station a slightly decreasing temporal trend for BOD_5, and an increasing one for suspended solids and water temperature (Figs. 20, 21, 22).

At 6 monitoring stations (Baziaș, Gruia, Pristol, Oltenița, Chiciu, Reni), a study (Țuchiu Elena, 2018, b) analysed the spatial and temporal variation (1996-2015) of physical-chemical and biological qualitative indicators selected to illustrate the general characteristics (general indicators), as well as the effect/impact of the main pressures identified on the Danube River Basin level: organic pollution, nutrient pollution, and hazardous substances pollution. The set of indicators selected for the evaluation of water quality from a physical-chemical point of view contained general indicators (thermal conditions; suspended solids; acidification status; salinity), oxygenation conditions, nutrient conditions, heavy metals, and metalloids, specific organic pollutants, and organic micropollutants (pesticides). With regards to biological elements/parameters, the water quality analysis took benthic macroinvertebrates and phytoplankton into consideration.

In this context, upstream – downstream variations have been established, showing that some determinants have a spatial decreasing trend (water temperature, conductivity, sodium, potassium, calcium, magnesium, chlorides, dissolved oxygen, BOD5, COD-Cr, COD-Mn, TOC, nitrates, nitrites, ammonium, nitrogen, iron, copper, arsenic, petroleum hydrocarbons, DDT, lindane, atrazine, chlorophyll) and some have an increasing trend (sulphates, ortho-phosphates, total phosphorus, manganese, zinc, lead, cadmium, mercury, nickel, macroinvertebrates); some have remained somewhat constant (alkalinity, phenols, detergents).

All analysed determinants have been evaluated from a temporal point of view, with observations on the improvement of water quality (for conductivity, sodium, potassium, calcium, magnesium, chlorides, phosphates, dissolved oxygen, BOD5, COD-Cr, COD-Mn, nitrates, nitrites, ammonium, total nitrogen, ortho-phosphates, iron, manganese, zinc, copper, chromium, lead, cadmium, mercury, petroleum hydrocarbons, chlorophyll-a biomass) or a slight decrease in water quality (nickel, arsenic, phenols, detergents). The majority of determinants/pollutants tend towards the improvement of water quality due to the closing of many industrial and agricultural sources of pollution, the reduction in the intensity of agriculture, the reduction in the number and magnitude of accidental pollution, and the measures taken for the reduction of pollution by the construction of wastewater treatment plants for urban agglomerations and industrial installations, the application of the best available technologies in industry and the best practices in agriculture, as well as the use of phosphorus-free detergents in accordance with the national and European legislation.

3. DANUBE BODIES OF WATER IN THE PONTIC SECTOR

The concept of body of water is defined in article 2 of the Water Framework Directive as “a discrete and significant element of surface waters such as river, lake, canal, river sector, canal sector, transitional waters, a part of coastal waters”. The definition of the body of water can be practically translated by dividing the hydrographic network into continuous and homogenous elements, both from the hydrological, morphological, and ecological point of view, as well as from the perspective of anthropogenic pressures and water status.

On the Danube between Baziaș - Isaccea 4 heavily modified surface bodies of water are delineated, 2 of which are rivers (Ostrovul Mare - Chiciu and Chiciu - Isaccea) and 2 are reservoirs (Iron Gates and Ostrovul Mare). (Țuchiu Elena, 2018, b).In the Danube Delta, on the 3 arms of the Danube River, there are 3 surface bodies of water, 2 natural bodies of water (Chilia and Sfântu Gheorghe), and 1 heavily modified body of water (Sulina). The evaluation of the ecological status/potential of the Danube bodies of water is based on the monitoring data provided by the qualitative monitoring stations, as presented above, and the results of the assessment are shown in the draft of the National Management Plan (2021 update) (Table 3).

Table 3. A classification of the Danube bodies of water.

Body of water	Natural/heavily modified	Ecological status/potential	Chemical status
Iron Gates Reservoir	Heavily modified body of water (HMWB)	moderate	good
Ostrovul Mare Reservoir	HMWB	moderate	good
Ostrovul Mare - Chiciu	HMWB	moderate	bad
Chiciu - Isaccea	HMWB	moderate	bad
Isaccea - Sulina	HMWB	good	bad
Chilia	Natural	good	bad
Sf. Gheorghe	Natural	good	bad

Additionally, in the Danube Delta, 63 lake water bodies were delineated, of which 59 are natural and 4 are heavily modified water bodies. According to the status classification, 62 lake water bodies are classified as having good ecological status/potential and 1 as having bad ecological status, while all 63 water bodies were granted good chemical status.

4. PROTECTED AREAS ON THE DANUBE LOWER SECTOR

For the identification of habitats and species, protected areas where water is an important factor, the natural protected areas which are linked to water bodies and which shelter species and natural habitats which are potentially dependent on the aquatic environment have been taken into consideration. The national legislation stipulates that, in order to ensure special protection and conservation measures for the natural patrimony, differentiated protection alongside a management regime must be instituted, delimiting several categories of protected natural areas.

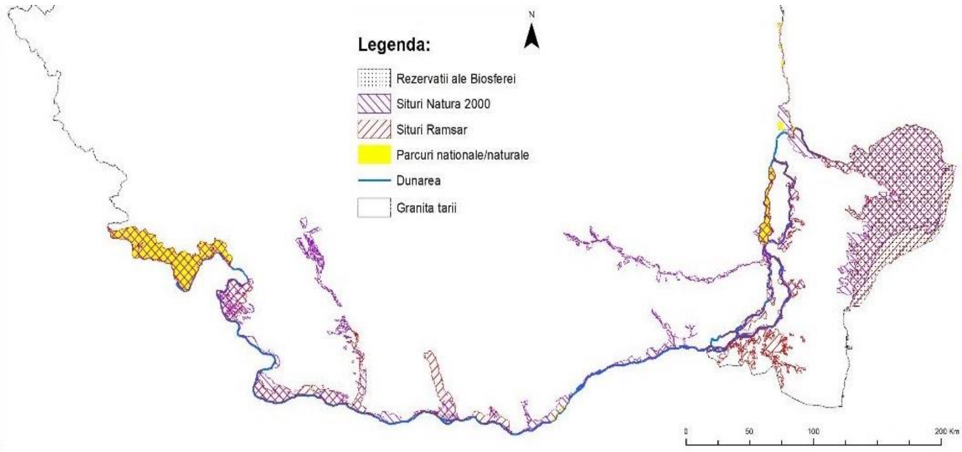

Fig. 21 Natural protected areas in the lower Danube River Basin.

On the lower sector of the Danube River, the identified natural protected areas are: 5 nature reserves under the International Union for Nature Conservation protection (e.g., Porțile de Fier/The Iron Gates Natural Park, Balta Mică a Brăilei Natural Park etc.), 13 RAMSAR sites, 15 community interest Sites (SCI – Natura 2000); 22 Special Protection Areas for Birds (SPA – Natura 2000) as well as the Danube Delta Biosphere Reserve (Fig.21).

The Danube Delta Biosphere Reserve was founded by the Romanian Government Decision No. 983/1990 and by Law No. 82/1993. It covers ***5,800 km²*** encompassing, beside the ***delta itself***, the ***Razim - Sinoie lagoons***, the ***coastal waters*** up to the 20 m isobath adjacent to the deltaic and lagoons front, the ***Danube floodplain upstream the delta*** to ***Isaccea***, and the ***Danube riverbed*** up to the Ukrainian border. In this area, the different categories of functional zones stand out: ***core areas (506.0 km²), buffer areas (2,233 km²), economic areas, and their localities (3,061 km²).*** The biosphere reserve concept does not exclude human activity, which is integrated with the environment so that economic actions fall in line with conservation and protection measures. Due to its international importance, the Danube Delta was listed (1990) among the world network of biosphere reserves under the ***"Man and Biosphere Programme (MAB)"*** etc. (Fig. 22).

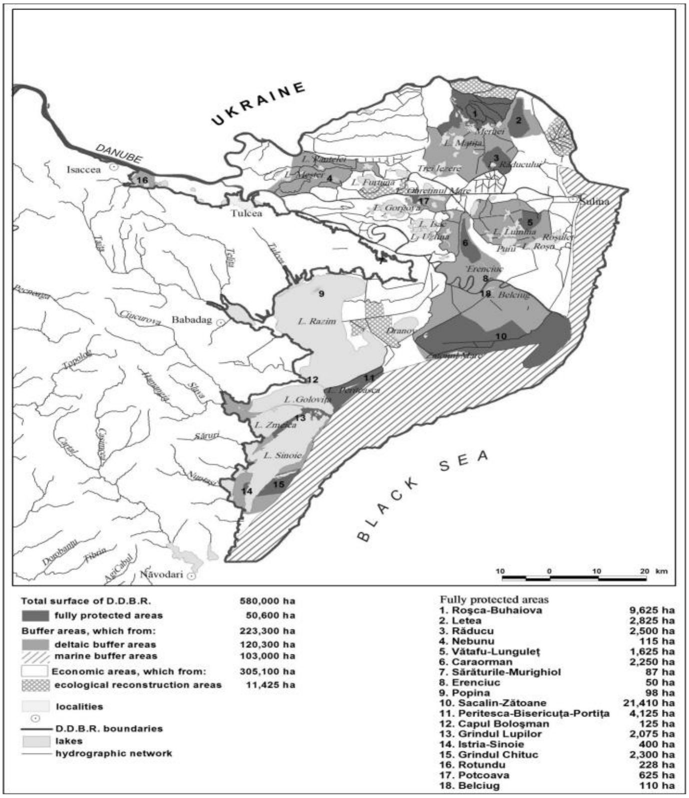

Fig. 22 –The Danube Delta Biosphere Reserve – functional areas.

Concerning the secondary delta of the Chilia branch on Ukrainian territory, the Ukrainian Government delta issued a decision (No.861/1998) establishing a ***Ukrainian Danube Delta Biosphere Reserve*** of over ***464 km²***.

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