MARITIME SPATIAL PLAN OF THE REPUBLIC OF BULGARIA 2012-2035

SPECIFIC FEATURES AND CLIMATE OF THE BLACK SEA REGION

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LIST OF ABBREVIATIONS

BSRBD Black Sea Region Basin Directorate

GWB Groundwater bodies

MFP Maritime and Fisheries Programme 2014—2020

NIMH National Institute of Meteorology and Hydrology

PHAR Photosynthetically active radiation

RBMP River basin management plan

SPECIFIC FEATURES AND CLIMATE OF THE BLACK SEA REGION

1. Specific features of the Black Sea region

The Black Sea is a closed intercontinental sea that connects to the Mediterranean basin through the Sea of Marmara. It is located between the continents of Europe and Asia, with six countries sitting on its shores: Bulgaria, Turkey, Georgia, Russia, Ukraine and Romania. The Bulgarian water area occupies the westernmost parts of the Black Sea basin.

In geological terms, a peculiarity of the Bulgarian Black Sea coast is that it is built of sedimentary rocks in its northern part, and of magmatic rocks accompanied by pyroclastic materials and less sedimentary rocks in its southern part. These rock formations continue under the sea waters. The coast covering the Danubian Plain is composed of Lower Sarmatian clays, marls and calcareous sandstones, Middle Sarmatian marl clays, calcareous sandstones, sands and Upper Sarmatian karst shell-ridden limestone. In addition to the Senonian flysch sediments, Miocene limestones and marls are discovered within the Stara Planina coast. The coast of the Burgas lowland is represented by Senonian limestones, marls and volcanics, Eocene, Oligocene, Sarmatian and Pliocene sediments, overlapped with Quaternary and modern deposits. The Strandzha coast is built of volcanic rocks, pyroclastics and, in very few places, of sediments.

Relatively powerful Quaternary deposits are established on the accumulative surface of the Burgas lowland and of the larger rivers.

Despite the pronounced variances in different parts of the Bulgarian Black Sea coast, the weak segmentation is a characteristic feature. There are no large islands in the coastal territorial waters, which is typical for the Black Sea in general. The existing 4 small islands are all close to the southern part of the coast — within the scope of the Burgas Bay.

Beaches occupy 1/3 of the Bulgarian coast stretch. The largest beaches are located to the north of Varna as well as between Burgas and Emine Cape.

There are 18 coastal lakes in total, with 223 million m^3 of lake water volume. By origin they are either estuaries (Beloslav, Varna, Atanasovsko, Burgas, Mandrensko, etc.) or lagoons (Pomorie, Balchik Tuzla, Nanevska Tuzla, etc.).

The geology and relief are crucial for the landslide activity along the Bulgarian Black Sea coast and are responsible for about 13 % of it. In the northern parts of the coast, the presence of significant sedimentary rocks and high slopes additionally activated by human intervention have led to the development of large-scale landslides. The presence of small patches of sedimentary rocks along the Strandzha coast has resulted in very few landslides covering a limited area.

The climate is formed under the influence of the general atmospheric circulation and the influence of the sea basin, which is strongly limited to the west. The openness of the Black Sea region to the north and northeast is another important circumstance. The lack of an orographic barrier is a prerequisite for significant inroads of cold air masses in winter and reporting of extreme negative

temperatures along the coast. This is one of the reasons why, at an approximately the same latitude, the Bulgarian sector of the Black Sea and its coast is colder in winter than the south-eastern sector of the sea and its south-eastern coast, with the latter being well protected by the high Caucasus mountain range. The prevailing north-northwest/east-southeast atmospheric transport and the presence of the Caucasus Mountains are the reasons for the significant showers on the south-eastern coast of the sea and for the record precipitation there. The average temperature in January in Batumi (41° N and 41° E) is 7ºC, while the annual precipitation is 2 560 mm, resulting in a specific subtropical climate.

The climate of the Bulgarian Black Sea coast and the adjacent waters fall within the Black Sea climate area. The climatic influence of the sea basin manifests mainly as an increase in air temperatures for January (between 1.0 and 3.2°C), and in the reported small annual temperature amplitudes of 19—21°C. The territory to the south of Sozopol is the only place in Bulgaria where the average temperature in January reaches and exceeds 3°C (Sozopol: 3.0°C, Tsarevo and Rezovo: 3.2°C). The winter in the area is milder and warmer than it is in the hinterland. The strong northeast and north winds have an unfavourable effect during this period. The average wind speeds on the high seas are higher than those along the coast and in the cold half of the year exceed 7 m/s. During the warm half of the year the fairly typical breeze circulation contributes to limiting the extremely high air temperatures. The breeze speed reaches 3—5 m/s during the day and 1—3 m/s at night. As a result of the sea's influence, a relative levelling of July and August air temperatures takes place, averaging 22—23°C.

Several peculiarities stand out with respect to the annual distribution of precipitation. Along the northern coast, the seasonal amounts of precipitation level off, while along the southern Black Sea coast precipitation during the cold half of the year prevails; this is evidence of a strengthening Mediterranean climatic influence. The reporting of the lowest annual precipitation in Bulgaria — below 450 mm in the area between Balchik and Kaliakra — is yet another specific feature.

The Black Sea's isolation is one of its most important characteristics. The sea's one and only link with the World Ocean goes through the Bosporus Strait. The Black Sea is connected to the small Sea of Azov through the Kerch Strait. This closed nature of the Black Sea is a prerequisite for a difficult exchange of water masses and retention of inflowing pollution. The large river inflow also maintains low salinity of the sea waters. The limited connection with the World Ocean, as well as the very difficult water exchange between surface and deep waters, is the reason behind the outstandingly slow water replacement in the Black Sea basin. A complete replacement is estimated to take place every 642 years and this is an important factor for the sea's environmental condition.

Black Sea's water masses are formed by the incoming river waters, precipitation, exchange with the waters of the Sea of Marmara and Azov Sea and through evaporation. The large river inflow of 350 million km^3 is a distinctive feature for the Black Sea. Its catchment area occupies over 2 million km^2, covering about a third of continental Europe's territory. Some of the largest European rivers flow here: the Danube (water volume 208 km^3/year), the Dnieper (43.4 km^3/year)

and the Dniester (9.1 km^3/year). The share of Bulgarian rivers is insignificant. The largest Bulgarian river that flows into the Black Sea is the Kamchia with a water volume of 0.61 km^3/year.

The Black Sea is one of the seas with a positive freshwater balance. This is due to the fact that more fresh water enters it from its inflowing rivers and precipitation than is lost in evaporation. Due to its being closed and its positive freshwater balance, the water level of the Black Sea is 30 to 50 cm higher than that of the Sea of Marmara. As a result, its excess water drains through the Bosporus into the Sea of Marmara. The water exchange between the Black Sea and the Sea of Marmara through the Bosporus is crucial for the vertical distribution of salinity and the density of water masses. Two currents are formed in the strait. The surface current carries water with a salinity of 17–18 ‰ from the Black Sea to the Sea of Marmara. The bottom current draws into the Black Sea water with a salinity of 38 ‰ from the Sea of Marmara.

The Black Sea waters are characterised by low salinity of 18 ‰. Near its shores, under the influence of inflowing river waters, the salinity decreases to 16 ‰ and 17 ‰, and the seasonal fluctuations are significant. A specific feature of the Black Sea is the presence of a permanent layer with higher salinity gradients, located between depths of 120 and 200 m. This layer complicates the processes of vertical mixing between water masses and maintains the existence of stable layers of oxygen and hydrogen sulphide.

An important peculiarity of the Black Sea is that a permanent hydrogen sulphide zone has been established at a depth of over 150—200 m. In it, oxygen is depleted. The Black Sea is the largest oxygen-free basin in the world. Hydrogen sulphide is toxic to living organisms consuming it, with the exception of some bacteria. The main source of hydrogen sulphide in the Black Sea is considered to be the processes of anaerobic decomposition of organic matter in sapropel sediments carried out by sulphate-reducing bacteria. Oxygen-rich surface waters on which marine life depends represent only about 13 % of the Black Sea water mass. This feature directly affects the ecological status of the marine environment and the diversity of organisms that depend on it.

Two closed circles of water movement have been formed in the Black Sea — one in its western and the other in its eastern part. The western current circle passes along the Bulgarian coast. The main mass of river water enters the north-western part of the sea, giving rise to a powerful coastal current. It heads south along the Romanian and Bulgarian coasts and is joined by the Main Black Sea Current (also known as the Crimean Current) in the area of Cape Kaliakra to form a powerful south-bound current. It drifts along the coast at an average distance of 10—30 miles. The highest-speed sea currents in the whole Black Sea basin have been registered along the Bulgarian coast. Current speeds tend to weaken nearer the coast, with conditions emerging for the occurrence of north-bound counter currents. Local currents often occur along the Black Sea shores, depending on coastal configurations. They run close to the shore and are weak, highly dependent on the wind.

After the Bulgarian stretch of the Black Sea, the current reaches the region of the Bosporus to the south where it continues to the east. At Cape Kerempe, part of it turns north to the Crimean Peninsula, thus forming the western circle of the Black Sea current. The remaining water masses continue their eastward movement. Skirting the Caucasian coast, the current heads northwest to

fork along the coast of the Crimean Peninsula. One prong heads south, thus shaping the eastern loop of the Black Sea current. The other one heads west to join the western circle of the Black Sea currents. There may be practically no currents in the high seas. Any water movement out there might only be generated by the winds.

The Black Sea is characterised by low wind-wave height. The average annual wave height in the north-western part of the Black Sea is about 2 m. The waves along the Bulgarian coast average only 31 cm, which is a consequence of the shallow shelf section. Although rarely, strong eastern and north-eastern winds, especially in winter, can form waves up to 5—6 m high and up to 70—80 m long. They can inflict serious damage on coastal facilities. Tsunami-type waves are not typical of the Black Sea. They have made very rare appearances, with low wave heights.

The Black Sea is characterised by small fluctuations in sea water at high and low tide. The largest tides (up to 17 cm) in the Black Sea are observed in the Odessa Bay. The shores near Burgas have seen maximum tides of 11.2 cm.

The Black Sea is characterised by a limited biodiversity. Its fauna is about three times poorer than that of the Mediterranean. This is due to the presence of hydrogen sulphide in the deep-water area of the basin, which occupies 87 % of its volume, and also to its low salinity and to its limited connection with the World Ocean. The Black Sea is inhabited by over 1 000 plant species and about 2 000 animal species. More than 1 650 species of unicellular phytoplankton algae are known, as well as 285 species of benthic macrophytes and several species of angiosperms.

Unlike seawater, the areas above the sea and the adjacent coast are known for their rich biodiversity. One of the most important European avian routes — *Via Pontica* — passes along the Bulgarian coast and adjacent waters. The importance of that area is evidenced by the fact that dozens of protected territories under the Protected Areas Act and NATURA 2000 protected areas have been declared here. The total protected area of the Bulgarian maritime space is 247 724 ha, and over 80 % of the area outside human settlements along the coastline are also under protection.

With regard to the pollution of the Black Sea waters, it has been established that 70 % of the total amount of pollutants entering the sea originate from the Black Sea countries. Some of these pollutants and the remaining 30 % (coming from the remaining 11 countries in the catchment area) flow into the Black Sea via the Danube. Due to the fact that the sea is closed and to the lack of substantial currents, the environmental impact significantly outweighs similar situations in other sea basins.

The Black Sea is one of the most affected due to excessive nutrient content and organic overload. This is mainly caused by the excessive use of fertilisers in agriculture, untreated wastewater from livestock farms and settlements as well as pollution from industrial centres. The north-western part of the Black Sea, with large rivers such as the Danube, Dnieper and Dniester flowing in it, is most affected by eutrophication. The large amounts of phosphates and nitrates flowing into the sea are the reason for massive phytoplankton growth. The end result is the extinction of benthic organisms.

Alien species invasion, bottom trawling and overfishing put additional strain on the marine environment. This results in fish stocks depletion, especially along the Bulgarian coast.

The natural resources of the Bulgarian maritime spaces and the adjacent coastal strip are a prerequisite for the development of various economic activities. The sea and coastal climate are outstandingly suitable for recreational activities. The combination of optimal sunshine with sea water and cool breeze is the basis for the development of sea tourism along the coast. The traditional industry is fishing, which is losing ground due to reduced fish stocks, but is successfully complemented by the breeding of marine organisms, especially in the newly established mussel farms. Other traditional activities that continue to develop are the extraction of sea salt through the natural evaporation of sea water in large specialised areas as well as the extraction of curative sea mud and lye. Maritime spaces are an excellent prerequisite for the development of various sports, e.g. sailing, surfing, rowing, swimming, etc.

The coast and the adjacent sea area are valuable in cultural and historical terms. The two peninsulas declared as architectural and historical reserves — the old towns of Sozopol and Nesebar — boast the largest concentration of cultural monuments of national importance. The underwater cultural heritage in the Bulgarian waters of the Black Sea is still insufficiently studied and promoted.

Maritime transport which is instrumental in a significant part of the country's foreign trade occupies an important place in the national economy. The two big seaports of Burgas and Varna are Bulgaria's gateway to the world. Almost the entire amount of the country's oil supply is imported through the port of Burgas. Thanks to the favourable transport links and geographic location, the large coastal cities have developed petrochemical industry, shipbuilding and ship repair as well as a number of other industries. The country now receives a large part of its natural gas import through a pipeline after the deep sea connection was put in place.

2. Climate

The climate of the Black Sea is influenced by a number of physical and geographic factors. First of all, this is the sea's geographical location. Located among large continental land areas, the sea and its climate elements are influenced substantially by continental air masses. The continental influence is felt in the Bulgarian part of the Black Sea waters through the incoming continental air masses.

The general atmospheric air circulation in the Northern Hemisphere also has a strong influence. The predominant western air transport ensures that the humid Atlantic air masses reach the Black Sea. Icelandic cyclones reaching the Black Sea bring bad weather, strong winds, sea storms and heavy rainfall. Mediterranean cyclones coming to the sea from the southwest during the winter carry warmer and humid Mediterranean air masses. In winter, the Black Sea is often affected by East European anticyclones, and in summer — by the Azores anticyclones.

The passage of air masses over the Black Sea is also affected by the seawater surface. For example, overpassing cold continental air masses in winter are being partially warmed, while in summer they are being cooled.

Adjacent land reliefs also exert a serious influence on the climate over the Black Sea. The low-lying shores of the Black Sea Lowland and Dobrudzha, which characterise the west and northwest, facilitate the dominant influence of Eastern European cold anticyclones in winter. The lowlands of western and eastern Thrace and the Dardanelles and Bosporus straits facilitate the movement of moist and warm air masses of Mediterranean cyclones and hot air from the Azores anticyclones to the Black Sea from the southwest.

The climate of the Bulgarian Black Sea coast is formed at the transition between two surfaces — water and land — with are entirely different in their nature; hence its specific elements. The sea's direct inland influence is moderate and reaches 40—60 km depending on the configuration of the terrain, but is mostly dependant on the location of the sea basin vis-a-vis the direction of the predominant transfer of atmospheric masses.

Data from the Climate Handbook of the Republic of Bulgaria, volumes 1—5, were used in describing the Black Sea climate.

2.1. Solar radiation regime

Sunshine is a very important element in assessing an area's natural potential. The actual annual duration of sunshine along the Bulgarian Black Sea coast ranges between 2 080 and 2 250 hours. The maximum duration of sunshine is seen in July, followed by August. As early as May, two thirds of the hours between 9—10 a.m. and 2—3 p.m. are sunny. Even in October there is sufficient sunshine of between 3 and 4 hours around noon. The sunless days stand below 10 % in the period May—October and below 5 % in June—September, while in July and August they are practically absent. The lowest total solar radiation is in December (3—3.5 kcal/cm^2) and the highest is in July (19.3—20.8 kcal/cm^2). Between May and September, the Black Sea region receives about 60 % of its annual amount of solar radiation, with direct radiation prevalent over diffuse radiation. During that period, direct solar radiation can be used most efficiently as an energy source.

Photosynthetically active radiation (PHAR) on the Bulgarian Black Sea coast is at its maximum in July (9—10 kcal/cm^2). The percentage useful for plants can be increased by 2—3 to 7—8 % through management and technical measures.

The Black Sea coast is close to the southern border of ultraviolet comfort. Under certain conditions, there is a real opportunity for heliotherapy from March through October with optimal opportunities between April and September. The period between June and August is a period of some ultraviolet radiation excess.

Thermal conditions are largely determined by the amount of radiation absorbed. At annual values of 105—115 kcal/cm^2 the latter comes to about 30 % of the total radiation. Its maximum is in July

(15.8—17.0 kcal/cm^2). About half of absorbed radiation is lost through effective radiation (with annual value at 51—56 kcal/cm^2).

The Bulgarian Black Sea coast has a positive annual radiation balance. Even the lowest values in December and January remain positive at 0.1—0.8 kcal/cm^2 per month. This is the reason for the warm winters with positive average monthly temperatures. The maximum of the radiation balance is in July at 9.5—10.6 kcal/cm^2. The average annual heat loss from evaporation stands at 24—31 kcal/cm^2. These values increase during the period between March and October, when the thermal resources are more than those necessary for the evaporation of the precipitation falling at that time. An inverse dependence is established during autumn and winter. The ratio of evaporation to volatility shows that the Black Sea falls below the optimal limit of humidity. Moisture shortages at the coast determine the approximate irrigation norms at anywhere between 230 and 330 mm.

The total annual evaporation (400—500 mm) does not differ much from the average annual precipitation. This explains the small outflow and insufficient humidification.

A significant amount of heat remains for turbulent heat transfer, which stands at 28—32 kcal/cm^2 per annum. The Black Sea coast has the highest level of heat exchange in Bulgaria. It peaks in July. The breeze circulation contributes to the intensification of the turbulent heat exchange by creating thermodynamic instability in the lower atmospheric layers.

2.2. Temperature regime

The annual temperatures on the Black Sea coast increase from north to south from 11.8 to 13.3°C. Annual temperature range is between 19.2 and 21.8°C. The highest winter temperatures in Bulgaria are reported here. For the Southern Black Sea coast they exceed by 1—2°C those in the area of Sandanski and Petrich. While negative average monthly temperatures are not excluded in some winters, they are rare. In December, the perennial average ambient temperatures stand between 4.0 and 6.1°C, with average daily temperatures between 5.1 and 10°C prevailing. In January, these temperatures stand between 0.8 and 3.2°C with prevailing daily averages between 0.1 and 5.0°C. In February the average values vary from 1.8 to 3.9°C at prevailing average daily temperatures from 0.5 to 5.0°C.

Spring on the Black Sea coast is cooler than in the hinterland. March sees the first summer days with maximum temperatures above 25.0°C, with average monthly temperatures ranging between 4.2 and 6.1°C. Average April temperatures are within 8.8 and 10.5°C without negative average daily temperatures, while average May temperatures are between 14.4 and 15.8°C.

Summers have more levelled out temperature variances. Average June values stand between 19.1 and 20.8°C with prevailing average daily temperatures from 20.1 to 22.0°C. Temperatures are nearly levelled out between July and August at 22.1—23.7°C, with prevailing daily average values of 22.1 to 24.0°C. Average daily temperatures typically do not exceed 28°C.

Early autumn on the Black Sea coast is characterised by thermal conditions very close to those in summer. September averages are 3.5—4.0°C higher than May ones, with prevailing daily average

values from 18.1 to 20.0°C. This amounts to a substantial reserve for both agriculture and recreation industries. October average temperatures drop to 13.9—15.8°C, while November ones go further down to 8.9—10.8°C. Summer-like days disappear in November.

In terms of cut-off dates of ambient temperature transitions, the following periods can be distinguished:

- Temperatures below 5°C. This period starts on 10 December and lasts until 15—20 March. For the southern coast it is between 15—20 December and 5—10 March. The overall number of days for the Northern Black Sea Coast is 90—100, and for the Southern Black Sea Coast — 60—90.
- Temperatures above 5°C. This period lasts 267 days for the Northern Black Sea Coast and 301 days for the Southern Black Sea Coast.
- Temperatures above 10°C. The sustainable spring shift over 10°C takes place between 15—20 April for the Northern and between 10—15 April for the Southern Black Sea Coast. The autumn dip below 10°C takes place around 10 November for the Northern and 10—20 November for the Southern Black Sea coast. The total duration of the period with temperatures above 10°C is between 203 and 224 days.
- Temperatures above 15°C. The sustainable shift over 15°C takes place between 15—20 May for the Northern and between 10—15 May for the Southern Black Sea Coast. The autumn dip below 15°C takes place around 10 October for the Northern and 10—20 October for the Southern Black Sea coast. The total duration of the period with temperatures above 15°C is between 145 and 150 days for the northern coast and up to 165 days for the southern coast.
- Temperatures above 18°C. This period starts on 29 May and continues until 20 September, lasting between 115 and 125 days. This is the period of the so-called “comfortable temperatures” which are an important recreational indicator.
- Temperatures above 20°C. This period begins between 15 and 20 June and ends by 5 September for the Northern Black Sea Coast. For the Southern Black Sea Coast, the period starts on 15 June and ends on 15 September. It coincides with the strongest part of the tourist season. It has a spell of 1—2 months in which temperatures remain permanently above 22°C. Such a period is not reported by weather stations not located in the coastal zone.

Temperature sums are compiled for each of these periods and are frequently used as a determining agriclimate indicator. Temperature sums above 10°C range between 3 600 and 3,750° for the Northern Black Sea coast and between 3 700 and 4 150° for the Southern Black Sea coast. These temperature sums are sufficient for the ripening of a number of earlier crops, also leaving temperature reserves for growing some second crops. Temperature sums above 15°C range

between 2 800 and 3,200° for the Northern Black Sea coast and between 2 950 and 3 400° for the Southern Black Sea coast.

Extreme temperatures are also an important thermal factor. January average minimum ambient temperatures range between 2.5 and 0°C, and August ones — between 18 and 20°C. An average minimum temperature around and above 15°C sets in as early as June, which is an indication of a stable summer weather.

The average of the absolute minimum annual temperatures ranges between -12 and -13°C for the Northern Black Sea coast between -9 and -12°C for the Southern Black Sea coast. Thermal conditions are more favourable along the coast, while inland adjacent areas see lower average absolute minimum temperatures. Negative temperature sums are also lower for the entire coast, standing below 40 % for its Southern part.

Another specific feature of the Black Sea coast is the earlier cessation of late spring sub-zero dips and frosts and the later dates of their occurrence in autumn compared to the hinterland. Frost risk assurance stands at 90% in early April or even in March for the southernmost parts of the coast. Early autumn frost dates are in October, while the average ones are in November and even December. These temperatures parameters lead to warmer autumns as well as to opportunities for growing late and second crops along the Bulgarian Black Sea coast. The coast has the longest frost-free period in Bulgaria — an average of 240 days in its northern section, 250 days in its middle section and 260 days in its southern section.

2.3. Cloud cover and precipitation

As clouds are related to atmospheric circulation, they are most frequent in winter when the transport of air masses is most intense in this part of the country. During the period between November and February the cloud cover is 7.0—7.8 tenths on average and clods are mostly low. It gradually tapers off in spring to reach 4.9—5.8 tenths in May. The cloud cover is the lowest in summer at 2.5—3.2 tenths. This is due to the fact that cyclonic activity is the most limited at that time of the year, as well as to sea breezes which limit the possibilities for intra-mass clouds. Cloud cover rises to 5.0 tenths in October.

The annual and monthly number of clear days along the coast is close to the national average. Their maximum is in the summer — 12—16 days in July and August, and their minimum is in December — 1.5—2.5 days on average. At 110, overcast days on the Black Sea coast stand slightly above the national average of 97 days. They max out in winter and reach their lowest values in summer. Due to the sea basin, the number of foggy days exceeds the national average. They reach their maximum in December and January, and their minimum in July and August.

The amount and mode of precipitation on the Black Sea coast depends on the atmospheric circulation and the presence of two surfaces — sea and land. Under the direct influence of Mediterranean cyclones, the southern Black Sea coast reports twice as much precipitation as the northern Black Sea coast. The northern parts of the coast and their adjacent territories are the

country's driest area. The average annual precipitation in the north is about 450 mm, while in the south it is 550—700 mm, reaching 812 mm in Rezovo.

The annual distribution of precipitation is approximately even along the Black Sea coast, with a maximum in November and December and a minimum in August and September. The predominant number of stations report a well-defined summer drought, lasting 2—3 months. The annual Mediterranean-type precipitation distribution is better expressed on the Southern than on the Northern Black Sea coast.

Snowfall days are on a par with those in the lower parts of Southern Bulgaria. However, due to higher temperatures, the number of days with snow cover ranges from 6 to 16 days. In the southernmost parts of the Black Sea coast, 4—5 consecutive years without snow cover are not uncommon.

Heavy rainfalls of over 60 mm occur once a year on the average on the Southern Black Sea coast, most frequently during the cold half of the year. Along the northern coast such torrential rains take place once or twice in a decade, mainly during the warm half of the year.

Dangerous ice overs are relatively common during the cold half of the year. The small amounts of supercooled precipitation and the strong north-eastern wind can result in ice layers that cause significant damage.

Table 1: Climatic data for Varna and Burgas stations

Station		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Win.	Spr.	Sum.	Aut.	Annual
Varna *43 m altitude*	average temperature	1.7	2.7	5.4	10.3	15.4	19.7	21.9	21.7	18.4	13.3	8.8	4.4	2.9	10.4	21.1	13.5	**12**
	monthly precipitation	38	41	34	44	40	46	37	32	31	36	50	45	124	118	115	117	**474**
Burgas *16 m altitude*	average temperature	2.1	3.4	6.3	10.8	15.9	20.1	21.9	22.1	18.9	13.9	9.1	4.7	3.4	11	21.4	14	**12.4**
	monthly precipitation	41	43	40	54	42	49	33	30	37	47	56	48	132	136	112	140	**520**

Source: https://www.stringmeteo.com/synop/bolc_eu_climate.php?pr=&regd=eu

2.4. Air humidity

The absolute air humidity is higher on the Black Sea coast than in the rest of the country. This is due to the significant water masses evaporating from the water basin. The minimum is in January and February — from 4.2 to 4.8 mm, and the maximum is in July and August — from 14.0 to 15.7 mm. The absolute daily humidity fluctuations are of a small amplitude, with the maximum being at 2 p.m. in all seasons.

The relative humidity on the Black Sea coast is high throughout the year, being second only to the high mountainous parts of the country. Unlike in the hinterland, days with relative humidity below 30 % are practically absent.

The average duration of droughts in summer and autumn is 17—18 days while in winter and spring it is 14—15 days. Droughts are more common in summer at (2—3 times for the entire season)

while in winter and spring they take place once a season on the average. July, August and September are often completely dry, with negligible rainfall, especially along the Southern coast.

2.5. Wind pattern

Northern winds prevail during the cold half of the year accounting for 30 to 43 % of windy weather. Their average speed is 5—7 m/s. Some of the strongest winds in the country were measured along the Black Sea coast at the Kaliakra and Galata stations — 44 m/s. Katabatic winds have occurred about 20 times per year in the Varna—Devnya low land. The specifics of these winds include their long duration of up to 4 days at a time without interruption and their high speed of 30—40 m/s. Southern and southwestern winds also occur during the cold half of the year. When north-bound Mediterranean cyclones pass along the Black Sea coast, their winds share a foehn nature. The frequency of winds from other directions is much lower.

Eastern winds are predominant during the warm half of the year due to the daily breeze circulation. Rare manifestations of western night breezes — during about 40 % of the nights — are typical for the Bulgarian Black Sea coast. At speeds between 1 and 2 m/s, they are 2—3 times slower. Northern quarter winds rank after east winds in spring and summer.

Wind occurrences along the Black Sea coast — 85—90 % of all 24-hour periods — significantly exceed those in the rest of the non-mountainous part of the country (55—60 %). The prevailing wind directions are north and northeast, with the average speed being about 2 times higher than the national average. Therefore, despite the relatively higher thermal levels in winter, the subjective sensation is of lower temperatures.

2.6. Climatic Zoning of the Bulgarian Black Sea Coast

In terms of climate (Tishkov, Velev, Vekilska, 1979) the coast is divided into the following 5 subregions:

1. ***Dobrudzha region,*** locked between the Romanian border and the valley of the Batova River. This region has the lowest temperatures during the cold half of the year as well as the lowest average annual precipitation. Average wind speeds are about twice higher than in the southern parts of the coast.
2. *The* ***Varna region*** differs from Dobrudzha region both in terms of its winter temperatures, which are significantly higher, and in terms of higher average annual precipitation.
3. *The* ***Stara Planina region*** differs from the other two regions in the north mainly in terms of precipitation volume — both its November maximum and its August minimum are significantly better expressed. There is also a slight increase in average annual temperatures due to higher winter temperatures.
4. *The* ***Burgas region*** is characterised by higher average annual and winter temperatures and a certain softening of wind speed compared to the northern regions. In terms of showers, there is a mixture of temperate continental with Mediterranean climatic influence. The stretch between Sozopol, Burgas and Pomorie has the longest period with temperatures

above 15 and 18°C — 164 and 146 days respectively, an important variable for the development of recreational industries and for the cultivation of heat-loving crops.

5. ***Strandzha region,*** characterised by the best pronounced Mediterranean influence in terms of precipitation pattern and by the highest annual precipitation volume. Local average annual temperatures are almost the same as in the Burgas region, with winter ones slightly higher.

Climate change

Adaptation to anticipated global climate changes is among the most important challenges for the development of the Black Sea region going forward. According to the Varna branch of the NIMH, the following changes in temperatures and precipitation are reported for the period between 1991 and 2011 by Varna station.

A total of 14 of the last 20 years have seen average annual temperatures higher than the 12°C climatic norm. 2007 was the warmest year while 1996 was the coldest one. The lowest temperature for the last 20 years was measured in the winter on 25 January 2010 (-17.8°C), and the highest was 40°C in the summers of 2004 and 2007. Compared to previous years, summers and winters are getting warmer and autumn is getting cooler.

Annual precipitation in Varna region fluctuates between 300 and 700 mm. Precipitation quantities higher than the climatic norm of 474 mm have prevailed for the last 20 years. Precipitation has been unevenly distributed throughout the year and, contrary to expectations, instead of spring, the highest precipitation has occurred in autumn, especially in September. The maximum 24-hour precipitation is 103 mm, measured on 18 October 2011. October again has seen the maximum monthly amount of 212 mm.

Snow cover and daily distribution analysis for the last 20 winter seasons in Varna city has resulted in the following ranking: 2009—2010 was the snowiest winter, followed by 2001—2002, 2004—2005, etc. The 2006—2007 winter had the most inconspicuous and insignificant snow cover. The thickest snow cover of 50 cm was measured in February 2005.

A climate modelling was done by basin management regions under two scenarios: “optimistic” (RCP4.5) and “pessimistic” (RCP8.5). It tried to establish a pattern of expected change in average temperatures and precipitation for three periods: first period up until 2027, second period 2021—2050 and third period 2071—2100. It showed increased vulnerability of the Black Sea coast from drought, extreme temperatures, heat waves and floods. As a result of climate change, the incidence of heavy rainfall is expected to increase, causing flash floods and damage amid general warming and drought in the region. The patterns show an increase in precipitation with large regional differences.

2.7. Areas exposed to the strongest potential impact

For the working climate change scenario adopted in the RBMP for the BSRBD — RCP 8.5 with gradually increasing greenhouse gas emissions over time (the most pessimistic scenario), the

following trends were projected for outflow changes by seasons, manifested as the most intensive for the period 2071—2100:

1. ***Black Sea Dobrudzha rivers, Provadia river and Kamchia river***

To the north of Stara Planina, for the Black Sea Dobrudzha rivers, Provadiyska and Kamchia rivers, the spring outflow is projected to decrease by 19 %, the summer one — by 38 %, the autumn one — by 9 %, and the winter one — by 17 %.

2. ***Rivers to the north of Burgas***

For rivers to the north of Burgas, the spring and summer outflows are projected to decrease significantly. To the north of Stara Planina, for the Vaya, Dvoinitsa, Panair Dere and Fandakliyska river valleys, the spring outflow is projected to decrease by 19 %, the summer one — by 38 %, the autumn one — by 9 %, and the winter one — by 17 %. To the south of Stara Planina, the spring outflow is projected to decrease by 30 % and the summer one — by 35 %. The autumn outflow is expected to increase by 9 % and the winter one — by 48 %.

3. ***Mandrenski rivers, South Burgas rivers, Veleka river and Rezovska river***

In the area of the Mandrenski and South Burgas rivers, the Veleka River and the Rezovska River, the spring outflow is projected to decrease by 30 %, and the summer one — by 35 %. The autumn outflow is expected to increase by 9 % and the winter one — by 48 %.

According to the approach for assessing the impact of climate change on the quantitative status of groundwater, the Basin Directorate has projected a 20 % reduction in the average annual recharge of groundwater bodies (GWB). The first two periods covered by the forecast (2013—2042 and 2021—2050) are expected to see a certain increase in natural groundwater resources mostly related to more abundant precipitation. With the two time periods overlapping for the most part, their results turn out fairly similar. The increase applies to both climate scenarios (CRP4.5 and CRP8.5).

A decrease in resources is projected during the third period covered by the forecast (2071—2100) and is associated not so much with less precipitation, but with an increase in evapotranspiration (due to higher temperatures). The decrease is almost ubiquitous and occurs in both climate scenarios.

3. Summarised Conclusions

The closed nature and isolation from the World Ocean, the permanent water layer with higher salinity, the hydrogen sulphide zone with depleted oxygen, the inflowing river waters of some of the largest rivers in Europe determine the unique character of the Black Sea. This affects the difficult water exchange and the slow purification of marine water pollution, yet at the same time provides a variety of opportunities to explore and utilise the untapped resources of the Black Sea, to study its cultural heritage preserved on the seabed and to protect its sensitive ecosystems.

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