

## THE BLACK SEA VIEWED FROM SPACE

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### ABSTRACT

The paper, has a strong methodological feature and its goal is to underline the advantages of the remote sensing in studying the seas. The Black Sea is an example. There are presented the most usual methods of geographical interpretation of some remote sensing documents concerning the sea surface temperature and the water chlorophyll concentration in a well-known period of time. The information was acquired directly, using dials that are enclosed in the analyzed materials, and indirectly (deductive), relating the two indexes to the Black Sea's oceanographically and geographical features. The objectivity of the acquired data permitted us to obtain correct and useful wordings from the scientific and economical point of view. And that, much more that the Black Sea, a continental sea with many peculiar features, has serious problems concerning the operation of the resources and environment protection.

### 1 INTRODUCTION

The study of the interior seas, like the Black Sea, is a priority because of their ecological vulnerability. In its category, the Black Sea has some peculiarities that can complicate the problems concerning the operation of the resources (especially biological ones) and the protection of the sea ecosystems. Among these, we underline the following: a poor communication with the Mediterranean Sea (narrow straits, a high threshold in the Bosphorus and Dardanells straits – the minimum depth is 27,5 m, a strong marked abysmal depression), an unique water stratification, from the density and gas distribution point of view (oxygen and sulphuretted hydrogen).

The remote sensing brings special contribution in global studying of this sea, which is in a critical ecological situation. This paper underline only some of the opportunities which the remote sensing offers, by geographical interpretation of two spatial documents with the sea surface temperature and the chlorophyll concentration of the Black Sea waters.

### 2 THE BLACK SEA'S FEATURES

The Black Sea is an inland sea, almost closed, being connected with the Mediterranean Sea by very narrow strains (Bosphorus and Dardanelles). Its oval basin, orientated from West to East, is narrowed in the central part by the Crimea Peninsula forming two parts: Western part and Eastern part (figure 1).

The length is 1.200 km; the maximum width is 610 km.

The length of seashore: 4.790 km.

The area is 413.490 km<sup>2</sup>; The Sea of Azov has an area of 38.000 km<sup>2</sup>.

The medium depth is 1.282 m.

The maximum depth is 2.245 m.

The volume is 529.955 km<sup>3</sup>.

The submarine relief has an evident asymmetry (figure 1):

- the main-land platform (shelf) is extended to the North-West (180 km from shore) and much narrowed to the South and East;
- the continental slope has tectonically dislocations, canyons and sliding; remarkable is "the Danube's cone";
- the abysmal depression has an even relief.

The annual medium temperature of the surface waters varies between 11<sup>0</sup>C in the NorthWest (Odessa Bay) and 16<sup>0</sup> C in the SouthEast, near Batumi.

The highest temperatures are in August (medium values of 21.5-25.5<sup>o</sup> C) and the lowest temperatures are in February (between 0<sup>o</sup> and 8<sup>o</sup>C), the way of growth is in both cases from the NorthWest to the SouthEast.

Vertically, there are several thermic levels. From the surface to the medium depth of 60 m, the temperature of the water follows the thermic changes of the air. To the maximum depth, the temperature diminishes to 7-8<sup>o</sup> C.

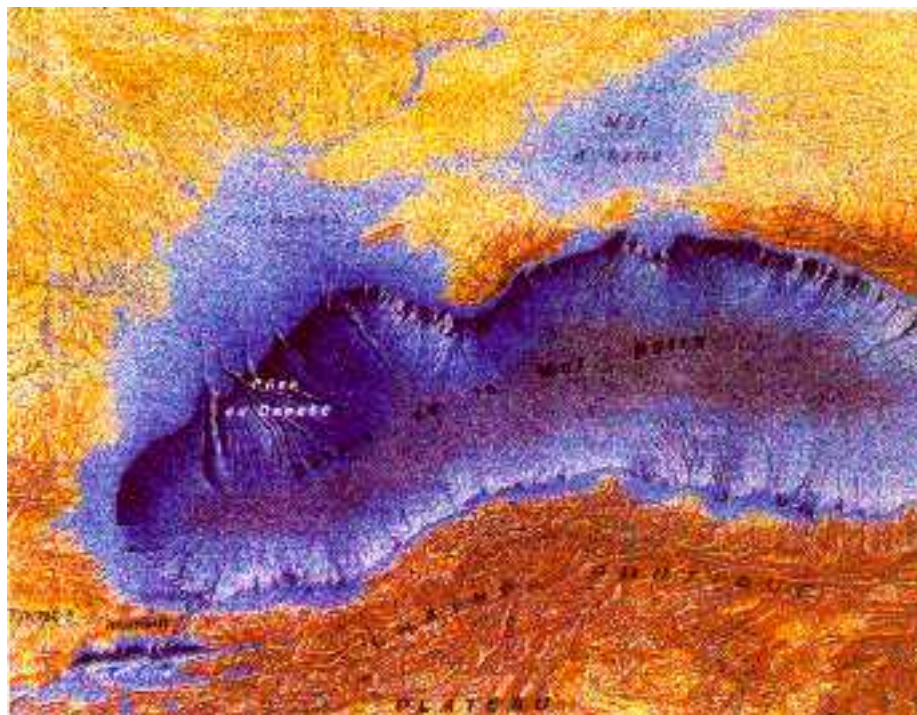


Figure 1. The Black Sea and the surrounding regions: a) the submarine relief was represented on the basis of the batimetric data collected by the ship Atlanta; b) The relief of the surrounding regions was made on the basis of the image satellites from LANDSAT.

A very important feature of the Black Sea is the presence of two levels of water with different chemical characteristics, the discontinuity being about 175 m depth.

- a surface level with low salinity (under 10‰ at the shore in the NorthWest and 17-18‰ out at sea).
- a very depth level with high salinity (22.3‰) without oxygen, but with hydrogen sulfide, a toxic gases (at a depth of 2000 m H<sub>2</sub>S is of 7-11 mg/l).

The chemical stratification of the waters has some important consequences from the ecological point of view. Life is possible only on the surface level (the biotic zone); the very deep level has the greatest volume of water and represents the abiotic zone, which represents 90% from the Black Sea water volume.

The Black Sea fauna is 4-5 times poorer than that of the Mediterranean Sea. Their multiplication is very high, though, because of the very abundant trophic base.

In the Black Sea, there is a cyclonic system of storms, which encircle the Black Sea basin in an opposite direction of the hands of the clock.

Between the Black Sea and the Mediterranean Sea there is a change of waters through the Bosphorus strait (the lower salted waters of the Black Sea are displaced on the surface).

The tide has amplitude of 9-12 cm.

The effective surface drained by the Black Sea and the Sea of Azov: 2.402.119 km<sup>2</sup>.

The riverside countries: Ukraine, Russia, Georgia, Turkey, Bulgaria, and Romania.

The Romanian coastline has 245 km, with a northern delta (The Danube Delta) and lagoonic area and a Southern cliff area.

Constanta is the greatest Romanian port at the Black Sea (about 400.000 inhabitants) and one of greatest ports of Europe.

The pollution of the coastline waters in Romania is quite advanced.

### 3 SEA SURFACE TEMPERATURES (SST)

#### 3.1 The spatial document which was interpreted: “The Mediterranean Basin from space” poster (fragment, figure 2).

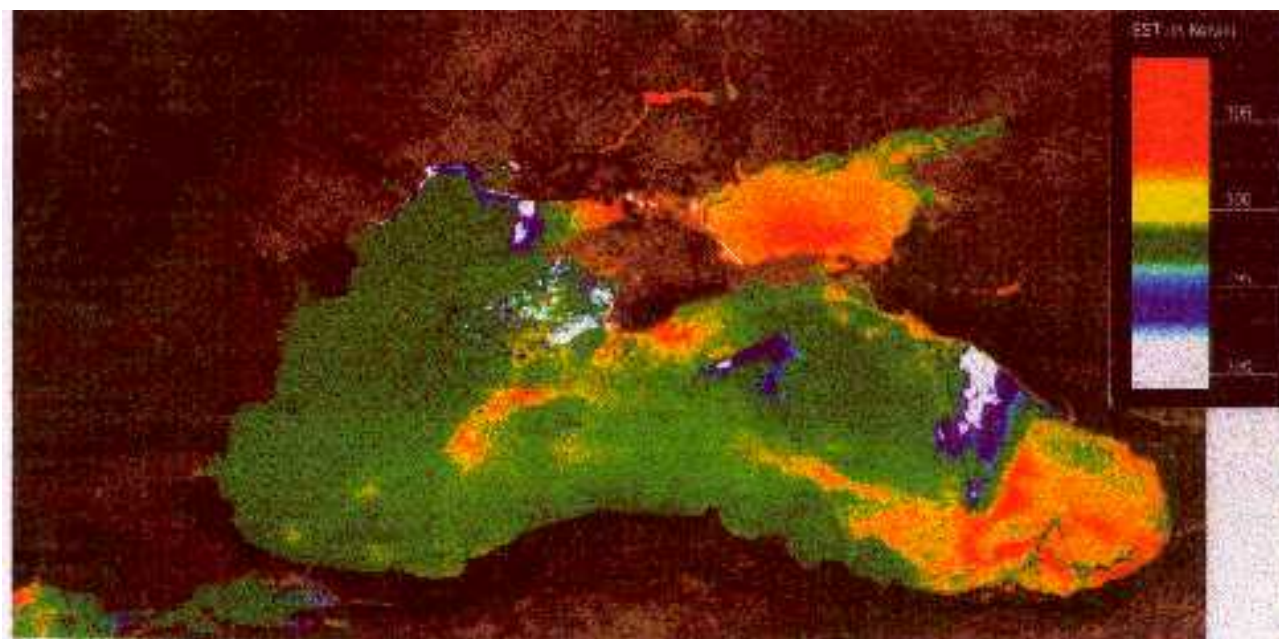


Figure 2. The Black Sea Basin from space (fragment from the “Mediterranean Basin from space”, document ESA/ESRIN. Sea Surface Temperatures (SST): 17 July – 7 August 1996

#### 3.2 The features of the poster

It was made by interpreting more than 400 images from the Along Track Scanning Radiometer, which was on the 2<sup>nd</sup> ERS satellite of European Spatial Agency.

The period of observation was 17<sup>th</sup> July-8<sup>th</sup> August 1996.

The hour of acquisition: varies between 8 o'clock (GMT) in the East and 11 o'clock (GMT) in the West.

The acquisition station: Kiruna (Sweden).

The spatial resolution: 1x1 km.

The projection: Plate Carrée.

The treatment of image: ESA/ESRIN, Frascati (Italy), as part of an ESRIN (EURISY) project.

The dates were treated with the help of a program developed at RAL.

#### 3.3 The premises of interpretation

The skin temperature of the Sea was obtained by combining the thermic dates of ATSR-2

The scale of colors: red (warm)-yellow-green-blue (cold).

The temperatures are in Kelvin degrees and were equalized by us in Celsius degrees ( $0^{\circ}\text{K} = -273^{\circ}\text{C}$ ).

Because of the frequency of ERS-2 passing, the Along Track Scanning Radiometer (ATSR), permits an accurate following of the evolution and distribution of the water skin temperature from the basin and the possibility of pointing out the marine streams.

### 3.4 The objectives of the interpretation

The correlation of up-to-date spatial data with all oceanographic data.

The causal-correlative explanation of the Sea Surface Temperatures (SST) distribution by taking into account the Black Sea's specific elements (geographical position, climate, configuration of the basin-inland Sea, almost closed, drainage, streams).

The determination of the marine streams by examining the distribution of different values of the surface waters.

### 3.5 The results of the interpretation (figure 3, figure 4)

The Sea Surface Temperature (SST) has important variations. Between 17<sup>th</sup> of July and 18<sup>th</sup> of August 1996, the difference was of 293-304<sup>0</sup> K (20-31<sup>0</sup> C), normal values for this period of summer, when the air diurnal temperatures varies generally between 25<sup>0</sup> and 35<sup>0</sup> C.

The values between 295-298<sup>0</sup> K (22-25<sup>0</sup> C) characterize most of the Black Sea's surface waters.

The Sea Surface Temperatures (SST) diminishes from the NorthWest to SouthEast. There are obvious thermic contrasts between the waters from the western part and those from the eastern, because of the climate differences and the drainage:

- Lower values (295-298<sup>0</sup> K, 22-25<sup>0</sup> C) are in almost the whole western basin, where an important number of colder rivers flow (Danube, Dnestr, Don) and where the colder deep water level, made during the cold winter (western temperate-continental climate) has a very important influence;
- Higher values (299-303<sup>0</sup> K, 26-30<sup>0</sup> C) are in the eastern basin and especially in the Caucasian end where the climate is subtropical moist, under the protection of The Great Caucasian Mountains and Iaila Mountains, which are in the northern part of the Black Sea.
- High temperatures (298-302<sup>0</sup> K, 25-29<sup>0</sup> C) are in the Sea of Azov, which has a small area (38.000 km<sup>2</sup>), not deep waters (14 m) a poor communication with the Black Sea (Kerci Strait), being under the influence of a warm dry continental wind specific to the summers from East European Pontic steppe and of the hot surrounding land. Only at the end of the Sea of Azov, where the Don river flows and brings colder waters, the temperatures are lower: 297<sup>0</sup> K/24<sup>0</sup> C.

The SST distribution, the colder and warmer waters respectively, gives us the opportunity to guess the marine streams, which were noticed only through traditional oceanographic investigations up to now:

- In the eastern basin, the distribution of the higher temperatures (yellow-orange-red) (298-304<sup>0</sup> K, 25-31<sup>0</sup> C) suggests us a warm stream, parallel to the coastline, which sketches an area of colder waters (green-blue). This is the eastern branch of the cyclonic stream, in an opposite direction of the hands of the clock.
- In the western basin, the stream brings about colder waters (296-298<sup>0</sup> K, 23-25<sup>0</sup> C) mostly because of the river waters under the influence of the NorthEastern winds.
- The similar thermic values of the western part of the Black Sea and the Sea of Marmara (296-298<sup>0</sup> K) are also because of the shifting of colder waters from the Black Sea through Bosphorus strait to the Mediterranean Sea (there is a change of waters between the two seas-compensatory streams in Bosphorus strait).

## 4 THE CONCENTRATION OF CHLOROPHYLL IN THE BLACK SEA IN JULY 1997

**4.1 The document which was explained:** ADEOS OCTS Chlorophyll-a concentration global map from June 1997 (resolution 10 km), CD-ROM "Resources in Earth Observation", CNES, 1997 (figure 5).

### 4.2 The objectives of interpretation

To establish causal links between physical-chemical features of the surface waters and the concentration of chlorophyll.

To point out the connections between the fertility of the marine waters and the productivity of the phytoplankton.

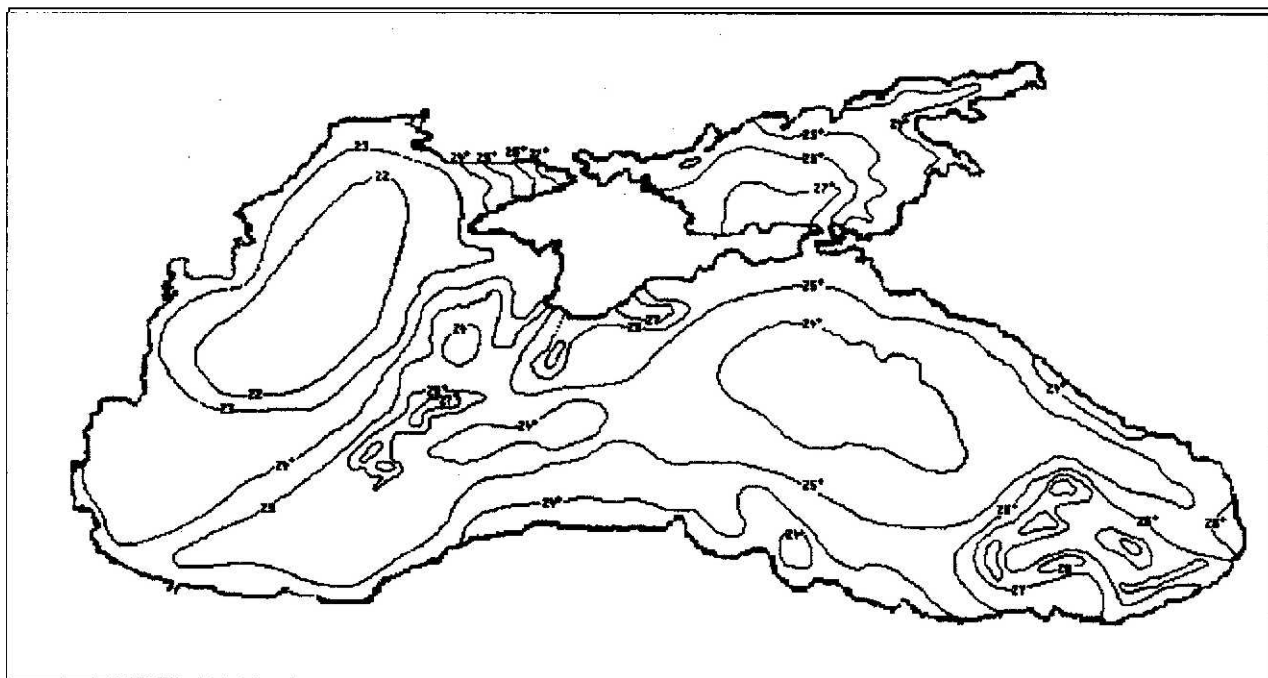


Figure 3. Sea Surface Temperatures (SST). The map with isotherms (17 July – 8 August 1996) realized on the basis of the interpretation of the spatial document “The Mediterranean Basin from space”.

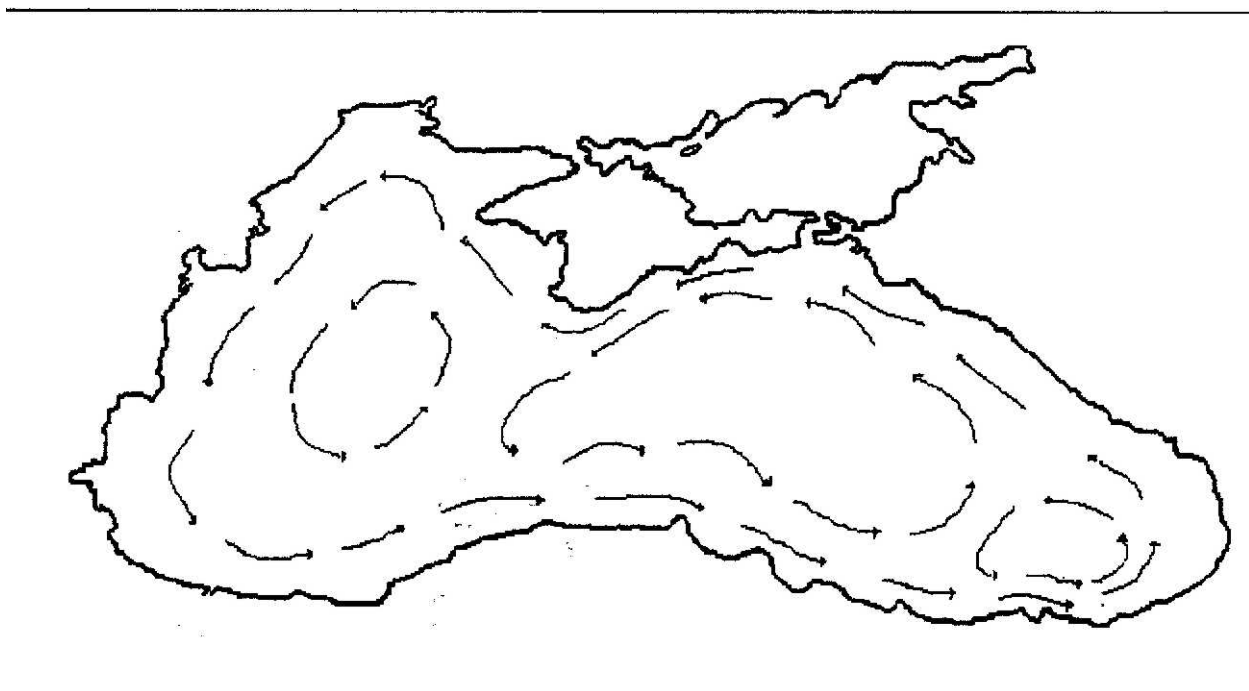


Figure 4. The map of the marine streams realized through the interpretation of spatial document and through the valuation of the existing data.

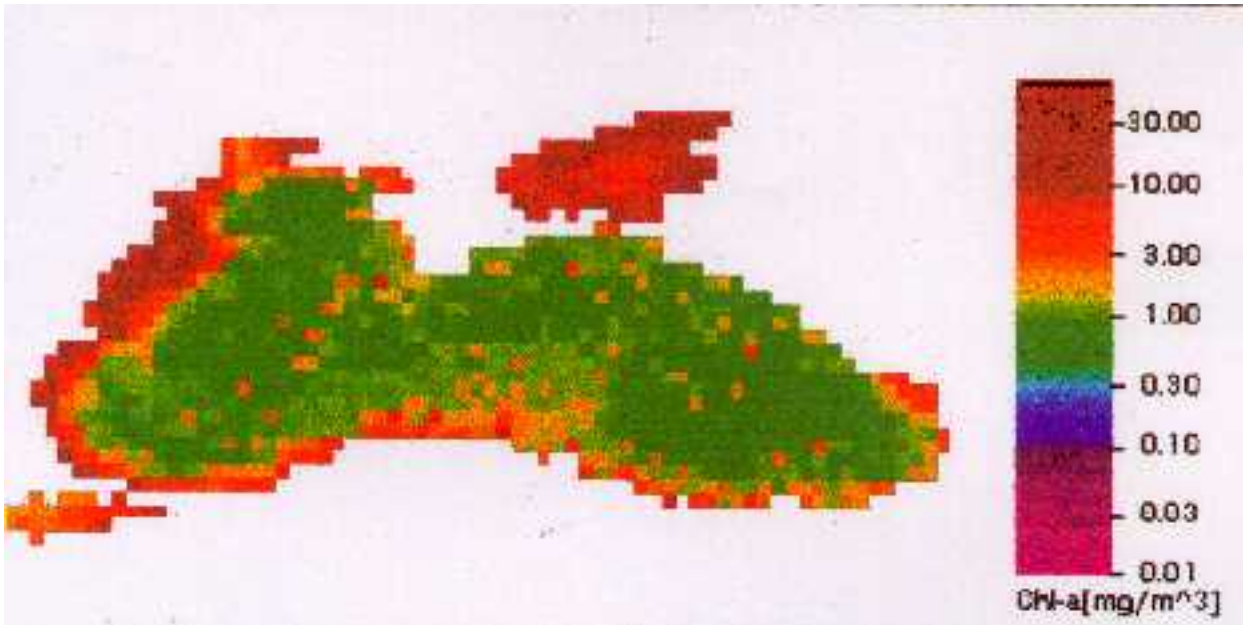


Figure 5. The Black Sea, the phytoplankton (fragment from the document” Chlorophyll-a concentration global map from June 1997”, CD-ROM “Resources in Earth Observation”, CNES, 1997)

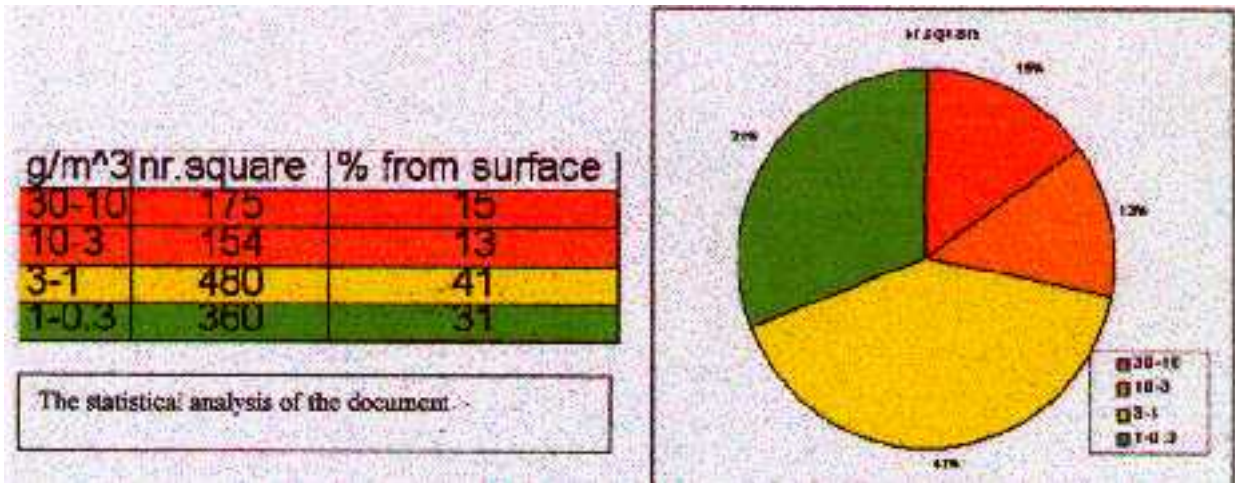


Figure 6. The proportion of the concentration levels of the chlorophyll in the surface waters of the Black Sea.

To establish the concordances between the distribution of the phytoplankton and of the nekton, of the piscicultural resources respectively, knowing that the floating vegetable microorganisms (bacteria, seaweeds) determine the distribution of animals from the whole alimentary chain of the sea.

#### 4.3 The results of the interpretation (table, figure 6, figure 7)

The concentration of chlorophyll ( $\text{mg}/\text{m}^3$ ) is directly proportional to the quantity of phytomass (the development of phytoplankton), to the fertility of the sea waters respectively.

The physical-chemical features of the waters determine the fertility of the sea: temperature, light, content of  $\text{CO}_2$ , nourishing elements. How much more the seawaters are warmer, brighter, with great quantities of  $\text{CO}_2$  and nourishing elements (especially nitrogen and phosphorus), the more phytoplankton will develop (especially seaweeds).

Depending of the degree of development of the phytoplankton, which is on the basis of the trophic chain of the sea, the marine fauna will develop (zooplankton and nekton). That is why, the document which was analyzed gives us the opportunity to establish a strong link between the distribution of the phytoplankton (by the concentration of chlorophyll) and the piscicultural fauna, standing out the richest and the poorest fishing areas.

It is clearly pointing out that the highest values of the concentration of chlorophyll ( $30\text{-}10 \text{ mg}/\text{m}^3$ ) are in the Sea of Azov and on the western coastline (15% from the area), followed by the Southern and Eastern coastlines with  $10\text{-}3 \text{ mg}/\text{m}^3$  (13% from the area). The explanation: there are no deep waters (only 14 meters in the Sea of Azov, up to 180 m in the wide North-Western shelf), there are upwelling coastlines, waters with higher temperatures (in July and August there are  $25\text{-}29^\circ\text{C}$  in the eastern coastline and  $24\text{-}27^\circ\text{C}$  in the Sea of Azov), there are waters with a higher content of nutritive substances because of the great tributary rivers (Danube, Dnepr, Don) and that is why they have a high fertility. Besides that there are the most polluted waters (port industries, maritime traffic, oil extraction from the continental plateau) which encourage the developments of some species of seaweeds, but in the same time they endanger the development of the fauna (especially the ichthyo-fauna). That is why the coastlines and the waters of the Sea of Azov are the most fertile, with the highest productivity of phytoplankton (red and brown seaweeds) and zooplankton, with the richest piscicultural resources (*Engraulis ponticus*, *Trachurus mediterraneus*). But they represent only 28% from the Black Sea's and the Sea of Azov's area.

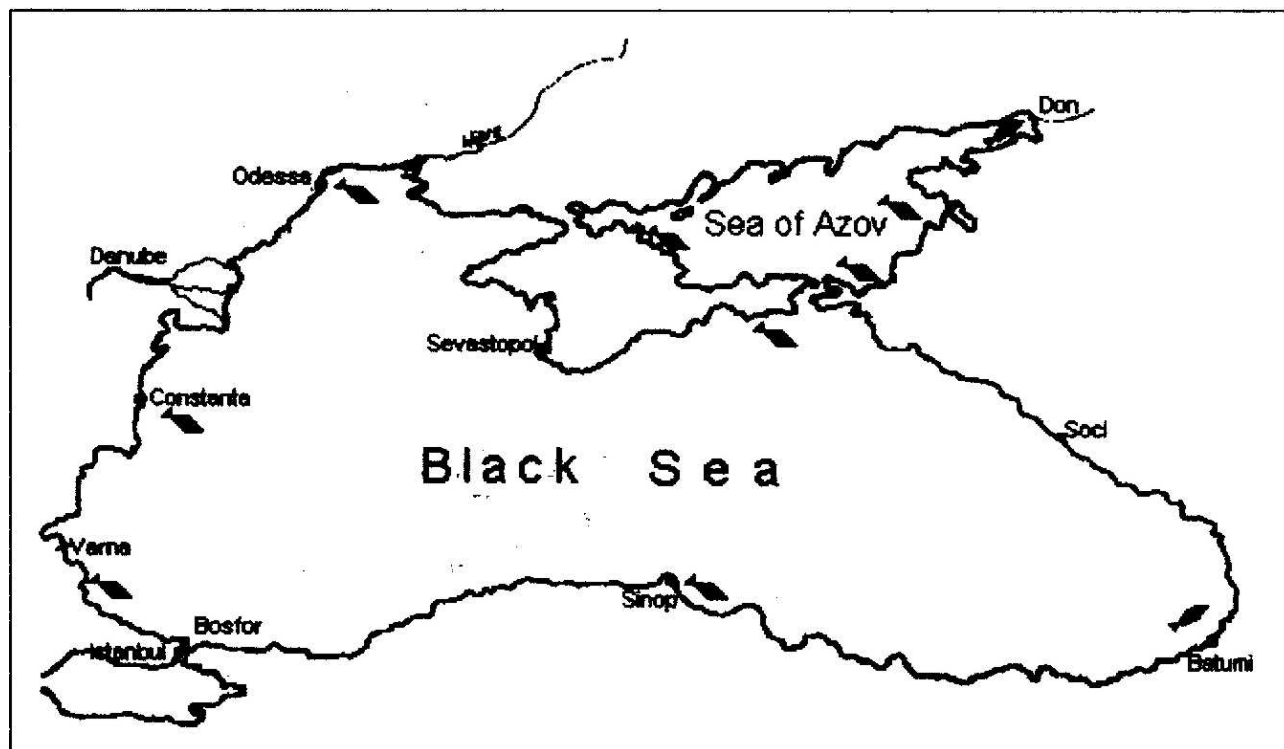


Figure 7. The distribution of the piscicultural resources of the Black Sea connected with the distribution of phytoplankton.

The lowest concentration of chlorophyll ( $3-1\text{ mg/m}^3$  which represent 41% from the area of the two seas;  $1-0.3\text{ mg/m}^3$  represent 31% from the area) are on the Northern coastline and the pelagic zone. The result is that 72% from the Black Sea's and the Sea of Azov's area is less fertile, the waters are poor in phytoplankton, zooplankton and nekton, in piscicultural resources respectively.

The study shows us that the Black Sea biological productivity is higher than in the Mediterranean Sea.

## 5 CONCLUSIONS

The research of the sea basins starting from the documents obtained by remote sensing techniques is very actual.

The application of the interpretation principles and methods of such materials and records permits to obtain valuable information's regarding different oceanographic parameters.

The data obtained by geographical interpretation of the two satellite documents with records about the Black Sea (sea surface temperature and chlorophyll concentration) has a scientific and practical significance. This sort of information's can be used in the Black Sea environmental management studies.

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