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THE EFFECTS OF CLIMATIC AND ANTHROPOGENIC CHANGES IN MARINE ECOSYSTEMS

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A STUDY ON MAPPING OF MARINE BENTIC FACIESES IN GÖCEK BAY (SOUTH-WESTERN COAST OF TURKEY)

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1. Introduction:

With a long coastal strip, Turkey has various important natural habitats that have different characteristics, and thus diverse in biodiversity. This diversity of the habitats results in the species richness at the coasts of the country which have a special importance in the Mediterranean ecosystems.

In Turkey, especially in the second half of the 20th century, immigration from rural areas to cities gave rise to an irregular and unplanned development in the coastal areas. During this period, applied politics and the subsidies resulted in the tourism and industrial development at the coasts. After human activites having increased along the coasts, most of the marine/coastal habitats and organisms were affected negatively.

Based on international conventions on the environment and biodiversity conservation, **"Environmental Protection Agency for Special Areas" (EPASA)** was established under the Prime Ministry in 1989. Since then,

EPASA as an authority has determined 14 areas as Special Environmental Protection Areas (SEPAs). The **EPASA** is not only responsible for the selection and effective management - including the protection and use equality - of the sites as SEPAs, but also carries out and encourages research progamme to support its former duties. In this context, EPASA conducted a study for determining the carrying yacht capacity of the Göcek Bay (one of the SEPAs) to be able to establish a sustainable life in the marine environment. This study is a part of this project and focused on the determination of the current status of the benthic life, especially the distribution pattern of marine benthic flora in the Göcek Bay.

2. Study Area, Material and Methods:

The study was carried out in the Göcek Bay with the logistic help of the R/V K.Piri Reis of the Dokuz Eylül University, Institute of Marine Sciences and Technology between 28 May and 01 June 2007.

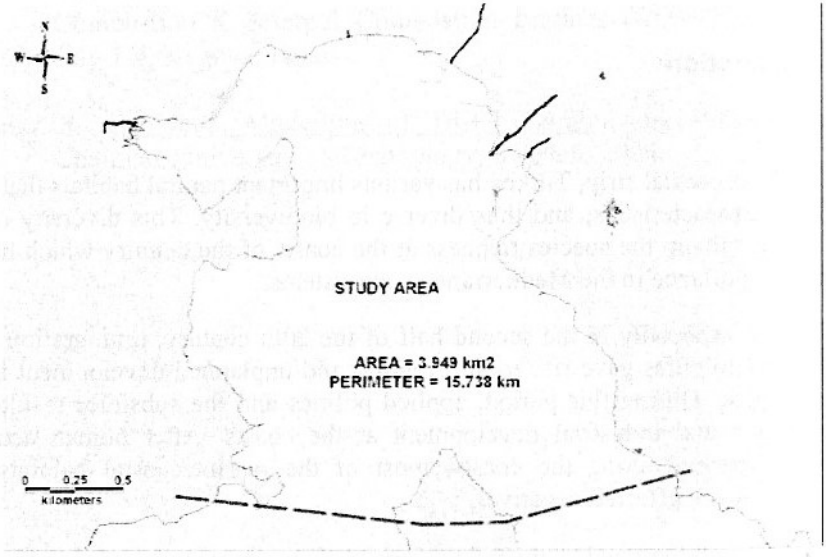


Figure 1. The location of the study area.

The Göcek Bay is located in the northern part of the Fethiye Bay, and is seperated from the Fethiye Bay with two islands; Göcek and Yassıca Islands (Figure 1). The bay, being circumscribed by the mountains, shows a natural refuge characteristic. Although it is located at the mixture point of the Aegean and Mediterranean Seas, it shows more Mediterranean characteristics. The depth of the bay increases from north to south towards the Göcek Island. A small river discharges to the bay at the northwest where they both form a small delta, and the depth of this location varies beetween 1 and 1.5 m.

The study was performed at a coastal area having a coastal strip of 16 km and a total area of 4 km^2. In the study area, 5-day field survey was conducted with both SKIN and SCUBA diving, and all the dives were carried out during the day-time between 08:30 and 17:30. During these dives, photographs and video films of the observed species were taken.

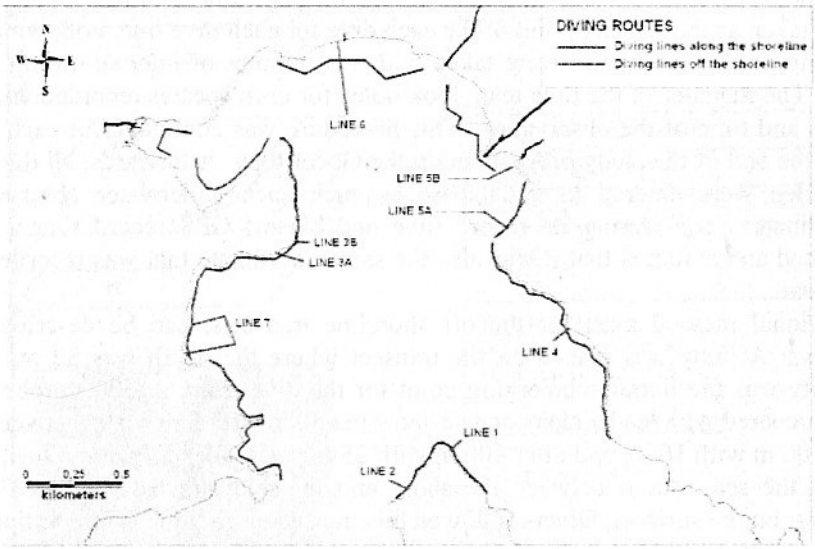


Figure 2. The dive lines of the fieldwork.

- ✓ In the first step of the field study, 0-5 m depth contour of the coastline was scanned by skin and SCUBA dives.
- ✓ Second, after the evaluation of data obtained from the first visual observations, SCUBA dives were carried out from 0-1 meter depth to deeper localities in a selected line perpendicular to the coastline. Dives were performed at seven such kind of lines some of which have a maximum depth of 40 meters (Figure 2).
- ✓ Furthermore, dives were conducted to determine the distribution of the *Posidonia oceanica* meadows and a larger area was studied by means of scooters to determine the distribution of the species.

In the Göcek Bay, all the dives were conducted with aid of GPS coordinates. These coordinates were detected by means of Magellan hand GPS. During each dive, dive team was taken to dive line with an inflattable boat, and the team was followed by the boat to take coordinates with the GPS by tracking. Dive team and the researcher remained on the boat took the start time, and first coordinates were taken as the starting point of the each dive for each dive line. Following the starting point, coordinates were taken with a 3 minutes of interval during each dive. The member of the dive team took notes for each species recorded with its depth and time of the observation. This procedure was continued for each dive until the end of the study programme in the Göcek Bay. Afterwards, all the data collected were entered to a database as such each underwater observation coordinate - considering its record time and closest GPS record time - was matched and assumed that it was also the same coordinate that was recorded on the boat.

Additional method used for the off shoreline transects, can be described as follows: A buoy was placed on the transect where the depth was 30 m. This locality was the initial submerging point for the dive team. A 600 m robe that was prepared with lead sinkers and scaled (first 50 m with 5 m scale, between 50 and 100 m with 10 m, and after 100 m with 25 m scale) for the transect line, was set at the sea bottom between the shore and the buoy placed to show 30 m contour on the surface. Divers followed this transect during their observations.

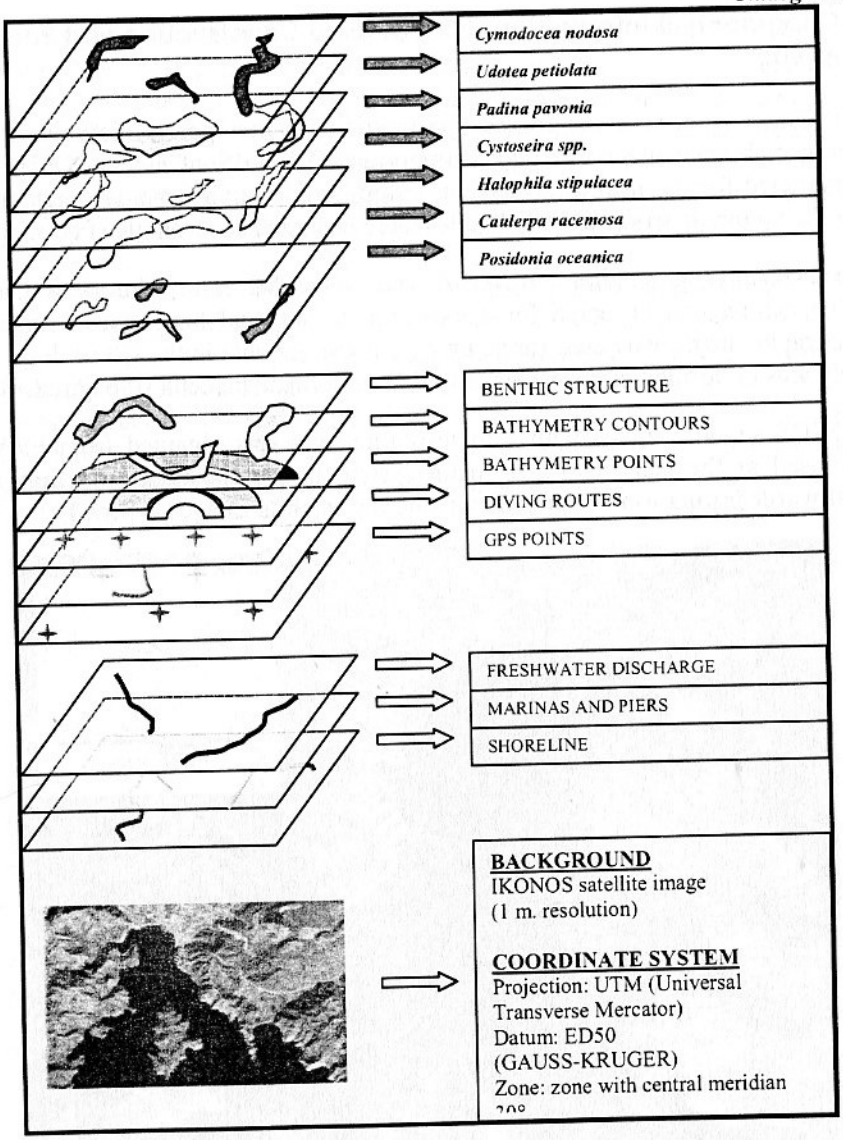


Figure 3. The GIS environment of the Göcek SEPA.

3. Geographical Information System (GIS) Construction and Facies Mapping

The GIS environment design and construction for the species distribution and presence/absence mapping is very important. The GIS of Göcek SEPA was constructed for the priorities of facies mapping and environmental relatedness, and the system layers and related tables were designed accordingly (Figure 3).

Gauss-Kruger projection (Universal Transverse Mercator, European Datum 1950), which was accepted for Turkey for 1/5000 and bigger scale standard topographic maps, was used for mapping the species data in the Göcek Bay. The study was performed in the 3-degrees UTM zone with the central longitude 30°.

IKONOS satellite image with 1 m resolution that was obtained from EPASA was used as the base map. The main system layers **coastline, marinas and freshwater inputs** were digitized by using the satellite image (Figure 4).

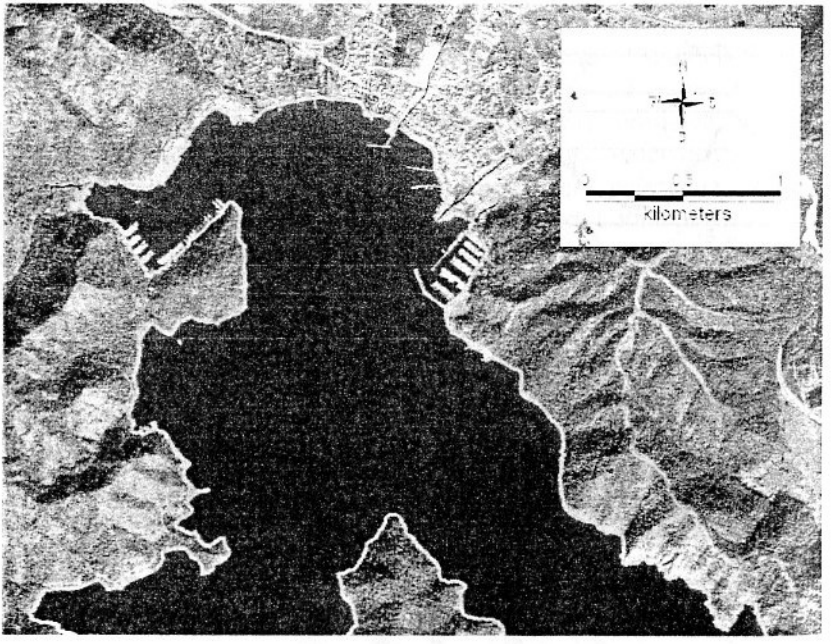


Figure 4. Satellite image and digitized layers.

Facies mapping was made in four stages: 1. importing of the GPS points that were collected during field survey to GIS environment, 2. constitution of the bathymetry contours, 3. biotop mapping, and 4. assessment and digitization of the facies distribution. It was paid attention to represent (with its frequency/ distribution) the borders of the facieses or critical areas in the point selection while taking points with GPS in the field. In order to be able to control with the bathymetry map, depth data was also collected at GPS points in the field.

In the field study, dive transects were designed perpendicular to shore and observation lines were designed paralel to shore. Observations were conducted in 0-16 m and 0-36 m of depth in 9 diving transects, and 0-12 m depth segments were searched in 10 observation lines. Along these lines, a total of 9.396 km line was observed in horizontal plane (slope was neglected) and facies presence/absence and benthic structure data was collected at 417 points (Figure 5) by means of GPS to pinpoint the coordinates on the map.

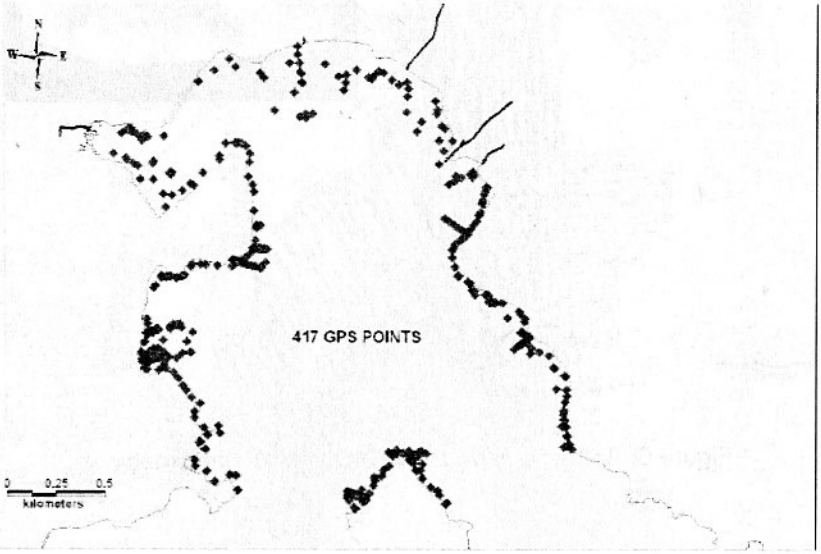


Figure 5. GPS points of the study.

4. Constitution of the Bathymetry Map

In order to evaluate depth structure and relate it with facieses of the Göcek Bay, bathymetry data obtained from EPASA was mapped by GIS, and 3-dimensional bathymetry map (Figure 6) was drawn. Moreover, field bathymetry points were interpolated (Simple Natural Neighbourhood Interpolation) to obtain 2 and 5 m depth contours. Two meter countoured bathymetry map (Figure 7) was used to control facies mapping.

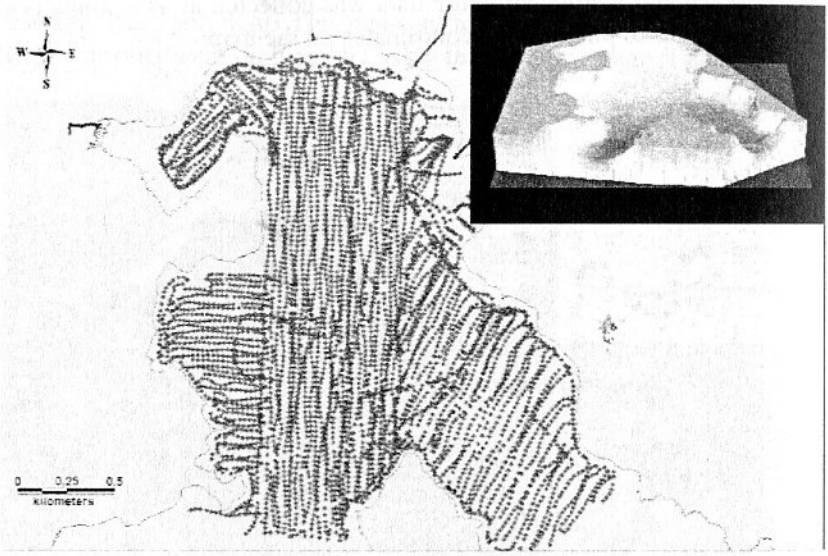


Figure 6. Bathymetry data and 3-D view of bathymetry.

5. Mapping Facies Distribution

Seven facieses (*Posidonia oceanica, Caulerpa racemosa, Halophila stipulacea, Cystoseira sp., Padina pavonia, Udotea petiolata* and *Cymodocea nodosa*) that were observed in the field were mapped with direct mapping. In this technique, the bordering points of each facieses, which were obtained during the field study, were combined with straignt lines to digitize the borders of facieses, and distributed by the use of the presence/absence data according to the depth contours. The area covered by each facies in the Göcek Bay was then calculated using distribution maps obtained. When calculating these areas, the benthic slope was neglected. Therefore, the true areas covered by the facieses should cover more area than the calculated ones depending on the benthic slope.

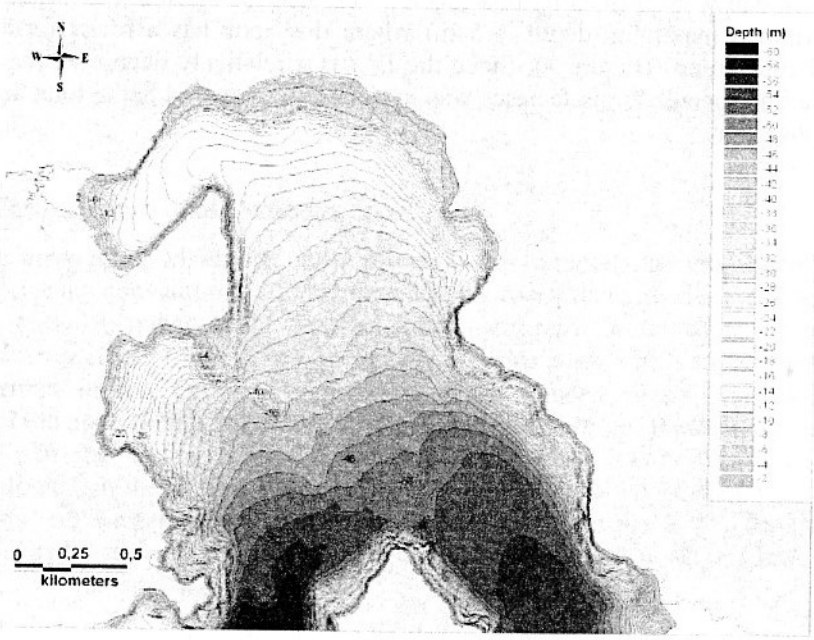


Figure 7. Bathymetry map with 2m interval.

6. Results

As a result of the underwater observations in the Göcek Bay, 7 species of facieses were determined. Among these, 4 of them were marine algeas (*Padina pavonia*, *Cystoseira* spp., *Udotea petiolata* ve *Caulerpa racemosa*) while 3 of them were marine meadows (*Posidonia oceanica*, *Cymodoce nodosa*, *Halophila stipulacea*). *Caulerpa racemosa* and *Halophila stipulacea* are not native species in the Mediterranean Sea and are among the exotic and invasive species.

1. The distribution of *Padina pavonia*

The Göcek Bay with its stone-rocky coastal structure forms a very suitable habitat for the settlement and development of the *Padina pavonia*. In general, facieses that were formed by this species were distributed in 3-4 m depth zone (determined maximum depth is 5 m) where this zone has a rocky formation (hard substratum) (Figure 8). Since the Bay is a relatively deep one, the zone where this species forms facieses was in a narrow strip, and had a total area of 0.140942 km^2.

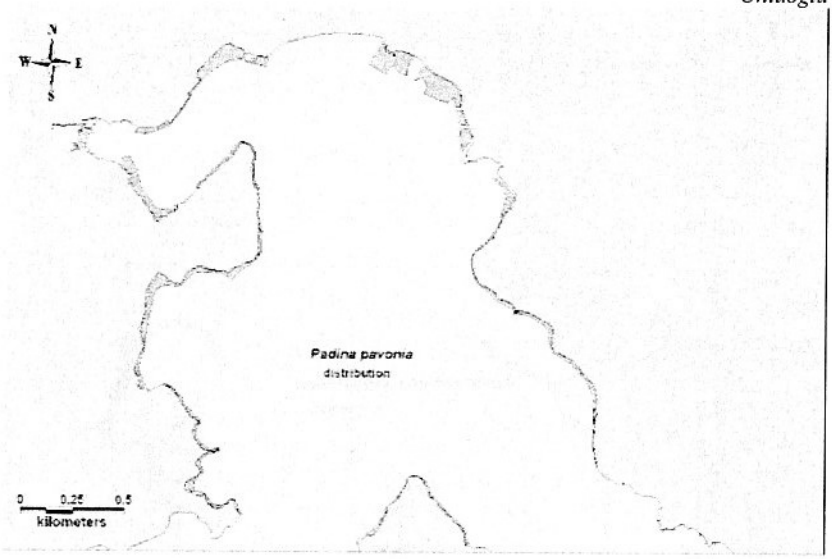


Figure 8. Distribution of Padina pavonia in the Göcek Bay.

2. The distribution of *Cystoseira* spp.

Cystoseira spp., which are under protection by international environment and biodiversity conventions, are distributed in the rocky and gravelly areas between 0.5 and 10 meters. The species like *Cystoseira amentacea, Cystoseira mediterranea, Cystoseira spinosa* and *Cystoseira zosteroide* can be frequently observed in the Turkish Aegean and Mediterranean coasts. In this study, observed species that belong to *Cystoseira* genus were not identified in species level. In the Göcek Bay, *Cystoseira* facieses were mainly observed to be distributed on the rocky biotops (up to 4-5 m depths) in the western and eastern coasts and western coast of the Göcek Island (Figure 9). In the Bay, it was calculated that the *Cystoseira* facieses covers a total area of 0.027551 km^2.

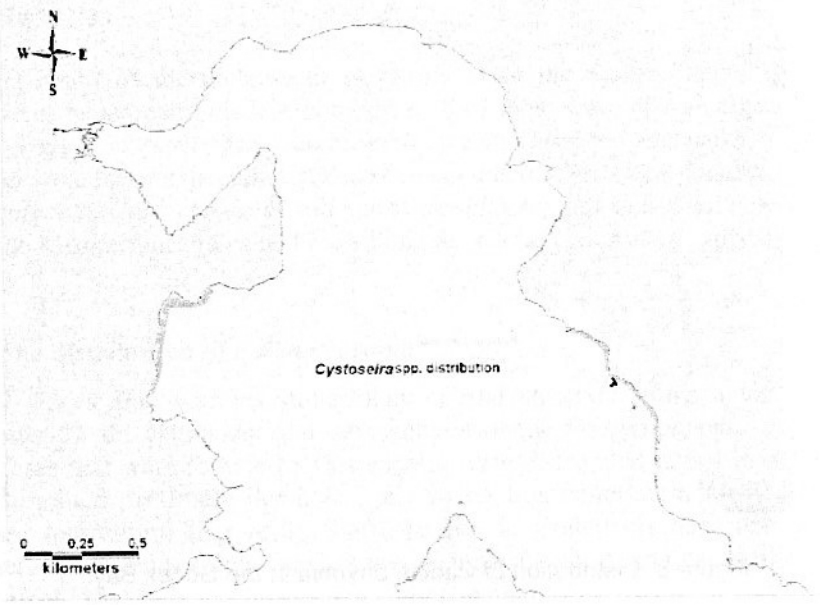


Figure 9. Distribution of Cystoseira spp. in the Göcek Bay.

Generally, it is known that *Cystoseira* spp. are sensitive to pollution. Therefore, the absence of the species' facieses in the northern part of the Bay can be explained by this fact. It is also probable that this can be due to lower salinity due to fresh water input in this part of the Bay.

3. The distribution of *Cymodocea nodosa*

Cymodocea nodosa, that is one of the protected marine meadows species by international environment and biodiversity conventions, is distributed in between 3 and 10 m depths in the Göcek Bay (Figure 10). In the Bay, the species was observed to be distributed after the rocky zone on the muddy-sandy substrata, and covered a total area of 0.126984 km^2'.

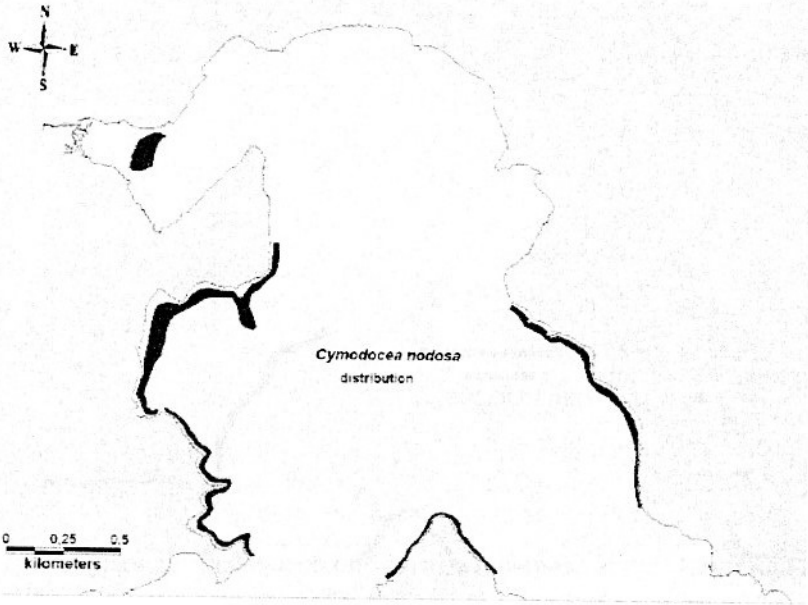


Figure 10. Distribution of Cymodocea nodosa in the Göcek Bay.

4. The distribution of *Posidonia oceanica*

Posidonia oceanica, that has a very important function and is endemic to the Mediterranean ecosystem, is one of the protected marine meadow species by international conventions. The species distribution was observed to be confined to a limited area (Figure 11). The facieses of *P. oceanica* had healthy formations on the east of the Göcek Island between 9 and 23 m depths. However, *P. oceanica* facieses were observed to be in unhealthy formations on the western part of the island due to anchorages of the yachtes. In the Bay, it was calculated that the *P. oceanica* facieses covered a total area of 0.050489 km^2.

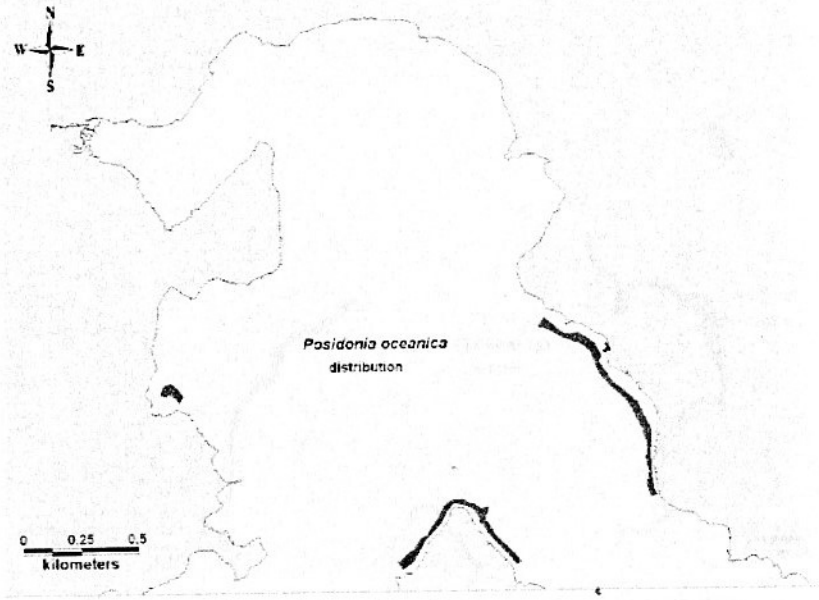


Figure 11. Distribution of Posidonia oceanica in the Göcek Bay.

5. The distribution of *Caulerpa racemosa*

The exotic and invaise species *Caulerpa racemosa* was observed only in the western coasts of the Göcek Island between the depths of 26 and 30 m (Figure 12). At the time of the study, the species only covered a small area (0.0002421 km^2).

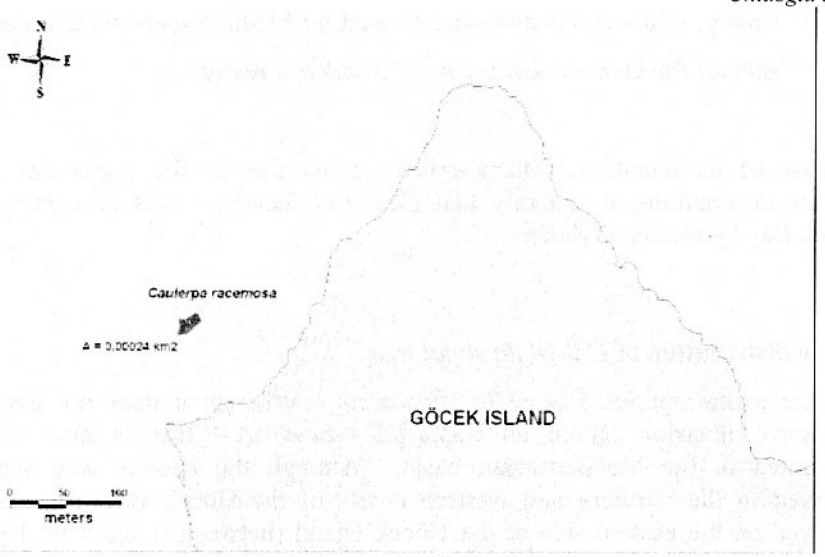


Figure 12. Distribution of Caulerpa racemosa in the Göcek Bay.

When the fact that the depth limits of the other facieses were 23 m is considered (*Posidonia oceanica* in the east and west sides of the Göcek Island), the locations where *Caulerpa racemosa* observed were found to be not covered by any other facieses. Therefore, it would not be surprising that the species will cover larger areas when considering its spreading and invasive characteristic. In time, *Caulerpa racemosa* may spread and become a dominat species in the following areas;

- primariliy in the suitable empty biotops,
- afterwards, in the areas where affected by the fresh water input and suspended matter, and as a result had low quality facieses formations. (For *Caulerpa racemosa*, increase in the amount of nutrients brought by fresh water inputs can be advantageous).

- finally, in the facies that were formed by Mediterranean-wide protected species *Posidonia oceanica* and *Cymodocea nodosa*.

Because of its recrational characteristics being one of the important yacht tourism destinations, it is likely that *Caulerpa racemosa* was brought to the Göcek Bay by means of yatches.

6. The distribution of *Halophila stipulacea*

Another exotic species *Halophila stipulacea* – although it does not have an aggressive invasion nature as *Caulerpa racemosa* – that is also widely distributed in the Mediterranean basin. Altough the species was densely observed in the northern and western coasts of the Göcek Bay, it was also observed on the eastern side of the Göcek Island (between 6 and 7 m depths) (Figure 13). When compared to facieses of the other species, *Halophila stipulacea* is distributed in a larger depth range. This may be seen as the adaptation capacity of species to different and degraded environments.

Halophila stipulacea covered a total area of 0.075523 km^2 in the Göcek Bay. However, after the observations made by the dive team, it is very probable that the species may also have been distributed towards north from the western side of the Bay. Therefore, these probable areas where *Halophila stipulacea* could be distributed were also shown on the map. In total, this area was calculated to be 0.146245 km^2. *Halophila stipulacea* covered the third largest facies at the study time, after the *Padina* and *Cymodocea* facieses in the Göcek Bay. When the observed and probable distributions are both taken into consideration, *Halophila* facies distribution becomes the largest one with 0.221768 km^2.

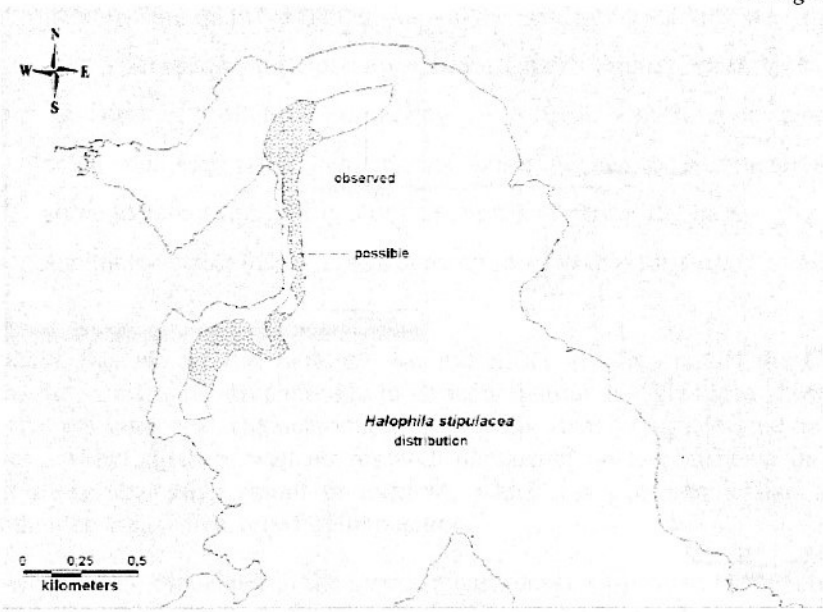


Figure 13. Distribution of Halophila stipulacea in the Göcek Bay.

7. The distribution of *Udotea petiolata*

In the Göcek Bay, *Udotea petiolata* facies could only been observed in the Club Marina coast between 8-10 m (especially the inner part of the marina) (Figure 14). Udotea facies approximately covered an area of 0.000101 km^2. The presence and facies formation of the *Udotea petiolata* in this area, where pollution originated from yacht tourism and marina activity is the densest, shows that the species is very resistant to pollution.

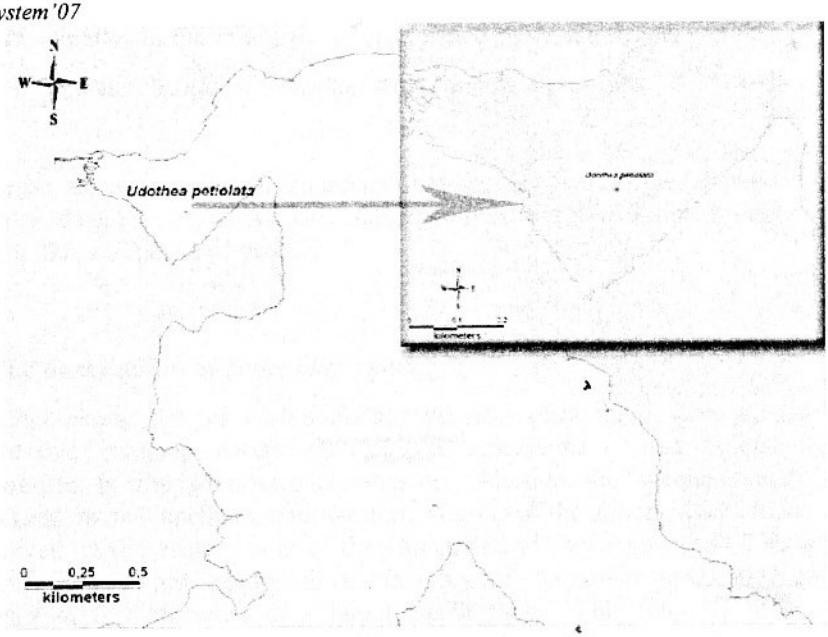


Figure 14. Distribution of Udotea petiolata in the Göcek Bay.

Discussion and Conclusions

There are some limiting factors for the distributions of the facies in the Göcek Bay. These can be given as follows:

- ✓ underwater topography (sudden increase in the depths) of the Bay plays a limiting role,
- ✓ fresh water input (sudden change in the salinity concentration) and lower visibility due to suspended matter along northwest and northeast coasts play a barrier role,

- ✓ degradation of the benthos due to the settlement of the suspended matter brought by the fresh water brooks play a limiting role,
- ✓ all sorts of pollution originating from fresh water input, coastal settlement and yacht tourism, and observed eutrophic structures at some locations, especially along the northern part of the Bay,
- ✓ anchorage effect (especially originated form yacht tourism).

The Göcek Bay, where the visibility was extremely low in front of the Club Marina; shows a fragile structure due to its natural structure. This area shows a "receptive environment" characteristic due to fresh water input and land-based pollution. Although there was no research conducted on the nutrients in the present study, excessive amout of nutrients which cause eutrophication also shows that the area is in a very fragile position.

In the Göcek Bay, especially in the northern part, dense suspended matter in the water column and settlement of this matter on the sea bed cause habitat loss and ecosystem degradation. It is predicted that after the sewage treatment system constructed by the EPASA becomes operational, the status of the ecosystem may be recovered.

The study also showed that GIS is an effective tool for mapping the distribution of marine and benthic species. In addition to visualization and analysis capabilities, it is probably the best choice for obtaining geographical attitudes such as area and perimeter of marine and coastal features. Furthermore, GIS provides the authorities, which are responsible for special area management such as Göcek SEPA, a monitoring system base with its data management capabilities.