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Mapping *Posidonia Oceanica* (Linnaeus) Meadows in the Eastern Aegean Sea Coastal Areas of Turkey: Evaluation of Habitat Maps Produced Using the Acoustic Ground-Discrimination Systems

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Mapping *Posidonia oceanica* (Linnaeus) Meadows in the Eastern Aegean Sea Coastal Areas of Turkey: Evaluation of Habitat Maps Produced Using the Acoustic Ground-Discrimination Systems

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Abstract

Coastal areas include highly complex ecosystems that encompass many different and productive resources worldwide. Although having such great importance, the lack of basic knowledge concerning the marine habitat distribution and biodiversity along the Turkish shoreline is an undeniable reality. In this study, seagrass beds in the bays along the Eastern Aegean Sea coast were located and mapped. Traditionally, sea-truth data used for satellite-image and other analysis are collected through direct observations requiring scuba divers or by aquatic video-camera observation. This study included a combination of acoustic technology, video recording and interpretation, geomorphological, oceanographic, and sedimentological evaluation in order to make significant contributions of current technology. The classification of the evaluated Subbottom Profiler (SBP) records exhibited their high discrimination capacity between different sea-bed features, making them appropriate for ground distinction. Linking of the SBP data sets to the Side Scan Sonar (SSS) records (object-based analysis) provide to full coverage, high resolution benthic habitat maps. For this purpose, Side Scan Sonar, 3.5/10 kHz Subbottom Profiler data were collected to a range of 50 m water depth, the data was recorded for a total 1600 km^2 coastal area that consists of approximately a total 3000 km long and 1km wide grid system for Edremit, Çandarlı, Gülbahçe, Ildır, Güllük and Gökova Bays. In the study area, it was determined that the seagrasses are under danger where high human influence is located. Dense distribution of invasive macroalgae (*Caulerpa cylindracea, Stypopodium schimperi*) were seen at the southern and northern part of the study area subjected to human activities.

Keywords: Seagrass, Habitat Mapping, Sonar Investigation, Surface Sediments, Aegean Sea

Introduction

Posidonia oceanica (Linnaeus) Delile (Magnoliophyta) is the most copious seagrass in the Mediterranean Sea and its distribution is fairly well recorded (Green & Short, 2003; Mateo et al., 1997; Boudouresque, & Meinesz, 1982). Seagrasses are marine plants that are defined as the lungs of the seas. From the biological and physical perspective, in terms of primary production, export of detritus towards other ecosystems (Pergent et al., 1994), species diversity (Boudouresque et al., 1994), spawning and nursery opportunities for species of fishery interest (Francour, 1997), water movement and sediment flows (Gambi et al., 1989), these meadows represent a key ecosystem (Leriche et al., 2004). They form widely distributed meadows which provides habitat for many species. They are also main source for oxygen in sea water with their ability to mass photosynthesis at marine ecosystems. *Posidonia oceanica* (L.) presence, dimensions, health status, distribution is an important ecological-bioindicators indicator, and gives an illuminating profile about the general situation of the environment is emphasized in various publications (Gazioğlu, 2018; Şeker et al., 2016; Simav et al., 2015; Boudouresque et al., 2012; Royo et al., 2011). As it's known, there are approximately 60 species of seagrass meadows which creates important ecological habitats in shallow water or tropical coastal areas of worldwide (Abadie et al., 2018). Amongst them, *Posidonia oceanica* is probably most studied species by researchers because of its ecological and economical importance. *Posidonia oceanica* is common to the Mediterranean Sea and is the most widespread seagrass species in the region. The seagrass *Posidonia oceanica* is a stenohaline species topical to the Mediterranean Sea, where it normally lives at a salinity of between 36.5 and 39.5 ppt. Surveys carried out at the North-eastern distribution limits revealed large beds in the Strait of Çanakkale (Dardanelles) and isolated beds in the Sea of Marmara, where the salinity ranges between 21.5 and 28 ppt (Meinesz, et al., 2016; Yüksek & Okuş, 2004). This endemic Mediterranean species is known to be stenohaline, living in a salinity range between 36.5 ppt (in the Alboran Sea: Ramirez et al., 2005) and 39.5 ppt (in the Aeagean Sea: Beşiktepe, 2003; Demir et al., 2016; Mutlu & Balaban, 2018).

This species forms commonly monospecific meadows from the intertidal to maximum depths of 45 m although can also be found forming mixed meadows with species such as *Halophila stipulacea* and *Cymodocea nodosa*. It can grow on different substrates from rocks to sandy bottoms (Öniz et al., 2015; Okuş et al., 2004, 2006-b, 2010; Okudan Aslan et al., 2011 Bethoux & Copin-Motegut 1986), with the exception of estuaries where the input of fresh water and fine sediments is too high for its growth. *Posidonia oceanica* is a large, long-living but very slow-growing species and takes a long time to recolonize areas from where it has been removed, although there is some evidence that it has recolonized sites where it has been protected (Pergent et al., 2016). Its shoots, which are able to live for at least 30 years, are produced at a slow rate from rhizomes which grow horizontally at a rate of a few centimetres each year. Over centuries, the rhizomes form mats which rise up into reefs that help to trap sediment and mediate the motion of waves, thus clarifying water turbidity and protecting beaches from erosion (Boudouresque et al., 2012; Pergent et al., 2016). The accumulation of *Posidonia oceanica* debris (berms) on the beaches provides also very effective protection against coastal erosion (Pergent et al., 2012; Pergent et al., 2016). *Posidonia oceanica* is an important habitat-forming species and provides habitat for many species and nursery grounds for the juveniles of many commercially important fishes and vertebrates. 50 species of fish were detected in P. oceanica meadows, of these, 56% were permanent, 22% were transient and 22% were occasionally seen. The most important families are Labridae, Scorpenidae, Serranidae and Centracanthidae (Harmelin-Vivien 2000). The resilience of *Posidonia oceanica* and the meadows it creates seems to be relatively high (Pergent et al. 2012; Pergent et al. 2016).

Materials and methods

This study was carried out along the coastal areas of Edremit, Çandarlı, Gülbahçe, Ildır, Güllük and Gökova bays of Eastern Aegean Sea, Turkey (Fig 1.). Acoustic data were collected within TUBITAK Research Project with Project No: 115Y180 in the period of 2016-2018. Total length of surveyed coastal section is around 800 km.

Three major active acoustic instrument types used in the project. Subbottom profiler, side scan sonar and a multibeam sonar system optimised for high definition sensing in shallow water. A range of video instruments used to monitor and quantify marine biota in selected shallow water locations for verification of acoustic data. The following complementary types of equipment were used during the survey. 100-300kHz side-scan sonar (C-MAX CM2), providing acoustic data (sonograms) for the seabed, Stratabox Sub Bottom Profiler with 3.5-10kHz capacities for data of vertical on/under seabed. GoPro™ and G-Eye 500 cameras attached on VALEPORT MIDAS CTD profiler for collecting pictures of seabed and seagrass habitats. An example of the detection of marine meadows by the Side Scan Sonar and Shallow Seismic data is presented in Fig. 2.

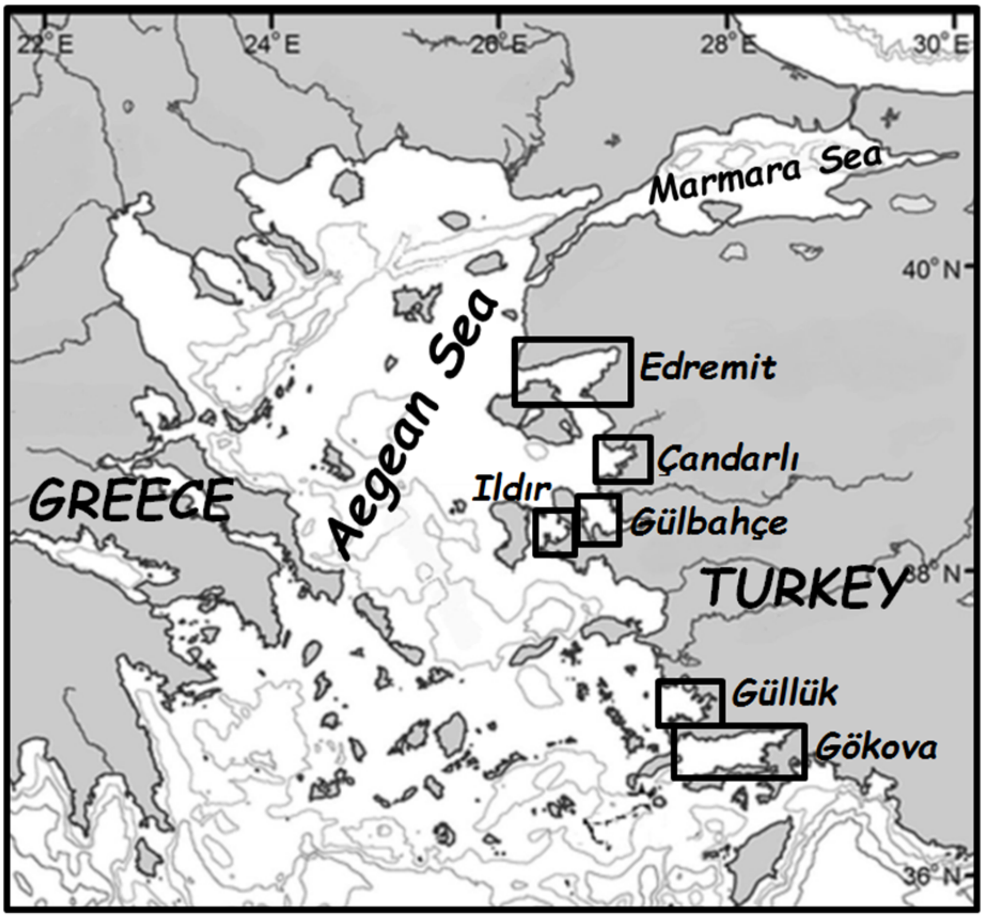

Fig. 1: Location map of working areas

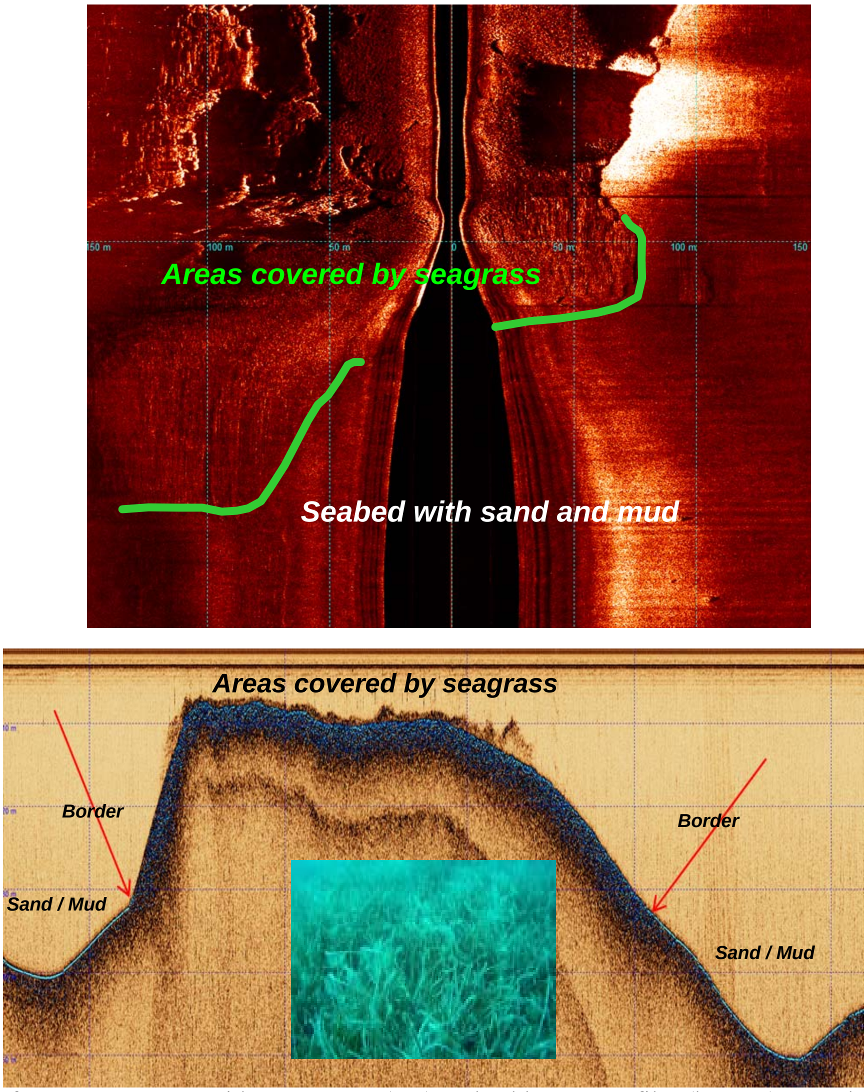

Fig. 2: Definition of seagrass areas on side scan sonar (top) and subbotom profiler (bottom) records. Video image sample from same area shown in below (center).

A mosaic of the sidescan-sonar data was produced using SonarWiz Sidescan Sonar Mapping & Post Processing software in order to produce a spatial image of the seabed features within the study area. The sidescan-sonar mosaic was imported into ArcGIS and Google Earth geotiff file. The data were evaluated by eye and distinct seabed features and acoustically discrete sections were defined. These areas were digitized into shape files to produce seabed map based on the backscatter.

Ground-truthing data using a drop-down, underwater video system with lights were collected from more than 350 stations across the study areas. These drop-down video stations were sampled for the purposes of signature development and positioned across the site for the purpose of accuracy assessment of the final habitat maps. During the most drop-video deployment, the research vessel was allowed to drift and the camera system was dragged on seabed and a height no greater than 2 m above for a period of approximately 10 to 30 min. Vessel position was stored throughout each tow and concerned to the video images using the time records from the video overlay and in the vessel position log. The video records were examined to identify distinct seabed classes (i.e. seabed habitats). The existence of each class along each video drop was enquired using the time record connected the logged positional data. In this way the existence of each seabed class along each video drop could be identified. The video and acoustic equipment were integrated with available aerial imagery where clarity and water depth allows images of the seabed to be gained. Those revealed borders and status of *Posidonia oceanica* habitats around coastal areas of Aegean Sea, Turkey.

Results

This study was carried out with the purpose of locate and status to seagrass habitats and creating habitat maps of study area. Seagrass distribution and habitats of study areas was determined with acoustic and shallow seismic profiles collections which correlated with video images from underwater cameras. In all surveyed areas, the distribution of sea meadows is shaped by the bathymetric structure of the seabed except external pressures like industrial, traffic, sediment load. The narrow bands along the coastal areas are observed due to the increase of depth at short distances and short distances to the aphotic zone around the steep slopes.

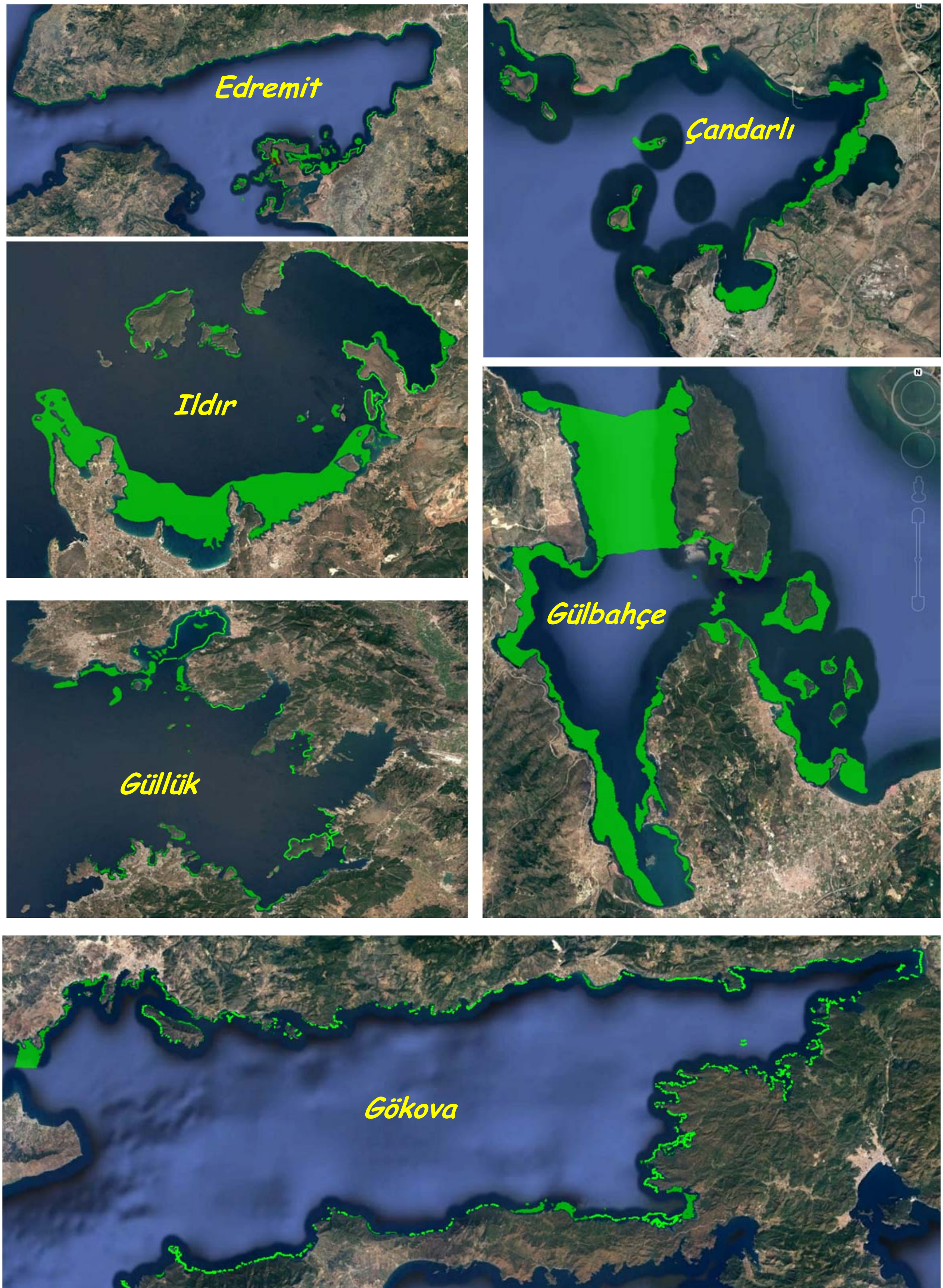

Fig. 3: Areal distribution of *Posidonia oceanica* in study areas.

The photic zones show a wider spread in areas with low slope and the existence of the light in larger areas, the sea meadows (*Posidonia oceanica* and *Cymodocea nodosa*) are also seen at longer distances from the shore. The areal distribution of seagrass zones (*Posidonia oceanica*) are shown in Fig. 3. Apart from the sea meadows, it has been identified in various benthic groups and invasive species of sea plants *Caulerpa cylindracea, Stypopodium schimperi* and a meadows of *Halophila stipulacea* have been identified in the gulfs studied under the project (Fig. 4). In addition, it was determined that there are many sponge types in the area.

Discussion and Conclusions

The distribution of seagrass in all regions is shaped by the morphological structure of the seabed and effects of anthropogenic activities. Low sloping areas more convenient from high sloping areas for development of seagrass habitats.

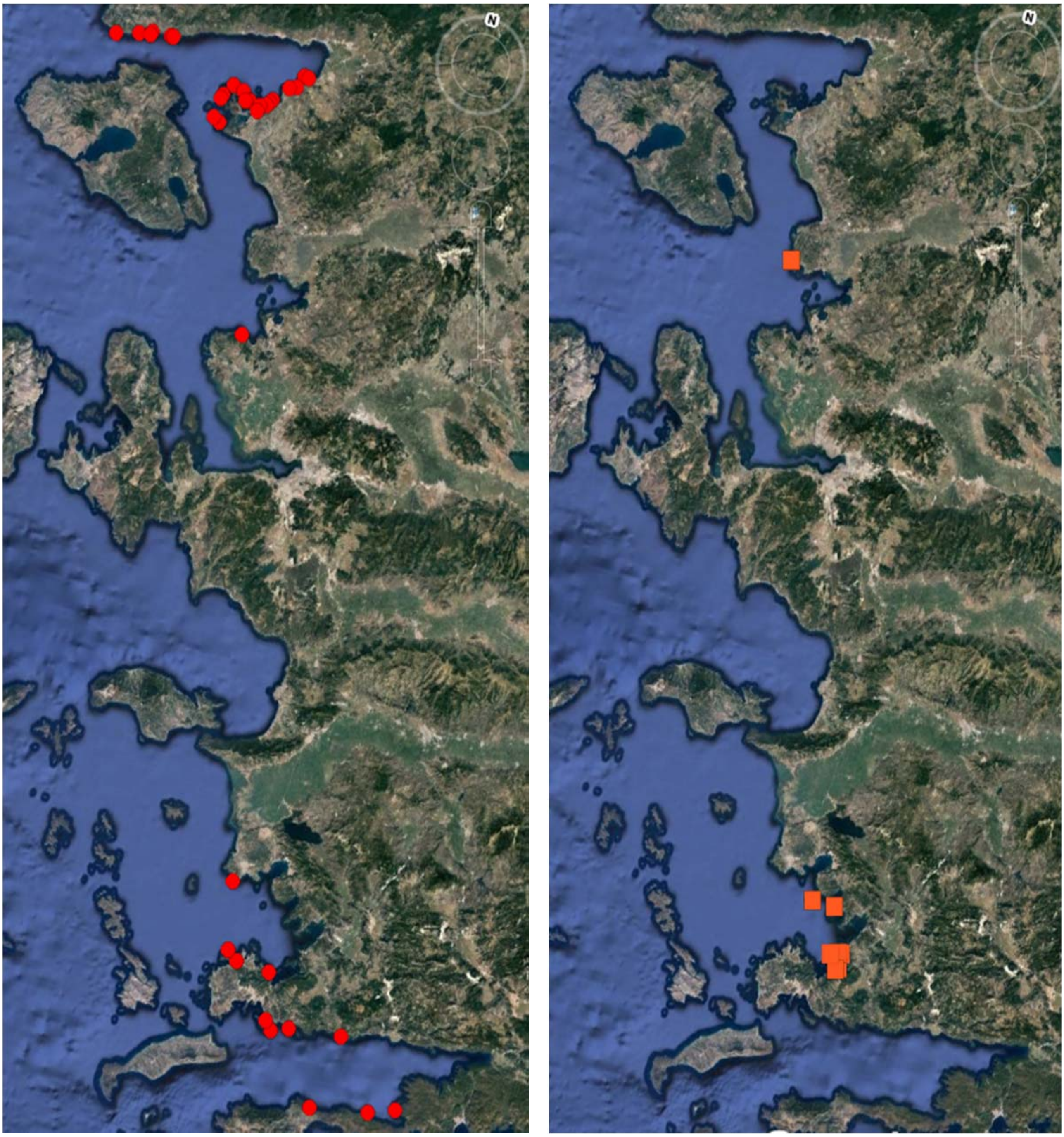

Fig. 4: The location of observed invasive species *Caulerpa cylindracea* (left) and *Stypopodium schimperi* (right).

The increase of depth at short distances on high slopes cause aphotic zones be observed more closely at coastal areas while photic zone could be observed more widespread on low slopes. Most widespread species of detected seagrass habitat in the study area is *Posidonia oceanica* which is endemic *to t*he Mediterranean Sea. Posidonia oceanica is greatly affected from light, turbidity, salinity fluctuations and increase of sedimentation rate (Pergent et al., 2016). It is threatened by mechanical damage from trawling, boat anchoring, and turbidity. Coastal development including shoreline hardening, urban and harbour infrastructure and sand mining affect the upper limit of Posidonia meadows. The discharges of agriculture nutrients, organic matter, aquaculture and urban waste from human activities cause eutrophication and pollution. Those create many problems especially in coastal regions that are heavily populated. Invasive macroalgae such as *Caulerpa taxifolia* and *Caulerpa cylindracea* can grow on Posidonia rhizomes. Sand and their proliferation could degrade sediment quality and accelerate the decline of the meadow (Marbá and Duarte 2010).

The proliferation of other epiphytic invasive species, such as Lophocladia lamellandii in the western Mediterranean can also threaten the survival and affect the density and complexity of the communities in the meadow. Climate change would be an additional threat through the warming of waters, sea level rise and extreme weather events. The accumulation of some of these factors with the lack of genetic variability and slow growth, makes Posidonia oceanica less resilient to disturbance. Regression of the meadows is often related to the impact of human activities, but meadows of Posidonia oceanica also seem to decline in areas where anthropogenic pressures are very low, indicating that other climatic or biological factors are taken part (Boudouresque et al. 2009; Pergent et al. 2016).

This study shows that seagrass meadows have the highest coverage 77.3 km^2 at Gülbahçe Bay with 37.3% percent of field. The seabeds covered by the meadows are respectively 54 km^2, 45.7 km^2, 45.2 km^2, 29.1 km^2, 17.6 km^2 and at Edremit, Gökova, Ildır, Güllük and Çandarlı. The data presented here are determined results of this study and they do not indicate regional priorities. Seagrass coverage areas have highest percent with 37.3% at Gülbahçe Bay, then Ildır, Çandarlı, Edremit, Güllük and Gökova follows with respectively with 22.3%, 10.3%, 5.1%, 4.6% and 2.7% percent's (Fig. 5).

The deepest *Posidonia oceanica* boundary was found at the Ildır area with 38 meters (Fig. 5). For other areas, the deep borders were respectively 35, 30, 30, 32, and 34m at Edremit, Çandarlı, Gülbahçe, Güllük and Gökova. Since the data of the maximum access depths of *Posidonia oceanica* cannot be precisely determined from sonar records, deep boundaries have been determined based on data from camera records integrated with the CTD system. Therefore, the values presented for these areas are based on direct camera data and need to include full fieldwork to determine the exact results for the relevant field overall.

When the seafloor substrate properties are examined from the other important parameters which are effective in the distribution of sea meadows, the substrate types of Sand-Silty Sand-Rock stands out in the Edremit and Çandarlı fields in the northern half of the Aegean Sea coastal zone. In the Gülbahçe area, silty sand predominantly forms the dominant substrate. In the central and southern areas of Ildır, Güllük and Gökova areas, the dominant sediment type of sea meadows is composed of sand to silty sand combination.

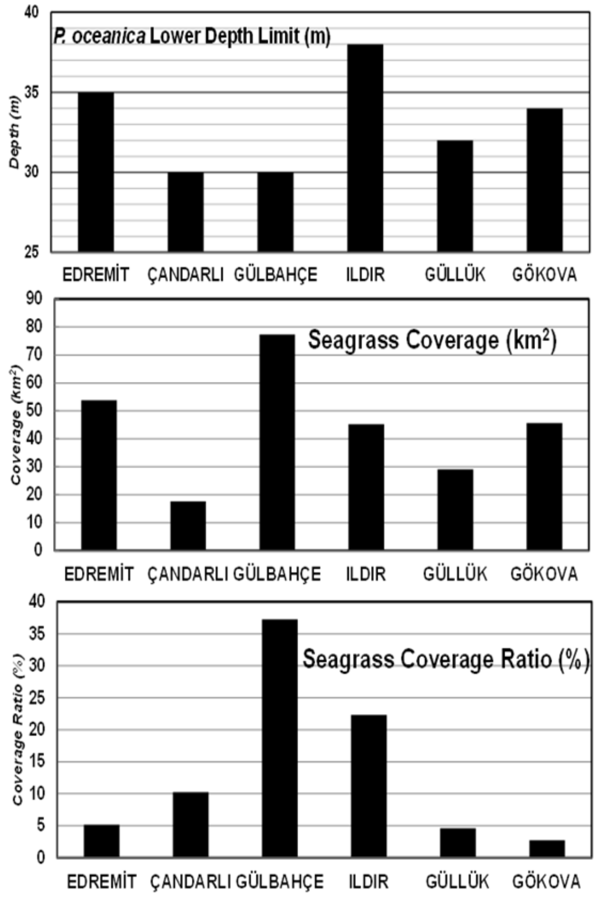

Figure 5. Graphical representation of depth limit and spatial distribution information of marine meadows mapped in study areas.

In the study area, it was determined that sea meadows are under threat especially in areas where human use is intense. In these regions regressions and tears which leave or shoot of *Posidonia oceanica* were observed in the meadows. It has been observed that seagrass habitats are negatively affected by water quality deteriorations, bottom scraper activities (trawl, ship anchoring, etc.) and other anthropogenic coastal developments (shoreline hardening, urban and harbour infrastructure, etc.). The areas abandoned by seagrass habitats have been invaded by invasive species and these species are spreading rapidly (Fig. 6). This invasive species poses a danger to

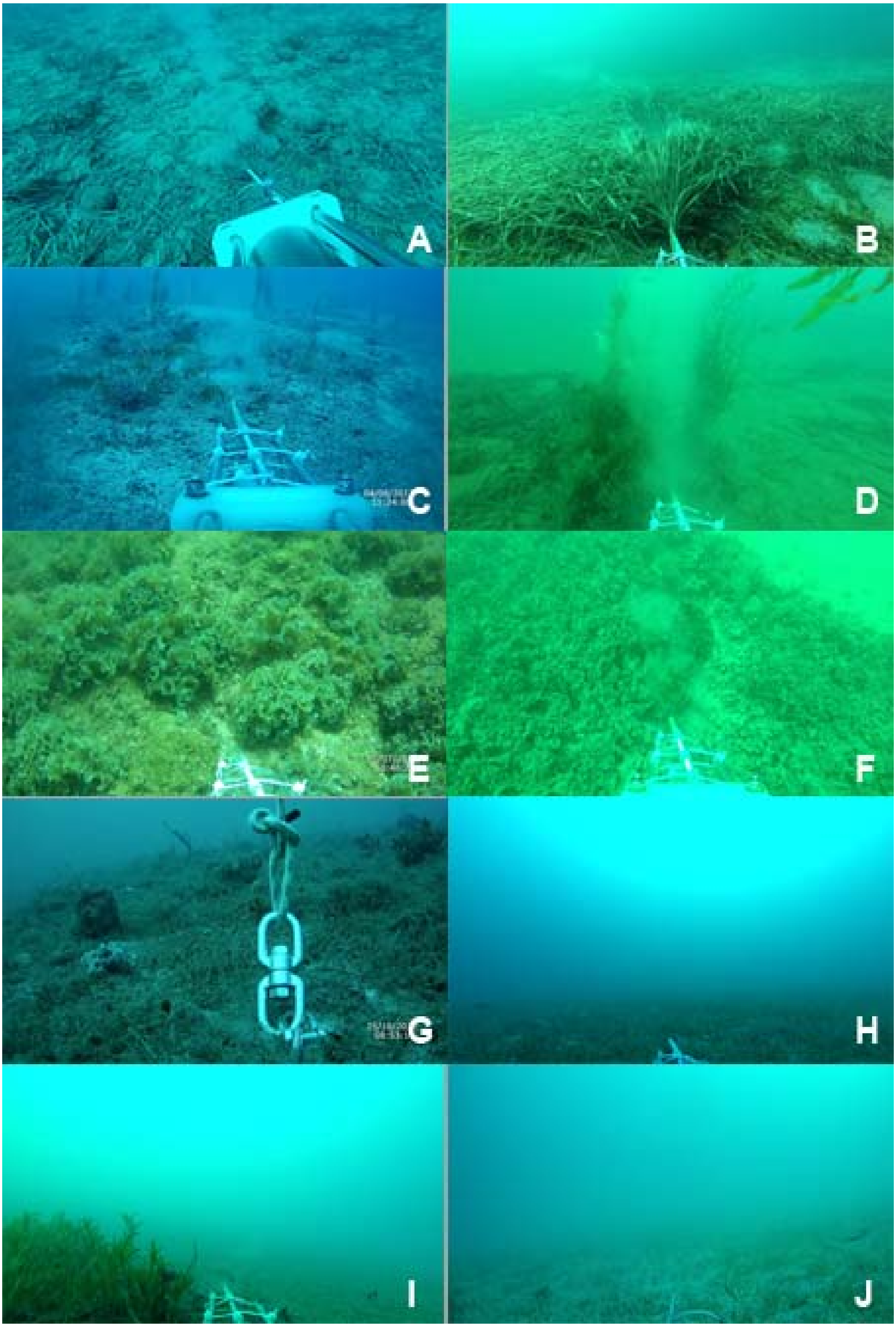

Fig. *6*: Video record samples of *Posidonia* meadow with dead matte (A, B), *Sargassum vulgare (C,D)*, *Stypopodium schimperi* (E-F), *Caulerpa racemosa* (G-H), *Halophila stipulacea* (I-J).

biodiversity and more often observed where tourism activities and coastal human activity are more intense especially at southern and northern parts of Aegean Sea coast. *Posidonia oceanica* is adversely affected by salinities higher than in its natural range. A significant growth reduction was detected when salinities exceeded 39 psu, and an increase of 4 psu over the average western Mediterranean salinity significantly increased mortality in short-term experiments. *Posidonia oceanica* controls seagrass meadows in the Mediterranean, which already have decreased because of other stresses such as bottom-trawling fisheries, illegal anchoring and uncontrolled-unconscious diving tourism activities. The most important actions to prevent seagrass loss are;

- Control and treatment of sewage to reduce the loading with nutrients, organic matter and chemicals, etc.
- Regulation of land use in catchment areas to reduce nutrients;
- Regulation of land reclamation, coastal constructions and downscaling of water exchange,
- Regulation of aquaculture, fisheries, etc.;
- Create awareness of the importance of seagrasses.

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