UNIVERSITY OF THE AEGEAN

MARINE SCIENCE DEPARTMENT

M. Sc. COASTAL MANAGEMENT

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Master thesis

The geographical distribution of fish, benthic coverage and sea urchins in the coastal zone of Lesvos island.

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Abstract

It is known that the last decades, global warming, overfishing and pollution are the main reasons for fish population declines, degradation of habitats and increase of barrens on shallow rocky reefs. Here, we investigated the levels of fish species richness, the benthic coverage categories and the sea urchin abundance along the coastline of the island Lesvos. For this purpose, 32 sampling sites were chosen randomly through the coastline with minimum distance 5.4 and maximum 20 km. In 21 sites we had mobile and in 11 hard substrate. Also, we categorized the sampling sites according to their geographical location. We found that between benthic coverage categories there is a small statistical difference between the east side of the island and the gulfs. The fish distributions for abundance have shown also some differences between different geographical areas. Finally, the sea urchin abundance did not appear to correlate with benthic categories.

Keywords: coastal biodiversity, fish, benthic coverage, sea urchins, Aegean sea, Lesvos.

Περίληψη

Τις τελευταίες δεκαετίες,, είναι γνωστό ότι η υπερθέρμανση του πλανήτη, η υπεραλίευση και η ρύπανση του περιβάλλοντος, έχουν οδηγήσει τα θαλάσσια ιχθυοαποθέματα σε πολύ χαμηλά επίπεδα. Επίσης, τα επίπεδα των βενθικών κοινωνιών απειλούνται άμεσα, καθώς είναι πολύ συχνό να μετατρέπονται σε ερημικά οικοσυστήματα. Σε αυτή την έρευνα, θέλουμε να εξετάσουμε τον πλούτο ειδών από τις ιχθυοκοινωνίες, τις κατηγορίες της βενθικής κάλυψης, καθώς και την αφθονία των αχινών, στην παράκτια περιοχή της νήσου Λέσβου. Για αυτό το σκοπό, πραγματοποιήσαμε τυχαίες δειγματοληψίες σε 32 σημεία σε όλη την ακτογραμμή. Η μικρότερη απόσταση μεταξύ των σημείων ήταν 5.4 χλμ και η μεγαλύτερη 20χλμ. 21 από τα σημεία δειγματοληψίας είχαν σκληρό υπόστρωμα και 11 μαλακό. Έπειτα κατηγοριοποιήσαμε τα σημεία δειγματοληψιών σύμφωνα με την γεωγραφική τους θέση. Βρήκαμε μία μικρή διαφορά μεταξύ των βενθικών κατηγοριών κάλυψης μεταξύ της ανατολικής πλευράς του νησιού και των κόλπων. Επίσης, οι κατανομές των ψαριών είναι διαφορετικές ανάλογα με την γεωγραφική περιοχή. Τέλος, οι κατηγορίες βενθικής κάλυψης φαίνεται να μην επηρεάζονται από την αφθονία των αχινών.

Λέξεις κλειδί: παράκτια βιοποικιλότητα, ψάρια, βενθική κάλυψη, αχινοί, Αιγαίο πέλαγος, Λέσβος.

Introduction

In benthic sublittoral Mediterranean assemblages, species of the algae genus *Cystoseira* are of outstanding ecological importance, where they function as ecosystem engineers (Sales & Ballesteros, 2009), and yield the vast majority of the biomass and production of the shallow benthic algal assemblages (Giakoumi et al., 2012). *Cystoseira* species are declining substantially in various areas of the Mediterranean (Cormaci & Furnari, 1999; Thibaut et al., 2005; Serio et al., 2006), which is mainly explained by eutrophication and pollution (Golubic, 1970; Munda, 1974, 1982, 1993; Arévalo et al., 2007), but might also be due to climate change and overgrazing (Thibaut et al., 2005; Serio et al., 2006; Sales, 2010).

Sea urchins and algae interact strongly by sea urchins severely consuming erect algae, maintaining a low erect algae/encrusting coralline algae ratio and hence causing the formation of coralline barrens (Sala et al., 1998). These new impoverished habitats form increasingly frequent globally along temperate coastal regions (Filbee-Dexter & Scheibling, 2014; Vergés et al., 2014; Tsirintanis et al., 2018). The abundance of sea urchins and expansion of those coralline barrens have been associated with the overfishing of predatory fish species (Prado et al., 2017). Sea urchin abundance is also depending on physical factors, such as water temperature, upwelling, sedimentation (Shears & Ross, 2010), wave action (Harrold & Reed, 1985; Micheli et al., 2005; Shears et al., 2008), floods (Andrew, 1991; Fernandez et al., 2006) and harvesting (Giancuzza et al., 2006), and can be influenced by infrequent disturbances, such as disease outbreaks that lead to mass mortality and reduce the population for decades after the disturbance (Boudouresque et al., 1980; Harrold & Reed, 1985; Anrew, 1991). Other anthropogenic stressors can lead (through interactive effects) to e.g. harmful algae blooms, that have an increasingly important impact on urchin populations (Shears & Ross, 2010; Hereu et al., 2012).

Most coastal fish resources have been overexploited over the last decades (Lauck et al., 1998; Castilla, 2000; Claudet et al., 2006). Progressively, juvenile fish are getting caught before they have matured and were able to spawn (Vasilakopoulos et al., 2014). Vasilakopoulos et al. (2014) analyzed nine species in the European Mediterranean over two decades, pointing out a steadily increasing exploitation rate with a rising amount of proportional juvenile exploitation and shrinking stocks. They describe the case of hake stocks, where fish were selected on average 0.6-1.9 years before they matured and some small pelagic stocks with a more sustainable selectivity, with sardines and anchovies being selected on average more than 0.4 years after they reached maturity. In the Mediterranean coastal zones, fish abundance is highest in shallow rocky habitats and in highly productive seagrass beds with *Posidonia oceanica* (Reademaeker et al., 2010).

Fish in coastal zones can be assessed with underwater visual survey methods that include five main quantitative or semi-quantitative methods for SCUBA or free diving or through the examination of photographic and video records: plot sampling (strip transects and point counts), distance sampling (line transects and point transects), rapid visual techniques and repetitive sampling for occupancy estimation (Katsanevakis et al., 2012; Thanopoulou et al., 2018).

In this study, I applied plot and distance samplings, with free diving, in random points at the coastline of the island Lesvos, in order to find the species richness in fish populations, the sea urchin abundance and the benthic coverage categories. Furthermore, I wanted to check the data distributions, in different substrates and geographical areas.

Materials and Methods

Study area

The study was conducted along the coastline of Lesvos island in the north-eastern Aegean (Greece), and close to the Turkish coast (north-eastern part). The island constitutes the third biggest island of Greece, having ~350 km of coastline (Rovere et al., 2011). It has also two big gulfs (the gulf of Gera and the gulf of Kalloni), which are ecologically very important due to their high productivity waters and furthermore for providing shelter for juvenile fish and places for spawning (Paspatis & Maragoudaki, 2005; Airoldi & Beck, 2007; Papantoniou et al., 2014).

I selected randomly 32 sampling sites with different substrate (mobile and hard) through the coastline of Lesvos with a minimum distance of coastline of 5.4 km and a maximum of 20 km, depending on the accessibility of each site. In the end, I had 21 sites with mobile and 11 sites with hard substrate. In each site, benthic coverage, abundance of sea urchins and abundance of fish were measured with plot sampling and line transect sampling (see Katsanevakis, 2009; Katsanevakis et al., 2012). Sampling was carried out during May and June 2017. The mean depth value was 2.6 m.

Fish abundance

At each sampling site, I measured the species abundance of fish by using a distance method. Line transect sampling is one of the most common used distance methods (Katsanevakis, 2009; Katsanevakis et al., 2012). To accomplish this, a line of 130 m was used, subdivided with swivels every 10 meters and marked with red color every 10 m starting from the 5^{th} m. At the beginning of the line there was a small anchor capable to keep the line stuck to any type of substrate. The observation was starting from the 5^{th} m and then I performed three replicates of 25 m observations with two 25 m without observation in between. In every transect, the snorkeling speed was fast enough to avoid counting a same individual more than once, but slow enough to have a high level of detection. In every site, all different species were identified and counted 2,5 m on either side of the transect line.

Macroalgal coverage

For the benthic coverage, a plot sampling method with imaging equipment was used (see Katsanevakis, 2009; Katsanevakis et al., 2012). To estimate the benthic coverage, a quadrat 50 x 50 cm with plastic pipes was constructed, with a steady base for a fixed camera in order to take pictures of the substrate. The camera used was a Nikon COOLPIX AW130. Pictures were taken every 5 m of a 25 m transect, starting from 0 m and from the left side of the line, with a three times repetition per sampling site (18 pictures/site: 576 in total).

Sea urchin abundance

At each sampling site, I measured the species abundance of sea urchins by using the plot transect method. Sea urchins abundance was estimated by using a 1 x 1 m quadrat as a reference frame area. The quadrat was made of plastic pipes and had an elastic line through it, so it could fold up without taking much space and be set up easily. On the same transect as for the benthic coverage, in every 5 m, starting from 0 and from the right side of the line, the quadrat was placed. I recorded the number of sea urchins on waterproof paper.

Image 1: The diver is ready for snorkeling with all the necessary equipment.

Statistical analysis

To deal with the big amount of benthic images, the software photoQuad was used (see Trygonis & Sini, 2012). To identify the benthic categories, the stratified random points method was used with N=100 points per image. After that, every benthic organism corresponding to a point was categorized. The final categories that came out from this study were 11 (table 2).

For the sea urchin data, the software LibreOffice 5.4 (Gamalielsson & Lundell, 2013) was used. With that, I was able to calculate the sea urchin abundance per transect and per site. For the final results, the mean value of the three transects was used. With the same software I also calculated the fish abundance. Furthermore, the fish data were categorized, based on the study of *Stergiou and Karpouzi (2002)*, into herbivores (TROPH = 2.0–2.1, mean = 2.02, SD = 0.03), omnivores (with a preference for vegetable material 2.1 < TROPH < 2.9, mean = 2.5, SD = 0.12), omnivores (with a preference for animal material 2.9 < TROPH < 3.7, mean = 3.4, SD = 0.19), carnivores (with a preference for decapods and fish 3.7 <TROPH < 4.0, mean = 3.85, SD = 0.09) and carnivores (with a preference for fish and cephalopods 4.0 <TROPH < 4.5, mean = 4.38, SD = 0.12).

All the data had a spatial analysis with geographical information systems, for this purpose the softwares QGIS (https://qgis.org) and ArcGis (http://www.arcgis.com) were used.

For the final results, the programs Primer 6.1.13 (Clarke & Gorley, 2006) and R3.5.1 (Venables & Smith, 2018) were used. To analyze potential differences in fish species composition between the sampling sites, a Bray-Curtis similarity matrix was made based on a square-root transformation of fish density data, which was then used to carry out cluster analysis and construct a non-metric multidimensional scaling (nMDS) plot. For the analysis of the latent differences in benthic categories among the sampling sites, a Bray-Curtis similarity matrix was made based on non-transformation of benthic data, which was then used to carry out cluster analysis and construct a non-metric multidimensional scaling (nMDS) plot. The data were sorted by geographical area and substrate type (Figure 1). In each nMDS, each category is represented with different color and shape. The east area with the sampling sites close to Turkey is shown as “S”, the area with the sampling site that is towards the open Aegean sea as “A” and the sampling sites inside the gulfs as “G”.

To find how the distribution is in our samples, we created some box plots. There, the diversity index H, the evenness index J, the species abundance N and the number of species S, are shown. The diversity index H shows how many different species indicate in a group of data and at the same time, considers how equally the individuals are distributed (Heip et al., 1998). With the evenness index J, we can see how similar the numbers of species are, we have in a population (Heip et al., 1998).

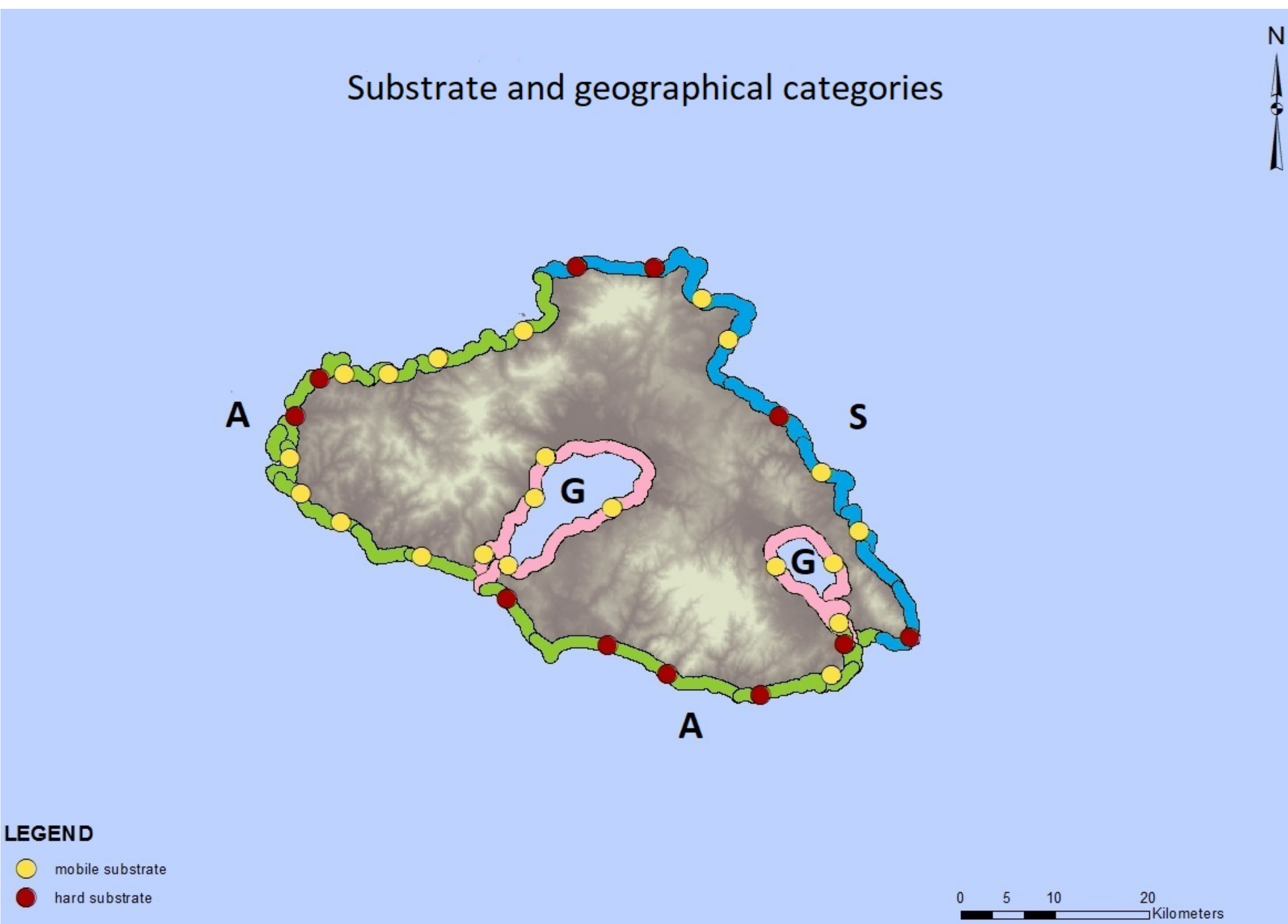

Figure 1: Substrate and geographical categorization, S= east Aegean, G= Gulfs, A= Aegean

Results

Maps

Benthic coverage

The types of benthic coverage are presented in two maps. The first map, Figure 2, shows the benthic categories on hard substrate and the second map, Figure 3, on mobile substrate.

In Figure 2, the benthic categories of the 11 sites that were on hard substrate are given. On the legend are 8 categories resulting from the 18 photo analyses of each site. The category "seasonal algal turf" has the highest coverage percentage with 51.8% on hard substrate. Then, second with 12,9% is the category "phanerogams". 10.7% is covered with "sand", 8.2% with "articulated", 6.7% with "foliose algae", 5.5% with "encrusting calcareous algae", 3% with "bushy algae and last, 1.2% is covered with "pebbles".

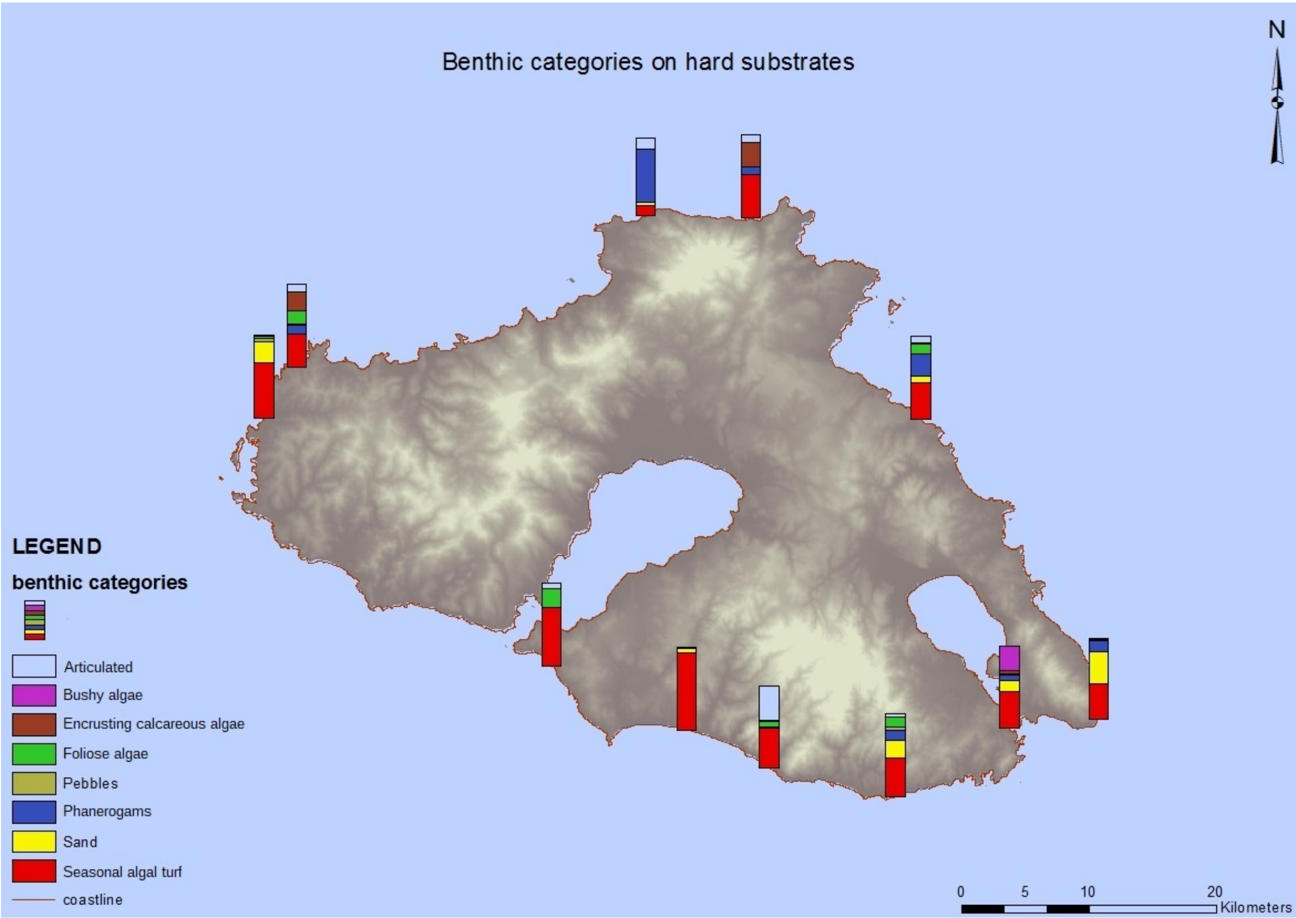

Figure 2: Benthic categories on hard substrate.

Figure 3 shows the map with the benthic categories on the 21 sites that were on mobile substrate. On the legend are 11 categories resulting from 18 photo analyses of each site. The most common category on mobile substrate is “sand” with 47.4%. Second with 22.5% is the category “phanerogams”, 20.9% are covered with “seasonal algal turf”, 2.7% with “pebbles”, 2% with “articulated”, 1.4% with “mucillagenous”, 1.3% with “foliose algae”, 0.6% with “canopy forming macrophytes”, 0.5% with “encrusting calcareous algae”, 0.5% with “bushy algae” and the remaining 0.2% with “perennial animal”.

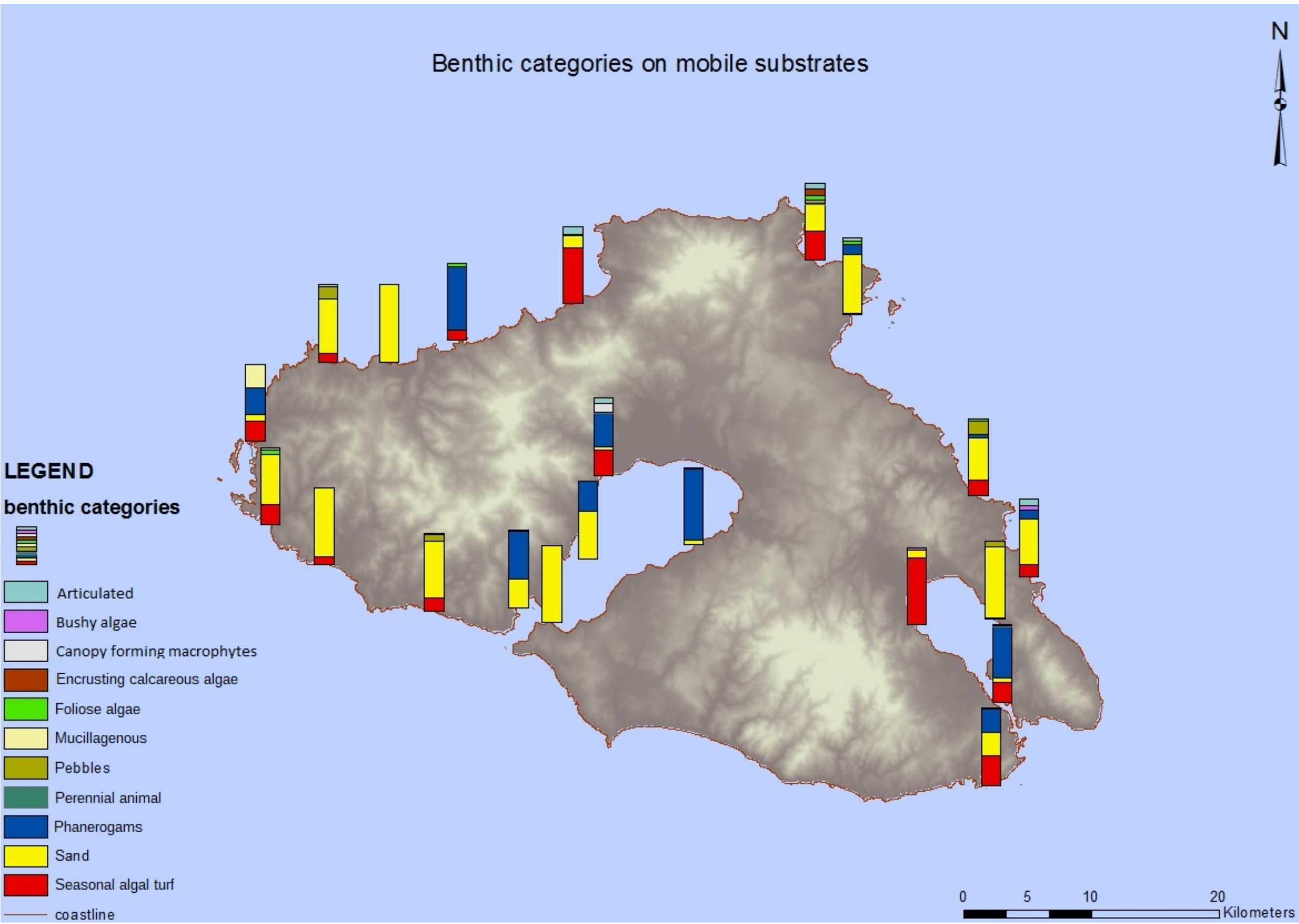

Figure 3: Benthic categories on mobile substrate.

Sea urchins

The sea urchin abundance is shown in the map in Figure 4. There, the average value of each sampling site is presented. On the legend are 5 categories that show the average number of individuals per site (sea urchin/6m²). The sea urchins have their biggest concentrations, with 4-18 individuals per sampling site, on the north coast of Lesvos. The highest abundance was 3.05 sea urchins per square meter.

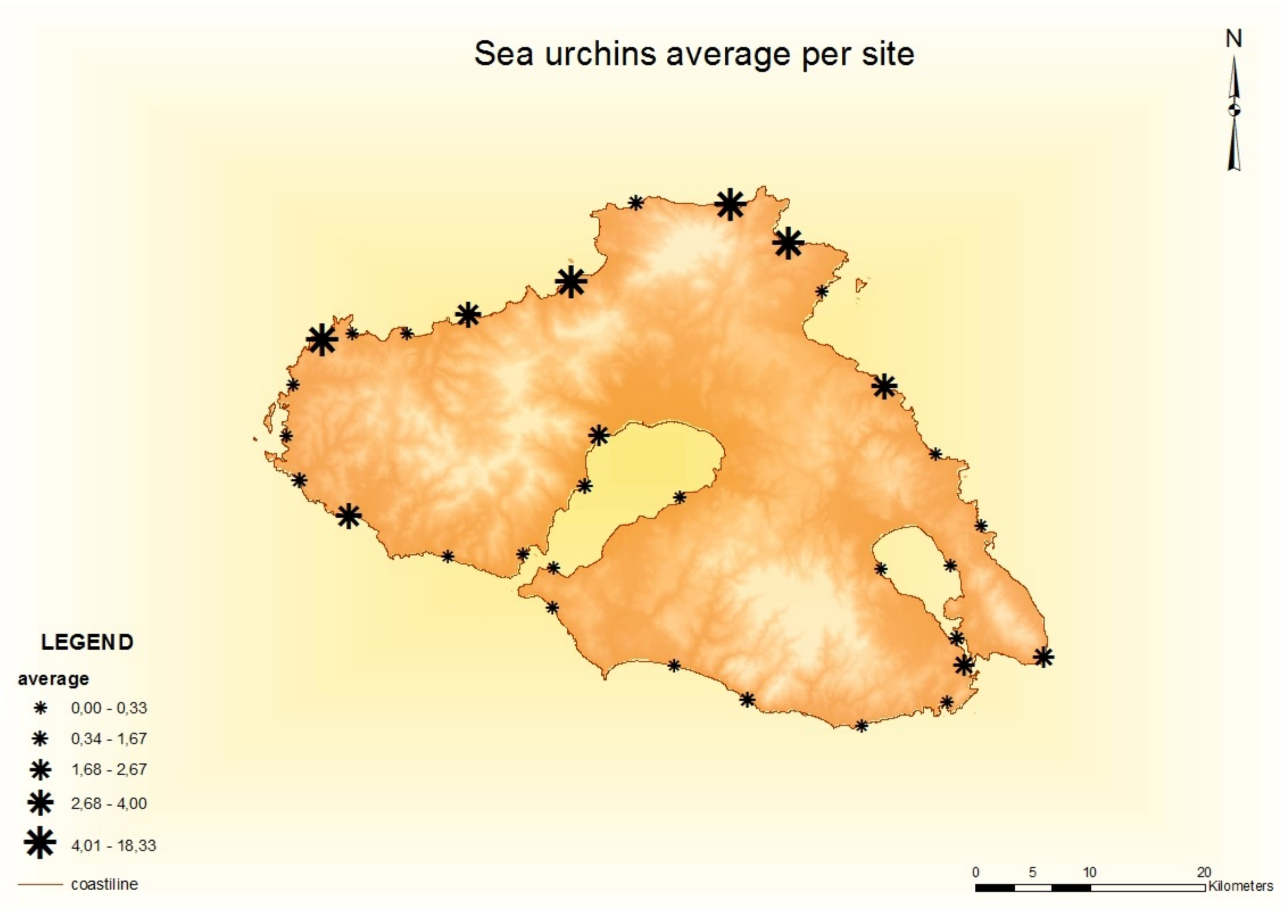

Figure 4: Sea urchin average.

Fish

The fish data are presented in two maps. The first map, Figure 5, presents for every site the total of the fish abundances of the three transect replicates (fish/375m²). The data are split into 7 classes. The first has values from 0-3, the second from 4-20, the third 21-34, the forth 35-67, the fifth 68-107, the sixth 108-180 and the seventh 181-378. In the fish abundance map, we can observe some of the biggest values close to the Gulfs' entrances. Also at the north coast, two of the sites belong to second highest category. The numbers from the fish classes on the map represent the total of the observed individuals in all three transects. The highest abundance was 378 species per site.

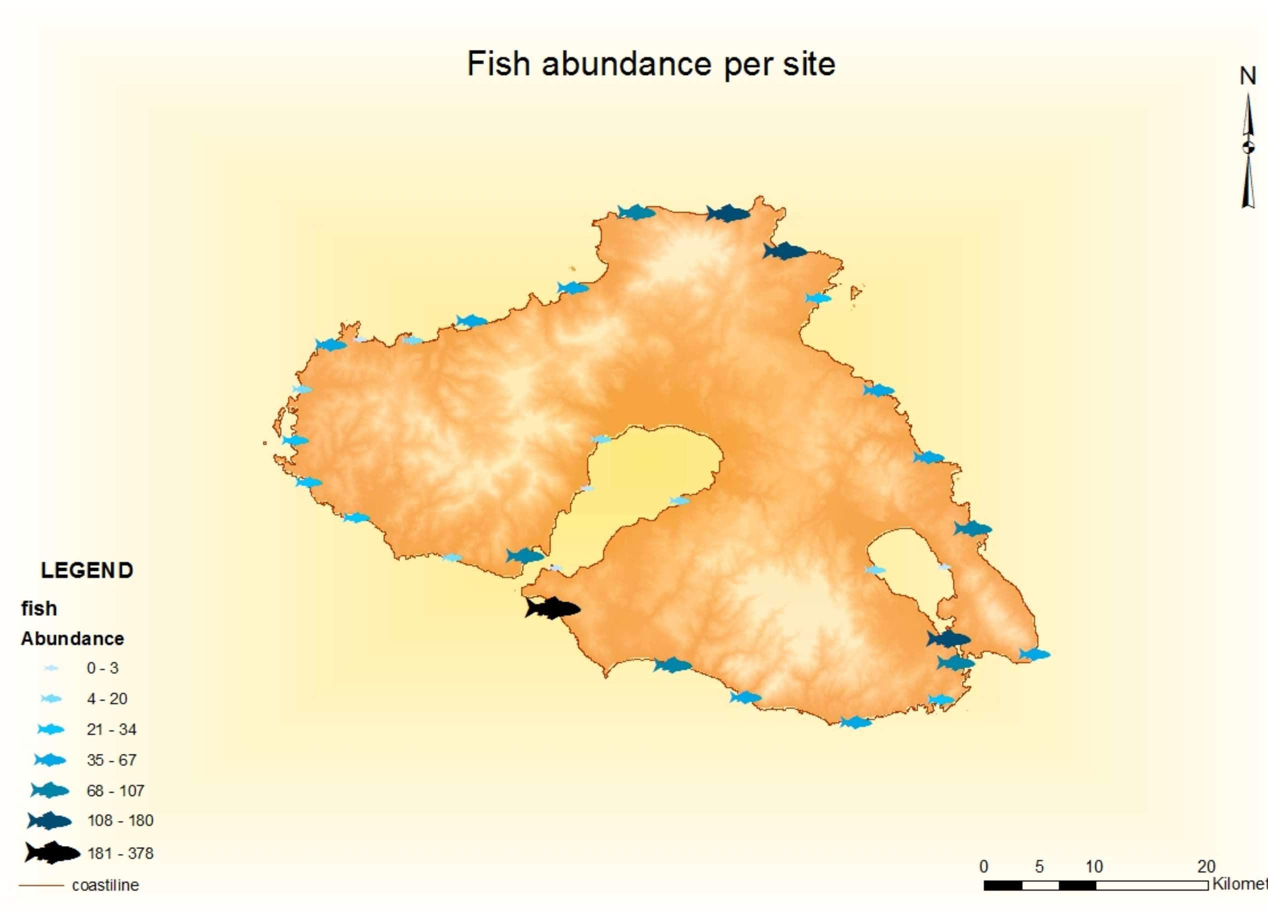

Figure 5: Fish abundance.

The second map, Figure 6, displays the distribution of fish trophic groups. The fish trophic category “carnivores” is represented with red color. The trophic group “grazers/herbivores” is represented with green color and the trophic group “omnivores” with blue color. The biggest part of the fish sample belongs to “omnivores”. More specific, the trophic group “omnivores” represents 84.2% of the total fish, 13.6% are “herbivores” and 2.2% of the sampled fish belong to “carnivores”.

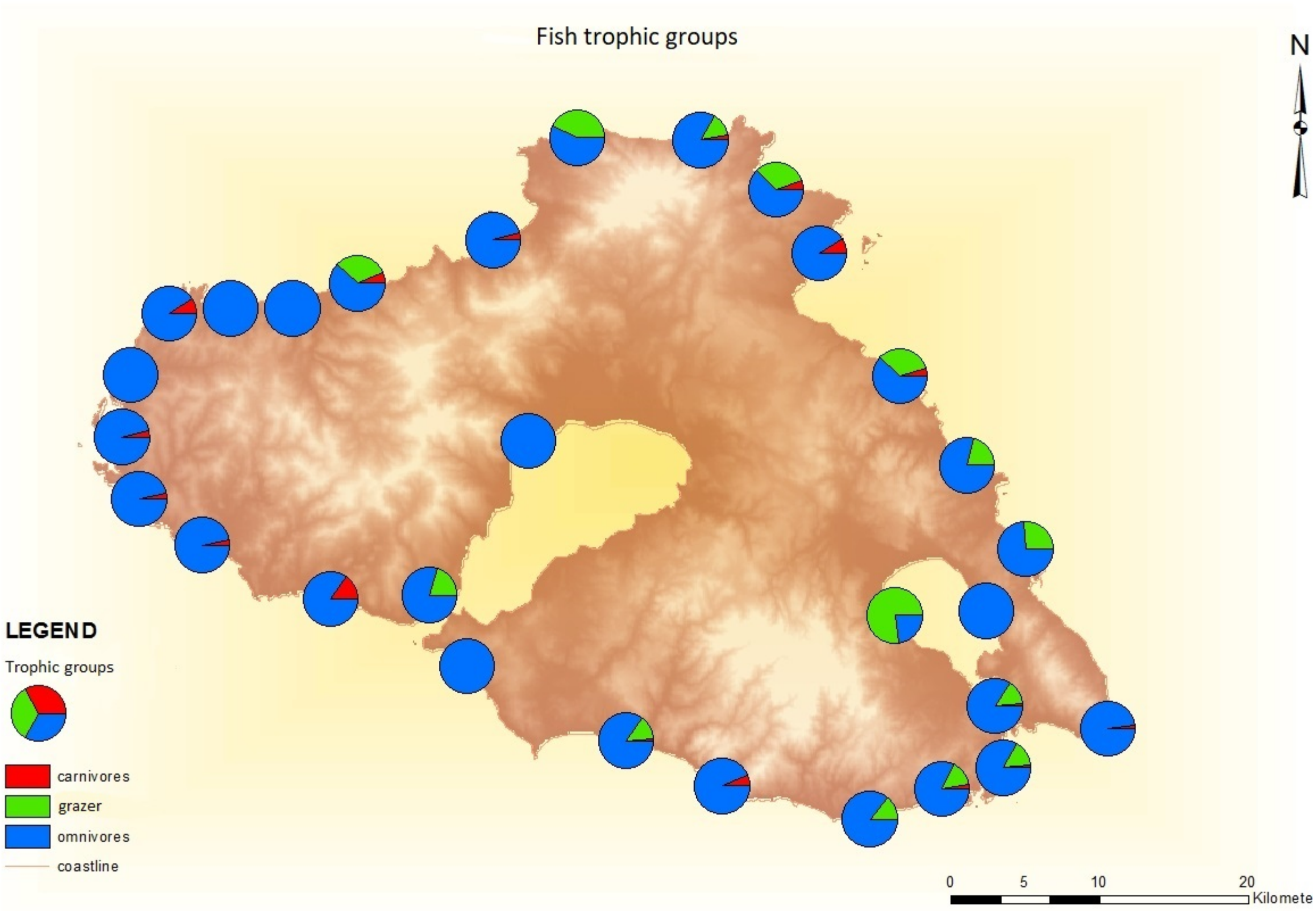

Figure 6: Fish trophic groups.

Non-metric multidimensional scaling plots

Benthic coverage

Figure 7 is a two-dimensional map with the results of a nMDS analysis, showing the similarity between the sampling sites. In this case, the benthic categories of each site, are compared with the different geographical areas. With green triangulars, the sites that belong to the East side of Lesvos are shown, with blue the area of the open Aegean and with bluish squares the sites at the Gulfs. Here, it can be observed that among sites there is not an obvious accumulation. The one-way analysis of similarities (ANOSIM, Figure 18), showed that "East side of Lesvos" and "Aegean" have a 76.9% significant level of statistic and "Gulfs" have a 7.8% with "East side of Lesvos" and 3.1% with "Aegean".

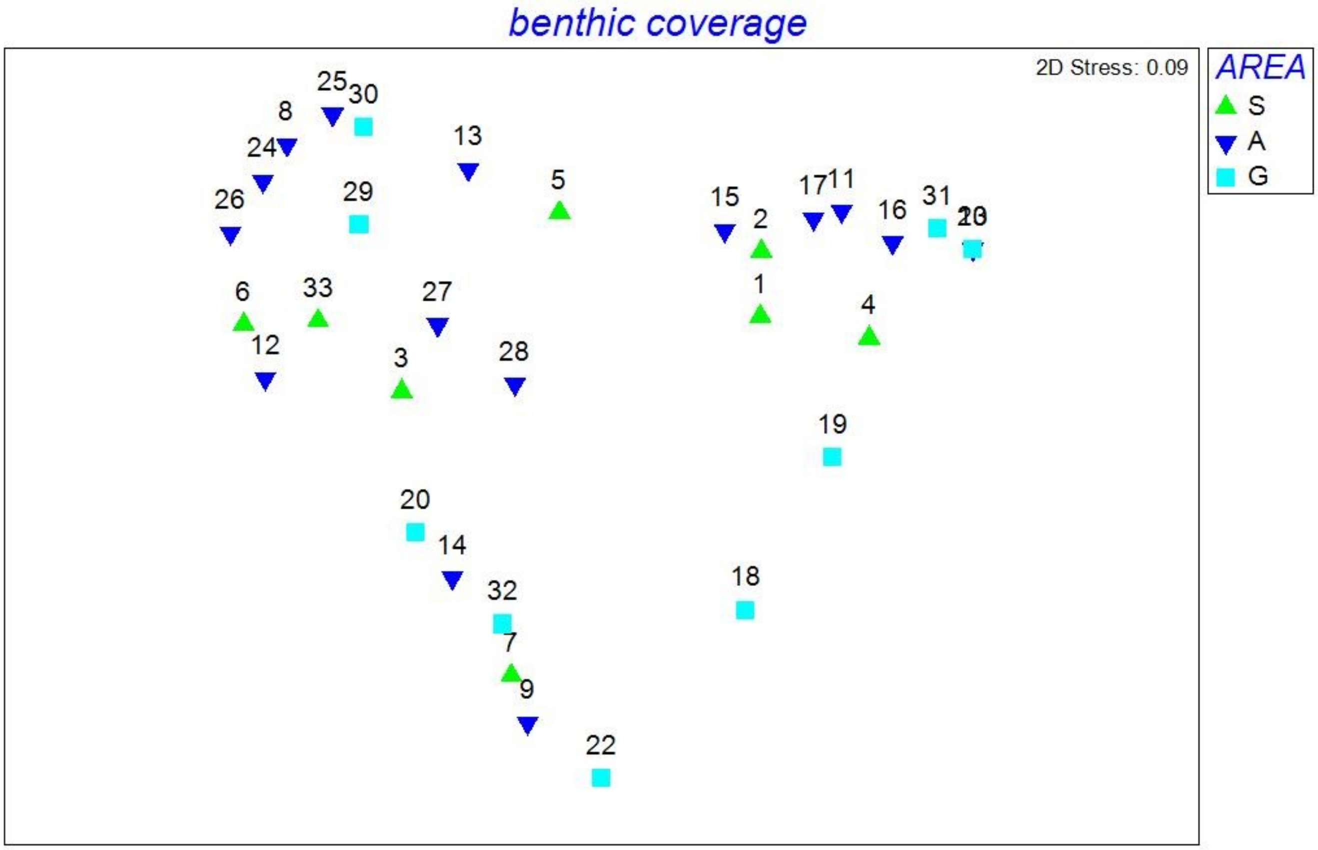

Figure 7: Non metric multidimensional scaling plot (nMDS) for 32 sampling sites, based on non-transformation density data and a Bray-Curtis similarity matrix. Legend colors and shapes correspond to different geographical areas: S= East side of Lesvos, A= Aegean sea, G= Gulfs. The "East side of Lesvos" region included the sampling sites 1-7 and 33, depicted with green color triangulars. The "Aegean" region included 8-17 and 24-29 , depicted with blue color triangulars and the "Gulfs" region included the sites 18-23 and 30-32, depicted with light blueish squares.

In Figure 8, the similarity of the sampling sites is shown. Now the benthic categories of each site are compared with the different substrate type. With green triangulars, sites that belong to mobile substrate are represented and with blue triangulars those that belong to hard substrate. Here, a pattern of accumulation of the two different categories can be observed. The sites that belong to hard substrate are gathered on the right top of the map. Sites of mobile substrate are mostly on the lower part of the map and on the left. The one-way analysis of similarities (ANOSIM, Figure 19) shows that the significant level of sample statistic is 0.2% and the Global R= 0.249.

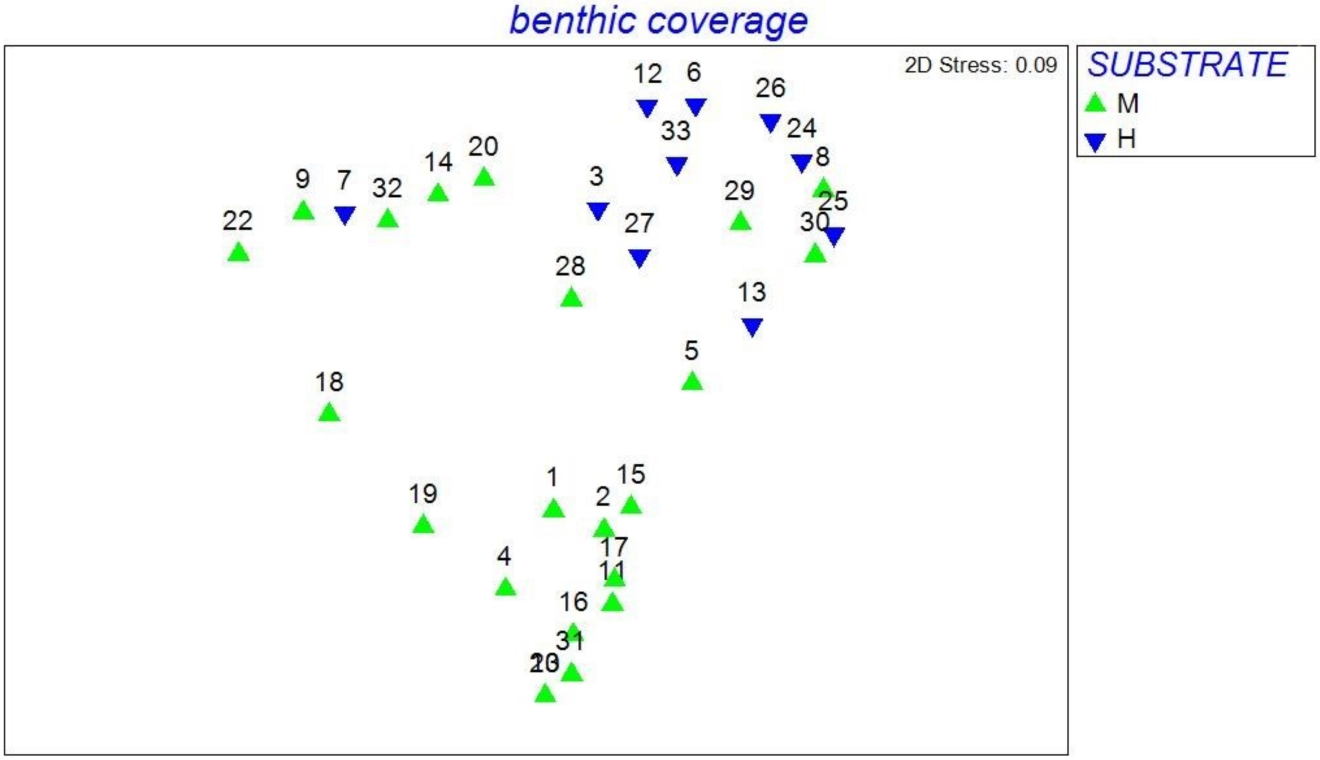

Figure 8: Non metric multidimensional scaling plot (nMDS) for 32 sampling sites, based on non-transformation density data and a Bray-Curtis similarity matrix. Legend colors and shapes correspond to different substrate type: M= moderate substrate, H= hard substrate. The moderate substrate type includes the sampling sites 1,2,4,5,8-11,14-23 and 28-32, depicted with green triangulars. The hard substrate includes the sampling sites 3,6,7,12,13,24-27 and 33, depicted with blue triangulars.

Fish

The following nMDS in Figure9 and Figure 10 show the similarity of the fish abundances in different sampling sites. In Figure9, the similarity of fish abundance per sampling site is compared with different geographical areas. The numbers over the signs represent the number of the sampling site. With green triangulars, the sites that belong to the East side of Lesvos are shown, with blue the area of Aegean and with bluish squares those that are in the Gulfs. In this map, it can be observed that sites of "East side of Lesvos" are gathered on the central area of the map. The same can be observed also for the sites of "Aegean". Sites of the "Gulfs" seem also to be a bit gathered on the top middle of the map. The one-way analyses of similarities (ANOSIM) (Figure 20) shows that the significant level of sample statistic of "East part of Lesvos" and "Aegean" is 67%. The "Gulfs" significant sample level of statistic with "East part" is 2% and with "Aegean" 0.4%.

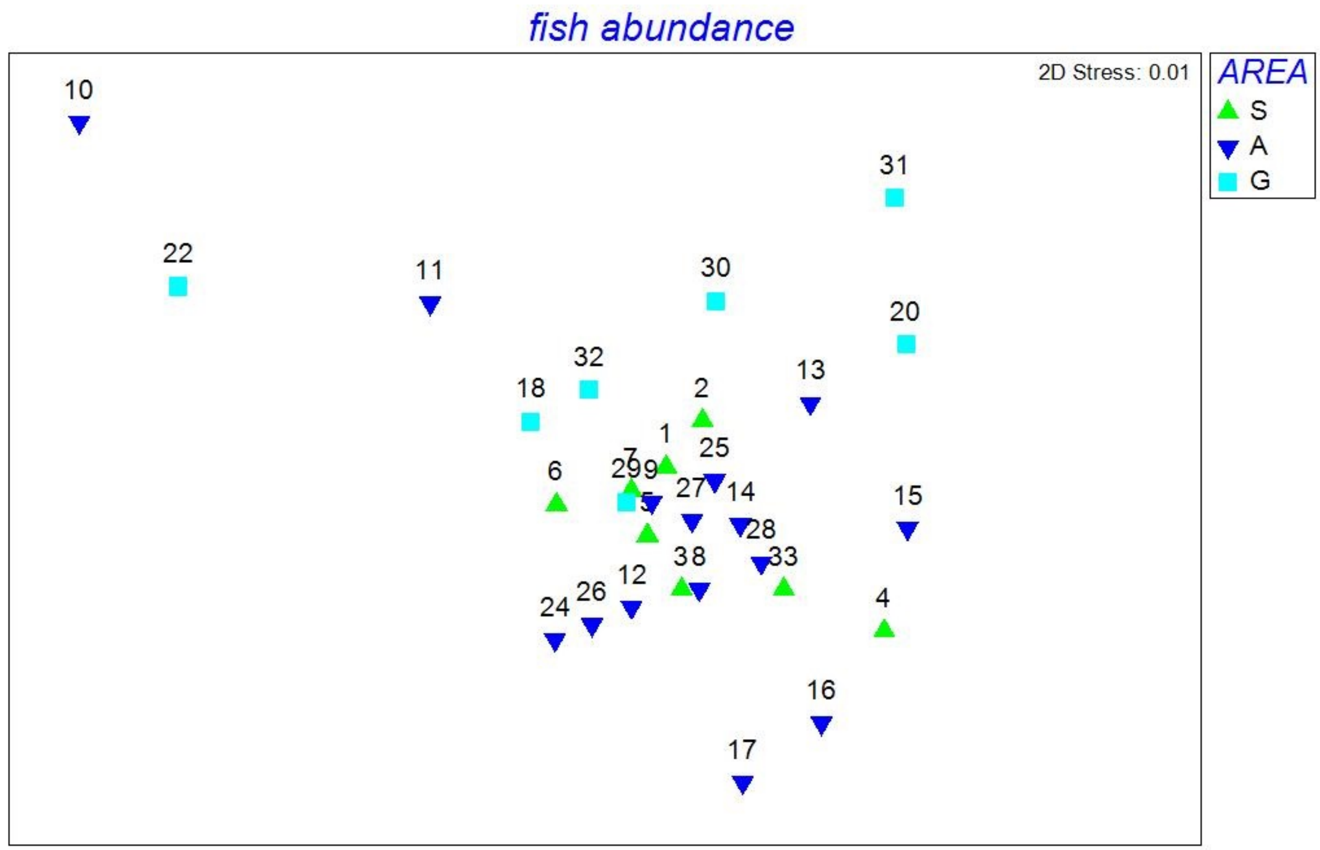

Figure9: Non metric multidimensional scaling plot (nMDS) for 32 sampling sites, based on square-root transformation density data and a Bray-Curtis similarity matrix. Legend colors and shapes correspond to different geographical areas: S= East side of Lesvos, A= Aegean see, G= Gulfs. The "East side of Lesvos" region includes the sampling sites 1-7 and 33, depicted with green color triangulars. The "Aegean" region includes the sites 8-17 and 24-29 , depicted with blue color triangulars and the "Gulfs" region includes the sites 18-23 and 30-32, depicted with light blueish squares. Two sampling sites are excluded from this plot due to their zero abundances.

In Figure 10, the similarity of fish abundance per sampling site is compared with the different substrate types. The numbers over the signs represent the number of the sampling site. With green triangular, the sites that belong to mobile substrate are represented and with blue triangular those that belong to hard substrate. Here, it can be observed a small accumulation of hard substrate's sites on the center of the map. Also sites with mobile substrate tend to concentrate on the center of the map, but a little bit wider. The analysis of similarities (ANOSIM, Figure 21), showed that the significance level of sample statistic is 95.1% with a global R= -0.133.

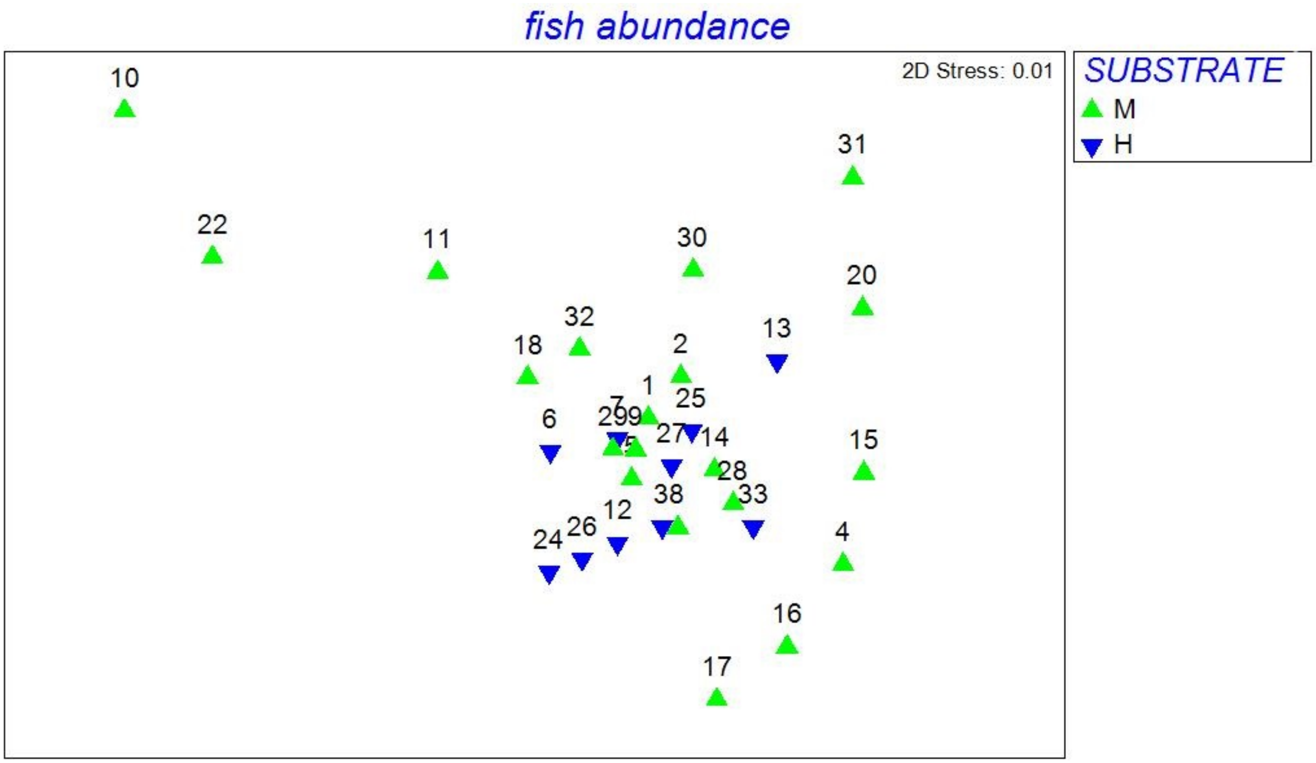

Figure 10: Non metric multidimensional scaling plot (nMDS) for 32 sampling sites, based on square-root transformation density data and a Bray-Curtis similarity matrix. Legend colors and shapes correspond to different substrate types: M= moderate substrate, H= hard substrate. The "moderate substrate" type includes the sampling sites 1,2,4,5,8-11,14-23 and 28-32, depicted with green triangulars. The "hard substrate" includes the sampling sites 3,6,7,12,13,24-27 and 33, depicted with blue triangulars. Two sampling sites are excluded from this plot due to their zero abundances.

Box plots

Benthic coverage

In order to have a better visualization of the data, whisker plots were created. In those, the central box covers 50% of the data, the whiskers extend to the minimum and the maximum values of the data, the vertical line within the box is the median and the black dot represents an extreme value. With red color, the hard substrate is represented and with blue, the mobile.

Here in Figure 11, the values of the benthic categories of different substrates is shown in different geographical areas. Most of the benthic category values have a normal distribution, except the values in the "Aegean" area on mobile substrate, that have a positive distribution. The "East side of Lesvos" region seems to have different distributions than the other two regions. More specifically, the “East side” with “Gulfs” has a statistically important difference (with p=0.04145) and also with “Aegean” (with p=0.0219443).

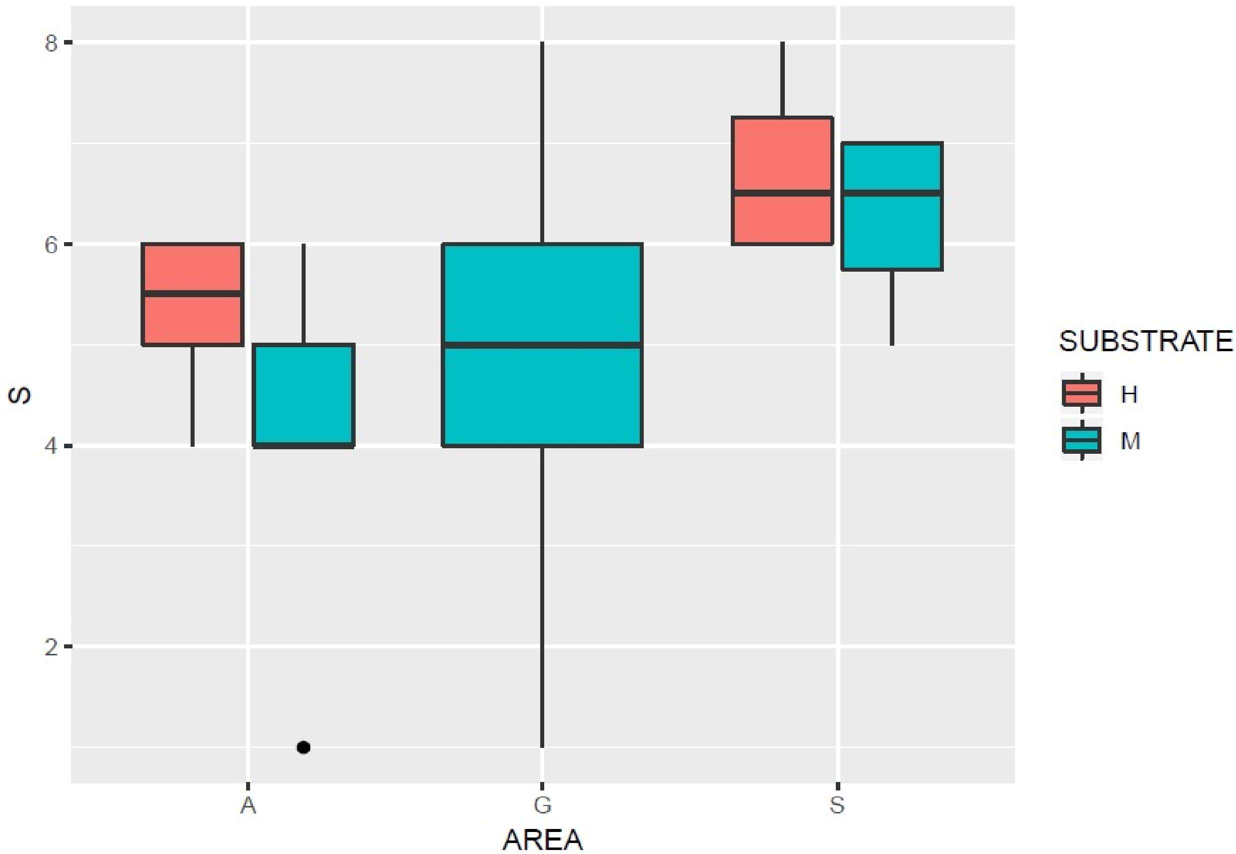

Figure 11: Whisker plot of bentic categories values of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. With red color is represented the hard substrate and with blue the mobile.

In Figure 11, the benthic diversity index values of different substrates by geographical area is displayed. The values of “East side of Lesvos” have a normal distribustion, in “Gulfs”, the distribution tends to be negative and in “Aegean”, in “hard substrate” positive and in “mobile substrate” negative. It turns out that there is a slight statistical difference between “East side of Lesvos” and “Gulfs” (with p=0.0523651).

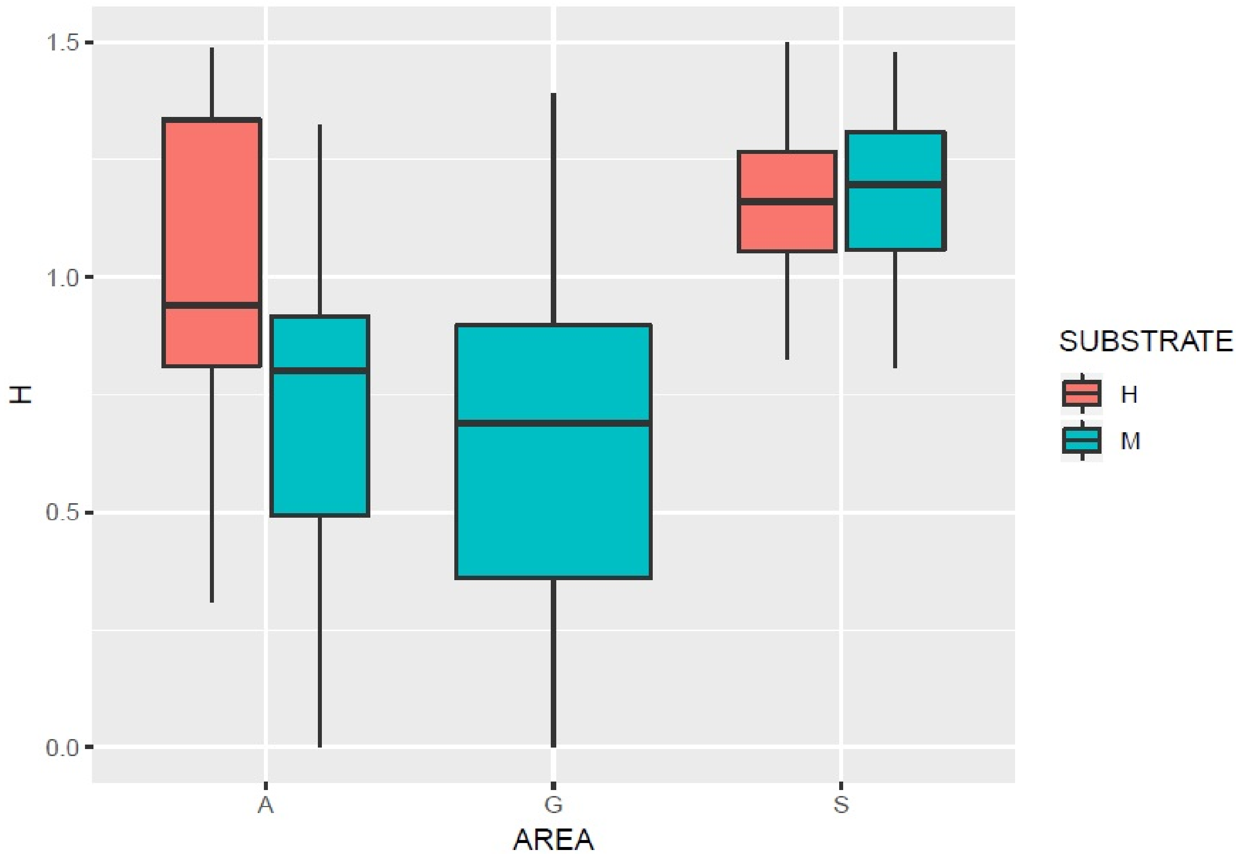

Figure 12: Whisker plot of benthic diversity index of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

In Figure 13, the benthic evenness index values of different substrates by geographical area is represented. In this box plot, the values of east side of Lesvos follow a normal distribution and the values of Gulfs a negative. The values of Aegean, in hard substrate a positive and the values in mobile a negative distribution. No statistical difference was found between evenness index distribution.

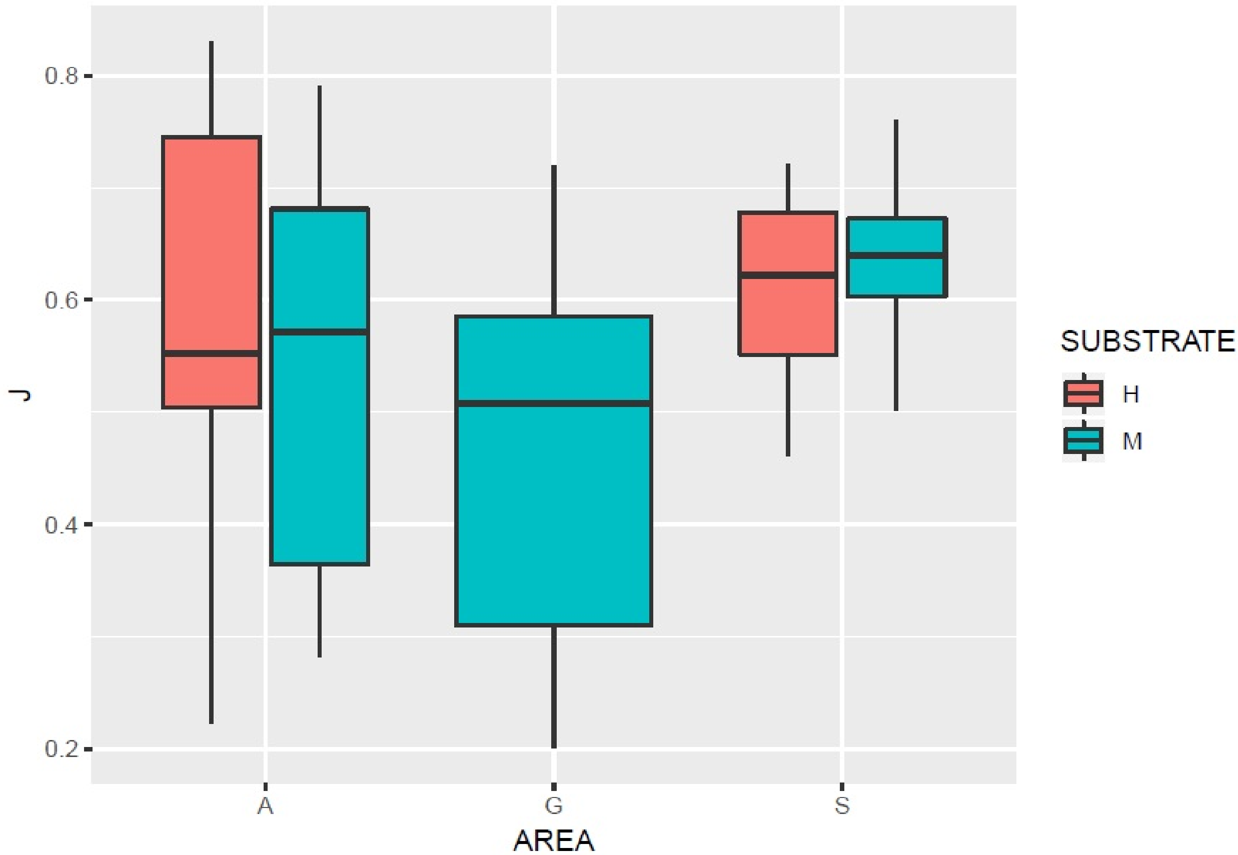

Figure 13: Whisker plot of the benthic evenness index of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

Fish

Next, the distributions of fish data of species richness (S), abundance (N), evenness index (J) and diversity index (H) are represented.

Figure 14 shows the species richness values of different substrate by geographical area. Most values of the data follow a normal distribution except the values in the Gulfs that follow a negative distribution. There are very low statistical correlations among different areas (with $p=0.0746$) and substrates (with $p=0.0827$).

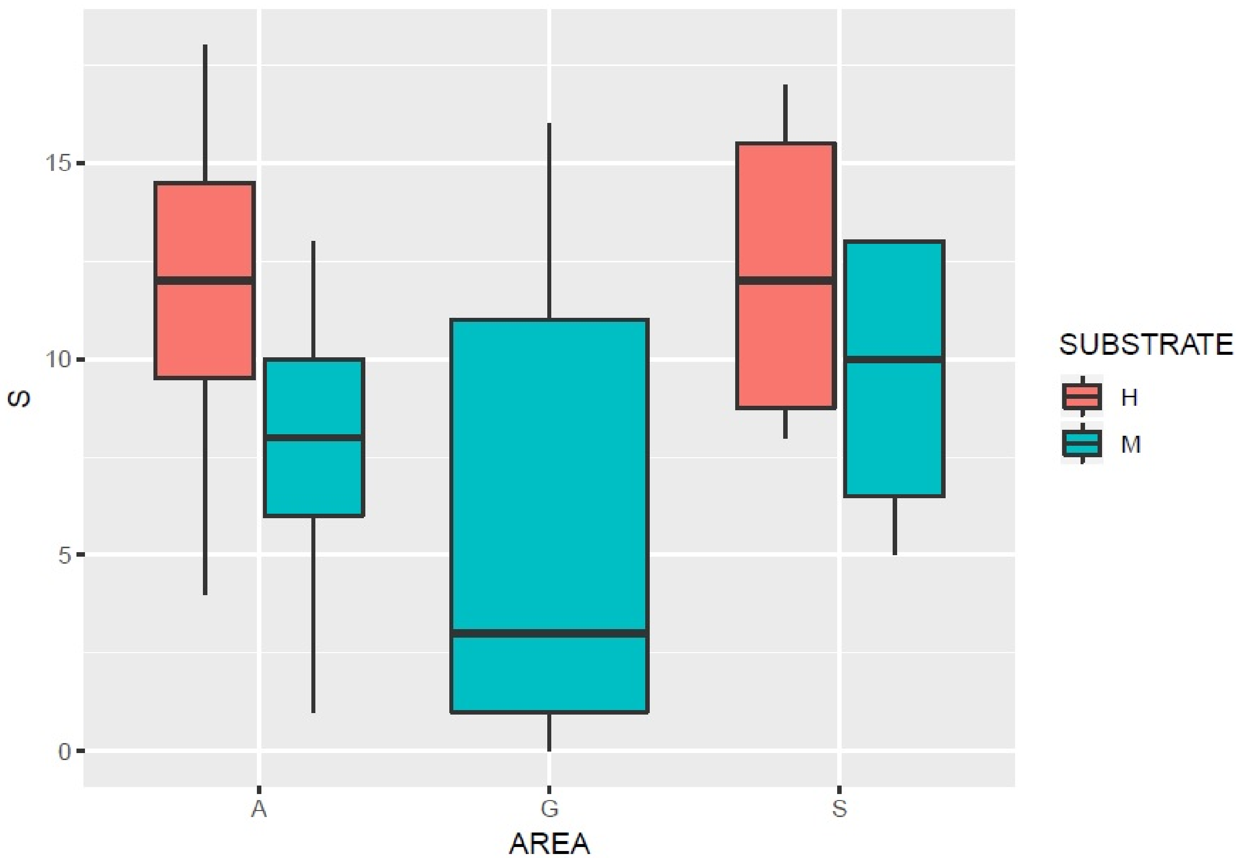

Figure 14: Whisker plot of fish species number of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

In Figure 15, the fish abundance values of different substrates by geographical area is represented. At the “East side of Lesvos”, the data on hard substrate follow a negative and on mobile substrate a normal distribution. In “Gulfs” area, the data follow also a negative distribution. In “Aegean” area, on hard substrate, there is a normal and on mobile substrate a positive distribution. Among the data there is no significant statistical correlation.

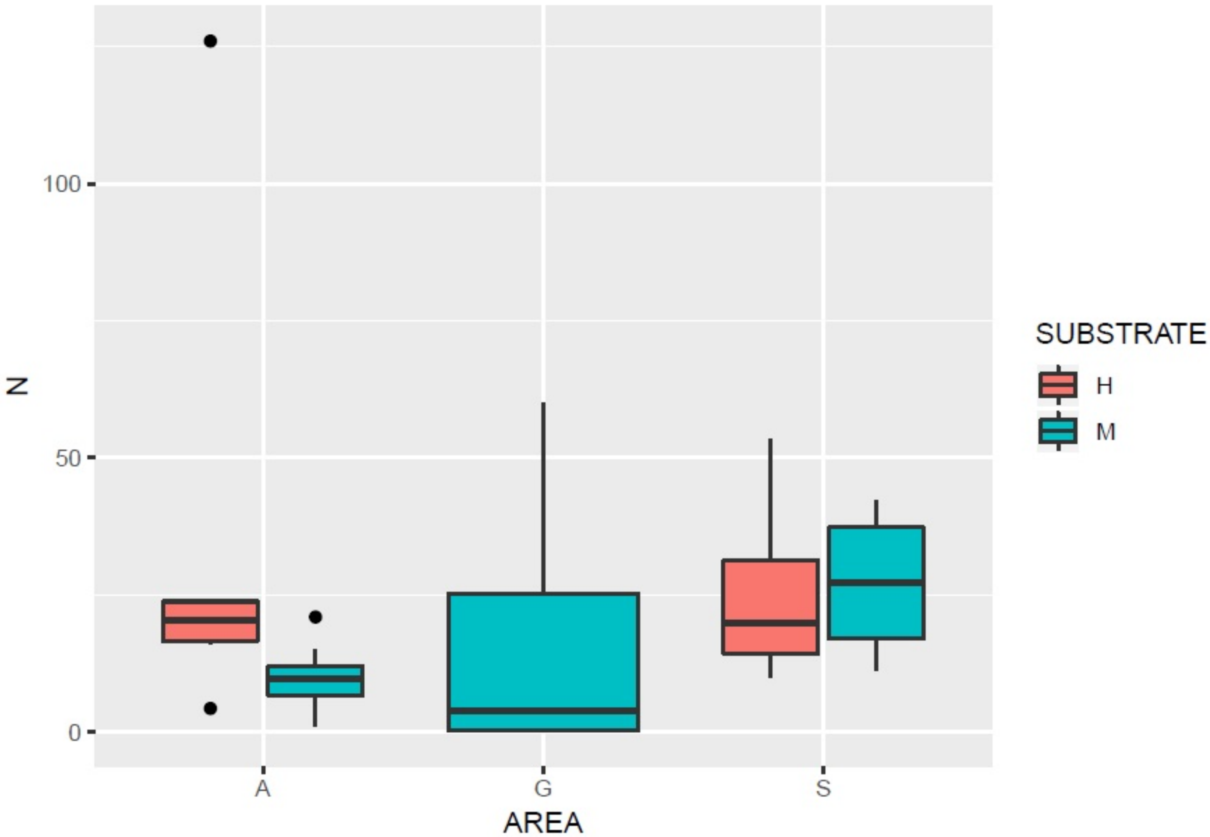

Figure 15: Whisker plot of fish abundance of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

Figure 16 shows the evenness index values of different substrate by geographical area. In this plot, the data of “East side of Lesvos”, on hard substrate follow a negative and on mobile a normal distribution. In “Gulfs” area the distribution is positive. In “Aegean”, on hard substrate the distribution of the data is positive and on mobile substrate normal. No significant statistical correlation exists among the data distributions.

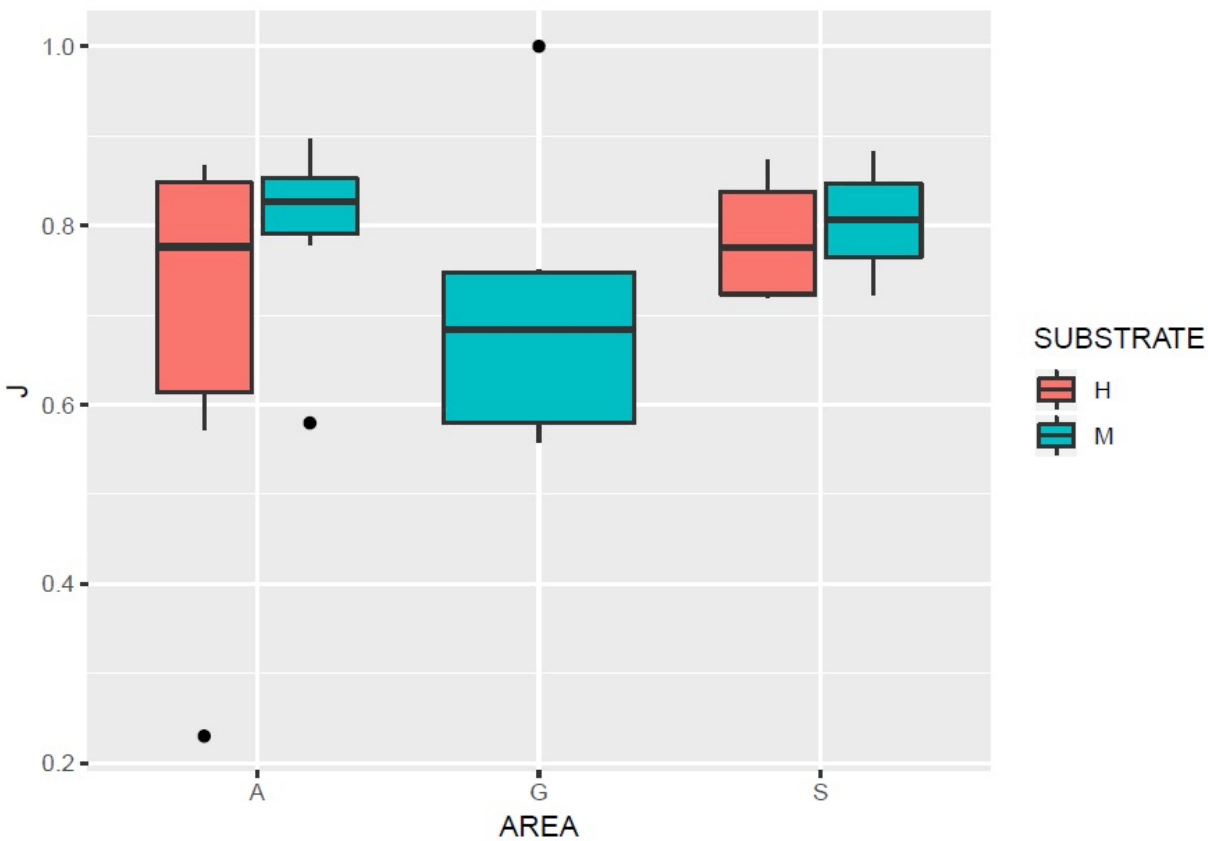

Figure 16: Whisker plot of fish evenness index of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

In Figure 17, we see the diversity index values of different substrates by geographical area. At the “East side of Lesvos”, on hard substrate the data follow a normal and on mobile a negative distribution. In the “Gulfs” sites, the distribution is also normal. Finally, in the “Aegean” area on both substrates the distributions are positive. Also, there is a significant statistical difference among areas (with p=0.0128). More specific, between “Gulfs” and “East part of Lesvos” (with p=0.0117005) and between “Gulfs” and “Aegean” (with p=0.0683436).

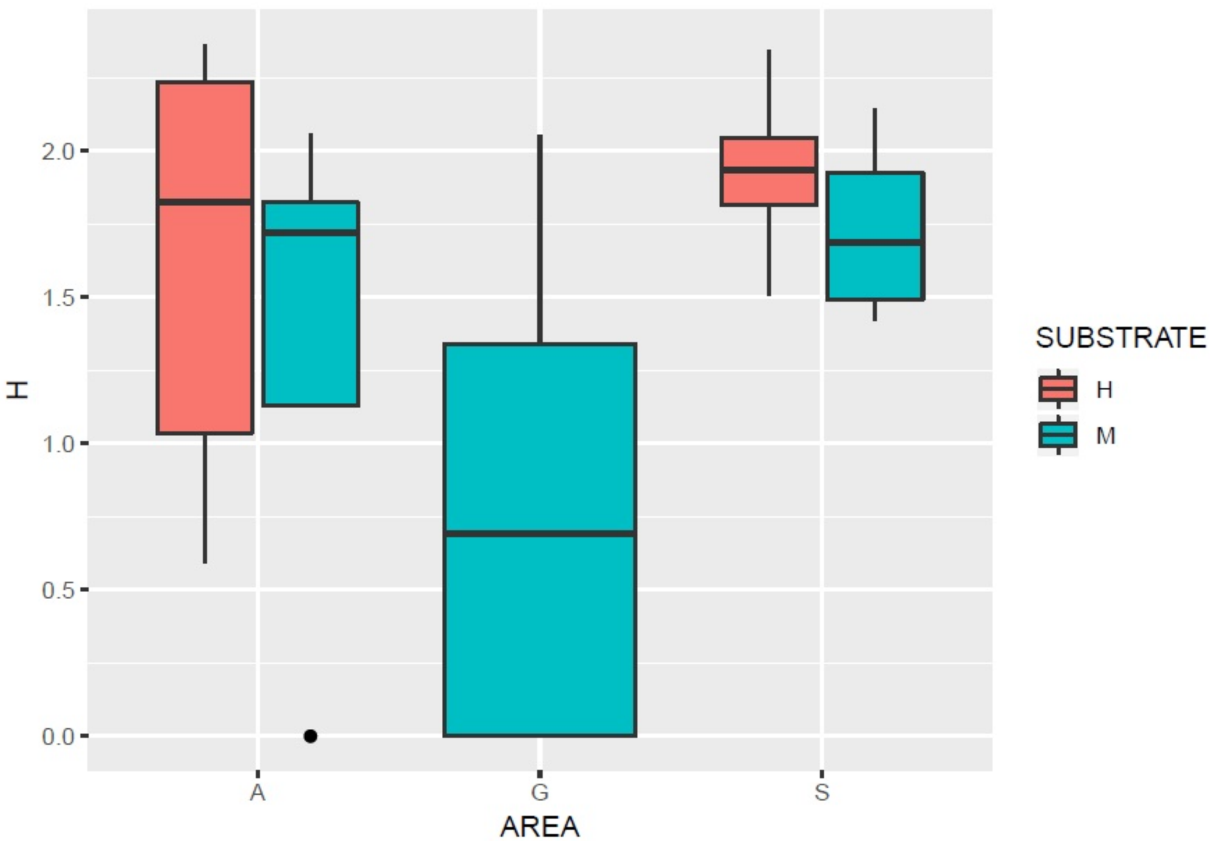

Figure 17: Whisker plot of fish diversity index of different substrates by geographical area. The central box covers 50% of the data, the whiskers extend out to the minimum and maximum values of the data, the vertical line within the box is the median and the black dot represent an extreme value. Hard substrate is represented with red color and mobile substrate with blue.

Discussion

In this study, 12,000 m² of coastline were sampled for fish abundance, 372 m² for sea urchin abundance and benthic images of 144 m² in total were analyzed for the benthic coverage categories. The most common benthic categories along the coastline of Lesvos were “Sand”, then “Seasonal algal turf” and “Phanerogams”. On hard substrates, “Seasonal algal turf” had the biggest abundance. This does not reflect to a healthy coastal ecosystem (Airoldi & Beck, 2007). Also in other studies at the Aegean see, on hard substrate, algal turf was one of the most dominant groups (Giakoumi et al., 2012). Further, we can see that “Phanerogams” and “Sand” were the second and third most common categories on hard substrate. These categories usually do not exist on hard substrates. In picture 1 is an example, where we can see these benthic categories existing very close to hard substrates.

On mobile substrate, the main benthic categories are “Sand”, “Phanerogams” and “Seasonal algal turf”. Phanerogams have an important ecological role in the Mediterranean coastal ecosystems, by creating their own habitats, which many times are home to many other organisms (Valentine & Heck, 1999). In Figure 3, if we have a close look, we can observe that the benthic category “Mucillagenous” exists only at one site on the west coast. It has been observed that species of this category developed certain advantages in algae environments (Boney, 1981). Here, they have been found on *Posidonia oceanica.*

The highest values of sea urchins were found on the north, northwest part of the island. They appear both on hard and mobile substrate. No significant relationship was found between benthic categories and sea urchins. Most of the sea urchin studies are about the species *Paracentrotus lividis* and *Arbacia lixula*. According to studies, both species consume erect algae (Guidetti & Dulcic, 2006; Sala et al., 2012). It has been found, that the extent of barrens is bigger when these species are found together (Guidetti and Dulcic, 2006).

In total, 37 different fish species were counted (table 1). *Atherina sp.* and *Syngnathus sp.* were excluded from the statistics due to their extreme numbers, so in total 35 species were used for the statistical analysis. The most abundant species were *Chromis chromis, Sarpa salpa* and *Diplodus vulgaris.* The main representative of the grazers category was *Sarpa salpa* and of the carnivores *Serranus cabrilla* and *Serranus scriba.* Although the carnivores have the smaller percentage in this study, they seem to have outspread wider. On the other hand, we can observe that the grazers category is absent from the south west part of the island.

With the nMDS analysis for the benthic coverage (Figure 7), it becomes clear that there is no statistically significant correlation between the benthic categories and the geographical area. It can only be observed a small difference between “Aegean sea” and “Gulfs”. This might be explained by the fact that in all areas there were both types of substrate. The other nMDS analysis (Figure 8) for benthic coverage and substrate type, showed a very low statistical correlation between them. That was more or less expected, due to the random choice of the sampling areas.

The nMDS analysis for the sea urchin abundance did not show any statistically relevant differences, neither for different areas nor for the substrate types.

The analysis in Figure9 showed a statistically significant relation between fish abundance and area. Mainly, there was a difference between the geographical areas “Aegean sea” and “East side of Lesvos”. Also, there was a correlation between fish abundance and substrate type (Figure 10). Many factors could affect fish abundance in this study. One of them could be the hour of sampling. It has been observed that in early mornings, fish activity was higher and fish were less afraid of the diver, the same in the afternoon. Furthermore, in the mornings more juvenile fish were around (personal observation).

The distribution of the benthic categories (Figure 11) shows a significant statistical difference of the “East side of the island” compared to the “Gulfs” and “Aegean sea” on the other hand. Also, at the distribution of the diversity index H (Figure 12), there was a small statistical difference between the “East side” and the “Gulfs”. But no statistical difference appeared on the evenness index J (Figure 13).

In the fish distributions, we have some more differences. As in the species richness (Figure 14), we can see that there are statistically low differences between the different areas. More specifically, we can see that the median of the “Gulfs’” fish distribution is lower than in both of the other geographical areas and they have a low statistical difference. Also, between the different substrates there was no statistically relevant difference found in the fish abundance (Figure 15). The extreme abundance values of some areas, usually come from some group fish, such as *Chromis chromis* or *Sarpa salpa.* Although in evenness index J (Figure 16), the median of the "Gulfs" seems quite different from the median of the other areas, there is no significant statistical difference. Finally, the diversity index H (Figure 17) shows a significant statistical difference between areas. Especially the "Gulfs'" fish distribution differs from both other areas.

Besides the high ecological importance of *Cystoseira* species algae, they do not belong to a frequently found category in this study. This might be explained by the reason that they appear mostly on hard substrate, but also it might be an example of its diminution. Studies in other regions of the Mediterranean sea showed already a steady decrease or even extinction of some species (Thibaut et al., 2005). Although sea urchins are one of the big threats of this taxa, here we did not find any correlation between them.

It is known that in Mediterranean coastal zones, fish abundance is higher in shallow rocky habitats and in highly productive seagrass beds with *Posidonia oceanica* (Raedemaecker et al., 2010), also in some other case, it has been found that the highest fish species richness was observed over *P. oceanica,* the second highest over rocky algal reef habitats and the lowest over unvegetated sand (Guidetti, 1999). In this study as well, the minimum species abundance was at the sand category.

Although human pressure was not one of the variables in this study, it might be one reason for my results. "East side" was chosen as a geographical category, due to the special characteristic of being in between of two mainlands, but also it happens to have the biggest coastal human activity on Lesvos island. The north part where "East side" category starts, is right after one of the most touristic places of the island and in the south lies the capital city of Lesvos, Mytilene. This coastal area hosts human activities for the last centuries (Juanes, 2001). "East side" category has ~100 km of coastline with 13 docks, 16 small ports and 1 big port along it.

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Appendix

Species name
Atherina sp.
Boops boops
Chromis chromis
Coris julis
Dasyatis pastinaca
Dentex dentex
Pagellus acarne
Diplodus annularis
Diplodus puntazzo
Diplodus sargus
Diplodus vulgaris
Labrus merula
Labrus mixtus
Labrus viridis
Lithognathus mormyrus
Mugilidae sp.
Mullus surmuletus
Oblada melanura
Pagrus pagrus
Sarpa salpa
Scorpaena notata
Serranus cabrilla
Serranus scriba
Soleidae sp.
Sparus aurata
Spicara maena
Spicara smaris
Spondyliosoma cantharus
Symphodus cinereus
Symphodus mediterraneus
Symphodus melanocercus
Symphodus ocellatus
Symphodus roissali
Symphodus rostratus
Symphodus tinca
Syngnathus sp.
Thalassoma pavo

table 1: Fish species.

Benthic categories
Articulated
Bushy algae
Canopy forming algae
Encrusting calcareous algae
Foliose algae
Mucillagenous
Pebbles
Perennial animal
Phanerogams
Sand
Seasonal algal turf

table 2: Benthic categories.

Global Test
Sample statistic (Global R): 0.084
Significance level of sample statistic: 8.6%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 85

Pairwise Tests					
Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
S, A	-0.061	76.9	490314	999	768
S, G	0.168	7.8	24310	999	77
A, G	0.17	3.1	1307504	999	30

Figure 18: One-way ANOSIM analyses results of Figure 7.

Global Test
Sample statistic (Global R): 0.249
Significance level of sample statistic: 0.2%
Number of permutations: 999 (Random sample from 64512240)
Number of permuted statistics greater than or equal to Global R: 1

Figure 19: One-way ANOSIM analyses results of Figure 8.

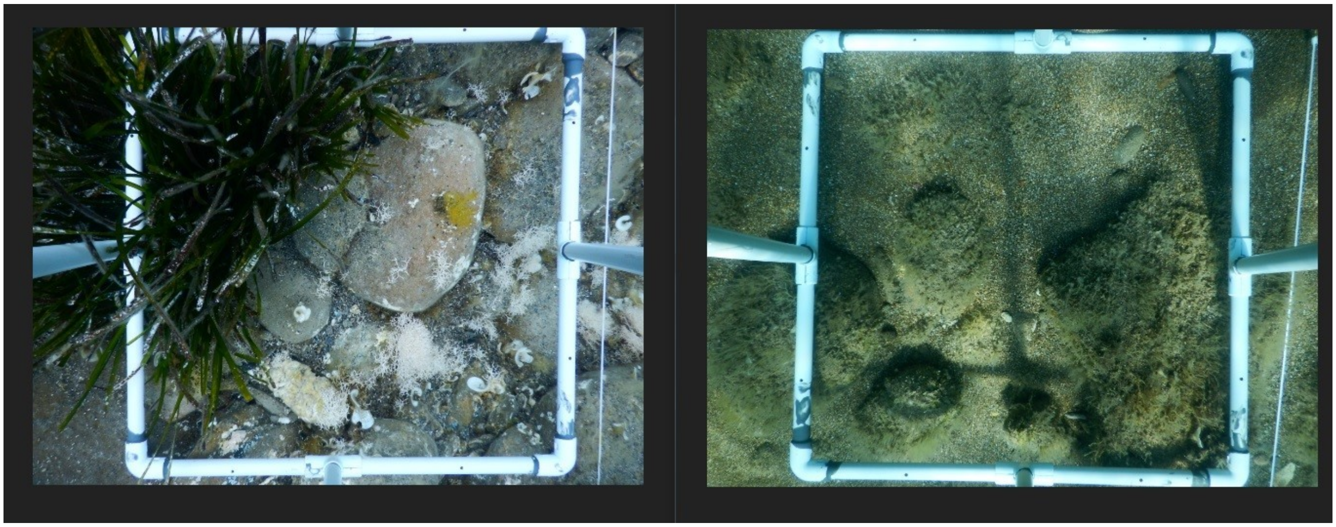
Global Test
Sample statistic (Global R): 0.148
Significance level of sample statistic: 2.6%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 25

Pairwise Tests					
Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
S, A	-0.055	67	490314	999	669
S, G	0.15	2	24310	999	19
A, G	0.31	0.4	1307504	999	3

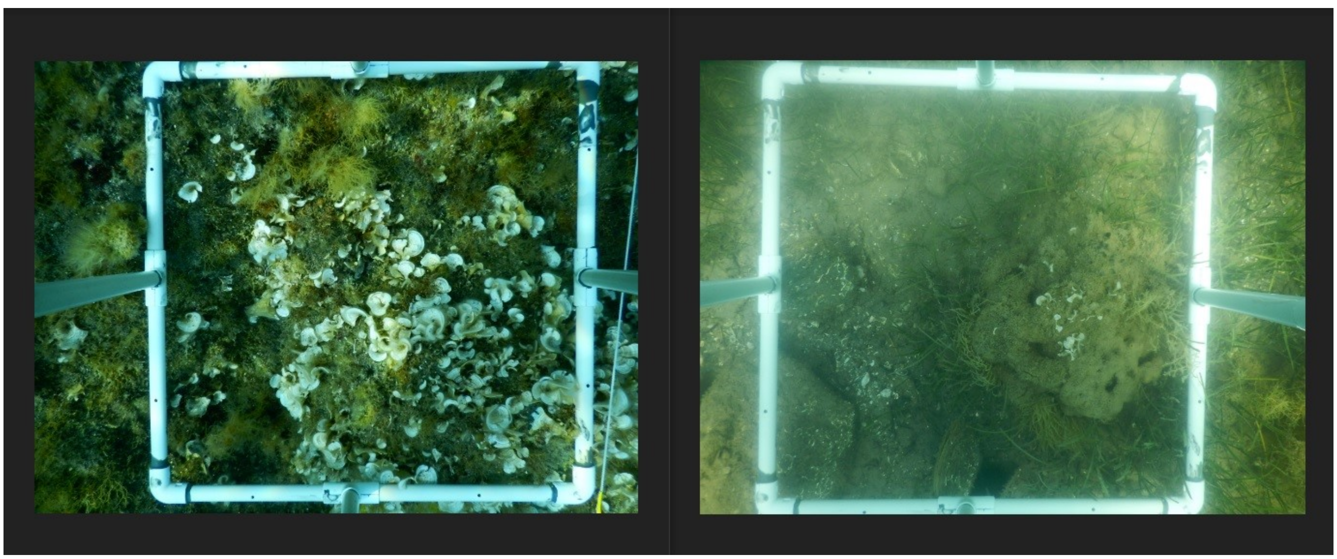
Figure 20: One-way ANOSIM analyses results of Figure 9.

Global Test
Sample statistic (Global R): -0.133
Significance level of sample statistic: 95.1%
Number of permutations: 999 (Random sample from 64512240)
Number of permuted statistics greater than or equal to Global R: 950

Figure 21: One-way ANOSIM analyses results of Figure 10.



picture 1: Images taken on hard substrate, showing that there are Phanerogams (left image), or Sand (right image) at a same transect.



picture 2: Images outside and inside gulf.

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