BRAZILIAN JOURNAL OF OCEANOGRAPHY, 60(4):447-462, 2012

MACROFAUNA ASSEMBLAGES IN A XVIIth CENTURY SHIPWRECK: COMPARISON WITH THOSE ON NATURAL REEFS AND SANDY BOTTOMS

Rui Coelho[1,], Pedro Monteiro[1], David Abecasis[1], Jean Yves Blot[2] and Jorge M. S. Gonçalves[1]*

[1] Centro de Ciências do Mar (CCMAR) - Universidade do Algarve
(Campus de Gambelas FCT Ed. 7, 8005-139 Faro, Portugal)

[2] Centro Nacional de Arqueologia Náutica e Subaquática
Instituto de Gestão do Património Arquitectónico e Arqueológico, IP
(1300-300 Lisboa, Portugal)

*Corresponding author: rpcoelho@ualg.pt

ABSTRACT

The macrofauna assemblages of a XVIIth century shipwreck off southern Portugal were studied and compared with those of nearby natural reefs and sandy bottoms, by underwater visual census. A total of 11 173 specimens of 224 different fauna taxa and 12 phyla were recorded. Natural reefs had the highest density of specimens (35 122 / 1000 m^2) followed by the shipwreck (21 392 / 1000 m^2) and the sandy bottoms (3771 / 1000 m^2). Three biodiversity indices were estimated (Margalef, Shannon-Wiener and Pielou), with the natural reefs showing the highest values. However, the shipwreck presented values relatively similar to those of the natural reefs for the Shannon-Wiener and Pielou indices. The three habitats were clearly distinguishable by multivariate statistical analysis, with the average dissimilarity between sand and shipwreck, and between sand and natural reefs being much higher than that between the shipwreck and the natural reefs. The shipwreck had higher abundances of some commercially important species, such as the pouting *Trisopterus luscus*, European conger *Conger conger*, and common spider crab *Maja squinado*, as well as some vulnerable and threatened species such as the pink seafan *Eunicella verrucosa*. The results presented emphasize the importance of this habitat on the southern Portuguese coast.

RESUMO

As comunidades de macrofauna de um naufrágio do século XVII ocorrido ao largo da costa Sul de Portugal, foram estudadas e comparadas com recifes naturais e fundos de areia através de census visuais subaquáticos. Foram registados 11 173 espécimes pertencentes a 224 taxa faunísticos e 12 phyla. Os recifes naturais apresentaram a maior densidade de espécimes (35 122 / 1000 m^2) seguidos do naufrágio (21 392 / 1000 m^2) e dos fundos de areia (3771 / 1000 m^2). Foram calculados três índices de biodiversidade (Margalef, Shannon-Wiener e Pielou), com os recifes naturais que apresentarem os valores mais elevados. No entanto, o naufrágio mostrou valores relativamente semelhantes aos fundos rochosos nos índices de Shannon-Wiener e Pielou. Os três habitats foram separados por estatística multivariada, com a dissimilaridade média entre areia e naufrágio, e entre areia e recifes naturais sendo muito superior à dissimilaridade entre os recifes naturais e o naufrágio. O naufrágio apresentou elevada abundância de algumas espécies comercialmente importantes, como a faneca *Trisopterus luscus*, o safio *Conger conger* e a santola *Maja squinado*, assim como de espécies vulneráveis e ameaçadas como a gorgonia rosa *Eunicella verrucosa*. Os resultados apresentados realçam a importância desse habitat para a costa Sul de Portugal.

Descriptors: Artificial reefs; Biodiversity, Underwater visual survey, Multivariate analyses; NE Atlantic.
Descritores: Recifes artificiais, Biodiversidade, Monitorização visual subaquática, Análise multivariada, Nordeste Atlântico.

INTRODUCTION

Artificial reefs are defined by the European Artificial Reef Research Network as submerged structures deliberately or accidentally placed on the substratum to imitate some of the characteristics of natural reefs. These structures can be built from a wide variety of materials, and have been deployed in many coastal regions of the world for diverse reasons such as enhancing tourism, coastal protection and fisheries management (BAINE, 2001). The potential use of these artificial structures for the restoration and rehabilitation of fisheries seems to be one of the main reasons for their use (CLARK; EDWARDS, 1999; BAINE; SIDE, 2003) and some studies have started to look into comparisons between artificial and surrounding natural reefs (e.g. ASELTINE-NEILSON et al., 1999; BADALAMENTI et al., 2002; PERKOL-FINKEL; BENAYAHU, 2004, 2007; ARENA et al., 2007). However, there is still only limited knowledge regarding the relations between these structures and the surrounding environments, and this lack of comparative knowledge has in some cases been given as the main reason for the poor understanding of the ecology of artificial reefs (SVANE; PETERSEN, 2001).

Most of the studies undertaken on the ecology of artificial reefs have focused on relatively young communities, as many of these reefs have only been deployed in recent years. Current knowledge on the communities that have established themselves in artificial reefs on the long term is still limited, but there is some evidence that the time frame required to develop a diversified artificial reef community is well over a decade (CUMMINGS, 1994; PERKOL-FINKEL; BENEYAHU, 2005; SANTOS; MONTEIRO, 2007). Because of this, accidentally sunken shipwrecks provide an excellent natural experimental arena, as some of these structures have lain submersed for many decades or, in some cases, centuries. However, and surprisingly, very few studies have been carried out comparing the ecology of these older shipwrecks with those of their surrounding environments (e.g. ZINGTEN et al., 2008), but even those have focused mainly on shipwreck sites with time spans inferior to 100-150 years.

The shipwreck site currently known to marine archeologists as "*Faro A*" (Fig. 1) was presumably an English cargo vessel traveling from Northern Europe to the Mediterranean port of Izmir/Smyrna as part of a large British convoy (BLOT et al., 2005). In June 1693, while sailing off the southern Portuguese coast, the convoy was attacked by the French navy and the "*Faro A*" ship sunk a few miles from the city of Faro in southern Portugal (BLOT et al., 2005). The wreck remained undiscovered until a team of recreational scuba divers accidentally located it in 1996, and has since been studied by marine archeologists and biologists. One among several dozens of historical wreck sites currently known off the coast of Portugal (BLOT, 2002), the "*Faro A*" immediately appeared as "different" to marine archeologists, mainly due to two features: 1) the significant protuberances caused by a cargo of iron bars and iron artillery, all heavily covered with marine concretions and 2) the single presence of seven pewter plates as part of the minor artifacts commonly found on wreck sites from the same period (BLOT et al., 2005). Due to its historical importance, the "*Faro A*" wreck site has been declared of national importance by the Portuguese Government and restrictions have been imposed on fishing activities (both commercial and recreational) and recreational scuba diving in the area in the attempt to preserve the site. Recreational scuba diving activities are only allowed if accompanied by authorized scuba divers who conduct tourists along a pre-established route, thus minimizing the impact on the wreck site.

The recent popularity of artificial reefs has led scientists to pose legitimate questions as to whether they are indeed an effective fishery management and habitat restoration tool (PICKERING; WHITMARSH, 1997). Understanding the fauna assemblages that are established on a long-term temporal scale provides a unique opportunity to answer some of these questions, particularly when comparisons are made with surrounding natural habitats. The objectives of the present study were, therefore, to 1) characterize the macrofauna assemblages of the "*Faro A*" shipwreck in southern Portugal, and 2) determine the ecological importance of the site by comparing the communities of this shipwreck with those of nearby natural reefs and sandy bottoms.

Fig. 1. Underwater photograph of the shipwreck "*Faro A*", showing part of the iron cargo. Original photograph by José Augusto Silva.

MATERIAL AND METHODS

Study Area

The present study was carried out in three different habitats: the "*Faro A*" shipwreck, three natural rock reefs ("*Cabeço do Robalo*", "*Pedra da Greta*" and "*Pé de Terra*") and four sandy bottom areas surrounding these reefs (Fig. 2). The "*Faro A*" shipwreck consists mainly of the remains of the iron bars of the cargo and the iron artillery of the original vessel, all covered with marine concretions (BLOT et al., 2005). The natural reefs are part of a linear 2 Km rocky outcrop lying parallel to the shoreline (TEIXEIRA, 1998), its lithology consisting of medium quartz sandstone and conglomerates with carbonate cement, with strong evidences that it formed part of the shoreline during the Holocene period (TEIXEIRA; PINTO, 2002). All the sampling sites were in the same area off southern Portugal, at approximately the same depth, between 18 and 22 m (Fig. 2).

Faunal Sampling

All the sites were sampled by underwater visual census using scuba diving techniques. Each of the 8 study sites was analyzed on triplicate transects, accounting therefore for a total of 24 transects investigated during the study: 3 transects in the shipwreck itself, 9 in the rocky natural reefs and 12 on the sandy bottoms surrounding the reefs. The random transect technique was used on each dive, adjusted for the three distinct faunal groups present in the area, specifically the invertebrate epibenthic macrofauna, the demersal and the criptobenthic fishes. All specimens found along each transect were identified, counted and recorded. Identification was made to the lowest possible *taxon*, and in cases where underwater identification was not possible, samples were collected and transported to the laboratory for posterior detailed analysis.

The same techniques, procedures and divers were used throughout the study, the effort (length) of each transect varying according to bottom type. On sandy bottoms, the demersal fishes were counted on transects 50 m long and 4 m wide, the criptobenthic fishes on transects 25 m in length and 1m in width, and the invertebrate benthic macrofauna on transects 50 m long and 4 m wide. On the reef bottoms (both in the shipwreck and on the natural reefs) the demersal fishes were counted on transects 20 m long and 4 m wide, the criptobenthic fishes on transects 10 m in length and 1 m in width, and the invertebrate benthic macrofauna on transects 5 m long and 1 m wide. In order to make comparisons between habitats possible, all the data were standardized and analyzed in terms of density, specifically in number of specimens per 1000 m^2.

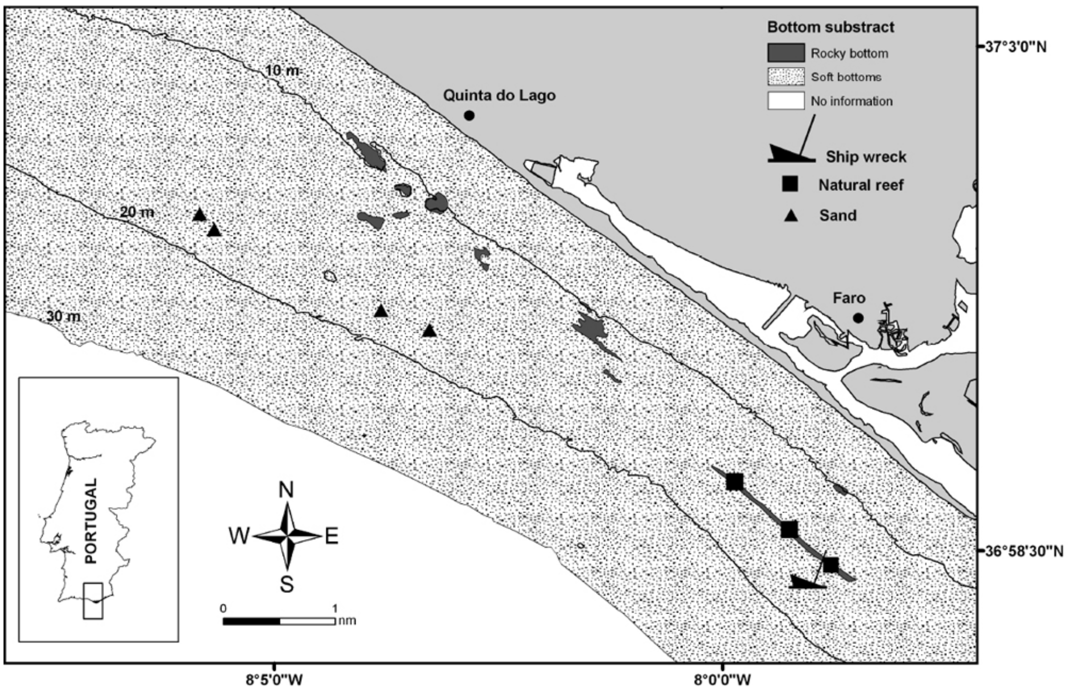

Fig. 2. Map of the southern Portuguese coastal area where the study was carried out indicating the bottom type and bathymetric lines. The locations of the "*Faro A*" shipwreck, the three natural reefs and the four sandy bottom locations that were sampled in this study are indicated.

Data Analysis

Each habitat was described in terms of the total number of *taxa* (*S*), and density (specimens / 1000 m^2) calculated as mean values ±SD for each *taxon* in each habitat. Furthermore, the frequency of occurrence (*FO*) was also calculated by:

$$FO = (Li/Lt) * 100$$

where *Li* is the number of transects where a particular species was recorded in a specific habitat and *Lt* is the total number of transects investigated in that habitat.

In order to estimate quantitative measures for comparing the different habitats, several diversity indices were calculated, namely the Margalef richness index (*R*), the Shannon-Wiener diversity index (*H'*) and the Pielou evenness index (*J'*). The Margalef richness index measures the number of species or *taxa* present in a given number of specimens (CLARKE; WARWICK, 2001) and is given by:

$$R = (S - 1) / \text{Log } N$$

where *S* is the total number of *taxa* and *N* is the total number of specimens.

The Shannon-Wiener diversity index, one of the most widely used biodiversity indexes (CLARKE; WARWICK, 2001), is based on the proportion of species abundance and accounts for the equitability and richness:

$$H = - \sum Pi \text{ Ln } (Pi)$$

where *Pi* is the proportion of specimens of species *i*.

The Pielou evenness index expresses how the *taxa* are distributed in the community (CLARKE; WARKICK, 2001) and varies from a minimum of 0 to a maximum of 1, where 1 represents a community where all species are equally abundant, and 0 represents a community where one species dominates all others (MAGURRAN, 1988):

$$E = H / \text{Ln } S$$

Each diversity index was calculated individually for each of the transects, and then each habitat was tested for differences with an Analysis of Variance (ANOVA). Whenever significant differences were detected, the Student Newman Keuls (SNK) test was used to calculate pairwise differences between the habitats. Whenever the parametric assumptions of data normality and homogeneity of the variances were not respected, alternative non-parametric tests were carried out, specifically the Kruskal-Wallis test followed by the pairwise Dunn test. A 5% significance level was considered in all cases.

Multivariate analysis was carried out with the PRIMER 6 software (CLARKE; GORLEY, 2006). A square-root transformation was applied to density data, and similarity matrices were constructed using the Bray-Curtis similarity index (CLARKE; WARWICK, 2001). Non-metric multidimensional scaling (nMDS) and cluster analysis were used for spatial ordination of the data, and analysis of similarity (ANOSIM) was used to statistically test differences in the data, using habitat type as the factor to test. An analysis of similarity in percentages (SIMPER) was carried out in order to assess the *taxa* that were most contributing to distinguish between pairs of habitats.

RESULTS

Species Richness and Diversity

During the underwater visual census, a total of 11 173 specimens, belonging to 224 different fauna *taxa* of 12 phyla, were recorded. Of these observations, 2083 records (18.6%) were of fish, belonging to 42 individual *taxa* (including 17 families), while the remaining 9090 (81.4%) recordings were of invertebrate macrofauna, belonging to 182 individual *taxa* (of 19 classes and 11 phyla). In terms of *taxa* per habitat, 87 *taxa* (10 phyla) were recorded in the sandy habitat, 33 *taxa* (9 phyla) were recorded in the shipwreck and 149 *taxa* (12 phyla) were recorded in the natural reefs. A Table presenting the complete fauna list recorded, with values of density and *FO* for each habitat is provided in an Annex as Supplementary Data.

The mean number of *taxa* (± SD) observed during the investigation of each transect was highest for the natural reefs with 46.2 (± 17.6), followed by the shipwreck with 21.7 (± 2.5) and finally the sandy habitat with 19.2 (± 15.9) (Fig. 3). There were statistical differences between the mean number of *taxa* in each habitat (ANOVA: F = 7.91; p-value = 0.003), with significant differences between the sand and the natural reefs (SNK: q = 5.470; p-value = 0.003) and between the shipwreck and the natural reefs (SNK: q = 3.28; p-value = 0.03), but not between the shipwreck and the sand (SNK: q = 0.35; p-value = 0.81).

In terms of mean density of specimens (± SD), the natural reef had the highest density, with 35 122 (± 23 935) specimens per 1000 m^2, followed by the shipwreck with 21 392 (± 1812) and finally the sand with 3771 (± 4199) (Fig. 3). Differences were found between the mean density of specimens in each habitat (Kruskal-Wallis: H = 16.48; p-value < 0.001), with significant differences between the sand and the natural reefs (Dunn: Q = 3.88; p-value < 0.05), but not between the other possible pairs (Dunn: p-values > 0.05 in both cases).

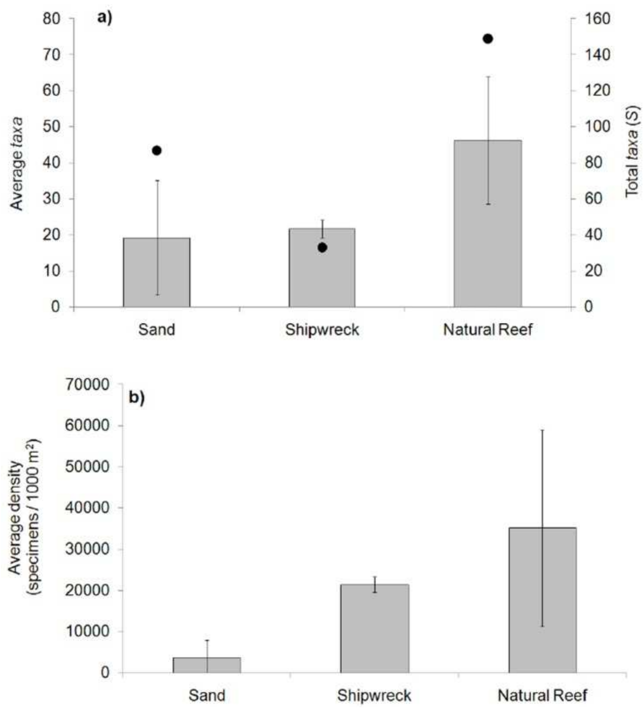

Fig. 3. Total (black circles) and average (grey bars) *taxa* (a) and average density of specimens (b) found in each habitat. Error bars refer to ± SD.

In terms of the density of each phylum in each of the three habitats, it was noteworthy that many phyla were proportionally more abundant on the natural reefs than in the other habitats, particularly the Chordata, Phoronida, Plathelminthes, Porifera and Urochordata. The densities of other phyla such as the Annelida, Arthropoda, Bryozoa, Cnidaria and Echiura were more evenly distributed between the natural reefs and the shipwreck, while on the sandy habitat the Arthropoda, Echinodermata and Mollusca assumed particular importance. In terms of number of species, the phyla Annelida, Bryozoa, Chordata, Cnidaria, Phoronida, Porifera and Urochordata had more species on the natural reefs. The Echiura had almost the same species on the natural reefs as in the shipwreck, while the Mollusca and Plathelminthes had almost the same number of species on the natural reefs as on the sand. The Arthropoda had more species on the sand (Fig. 4).

Regarding the diversity indices, it was noticeable that the natural reefs had higher values in all cases. For the Margalef richness index the values on the sand and in the shipwreck were relatively similar, but for the other indices the sandy habitat presented lower values, while the shipwreck tended to have values lying between those for the sand and the natural reefs (Fig. 5). There were statistical differences between the values of the Margalef richness index for the three habitats (ANOVA: $F = 5.7$; p-value = 0.01), the values of the Shannon-Wiener diversity index (ANOVA: $F = 11.9$; p-value < 0.001) and the values of the Pielou evenness index (ANOVA: $F = 5.6$; p-value < 0.01). As for the Shannon-Wiener and the Pielou evenness indices, only the sandy habitat presented differences from the other two habitats (SNK: p-values < 0.05), while for the Margalef richness index both the sand and the shipwreck presented differences from the natural reefs (SNK: p-values < 0.05).

Multivariate Analysis

When all the data combined (both vertebrates and invertebrates) were used for multivariate analysis, the differences between habitats became clear. Samples from the same habitat were clustered together and separately from those from different habitats, indicating relatively high similarity between assemblages at the same site compared with those at the other sites. All the transects investigated on the sand are highly different from those of both the shipwreck and the natural reefs, with the sand group being the first to separate out, being characterized by a relatively high dispersion and variability between transects (Fig. 6).

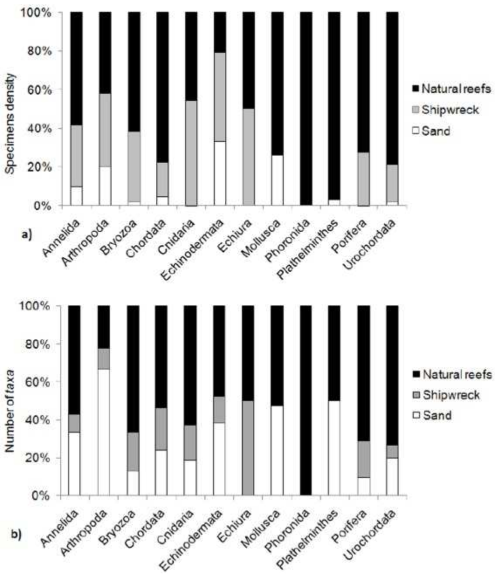

Fig. 4. Specimen density (a) and number of *taxa* (b) as percentages of each phylum in each of the three habitats studied.

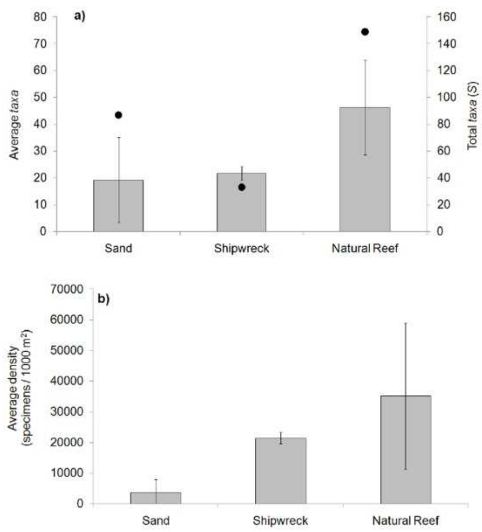

Fig. 5. Margalef richness index (a), Shannon-Wiener diversity index (b) and Pielou evenness index (c) for each of the three habitats studied. Histogram bars refer to average values and error bars refer to ± SD.

The natural reef versus shipwreck transects also showed high dissimilarity, with the shipwreck transects forming a closely similar group, while the natural reefs presented greater dispersion (Fig. 6). There were significant differences between the three habitats (ANOSIM: R = 0.91; p-value = 0.001), with significant differences between the three possible pairs (ANOSIM pairwise tests: p-values < 0.05 in all cases).

The average dissimilarity between the sand and the shipwreck and between the sand and the natural reefs was much greater than that between the shipwreck and the natural reefs. The *taxa* which most contributed to the differences between the shipwreck and the natural reefs were invertebrates of the phylum Cnidaria. Specifically, the sea beard *Nemertesia antennina* and the pink seafan *Eunicella verrucosa*, occurred in higher abundances in the shipwreck, while the anemones *Corynactis viridis* and *Anemonia sulcata* were more abundant on the natural reefs. Two important bony fishes were the pouting *Trisopterus luscus*, and the gobid *Pomatoschistus* cf. *quagga*, the former being more abundant in the shipwreck and the latter more abundant on the natural reefs. Other important species for distinguishing these two habitats were the sea cucumber *Pawsonia saxicola* and the sponge *Leucosolenia complicata*, that occurred in higher densities in the shipwreck, and the bryozoan *Schizobrachiella sanguinea* and the sponge *Phorbas fictitius* that occurred in higher densities on the natural reefs (Table 1). The differences between both the shipwreck and the natural reefs and the sand were mainly due to *taxa* present either in the shipwreck or on the natural reefs, but absent from the sand. The only exceptions were the brittlestar *Ophiura albida* and the gobids *Pomatoschistus* spp., present in higher densities on the sand (Table 1).

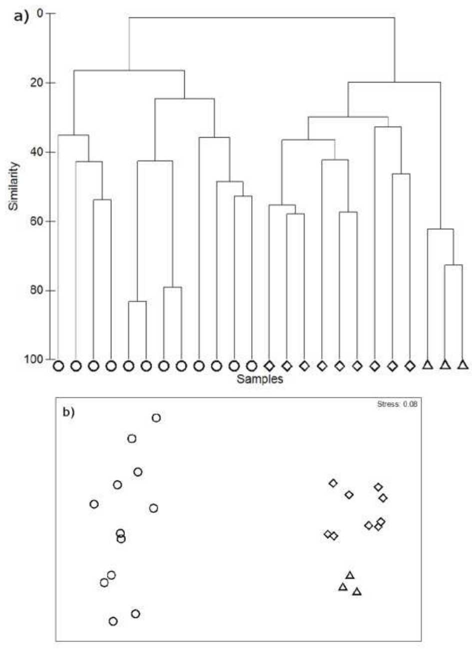

Fig. 6. Cluster (a) and multidimensional scaling (b) of transects carried out in the various habitats: ○ sand; ◊ natural reefs; Δ shipwreck.

Table 1. Cumulative list of the 10 most important *taxa* contributing to the differences found between pairs of habitats. The values refer to the contribution that each *taxon* makes to each habitat characterization: Contrib% refers to the contribution in percentage and Cum% refers to the cumulative sum of values of Contrib%.

Shipwreck vs. Natural reefs (average dissimilarity = 80.2)	Shipwreck	Nat. reefs	Contrib %	Cum %
Nemertesia antennina	31.6	2.9	8.4	8.4
Corynactis viridis	1.5	19.0	4.6	13.1
Eunicella verrucosa	14.4	5.5	3.4	16.5
Trisopterus luscus	11.4	0.6	3.2	19.6
Pomatoschistus cf. *quagga*	0.0	13.9	3.1	22.7
Anemonia sulcata	0.0	9.4	2.8	25.5
Pawsonia saxicola	10.9	1.9	2.7	28.2
Leucosolenia complicata	8.9	0.0	2.6	30.8
Schizobrachiella sanguinea	2.1	9.9	2.2	33.0
Phorbas fictitious	2.1	9.1	2.0	35.0
Sand vs. Shipwreck (average dissimilarity = 99.2)	Sand	Shipwreck	Contrib %	Cum %
Nemertesia antennina	0.1	31.6	15.6	15.6
Eunicella verrucosa	0.0	14.4	7.0	22.6
Trisopterus luscus	0.0	11.4	5.6	28.2
Pawsonia saxicola	0.0	10.9	5.6	33.8
Pentapora foliacea	0.0	10.4	5.1	38.9
Leucosolenia complicata	0.0	8.9	4.4	43.3
*Holothuria*cf. *forskali*	0.0	6.9	3.5	46.8
Ophiura albida	7.3	0.0	3.3	50.1
Hemimycale columella	0.0	6.3	3.2	53.3
Sabellidae n. id.	0.9	6.6	3.1	56.4
Sand vs. Natural Reefs (average dissimilarity = 98.9)	Sand	Nat. reefs	Contrib %	Cum %
Corynactis viridis	0.0	19.0	4.9	4.9
Schizobrachiella sanguinea	0.0	9.9	3.2	8.1
Anemonia sulcata	0.0	9.4	3.2	11.3
Pomatoschistus cf. *quagga*	0.0	13.9	3.1	14.4
Phorbas fictitious	0.0	9.1	2.9	17.3
Ophiura albida	7.3	0.0	2.3	19.6
Pentapora foliacea	0.0	7.2	2.2	21.7
Gobius xanthocephalus	0.0	5.0	1.8	23.5
Pomatoschistus spp.	4.8	2.1	1.7	25.2
Diplosoma spongiformis	0.0	4.4	1.7	27.0

DISCUSSION

In general, shipwreck sites such as that of the "*Faro A*" appear as high-resolution long-term markers of the marine biotope (BLOT, 1996) and which, as such, deserve systematic interdisciplinary approaches related to the biological and physical/chemical "memories" of the underwater historical site (RODGERS, 1989; FERRARI; ADAMS, 1990; OXLEY, 1990; GUNTHRIE et al., 1994; GREGORY, 1995; THOMSON, 1997; RANDELL, 1998). The potential information for both archaeologists and biologists which can be gathered by studying the thick layers of marine concretions covering shipwrecks would appear to be a rewarding challenge and a powerful drive to such interdisciplinary investigations on such sites.

In general, the southeastern Portuguese coast where this study was carried out is composed mainly of soft bottom habitats, with some scattered and isolated rocky reefs throughout the area (TEIXEIRA; PINTO, 2002; GONÇALVES et al., 2004). In the present study, the species count and biodiversity indexes of the shipwreck were generally lower than those found on nearby natural reefs, but higher than those on the surrounding sandy bottoms. Assuming that this particular shipwreck has had enough time to establish a long-term stable community, we can then hypothesize that the lower biodiversity, as compared to those of the natural reefs, may be a result of factors other than age. These findings may corroborate what was found by Perkol-Finkel et al. (2006) when they stated that structural features seem to play a more important role than age in the biological communities established on an artificial reef. Therefore, if that is the case, we may then assume that the natural reefs occurring in the Algarve region have more structural complexity than this vessel-reef, and are therefore able to accommodate a more complex and diverse community of organisms. This hypothesis seems to fit well into what is known about the region and has been observed on these sites: while the natural reefs are part of a linear structure that rises some 2 m above the surrounding sandy bottom and are entirely segmented by vertical cracks of some 2 to 5 m in width, providing structural complexity (TEIXEIRA; PINTO, 2002), the "*Faro A*" shipwreck is a much flatter and less complex structure, composed mainly of the remains of the cargo of iron bars and some iron artillery (BLOT et al., 2005). Another hypothesis that must be considered is that the lower biodiversity in the shipwreck may be the result of the smaller size of this structure as compared to that of the natural reefs. Again, this hypothesis fits in well with what has been observed and is known about those environments: while the natural reefs are part of a structure of some 2 Km in length, 50 to 100 m in width, and 2 m in height (TEIXEIRA; PINTO, 2002), the "*Faro A*" wreck site is much smaller - some 30 m long, 10 m wide and 1 m high. Finally, it needs to be said that some of our conclusions regarding these differences between the habitats should be regarded with caution, as some of the differences may result from the different sampling efforts made in each location. Even thought the analysis was performed in terms of species density, the total effort was not constant between locations, which may, in part, be biasing the results.

Analyzing the diversity indices in greater detail, this study showed that when the Margalef richness index is considered the shipwreck presents values lower than those of the natural reefs and more closely similar to those of the sandy bottoms. On the other hand, if we consider indices such as the Shannon-Wiener diversity that uses both richness and distribution of species within the community, or the Pielou evenness that accounts for the species distribution, then the shipwreck values were higher than those found for the sandy bottoms and only slightly lower than those for the natural reefs. Therefore, it seems that even though the shipwreck does not constitute a particularly rich environment in terms of numbers of *taxa*, those *taxa* that do occur are more equitably distributed and show no particular dominant species. These results are typical of well-established and fairly undisturbed reef environments, where no species is able to gain advantage and dominate the community (CLARKE; WARWICK, 2001). Likewise, when multivariate analysis was applied to these habitats, it was noteworthy that the natural reefs and the shipwreck were distinct though closely related, and much more closely similar to each other than to the adjacent sandy bottoms.

In terms of fish density in both reef type environments, it was noticeable that even though the natural reefs had a much higher density of fish than the shipwreck, much of this higher density was due to the presence of the gobid *Pomatoschistus* cf. *quagga* in high numbers. If we exclude this particular species from the analysis, the fish abundances on the natural reefs and the shipwreck become much more closely similar, with 2192 specimens / 1000 m^2 for the shipwreck and 2389 specimens / 1000 m^2 for the natural reefs. The *Pomatoschistus* cf. *quagga* is a species that schools and aggregates in very large numbers but with relatively low frequency of occurrence. Thus although it is only recorded on some of the transects, wherever it is found it occurs in very large numbers. Also in this case, the issue of a different sampling effort in each location may be playing an important role, as the greater effort that was expended on the natural reefs may have increased the odds of finding those species that tend to aggregate in schools, with a relatively low frequency of occurrence.

One important question that still remains unanswered is whether artificial reefs are indeed contributing to fishery enhancement (PICKERING; WHITMARSH, 1997) and it is, therefore, important to compare the densities of commercially important species between the artificial and natural reefs. It was interesting to note that the most abundant fish species in the shipwreck was the pouting, a species of some commercial importance for the region (DGPA, 2007). Other species of relatively high commercial importance that also occur in the shipwreck include the European conger *Conger conger*, the common two-banded seabream *Diplodus vulgaris*, and the common spider crab *Maja squinado*. Another important aspect to consider is the adequacy of these artificial structures for creating habitats for vulnerable and protected species, and one particularly vulnerable species that was found in the shipwreck in relatively high densities was the pink seafan *Eunicella verrucosa*, that is considered vulnerable under the IUCN Red List Criteria (WORLD CONSERVATION MONITORING CENTRE, 1996). This may be due either to the shipwreck's being a more suitable habitat, or to the fact that fishing activities are forbidden in the area and that vulnerable species, easily damaged by commercial fishing gear, find greater protection there. Still, we were not fully able to test these hypotheses in this study, and future studies should address those important issues.

During the present study we were able to ascertain that the biodiversity at "*Faro A*", a three century-old shipwreck site located off the southern coast of Portugal, is greater than that in the surrounding sandy bottom habitats. We found significant differences between the shipwreck and the natural reefs which also occur in the area, but hypothesized that the similarities between these two reef habitats (natural and artificial) are much greater than those with the surrounding sandy bottoms. We also hypothesized that the reduced dimensions and lower structural diversity found in this particular shipwreck might account for some of the differences from the larger and more complex natural reefs found in the area. The results, along with the presence of both commercially important and biologically vulnerable species in the shipwreck, bring out the importance of this habitat on the southern Portuguese coast.

ACKNOWLEDGMENTS

Part of this study was supported by the CCDR-Algarve (Comissão de Coordenação e Desenvolvimento Regional do Algarve) through funding of the research project "RENSUB I - Evaluation of the impact of dredging for beach nourishment on the marine communities off the Central Algarve". The authors would like to thank José Augusto Silva, co-discover of the wreck site, for providing the underwater photographs. Further acknowledgments are due to all the divers and researchers of the CCMAR/University of Algarve who helped with the diving operations and identification of specimens, particularly Luis Bentes, Carlos Afonso, Frederico Oliveira, Joaquim Ribeiro, Cheila Almeida, Pedro Veiga and Daniel Machado.

REFERENCES

ARENA, P. T.; JORDAN, L. K. B.; SPIELER, R. E. Fish assemblages on sunken vessels and natural reefs in southeast Florida, USA. **Hydrobiologia**, v. 580, p. 157-171, 2007.

ASELTINE-NEILSON, D. A.; BERNSTEIN, B. B.; PALMER-ZWAHLEN, M. L.; RIEGE, L. E.; SMITH, R. W. Comparisons of turf communities from Pendleton Artificial Reef, Torrey Pines Artificial Reef, and a natural reef using multivariate techniques. **Bull. Mar. Sci.**, v. 65, p. 37-57, 1999.

BADALAMENTI, F.; CHERMELLO, R.; D'ANNA, G.; RAMOS, P.H.; RIGGIO, S. Are artificial reefs comparable to neighbouring natural rocky areas? A mollusc case study in the Gulf of Castellammare (NW Sicily). **ICES J. Mar. Sci**., v. 59, p. 127-131, 2002.

BAINE, M. Artificial reefs: a review of their design, application, management and performance. **Ocean. Coast. Manag**., v. 44, p. 241-259, 2001.

BAINE, M.; SIDE, J. Habitat modification and manipulation as a management tool. **Rev. Fish Biol. Fish**., v. 13, p. 187-199, 2003.

BLOT, J-Y. **Underwater archaeology:** exploring the world beneath the sea. London: Thames and Hudson, 1996.

BLOT, J-Y. New courses in maritime archaeology in Portugal. In: RUPPE, C.; BARSTAD, J. (Ed.). **International handbook of underwater archaeology.** New York: Kluwer Academic/Plenum, 2002.

BLOT, J-Y.; FRAGA, T.; CALEJA, P.; BISPO, J.; SILVA, J.A.; GALVÃO, M.; WORTHINGTON, A.; MARTINS, R.; SASAKI, R.; GONÇALVES, J.; COELHO, R.; MONTEIRO, P.; GONÇALVES, P.; TISSOT, I.; TISSOT, M. Faro A, um sítio de naufrágio ao largo do Algarve. **XELB - Rev. Arqueol. Arte Etnol. Hist.,** v. 5, p. 283-302, 2005.

CLARK, S.; EDWARDS, A. J. An evaluation of artificial reef structures as tools for marine habitat rehabilitation in the Maldives. **Aquat. Conserv. Mar. Freshw. Ecosyst**., v. 9, p. 5-21, 1999.

CLARKE, K. R.; GORLEY, R. N. **PRIMER v6**: User manual/tutorial. Plymouth: PRIMER-E, 2006.

CLARKE, K. R.; WARKICK, R. M. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth: PRIMER-E, 2001

CUMMINGS, S. L. Colonization of a nearshore artificial reef at Boca Raton (Palm Beach County) Florida. **Bull. Mar. Sci**., v. 55, p. 1193-1215, 1994.

DGPA. **Recursos da Pesca** 2006. v. 20 A-B. Lisboa: DGPA, 2007.

FERRARI, B.; ADAMS, J. Biogenic modifications of marine sediments and their influence on archaeological material. **Int. J. Naut. Archaeol**., v. 19, p. 139-151, 1990.

GONÇALVES, J. M. S.; MONTEIRO, P.; COELHO, R.; AFONSO, C.; RIBEIRO, J.; ALMEIDA, C.; VEIGA., P.; MACHADO, D.; BERECIBAR, E.; OLIVEIRA, F.; BENTES, L. **Mapeamento das biocenoses marinhas da reserva ecológica nacional submarina entre Albufeira e Vale do Lobo.** Faro: Universidade do Algarve, 2004. (Final Project Report).

GREGORY, D. Experiments into the deterioration characteristics of materials on the Duart Point wreck site: an interim report. **Int. J. Naut. Archaeol.,** v. 24, p. 61-65, 1995.

GUNTHRIE, J.; BLACKALL, L.; MORIARTY, D.; GESNER, P. Wrecks and marine microbiology: a case study from the Pandora. **Bull. Aust. Inst. Mar. Archaeol.,** v. 18, p. 19-24, 1994.

MAGURRAN, A. E. **Ecological diversity and its measurement**. Princeton, NJ: Princeton Univ. Press, 1988.

OXLEY, I. Factors affecting the preservation of underwater archaeological sites. **Int. J. Naut. Archaeol.,** v. 19, p. 340-341, 1990.

PERKOL-FINKEL S.; BENAYAHU, Y. Community structure of stony and soft corals on vertical unplanned artificial reefs in Eilat (Red Sea): comparison to natural reefs. **Coral Reefs**, v. 23, p. 195-205, 2004.

PERKOL-FINKEL, S.; BENAYAHU, Y. Recruitment of benthic organisms onto a planned artificial reef: shifts in community structure one decade post-deployment. **Mar. Environ. Res**., v. 59, p. 79-99, 2005.

PERKOL-FINKEL, S.; BENAYAHU, Y. Differential recruitment of benthic communities on neighboring artificial and natural reefs. **J. Exp. Mar. Biol. Ecol**., v. 340, p. 25–39, 2007.

PERKOL-FINKEL, S.; SHASHAR, N.; BENAYAHU, Y. Can artificial reefs mimic natural reef communities? The roles of structural features and age. **Mar. Environ. Res**., v. 61, p. 121–135, 2006.

PICKERING, H.; WHITMARSH, D. Artificial reefs and fisheries exploitation: A review of the "attraction versus production" debate, the influence of design and its significance for policy. **Fish. Res**., v. 31, p. 39-59, 1997.

RANDELL, S. Marine growth on shipwrecks. **Bull. Aust. Inst. Mar. Archaeol**., v. 22, p. 107-108, 1998.

RODGERS, B. A. The case for biologically induced corrosion at the Yorktown shipwreck archaeological site. **Int. J. Naut. Archaeol**., v. 18, p. 335-340, 1989.

SANTOS, M. N.; MONETIRO, C. C. A fourteen-year overview of the fish assemblages and yield of the two oldest Algarve artificial reefs (southern Portugal). **Hydrobiologia**, v. 580, p. 225-231, 2007.

SVANE, I.; PETERSEN, J. K. On the problems of epibioses, fouling and artificial reefs, a review. **Mar**. **Ecol.,** v. 22, p. 169-188, 2001.

TEIXEIRA, S. B. Identificação e caracterização de arribas holocénicas submersas ao largo do litoral do Algarve (Portugal). **Comum. Inst. Geol. Min**., v. 84, p. C35-38, 1998.

TEIXEIRA, S. B.; PINTO, C. A. **Submarine evidences of Holocene shoreline migration on Quarteira coast** (**Southern Algarve-Portugal**). Littoral 2002: The Changing Coast. Porto: Eurocoast/EUCC, 2002.

THOMSON, L. The biodegradation of the wreck Day Dawn. **Bull. Aust. Inst. Mar. Archaeol**., v. 21, p. 119-124, 1997.

WORLD CONSERVATION MONITORING CENTRE *Eunicella verrucosa*. IUCN Red List of Threatened Species. 1996. <www.iucnredlist.org>. Accessed 17 Sep 2010.

ZINTZEN, V.; NORRO, A.; MASSIN, C.; MALLEFET, J. Spatial variability of epifaunal communities from artificial habitat: Shipwrecks in the Southern Bight of the North Sea. **Estuar. Coast. Shelf. Sci**., v. 76, p. 327-344, 2008.

(Manuscript received 28 September 2011; revised 02 December 2012; accepted 03 December 2012)

Supplementary Data: Table with the taxa observed in the three different habitats. Density refers to n / 100m2 and FO% is the frequency of occurrence as a percentage. The taxa are organized alphabetically by phylum and class.

Taxa	Sand		Shipwreck		Natural reef	
	Density	FO%	Density	FO%	Density	FO%
Annelida						
Polychaeta						
Annelida n. id.	23.3 (71.9)	16.7				
Epitonium clathrus					66.7 (100.0)	33.3
Eupolymnia sp.					22.2 (66.7)	11.1
Eurythoe sp.					22.2 (66.7)	11.1
Filograna sp.			66.7 (115.5)	33.3	44.4 (88.2)	22.2
Lanice conchilega	1.3 (3.1)	16.7			22.2 (66.7)	11.1
Myxicola sp.					155.6 (278.9)	33.3
Nereis sp.	1.3 (3.1)	16.7				
Polycirrus sp.					266.7 (264.6)	66.7
Protula sp.					66.7 (141.4)	22.2
Sabella pavonina					88.9 (202.8)	22.2
Sabella spallanzani	0.4 (1.4)	8.3			44.4 (133.3)	11.1
Sabellidae n. id.	27.9 (72.9)	41.7	733.3 (945.2)	66.7	88.9 (266.7)	11.1
Serpula vermicularis					577.8 (659.1)	55.6
Serpulidae n. id.	106.7 (196.9)	50.0				
Spirorbidae n. id.	83.3 (162.8)	25.0				
Arthropoda						
Malacostraca						
Anapagurus laevis	3.3 (10.1)	16.7				
Crangon crangon	1.7 (4.4)	16.7				
Galathea intermedia	25.4 (71.3)	33.3				
Inachus dorsettensis					22.2 (66.7)	11.1
Macropodia rostrata	2.1 (3.3)	33.3				
Maja squinado			133.3 (115.5)	66.7	22.2 (66.7)	11.1
Paguristes eremita	0.8 (2.9)	8.3				
Pagurus cuanensis	1.7 (5.8)	8.3				
Pagurus prideaux	6.7 (21.6)	16.7				
Parthenope angulifrons	4.6 (14.4)	16.7				
Pilumnus hirtellus					22.2 (66.7)	11.1
Pisidia longicornis	18.8 (35.0)	33.3				
Polybius puber			66.7 (115.5)	33.3		
Polybius pusillus	0.4 (1.4)	8.3				
Xantho pilipes	0.4 (1.4)	8.3				
Maxillopoda						
Cirripedia n. id.	41.7 (97.3)	16.7				
Megabalanus sp.					155.6 (466.7)	11.1
Bryozoa						
Gymnolaemata						

Taxa	Sand		Shipwreck		Natural reef	
	Density	FO%	Density	FO%	Density	FO%
Adeonella calveti					22.2 (66.7)	11.1
Bugula cf. *turbinata*			133.3 (115.5)	66.7		
Bugula fulva					22.2 (66.7)	11.1
Chartella papyracea					22.2 (66.7)	11.1
Frondipora verrucosa					22.2 (66.7)	11.1
Pentapora foliacea			1,133.3 (577.4)	100.0	622.2 (405.5)	88.9
Schizobrachiella sanguinea			133.3 (230.9)	33.3	1,022.2 (380.1)	100.0
Schizobrachiella sp.					22.2 (66.7)	11.1
Schizomavella cf. *linearis*	69.6 (173.1)	25.0				
Schizomavella sp.					22.2 (66.7)	11.1
Turbicellepora cf. *magnicostata*					222.2 (352.8)	33.3
Turbicellepora spp.					377.8 (717.2)	44.4
Watersipora subovoidea	3.3 (11.5)	8.3				
Chordata						
Chondrichthyes						
Torpedo torpedo	0.4 (1.4)	8.3				
Osteichthyes						
Arnoglossus sp.	3.3 (11.5)	8.3				
Boops boops					69.4 (141.3)	22.2
Bothus podas			33.3 (57.7)	33.3		
Callionymus spp.	13.3 (46.2)	8.3				
Centrolabrus exoletus					47.2 (85.0)	44.4
Chelidonichthys obscurus	4.2 (11.4)	25.0				
Chromis chromis					1.4 (4.2)	11.1
Conger conger	3.3 (11.5)	8.3	100.0 (100.0)	66.7		
Coris julis			208.3 (170.2)	100.0	298.6 (301.8)	100.0
Ctenolabrus rupestris			133.3 (152.8)	66.7	127.8 (98.8)	88.9
Diplodus annularis					11.1 (11.6)	66.7
Diplodus bellottii			33.3 (31.5)	66.7	23.6 (49.4)	22.2
Diplodus cervinus					2.8 (5.5)	22.2
Diplodus sargus					47.2 (60.8)	55.6
Diplodus vulgaris			25.0 (12.5)	100.0	256.9 (196.5)	100.0
Gobiesocidae n. id.	6.7 (15.6)	16.7				
Gobius cobitis					11.1 (33.3)	11.1
Gobius cruentatus			33.3 (57.7)	33.3	100.0 (132.3)	44.4
Gobius gasteveni					222.2 (263.5)	66.7
Gobius paganellus			33.3 (57.7)	33.3		
Gobius spp.	16.7 (46.6)	16.7				
Gobius xanthocephalus					311.1 (261.9)	88.9

Taxa	Sand		Shipwreck		Natural reef	
	Density	**FO%**	**Density**	**FO%**	**Density**	**FO%**
Gobiusculus flavescens					44.4 (133.3)	11.1
Labrus bergylta					5.6 (11.0)	22.2
Parablennius gattorugine					22.2 (44.1)	22.2
Parablennius pilicornis					277.8 (396.2)	66.7
Pomatoschistus cf. quagga					7,222.2 (16,414.8)	33.3
Pomatoschistus spp.	433.3 (637.5)	75.0			244.4 (661.6)	22.2
Scorpaena notata			200.0 (100.0)	100.0	116.7 (89.0)	88.9
Serranus cabrilla	0.8 (2.9)	8.3	25.0 (12.5)	100.0	48.6 (36.7)	88.9
Serranus hepatus	42.1 (125.9)	33.3				
Solea sp.	3.3 (11.5)	8.3				
Spondyliosoma cantharus					41.7 (71.5)	66.7
Symphodus bailloni					20.8 (23.4)	77.8
Symphodus cinereus					2.8 (5.5)	22.2
symphodus mediterraneus					2.8 (5.5)	22.2
Symphodus roissali			12.5 (12.5)	66.7	5.6 (9.1)	33.3
Symphodus rostratus					5.6 (12.7)	22.2
Syngnathus acus	3.3 (11.5)	8.3				
Trachinus draco	7.9 (15.1)	41.7				
Trisopterus luscus			1,354.2 (607.0)	100.0	19.4 (53.8)	22.2
Cnidaria						
Anthozoa						
Actinothoe sphyrodeta					22.2 (66.7)	11.1
Aiptasia diaphana			200.0 (200.0)	66.7	66.7 (141.4)	22.2
Aiptasia mutabilis					133.3 (282.8)	22.2
Aiptasia spp.					422.2 (703.2)	55.6
Alicia mirabilis	0.8 (1.9)	16.7			88.9 (145.3)	33.3
Anemonia sulcata					1,222.2 (1,387.2)	88.9
Calliactis parasitica	7.9 (22.8)	33.3			22.2 (66.7)	11.1
Caryophyllia spp.					177.8 (338.3)	33.3
Cerianthus membranacea	0.4 (1.4)	8.3	266.7 (305.5)	66.7	155.6 (218.6)	44.4
Corynactis viridis			66.7 (115.5)	33.3	5,555.6 (4,639.8)	66.7
Eunicella verrucosa			2,266.7 (1,616.6)	100.0	911.1 (1,396.8)	33.3
Leptogorgia sarmentosa					666.7 (692.8)	66.7
Veretillum cynomorium	2.5 (5.8)	25.0				
Hydrozoa						
Aglaophenia cf. *pluma*					600.0 (1,655.3)	22.2
Aglaophenia sp.					22.2 (66.7)	11.1
Gymnangium montagui					311.1 (375.6)	44.4
Nemertesia antennina	1.7 (5.8)	8.3	10000.0	100.0	155.6 (166.7)	55.6
Synthecium evansii					355.6 (545.7)	33.3

Taxa	Sand		Shipwreck		Natural reef	
	Density	**FO%**	**Density**	**FO%**	**Density**	**FO%**
Echinodermata						
Crinoidea						
Antedon cf. *bifida*					111.1 (266.7)	22.2
Echinoidea						
Echinocardium cordatum	3.3 (6.5)	25.0				
Paracentrotus lividus					133.3 (223.6)	33.3
Psammechinus miliaris	428.3 (725.4)	58.3				
Spatangus purpureus	3.3 (8.9)	16.7				
Sphaerechinus granularis	25.0 (27.1)	100.0			66.7 (141.4)	22.2
Holothuroidea						
Cucumaria spp.					22.2 (66.7)	11.1
Holothuria cf. *forskali*			533.3 (416.3)	100.0	155.6 (166.7)	55.6
Holothuria cf. *tubulosa*	0.8 (1.9)	16.7			44.4 (88.2)	22.2
Pawsonia saxicola			1,333.3 (1,101.5)	100.0	155.6 (312.7)	22.2
Ophiuroidea						
Ophioderma longicauda			133.3 (230.9)	33.3	88.9 (202.8)	22.2
Ophiothrix fragilis	0.8 (2.9)	8.3			66.7 (100.0)	33.3
Ophiura albida	948.8 (1,159.0)	83.3				
Stelleroidea						
Astropecten aranciacus	22.5 (32.1)	58.3				
Echinaster sepositus					44.4 (88.2)	22.2
Echiura						
Echiuroidea						
Bonellia viridis			66.7 (115.5)	33.3	66.7 (100.0)	33.3
Mollusca						
Bivalvia						
Acanthocardia spinosa	1.3 (3.1)	16.7				
Aequipecten commutatus	1.7 (4.4)	16.7				
Aequipecten opercularis	2.9 (7.5)	16.7				
Anomia ephippium	751.3 (1,569.7)	50.0			22.2 (66.7)	11.1
Atrina pectinata	0.8 (2.9)	8.3			22.2 (66.7)	11.1
Capsella variegata	0.8 (2.9)	8.3				
Chamelea gallina	1.7 (3.9)	16.7				
Chlamys flexuosa	150.0 (432.1)	41.7				
Chlamys varia	0.4 (1.4)	8.3				
Clausinella fasciata	7.1 (11.4)	33.3				
Clavagella melitensis					488.9 (707.9)	44.4
Corbula gibba	21.7 (72.0)	16.7				
Gari fervensis	0.4 (1.4)	8.3				
Gastrochaena dubia					44.4 (88.2)	22.2

Taxa	Sand		Shipwreck		Natural reef	
	Density	FO%	Density	FO%	Density	FO%
Gouldia minima					44.4 (88.2)	22.2
Hiatella arctica	1.3 (4.3)	8.3				
Laevicardium crassum	0.8 (2.9)	8.3				
Lima exilis					22.2 (66.7)	11.1
Mactra glauca	0.4 (1.4)	8.3				
Modiolus adriaticus	1.3 (4.3)	8.3				
Modiolus barbatus					133.3 (173.2)	44.4
Papillicardium papillosum					66.7 (100.0)	33.3
Pecten maximus	30.0 (72.0)	41.7				
Pteria hirundo					22.2 (66.7)	11.1
Tellina incarnata	0.4 (1.4)	8.3				
Tellina nitida	0.4 (1.4)	8.3				
Cephalopoda						
Octopus vulgaris	0.4 (1.4)	8.3			44.4 (88.2)	22.2
Sepia officinalis	2.1 (4.0)	25.0				
Gastropoda						
Acteon tornatilis	0.4 (1.4)	8.3				
Aglaja tricolorata					22.2 (66.7)	11.1
Aporrhais pespelecani	47.9 (143.6)	33.3				
Bittium cf. *jadertinum*					22.2 (66.7)	11.1
Bolma rugosa					422.2 (307.3)	77.8
Calliostoma zizyphinum					22.2 (66.7)	11.1
Calyptraea chinensis	56.7 (97.0)	33.3				
Cerithium vulgatum					177.8 (307.3)	33.3
Chauvetia brunnea					22.2 (66.7)	11.1
Chauvetia retifera					22.2 (66.7)	11.1
Chromodoris krohni					44.4 (88.2)	22.2
Clanculus cruciatus					22.2 (66.7)	11.1
Clanculus jussieui					22.2 (66.7)	11.1
Crimora papillata					22.2 (66.7)	11.1
Dondice banyulensis	0.8 (2.9)	8.3				
Doriopsilla areolata	0.4 (1.4)	8.3			111.1 (333.3)	11.1
Doris verrucosa					22.2 (66.7)	11.1
Euspira pulchella	1.3 (4.3)	8.3				
Flabellina affinis	0.8 (2.9)	8.3				
Flabellina babai					22.2 (66.7)	11.1
Gibbula magus	60.0 (111.4)	41.7				
Hexaplex trunculus					88.9 (145.3)	33.3
Hypselodoris bilineata					22.2 (66.7)	11.1
Hypselodoris cf. cantabrica					133.3 (173.2)	44.4
Hypselodoris fontandraui					22.2 (66.7)	11.1

Taxa	**Sand**		**Shipwreck**		**Natural reef**	
	Density	**FO%**	**Density**	**FO%**	**Density**	**FO%**
Hypselodoris picta					155.6 (397.2)	22.2
Hypselodoris villafranca					88.9 (202.8)	22.2
Melanella cf. *polita*					22.2 (66.7)	11.1
*Melanella*spp.					22.2 (66.7)	11.1
Mitra zonata					44.4 (133.3)	11.1
Nassarius incrassatus	5.8 (17.3)	16.7			844.4 (1,745.8)	33.3
Nassarius pygmaeus	91.7 (191.7)	33.3				
Neosimnia spelta					111.1 (226.1)	22.2
Ocenebra erinaceus	2.1 (5.0)	16.7			133.3 (223.6)	33.3
Ocinebrina aciculata	64.2 (216.1)	16.7			22.2 (66.7)	11.1
Philine aperta	0.4 (1.4)	8.3				
Roboastra europaea					111.1 (145.3)	44.4
Phoronida						
Phoronopsis cf. *californica*					200.0 (424.3)	22.2
Plathelminthes						
Turbellaria						
Planoceros sp.	2.1 (7.2)	8.3				
Prostheceraeus giesbrechtii					66.7 (141.4)	22.2
Porifera						
Calcarea						
Clathrina clathrus					88.9 (145.3)	33.3
Clathrina coriacea					44.4 (133.3)	11.1
Leuconia sp.	0.4 (1.4)	8.3				
Leucosolenia complicata			800.0 (200.0)	100.0		
Desmospongiae						
Axinella damicornis					22.2 (66.7)	11.1
Chondrosia reniformis					66.7 (141.4)	22.2
Ciocalypta penicillus					66.7 (100.0)	33.3
Cliona celata	7.9 (18.8)	16.7				
Cliona viridis					44.4 (133.3)	11.1
Dysidea avara					22.2 (66.7)	11.1
Hemimycale columella			600.0 (529.2)	66.7	511.1 (539.5)	77.8
Hymeniacidon sanguinea			66.7 (115.5)	33.3		
Ircinia cf. *fasciculata*					66.7 (141.4)	22.2
Ircinia cf. *oros*					111.1 (202.8)	33.3
Ircinia spp.					44.4 (88.2)	22.2
Phorbas fictitius			133.3 (230.9)	33.3	888.9 (448.5)	100.0
Porifera n. id.					66.7 (200.0)	11.1
Spirastrella sp.					244.4 (466.7)	33.3
Tethya aurantium					22.2 (66.7)	11.1

Taxa		Sand		Shipwreck		Natural reef	
		Density	FO%	Density	FO%	Density	FO%
Urochordata							
Ascidiacea							
	Aplidium proliferum					22.2 (66.7)	11.1
	Aplidium punctum					244.4 (444.7)	33.3
	Aplidium sp.					22.2 (66.7)	11.1
	Botryllus schlosseri					22.2 (66.7)	11.1
	Ciona intestinalis					22.2 (66.7)	11.1
	Clavelina sp.					22.2 (66.7)	11.1
	Dendrodoa grossularia					22.2 (66.7)	11.1
	Didemnum cf. *lahillei*	16.7 (30.6)	33.3				
	Diplosoma spongiformis					333.3 (412.3)	66.7
	Lissoclinum perforatum					266.7 (300.0)	55.6
	Phallusia fumigata			333.3 (577.4)	33.3	177.8 (233.3)	44.4
	Phallusia mammillata	9.6 (8.6)	66.7				
	Pyura microcosmus	9.2 (18.8)	25.0				
	Pyura sp.					177.8 (233.3)	44.4