# Preliminary results from the establishment of experimental artificial reefs in the N. Aegean Sea (Chalkidiki, Greece)

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ABSTRACT. Twenty-four artificial reef units were designed and set in the coastal waters off Neos Marmaras (Chalkidiki, North Aegean Sea, Greece) in July 1998, at depths ranging between 7 and 22 m. The volume of each unit was between 0.8 and 2.25 $m^3$ and the maximum weight was up to one t. Three different types of material were used for the construction of the units, namely cement, ceramic and car tyres. The units were set along a main axis and along secondary axes that were perpendicular to the main one. The artificial reef units were monitored both directly, by diving, as well as through underwater photos and experimental sampling. Our results indicated that there was a tendency: (a) of sessile organisms to inhabit the reef units and (b) for fish to find refuge in the reef units with higher number of species generally recorded after the deployment of the reef units.

KEY WORDS: Artificial reefs, fish communities, N. Aegean Sea, Mediterranean.

## INTRODUCTION

The establishment of artificial reefs ranks among the most important measures for the enhancement and protection and management of fisheries resources, especially so for the highly oligotrophic environment of the SE Mediterranean Sea (e.g. SPANIER et al., 1990; BOMBACE et al., 1993). Most of the available information on artificial reefs has been published during the last ten years (e.g. BAYNES & SZMANT, 1989; BEETS 1989; POLOVINA, 1989, 1991; POLOVINA & SAKAI, 1989; ODY & HARMELIN, 1994). Recent examples of artificial reef establishment (e.g. RELINI et al. 1995; SANTOS et al. 1996) clearly indicate that fish abundance and diversity both increase considerably after the deployment. The present study is the first attempt to evaluate the effect of the deployment of artificial reefs on the local fish communities in Greek waters (i.e. North Aegean Sea, Chalkidiki).

## MATERIAL AND METHODS

### The artificial reefs

Artificial reef units were designed using different shapes, sizes and types of materials. The shapes of the units were selected in terms of time required to inhabit the reef units and the ultimate protection of the fisheries resources that will eventually find refuge there. The settlement area was selected after scuba-diving observations undertaken in the wider study area. Artificial units were set in *Posidonia* beds because their dense rhizomes could withstand the weight of the units and their leaves could reduce the overall sedimentation rate.

Overall, 24 artificial reef units were deployed in the coastal waters off Neos Marmaras (North Aegean Sea, Greece), at depths ranging between 7 and 22 m, on 19th July 1998. Three different types of material were used for the construction of the units, namely cement, ceramic and car tyres, and the reef units belonged to eight different types:

1. Three units each measuring 1x1x1.2 m, made of cement.
2. Three units each measuring 0.9x0.9x1 m, made of cemented square grids.
3. Three units each measuring 1.2x1.2x1.2 m, made of cemented plates.
4. Three units each measuring 1.5x1.05x1.05 m, made of ceramic bricks.
5. Three units each measuring 1x1x1 m, made of cemented tubes with a diameter of 20cm.

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6. Three units each measuring 1.5x1.5x1 m, made of cemented pipes with a diameter of 50cm.
7. Three cemented pipes 1 m long and with a diameter of 80 cm each.
8. Three units each measuring 1.2x0.9x0.9 m, made of car tyres.

The volume of each unit was, depending on the type used, between 0.8 and 2.25 $m^3$ and the maximum weight was up to one t. The units were set along a main axis and along secondary axes that were perpendicular to the main one (Fig. 1).

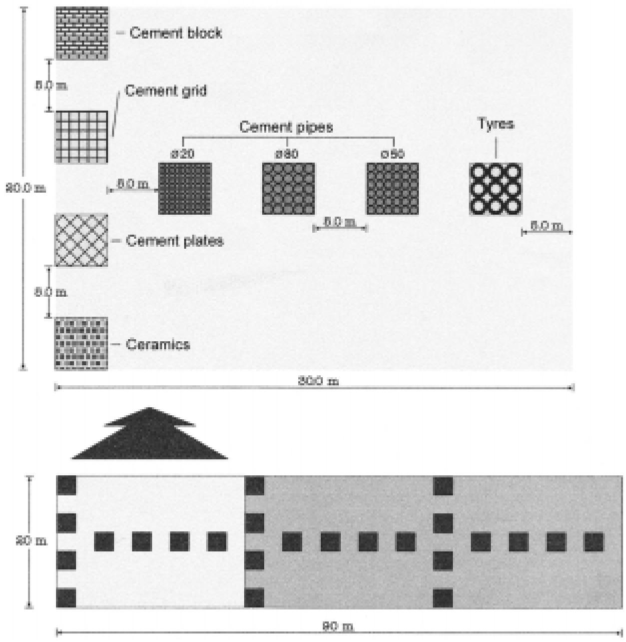



Fig. 1. – Spatial arrangement of artificial reefs.

### Data collection

The abundance of benthic organisms and fisheries resources was monitored both before (in November 1996, and January, April and July 1997) and after the deployment of the reefs (August and November 1998). Biological monitoring was conducted: (a) by scuba diving; (b) through underwater photos; (c) by taking parts of the reef units to the laboratory for further analysis; and (d) by experimental fishing using gill nets of different mesh sizes (18, 22 and 28 mm bar length, each net having a length of 219 m and a height of 1, 5.5 and 3.7 m respectively) in order to sample efficiently the local fisheries communities. After the gill nets were hauled, total catch was removed and separated into species**.**

### Data analysis

For the analysis of the fish catches per mesh size and sampling period, a matrix comprising the numbers of each species from each mesh size and each season was constructed. Numbers were expressed per 250 m of gill nets. From this matrix, a triangular matrix of similarities between all pairs of gear was computed using the Bray-Curtis coefficient (BRAY & CURTIS, 1957). Prior to this computation, data were transformed using the double square root transformation in order to reduce the weighting of abundant species (FIELD et al., 1982). Subsequently, the similarity matrices were subjected to both clustering (employing group-average linking) and ordination (employing non-metric multidimensional scaling, MDS) analysis techniques. The adequacy of the representation in two, rather than more dimensions is expressed by a "stress coefficient" (FIELD et al., 1982). In general, stress values <0.1 imply good representation, and discontinuities between mesh/season combinations may be accepted as real when the results of the two methods agree (FIELD et al., 1982; CLARKE & GREEN, 1988).

## RESULTS AND DISCUSSION

The analysis of the benthic samples collected from the study area revealed two different communities, one dominated by organisms abundant in *Posidonia oceanica* beds, and another one, which included organisms that are typical of the semi-dark grottoes and open-sea rocks. These two communities have been previously described by PERES & PICKARD (1964) and PERES (1967). The typical species included *Petrosia dura* (Nardo, 1833), *Agelas oroides* (Schmidt, 1864), *Axinella cannabina* (Esper,1794), *Axinella verrucosa* (Esper, 1794), *Caryophyllia smithii* Stokes & Broderip, 1828, *Parazoanthus axinellae* (Schmidt, 1862), *Cladocora caespitosa* (Linnaeus, 1767*), Echinus melo* Lamarck, 1816*, Echinaste sepositus* (Retzius, 1783), and *Halocynthia papillosa* (Linnaeus, 1767), all of which were found in the study area in relatively high abundance.

Visual censuses and the comparison of photos taken before and after the set of the units revealed a continuous increase in the settlement rate of various benthic organisms as well as in the presence of various fish species. Overall, 38 taxa were caught with experimental fishing before the deployment of the units (Table 1). The comparison of the results of experimental fishing four months after the deployment of the reefs with those for the corresponding month before the deployment revealed eight new species (19 and 11 species respectively). When comparisons were pooled across all months of experimental fishing the number of new species fell to six (*Dentex dentex, Labrus merula, Pagrus pagrus, Sphyraena sphyraena, Spondyliosoma cantharus, Umbrina cirrosa*), the majority of which were of high commercial value.

Catch species composition changed greatly with sampling period (Fig. 2). Thus, *Mullus surmuletus* and *Scorpaena scrofa* dominated the catches in November 1996 whereas *Spicara maena* and *Boops boops* dominated the catches during the same month after the deployment of the units (Fig. 2). Overall, *Sardinella aurita* dominated the catch of all mesh sizes combined in terms of both number and weight (Fig. 3), a fact attributed to its occasional high abundance in April 1997 (Fig. 2).

TABLE 1

Species caught with experimental fishing in the study area, all seasons and mesh sizes combined. * denotes species that were only caught after the deployment of the artificial reefs.

| | |
|---|---|
| *Apogon imberbis* (Linnaeus, 1758) | *Sardinella aurita* Valenciennes, 1847 |
| *Boops boops* (Linnaeus, 1758) | *Scorpaena notata* Rafinesque, 1810 |
| *Chromis chromis* (Linnaeus, 1758) | *Scorpaena porcus* Linnaeus, 1758 |
| *Coris julis* (Linnaeus, 1758) | *Scorpaena scrofa* Linnaeus, 1758 |
| *Dentex dentex** (Linnaeus, 1758) | *Sepia officinalis* Linnaeus, 1758 |
| *Dicentrarchus labrax* (Linnaeus, 1758) | *Serranus cabrilla* (Linnaeus, 1758) |
| *Diplodus annularis* (Linnaeus, 1758) | *Serranus scriba* (Linnaeus, 1758) |
| *Diplodus vulgaris* (Geoffroy St. Hilaire, 1817) | *Spicara maena* (Linnaeus, 1758) |
| *Epinephelus alexandrinus* (Valenciennes, 1828) | *Spicara smaris* (Linnaeus, 1758) |
| *Gobius niger jozo* Linnaeus, 1758 | *Sphyraena sphyraena** (Linnaeus, 1758) |
| *Labrus bimaculatus* Linnaeus, 1758 | *Spondyliosoma cantharus** (Linnaeus, 1758) |
| *Labrus merula** Linnaeus, 1758 | *Symphodus melanocercus* (Risso, 1810) |
| *Mullus surmuletus* Linnaeus, 1758 | *Symphodus melops* (Linnaeus, 1758) |
| *Oblada melanura* Linnaeus, 1758 | *Symphodus rostratus* (Bloch, 1791) |
| *Octopus vulgaris* Cuvier, | *Symphodus tinca* (Linnaeus, 1758) |
| *Pagellus bogaraveo* Brönnich, 1768 | *Trachurus mediterraneus* (Steindachner, 1868) |
| *Pagellus erythrinus* (Linnaeus, 1758) | *Trachurus picturatus* (Bowdich, 1825) |
| *Pagrus pagrus** (Linnaeus, 1758) | *Trachurus trachurus* (Linnaeus, 1758) |
| *Palinurus elephas* (Fabricius, 1787) | *Trisopterus minututs capelanus* (Linnaeus, 1758) |
| *Phycis phycis* (Linnaeus, 1766) | *Trigloporus lastoviza* (Bonnaterre, 1788) |
| *Raja radula* Delaroche, 1809 | *Umbrina cirrosa** (Linnaeus, 1758) |
| | *Uranoscopus scaber* Linnaeus, 1758 |
| | *Zeus faber* Linnaeus, 1758 |

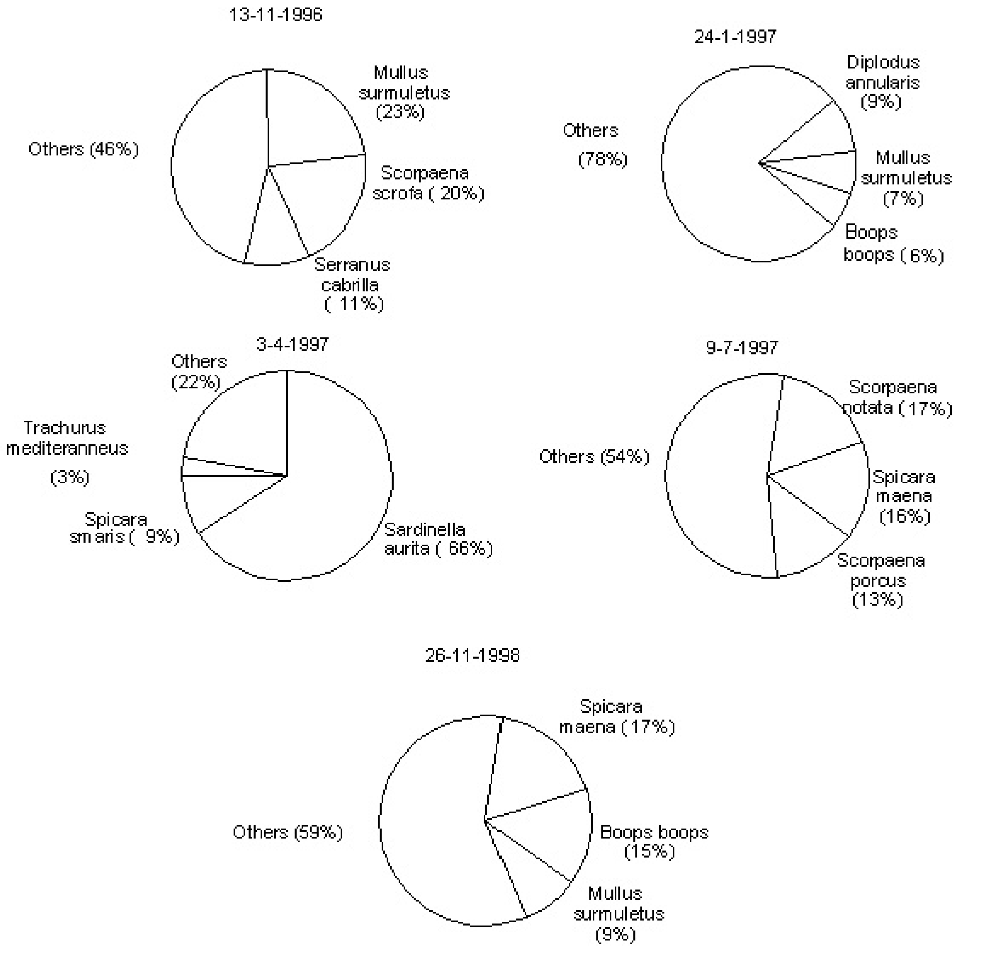



Fig. 2. – Seasonal species composition by weight of the total catch, all mesh sizes combined.

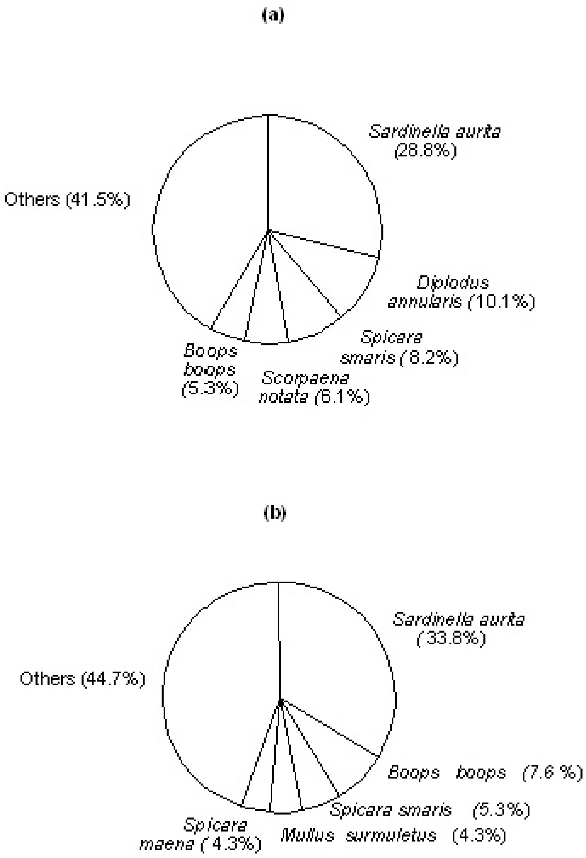
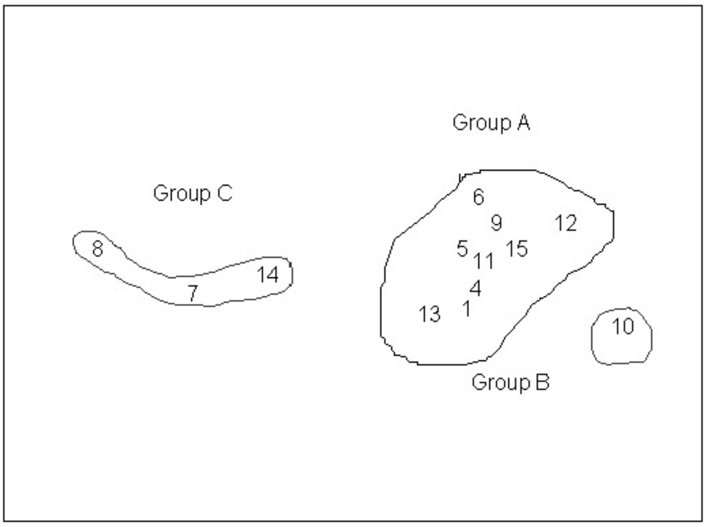



Fig. 3. – Species composition of the total catch by (a) number and (b) weight, mesh sizes and seasons combined.




| | Mesh size (mm, bar length) | | |
|---|---|---|---|
| Date | 18 | 22 | 28 |
| 13/11/1996 | 1 | 2 | 3 |
| 24/1/1997 | 4 | 5 | 6 |
| 3/4/1997 | 7 | 8 | 9 |
| 8/7/1997 | 10 | 11 | 12 |
| 26/11/1998 | 13 | 14 | 15 |

Fig. 4. – Results of multidimensional scaling analysis applied to the similarity matrix between numbers of individuals per species/mesh-size/season combinations. The combinations 1 to 15 are shown in the legend.

The results of multidimensional scaling (Fig. 4) agreed with those of cluster analysis (not shown here) and revealed three main groups of gear/season combinations: (a) Group A, including various gear/season combinations, (b) Group B, including the sample taken with the 18 mm gill net in July 1997 and (c) Group C, which included the samples collected with the 22 mm mesh in April 1997 and November 1998 and that caught with the 18 mm mesh in April 1997. It must be pointed out that the samples taken with the three different mesh sizes after the deployment of the units (Fig. 4: combinations 13, 14 and 15) did not form a distinct group by themselves. Yet, two out of three (i.e. combinations 13 and 15) were separated from the remaining combinations of the subgroups in which they belong (Fig. 4).

To sum up, our results indicated that there is a tendency: (a) of sessile organisms to inhabit the reef units and (b) for fish to find refuge in the reef units with higher number of species generally recorded after the deployment of the reef units. It must be stressed, however, that it takes many years for the results of the establishment of artificial reefs to become apparent (Bombace et al., 1993). In addition, we also believe that the results would have been rather different if commercial fishing was prohibited in the wider area of reef deployment, a fact that was not true in the study area. Seasonal monitoring of the artificial reef units is also in progress for 2000.

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