ICES Journal of Marine Science, 59: S127–S131. 2002
doi:10.1006/jmsc.2002.1265, available online at http://www.idealibrary.com on IDEAL®

Are artificial reefs comparable to neighbouring natural rocky areas? A mollusc case study in the Gulf of Castellammare (NW Sicily)

F. Badalamenti, R. Chemello, G. D'Anna,
P. Henriquez Ramos, and S. Riggio

Badalamenti, F., Chemello, R., D'Anna, G., Henriquez Ramos, P., and Riggio, S. 2002. Are artificial reefs comparable to neighbouring natural rocky areas? A mollusc case study in the Gulf of Castellammare (NW Sicily). – ICES Journal of Marine Science, 59: S127–S131.

Mollusc assemblages of three concrete artificial reefs (ARs) in the Gulf of Castellammare were compared with those of two nearby natural reefs (NRs). The reefs were located in areas characterized by different degrees of water transparency, with average annual Secchi disk visibility ranging from clear (>20 m) to turbid waters (<6 m). In spring 1995, 28 samples of 400 cm^2 were scraped off the reefs at depths of 16–22 m (20 from ARs; 8 from NRs), which yielded a total of 116 species and 1084 specimens of molluscs. The assemblage derived from a NR in clear water showed the highest diversity, species richness, and evenness, while the highest number of specimens and dominance values were observed at an AR in turbid water. The lowest values of diversity and species richness were found at ARs in turbid water and the lowest number of specimens at a NR in turbid water. Comparison of the five reefs showed significant differences in average number of species and in diversity values, while differences in the number of specimens were not significant. Factorial correspondence analysis showed a pattern that was strongly polarized along the first axis by the NR in clear water and by the AR in turbid water. The most distinctive feature was the dominance of *Bittium latreillii* at AR sites. Three years after deployment, mollusc assemblages of ARs in the Gulf remain entities that are distinct from those of nearby natural reefs. However, the potential of the assemblages in terms of density of individuals is comparable to that of natural reefs.

Keywords: artificial reefs, molluscs, natural rocky areas, NW Sicily.

Accepted 16 November 2001.

F. Badalamenti, G. D'Anna, and P. Henriquez: Laboratorio di Biologia I.R.M.A. – CNR, Via G. da Verrazzano, 17–91014 Castellammare del Golfo, Italy; e-mail: danna@tin.it. R. Chemello and S. Riggio: Dipartimento di Biologia Animale, Via Archirafi 18, Palermo, Italy.

Introduction

The success of fish resource enhancement initiatives employing artificial reefs (ARs) is related to the environmental factors characterizing deployment sites and the distance from natural reefs (NRs; Chang, 1985; Ardizzone *et al.*, 1989). One way of evaluating AR efficacy is by comparing fish assemblages of natural and artificial environments (Ambrose and Swarbrick, 1989; D'Anna *et al.*, 1995). In contrast, few papers have addressed comparisons of benthic invertebrates (Ardizzone *et al.*, 1997), even though several benthic taxa, such as molluscs, are considered excellent descriptors of benthic communities (Gambi *et al.*, 1982) and thus might be used for this purpose.

In the Gulf of Castellammare, four ARs have been deployed on sandy bottom areas characterized by different environmental features and at different distances from natural reefs (NRs) (Badalamenti *et al.*, 2000). The heterogeneous hydrological conditions in the Gulf, especially with reference to water transparency, affect the success of settlement and development of benthic communities on both ARs and NRs (D'Anna *et al.*, 2000). We compare mollusc assemblages of three ARs

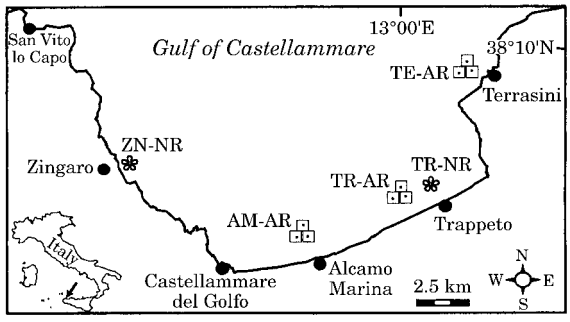


Figure 1. Location of study sites (ZN=Zingaro; AM=Alcamo Marina; TR=Trappeto; TE=Terrasini; NR/stars=natural reef; AR/blocks=artificial reef).

and two NRs, varying in water clarity and with varying in-between distances, with the aim of unravelling underlying patterns.

Materials and methods

Study area and sampling

The Gulf of Castellammare is located in the southern Tyrrhenian Sea (38°03′N 12°54′E). The eastern and western coasts of the Gulf are characterized by steep dolomitic cliffs, while the central part is composed of sandy seabed with coastal calcareous rocky outcrops. Several rivers flow into the central part, where the water is generally richer in particulate and organic suspended matter and more turbid than in the eastern and western-most parts (Riggio *et al.*, 1992). About 13 000 m^3 of cubic concrete boulders (2 × 2 × 2 m), mostly assembled to form pyramids of 14 elements, have been deployed on the coastal sandy seabed (Badalamenti *et al.*, 2000). We selected three ARs for our study (Figure 1). Alcamo Marina (AM-AR) is located at about 4.5 km distance from the nearest NR area, Trappeto (TR-AR) and Terrasini (TE-AR) at about 500 m distance. In addition, two NRs were selected: Zingaro (ZN-NR) and Trappeto (TR-NR).

Secchi disk visibility (SDV) has been commonly used as a simple and inexpensive tool to measure light attenuation (Cialdi and Secchi, 1968). At monthly intervals over 3 years (1993–1995), SDV has been recorded by means of a standard Secchi disk of 30 cm diameter and average annual values were calculated for each area. In the western Mediterranean, SDV may reach 40 m (Flos, 1985). We classified water as clear (SDV>20 m), intermediate (7 m<SDV<20 m) or turbid (SDV<6 m).

In spring 1995 (3 years after deployment), 20 samples of 400 cm^2 were scraped off ARs (AM-AR: 8; TR-AR: 4; TE-AR: 8) and 8 off NRs (ZN-NR: 4; TR-NR: 4), all within a depth range of 16–22 m. Molluscs were sorted, identified at species level, and counted.

Analysis

One-way ANOVA was applied to investigate differences in mean annual SDV values. Cochran's C-test was performed to check for homogeneity of variance (Underwood, 1997) after transformation (Ln[x]) of the variable. When ANOVA indicated significant differences between means, these were compared *a posteriori* using the Student–Newman–Keuls (SNK) test (Sokal and Rohlf, 1981).

Factorial correspondence analysis (FCA) was performed on a quantitative 28 × 116 station/species correlation matrix from log-transformed (ln[x+1]) abundance data (Benzecrì, 1982) to investigate colonization patterns and differences among sites. The significance of the axes was assessed using Lebart (1975) tables. Number of specimens (N), species richness (S), Shannon–Wiener diversity (H′), Simpson dominance (λ′) and Pielou evenness (J′) were calculated. Kruskal–Wallis and Mann–Whitney U tests were used to detect differences among community metrics. Hartley M test was used to verify the homogeneity of variances (Pearson and Hartley, 1958).

Results

TR-AR and TR-NR (SDV=5.1 ± 1 m) and AM-AR (5.8 ± 1.2 m) sites were classified as located in turbid waters. TE-AR (12.3 ± 3.2) was located in an area classified as intermediate water, while ZN-NR (20.5 ± 3.2 m) was in clear water. Differences between sites were statistically significant (d.f.=4, F=116, $p<0.0001$), with ZN-NR>TE-AR>TR-NR=TR-AR=AM-AR (SNK tests; $p<0.05$).

In total, 116 species of molluscs were collected: 59 from ARs and 89 from NRs, with 49% of all species being exclusive to NRs, 28% exclusive to ARs and only 23% being common to both types (Figure 2).

A total of 1084 specimens were collected: 842 from ARs and 242 from NRs. *Bittium latreilli*, *Gastrochaena dubia*, *Pseudochama gryphina*, and *B. reticulatum* were the most abundant species, accounting for 69% of all specimens collected from AR sites (Figure 3). The NR assemblage showed a different pattern, characterized by a large number of species with low percentage abundance values.

Statistical comparison detected significant differences ($p<0.01$) between reef sites for mean S, H′, J′ and λ′ and no difference for mean N (Figure 4). ZN-NR was characterized by the highest values of S, H′ and J′, while TR-AR showed the highest mean values of N and λ′. The lowest values of S and H′ were found at AM-AR

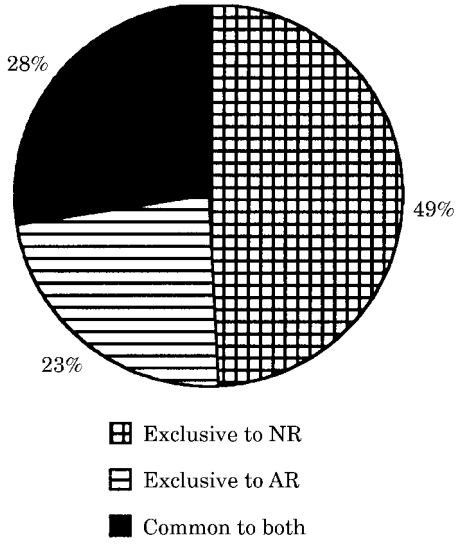


Figure 2. Percentage distribution of the number of species exclusive and common to the natural (NR) and artificial reefs (AR).

and TR-AR, respectively, while the lowest values of N were recorded at TR-NR.

The first two axes of FCA were significant ($p<0.05$), accounting for as much as 29% of the total variance (Figure 5). The model displayed a pattern that was strongly polarized along the first axis by ZN-NR (clear water) and by TR-NR (turbid water). The AR samples formed an isolated cluster located in the IV quadrant of the FCA.

Discussion

The environmental characteristics of the different sites are related to their location in the Gulf. Water transparency and other associated features, such as suspended sediment concentrations and siltation rate, appear to be the main factors influencing settlement and succession of the benthic community, both on ARs and NRs (D'Anna *et al.*, 2000). Our case study confirms that the environmental factors influencing water transparency also affect mollusc assemblages of both reef types, apparently promoting greater species diversity on reefs located in clear water.

The mollusc assemblage of ZN-NR, in clear water, revealed especially high values of species richness, diversity, and evenness. It also included many species (e.g. *Alvania* spp. and *Rissoa* spp.) linked to the photophilous algal assemblage dominated by *Cystoseira* spp. and *Sargassum* spp. The presence of these algae increases the complexity of the substratum and provides shelter, food, and therefore suitable habitat (Chemello and Russo, 1997).

The TR-NR assemblage was characterized by lower species richness and lower abundance associated with the turbidity of the water at this site. However, Pielou evenness and Shannon–Wiener diversity remained

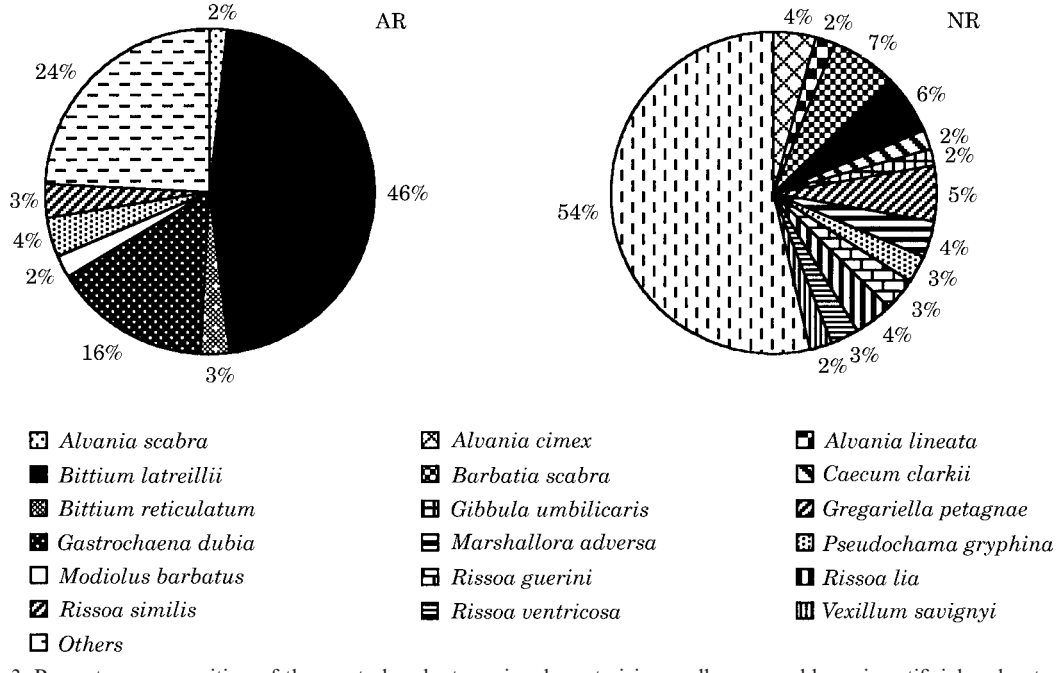
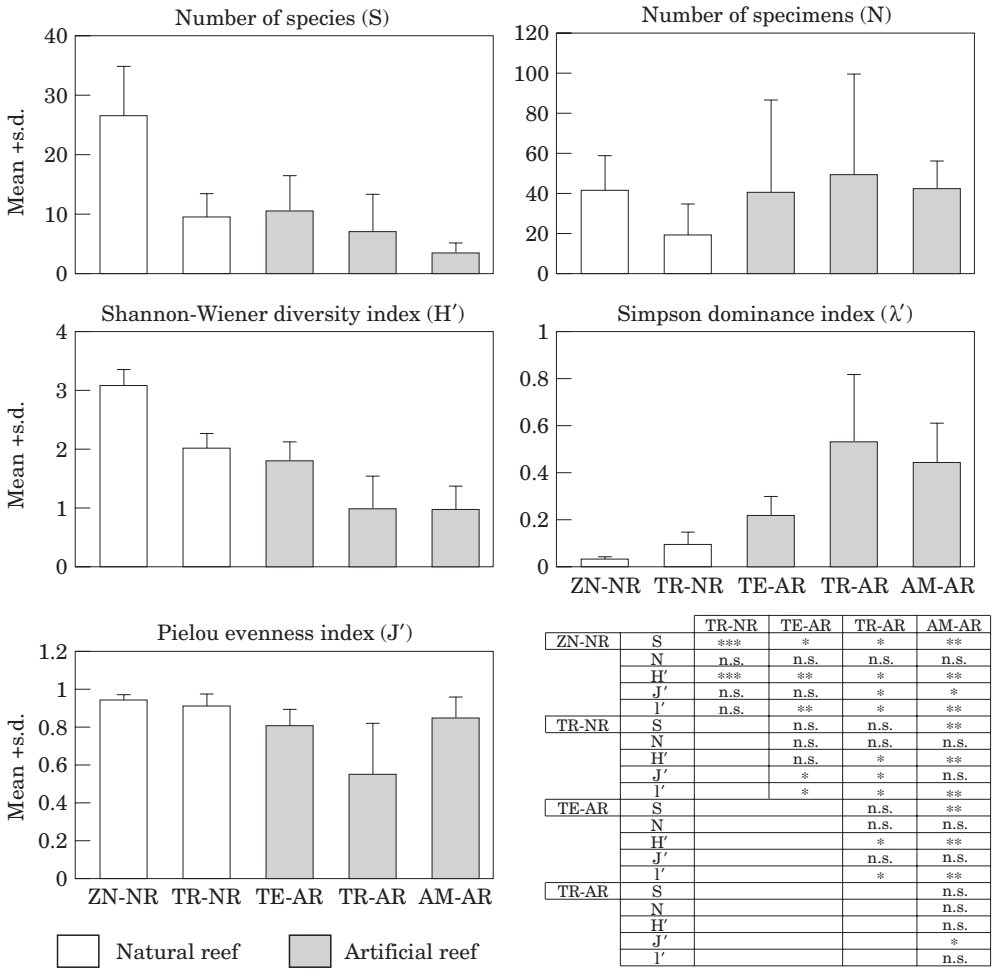


Figure 3. Percentage composition of the most abundant species characterizing mollusc assemblages in artificial and natural reefs (only species with an abundance $\geq 2\%$ are displayed individually).



		TR-NR	TE-AR	TR-AR	AM-AR
ZN-NR	S	***	*	*	**
	N	n.s.	n.s.	n.s.	n.s.
	H′	***	**	*	**
	J′	n.s.	n.s.	*	*
	l′	n.s.	**	*	**
TR-NR	S		n.s.	n.s.	**
	N		n.s.	n.s.	n.s.
	H′		n.s.	*	**
	J′		*	*	n.s.
	l′		*	*	**
TE-AR	S			n.s.	**
	N			n.s.	n.s.
	H′			*	**
	J′			n.s.	n.s.
	l′			*	**
TR-AR	S				n.s.
	N				n.s.
	H′				n.s.
	J′				*
	l′				n.s.

Figure 4. Mean values (+s.d.) of community metrics at natural and artificial reef sites (for codes, see Figure 1), and results of U-tests for differences among sites (***p>0.001; **p>0.01; *p>0.05; n.s.=not significant).

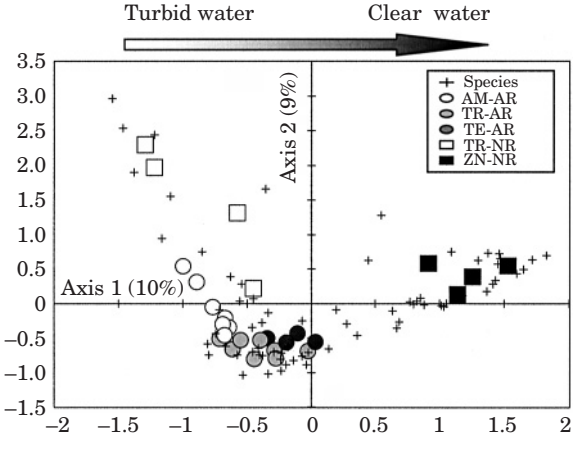


Figure 5. Ordination of sites and species derived from Factorial Correspondence Analysis (for abbreviations, see Figure 1).

relatively high and dominance was less than for AR, owing to the parallel reduction in both species richness and low abundance.

The mollusc assemblages of ARs in turbid water (TR-AR and AM-AR) showed completely different characteristics compared to the NR assemblages: a small number of species with high abundance (low species richness and diversity). The benthic community of these reefs was characterized mainly by erect or semi-erect colonies of filter feeders (mainly hydroids and bryozoa) living on the vertical facies and in the tunnels and hollows of the concrete cubes (Badalamenti *et al.*, 2000). A thick layer of sediment was found on the horizontal facies in AM (Tumbiolo *et al.*, 1997) and TR, apparently inhibiting the development of algae but allowing the conspicuous settlement of the endolithic bivalve *G. dubia* and other small bivalves, such as *P. gryphina*, *Modiulus*

barbatus and *Gregariella petagnae* (Tumbiolo *et al.*, 1997).

The intermediate-water mollusc assemblage of TE-AR showed features that were intermediate between those of ARs in turbid water and those of the NRs in clear water. The blocks were overgrown by a luxuriant canopy of brown algae hiding a rich fauna (Badalamenti *et al.*, 2000). Both filter-feeder molluscs (bivalves) and species associated with the algal assemblage (mainly gastropods) were present and diversity was significantly higher than for AM-AR and TR-AR. This feature is confirmed by the position occupied by TE-AR in the FCA ordination pattern (Figure 5). However, the common characteristic that unites AR assemblages is the high abundance of *B. latreillii*. This species accounted for 46% of all molluscs collected at AR sites.

In conclusion, artificial reefs in the Gulf of Castellammare can be viewed as islands on the sandy-bottom assemblage continuum that allow for a small number of mollusc species in large numbers. As a result, the AR mollusc assemblage remains, even 3 years after deployment in both turbid and intermediate water, an entity distinct from that of nearby natural reefs. However, the potential of the assemblage in terms of total density of individuals, and possibly of biomass and production, is comparable to that of natural reefs.

References

Ambrose, R. F., and Swarbrick, S. 1989. Comparison of fish assemblages on artificial and natural reefs off the coast of Southern California. Bulletin of Marine Science, 44: 718–733.

Ardizzone, G. D., Gravina, M. F., and Somaschini, A. 1989. Temporal development of epibenthic communities on artificial reefs in the Central Mediterranean Sea. Bulletin of Marine Science, 44: 592–608.

Ardizzone, G. D., Somaschini, A., and Belluscio, A. 1997. Biodiversity of European artificial reefs. *In* European Artificial Reef Research, pp. 39–59. Ed. by A. C. Jensen. Proceedings of the 1st EARRN Conference, Ancona, Italy, March 1996. Southampton Oceanography Centre, Southampton. 449 pp.

Badalamenti, F., D'Anna, G., and Riggio, S. 2000. Artificial reefs in the Gulf of Castellammare (northwest Sicily): a case study. *In* Artificial Reefs in the European Seas, pp. 75–96. Ed. by A. C. Jensen, K. J. Collins, and A. M. P. Lockwood. Kluwer, London. 508 pp.

Benzecrì, J. P. 1982. L'analyse des données. II. L'analyse des correspondances, 3ème édition. Dunoud, Paris. 632 pp.

Chang, K. H. 1985. Review of artificial reefs in Taiwan: emphasizing site selection and effectiveness. Bulletin of Marine Science, 37: 143–150.

Chemello, R., and Russo, G. F. 1997. The molluscan taxocoene of photophilic algae from the Island of Lampedusa (strait of Sicily, southern Mediterranean). Bollettino Malacologico, Milano, 33(5–8): 95–104.

Cialdi, A., and Secchi, P. A. 1968. On the transparency of the sea. Translation by Professor Albert Collier. Limnology and Oceanography, 13: 391–394.

D'Anna, G., Badalamenti, F., Lipari, R., Cuttitta, A., and Pipitone, C. 1995. Fish assemblage analysis by means of a visual census survey on an artificial reef and on natural areas in the Gulf of Castellammare (NW Sicily). Proceedings of ECOSET'95. Japan International Marine Science and Technology Federation, Tokyo, 1: 221–226.

D'Anna, G., Badalamenti, F., and Riggio, S. 2000. Artificial reefs in north-west Sicily. *In* Artificial Reefs in the European Seas, pp. 97–112. Ed. by A. C. Jensen, K. J. Collins, and A. M. P. Lockwood. Kluwer, London. 508 pp.

Flos, J. 1985. The driving machine. *In* Western Mediterranean, pp. 60–99. Ed. by R. Margalef. Pergamon Press, Oxford. 363 pp.

Gambi, M. G., Fresi, E., and Giangrande, A. 1982. Descrittori efficaci di comunità bentoniche. Naturalista Siciliano, S. IV, VI (Suppl.), 3: 489–497.

Lebart, L. 1975. Validité des résultats en analyse des données. Centre de Recherches et de Documentation sur la Consommation, Paris. L.L/cd. No. 4465. 157 pp.

Pearson, E. S., and Hartley, H. O. 1958. Biometrika Tables for Statisticians, vol. 1. Cambridge University Press, Cambridge. 240 pp.

Riggio, S., D'Anna, G., and Sparla, M. P. 1992. Coastal eutrophication and settlement of mussel bed in N/W Sicily: remarks on their significance. *In* Marine Eutrophication and Population Dynamics, pp.117–120. Ed. by G. Colombo, I. Ferrari, V. U. Ceccherelli, and R. Rossi. Proceedings of the 25th European Marine Biology Symposium, September 1990, Lido degli Estensi, Ferrara. 395 pp.

Sokal, R. R., and Rohlf, F. J. 1981. Biometry. The Principles and Practice of Statistics in Biological Research, 3th edn. W. H. Freeman & Co., New York.

Tumbiolo, M. L., Badalamenti, F., and D'Anna, G. 1997. Preliminary assessment of zoobenthic biomass living on an artificial reef in the Gulf of Castellammare (N/W Sicily). *In* The Response of Marine Organisms to Their Environments, pp. 353–359. Ed. by L. E. Hawkins, S. Hutchinson, A. C. Jensen, M. Sheader, and J. A. Williams. Proceedings of the 30th European Marine Biology Symposium, September 1995, Southampton. 362 pp.

Underwood, A. J. 1997. Experiments in Ecology. Their Logical Design and Interpretation Using Analysis of Variance, 1st edn. Cambridge University Press, Cambridge. 504 pp.