GENERAL FISHERIES COMMISSION
FOR THE MEDITERRANEAN

COMMISSION GÉNÉRALE DES PÊCHES
POUR LA MÉDITERRANÉE

SCIENTIFIC ADVISORY COMMITTEE (SAC)

Sixteenth session

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Report of the GFCM Workshop on Artificial Reefs in the Mediterranean and Black Sea

Izmir, Turkey, 27 September 2013

OPENING AND ARRANGEMENT OF THE MEETING

1. The GFCM Workshop on Artificial Reefs in the Mediterranean and Black Sea was held in Izmir, Turkey, on 27 September 2013. It was organized in collaboration with FAO EastMed Project and the Ege University of Izmir within the framework of the 10th International Conference on Artificial Reefs and Aquatic Habitats (23–27 September 2013, Izmir, Turkey); the last day of the conference was dedicated to the GFCM Workshop on Artificial Reefs in the Mediterranean and Black Sea.

2. The Workshop was attended by 27 participants from 8 Mediterranean and from 3 non-Mediterranean countries (List of participants in Appendix B).

3. Ms Pilar Hernández, from the GFCM Secretariat, welcomed the participants and thanked the Turkish organizers for the excellent organization of the event as well as the FAO EastMed and CopeMed projects for supporting participants from eastern and western Mediterranean countries.

4. Ms Hernández then introduced the General Fisheries Commission for the Mediterranean (GFCM) to the participants and recalled the role of the Commission to manage fisheries and aquaculture in a sustainable way, and to promote the conservation of living marine resources and their environment. Within this framework, artificial reefs (henceforth ARs) are seen by GFCM as potential management tools, which if properly managed could help preserve and restore the marine environment, enhance fish stocks, provide new fishing grounds, improve fisheries management and enhance small-scale fisheries. She informed about the request of GFCM Members to produce some kind of guidelines to assist them in a regulated use of ARs in order to maximize positive effects and to avoid possible negative aspects that sometimes may arise from the lack of adequate planning, control and management.

5. Ms Aurora Nastasi from the GFCM Secretariat gave a brief presentation to introduce the work done within the framework of FAO/GFCM with respect to ARs. She introduced the main topics of the workshop and presented the new regional database on ARs that will be available on the GFCM website by the end of 2013.

6. Ms Gianna Fabi, who acted as a chairperson, introduced the agenda (Appendix A) and explained that the first part of the meeting was dedicated to the presentation of selected contributions to review the status of the ARs in the Mediterranean and Black Sea and that the second part consisted of a

roundtable to present and discuss the **Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea.**

7. Ms Nastasi and Ms Hernández acted as rapporteurs.

SESSION 1: REVIEW THE STATUS OF ARTIFICIAL REEFS THE MEDITERRANEAN AND BLACK SEA

8. Mr Argyris Kallianiotis presented **Greek artificial reefs: A tool for the management of biological marine resources.** He explained that the need to create artificial reefs in Greece had not been perceived until recently in comparison with other Mediterranean European countries, mainly because of the high number of small and large islands around the country's coastline, with many natural reefs between them. Therefore the need for artificial reef creation had not been considered as a priority. In the late 1990s, a pilot plan was developed, aiming at the creation of protected areas in which specific management rules should be applied. At that time, the need for protection of nursery grounds was not perceived as necessary. It became obvious during the pilot programme that artificial reefs could be a priceless tool for the protection and management of the coastal zone. During the next 10 years, four artificial reefs have been constructed around the country, all made of fortified concrete. Three more plans for new artificial reef deployment have been developed during the past 5 years. In the meantime, new regulations which underlined the need for the creation of protected areas with special management regimes have been applied. These regulations state that at least some stocks should be managed with specific care. Artificial reefs are now included in marine protected areas which additionally protect nursery grounds. Nowadays the pressure towards the creation of protected coastal areas, with or without artificial reefs, comes from the local communities around the country.

9. Mr Vahdet Ünal presented **Artificial reef demand and perception of relevant local groups in Altınoluk (Turkey).** This first on-site study aimed at assessing approximate artificial reef demand from relevant local groups including commercial fishers, recreational fishers, local residents and a diving charter had been conducted via face-to-face interviews in Altınoluk. The field studies were concluded before the concrete reef structures of the Altınoluk Pilot Project under the Turkish National Artificial Reefs Master Plan were deployed in April 2011. According to the perceptual analysis made via 13 statements of different groups, ARs were perceived as positive. In addition to perceptual analysis, the deployment of ARs in the region contributed both to the number of recreational fishing days (158% increase) and the number of commercial fishing days (31% increase) resulting in increased social and economic activity in the region. In light of these findings, he explained that the lack of stakeholder involvement and interest at all stages of ARs deployment, especially in the deployment and management processes, could result in ineffectiveness and conflicts among stakeholders.

10. Mr Giorgos Bayadas presented **Artificial Reefs in Cyprus: an alternative fisheries management tool.** He illustrated that in Cyprus, Artificial Reefs (ARs) were being deployed in coastal areas. According to the respective national strategy, ARs had been primarily considered as an alternative tool for fisheries management, providing habitats for marine organisms but they also serving other objectives such as scientific work, awareness-raising, environmental education and diving tourism. By the time ARs have been deployed, significant areas in terms of surface surrounding the ARs, have been legally designated as No-Take Zones. Those coastal areas extend from shore to 35 meters. Marine Protected Areas (MPAs) with ARs in Cyprus include species and habitats which are protected by national and international legal framework and conventions, like *Posidonia oceanica* and *Epinephelus* spp. For those reasons, the Department of Fisheries and Marine Research (DFMR) applies policies such as monitoring regulation of fishing, diving and access and has taken the decision to establish management bodies and to prepare management plans for each of the MPAs with AR areas. DFMR considers that MPAs with ARs are an integral part of the coastal zone planning where a number of human activities occur and therefore consultation with stakeholders has been a fundamental policy of the Department since the beginning of the initiatives.

11. The author answered questions from participants adding that, in Cyprus, MPAs with ARs inside were being developed to enhance the production of fish stocks and to support small-scale fisheries. They were located near harbors to facilitate accessibility for safety, inspection and control over 35 m depth. He then highlighted the importance of having a well-defined management plan regulating all activities in order to create a win-win situation for all stakeholders and end-users. These activities were funded by the EU through the national programme for fisheries and were foreseen also until 2020.

12. Mr Giuseppe Scarcella presented **Time series analyses of fish abundance from an artificial reef and a reference area in the middle Adriatic Sea.** The study aimed at evaluating the variation over time of twenty commercial fish species collected in an artificial reef (AR) and in a control site in the middle of the Adriatic Sea. The species considered were: *Boops boops, Chelidonichthys lucerna, Dicentrarchus labrax, Diplodus annularis, Diplodus sargus, Gobius niger, Lithognathus mormyrus, Liza ramada, Mullus barbatus, Pagellus erythrinus, Pegusa impar, Raja asterias, Sciaena umbra, Scomber scombrus, Scophthalmus rhombus, Scophthalmus maximus, Scorpaena porcus, Solea solea, Trachurus mediterraneus* and *Umbrina cirrosa*. From 1988 to 2012, the mean yearly catch rates had been computed from data collected during experimental trammel net monthly surveys carried out in both areas. Mean yearly log-ratios by species between artificial reef and control site catches had been calculated. The time series analyses had been carried out on three groups of species showing similar pattern of temporal cross correlation by means of min/max auto-correlation factor analysis and dynamic factor analysis. Moreover, other time series tools (ordinary clustering), had been applied to identify sudden changes in group trends. The analyses highlighted a general decreasing trends in the catch ratio for groups 1 and 2 (mostly reef dwelling species) from 2000 to the end of the series. Differently group 3 species had shown an inverse pattern of the previous two. He finally explained that particular caution should be paid in interpreting the changes in the trends of some groups species taking into account the increase of mussel farming in the surrounding area, the general deterioration of AR modules, and the commercial and recreational fisheries carried out illegally inside AR.

13. Ms Elisa Punzo presented **Fish detection around artificial structures in the Adriatic Sea.** This study was focused on investigating the spatial distribution of fish assemblages along the water column surrounding two offshore extractive structures placed in Adriatic Sea using Multibeam Echosounder (MBES). The first structure (A) was a four leg platform located at about 60 m depth, the second one (B) was a well site situated at about 82 m depth. During 2011, the MBES surveys had been performed monthly for a total of 10 surveys in A and 9 in B, and enabled were able o record water column data in an area of about 4 square km surrounding each structure. Data had been processed through the Echoview software in order to produce bi - or tri-dimensional maps of fish schools and to extract both metrics features and acoustic variables for each detected school. This information had been integrated with data from experimental fishing surveys performed at the same time using trammel nets. The results obtained through the integration of the both techniques showed that the two artificial structures, due to their different scopes, had different effects in attracting fish assemblages. In A, 231 fish schools (mainly composed of demersal species) had been found, mostly located close to the seabed at about 50–1200 m from the platform. In B, 53 fish aggregations (mainly represented by pelagic species) had been detected at about 40–80 m depth and at 60–1200 m from the well site.

14. Ms Benal Gül presented **Bluefish (*Pomatomus saltatrix*) fishery around artificial reefs.** She explained that bluefish occured in temperate and tropical waters on the continental shelf and in estuarine habitats around much of the world. In the coastal areas of Turkey, bluefish migrated between the Black Sea and the Aegean Sea for foraging and spawning in spring and autumn. During the winter, bluefish could occur in and around the Altinoluk artificial reefs, deployed at the Edremit Bay at end of the summer / beginning of autumn 2011. Commercial fishing (by trolling) had become an effective way of catching bluefish in this area just after 3 months of artificial reef deployment. Two months fishing data had been provided from the local fisheries cooperative. Some morphological data had been taken from some fishing operations. The results showed that all individuals were bigger than 20 cm, which is the legal minimum limit for bluefish. This study also presented details of fishing technique, landing data and some morphological data of bluefish caught around the Altinoluk artificial reefs.

15. Some participants asked about the collection of evidences of increased biomass around the ARs and, according to the author of the study, fishers had confirmed that bluefish, before the deployment of artificial reefs, were more rare and scattered while after the deployment of the ARs they were more abundant and concentrated in the area and they could use trawling to fish.

16. Ms Fabi announced three interventions from participants of southern and eastern Mediterranean countries that were not included in the original programme.

17. Mr Saed Ashor and Mr Eli Fituri, from Libya, underlined that in Libya ARs were not present and that their deployment should be considered as a priority for the national administration in order to protect Libyan coasts from indiscriminate illegal trawling which destroyed the coastal marine habitat.

18. Mr Milad Fakhri, from Lebanon, explained that in his country the only ARs deployed so far consisted of wreaks of retired military vehicles. After several years of its deployment and further monitoring made by the University of Balamand, the administration was currently working on a national plan for ARs deployment. He underlined that these wrecks were treated before the deployment in order to remove all possible water pollutants and toxic materials.

19. Mr Ben Hadj Hamida, from Tunisia, presented the work that was being carried out to regularly monitor Tunisian ARs within the framework of a cooperative project funded by Japan. He showed a movie to illustrating the positive effects of artificial reefs (for protection and restoration) deployed in different sites. Nevertheless some ghost nets remained on the ARs site.

SESSION 2: ROUNDTABLE DISCUSSION ON THE DRAFT GUIDELINES FOR THE USE OF ARTIFICIAL REEFS IN THE CONTEXT OF AN INTEGRATED MARITIME APPROACH IN THE MEDITERRANEAN AND BLACK SEA

20. The Chair presented to participants the **Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea.** Ms Hernández recalled that the scope of the guidelines was to provide GFCM Members with a full comprehensive document containing all the necessary information to plan, deploy and manage artificial reefs within an integrated maritime approach. This document was intended to be very practical and adapted to the Mediterranean area.

21. Participants were provided with hard and electronic copies of the document and the Chair presented the main elements of the guidelines.

22. In the ensuing debate, participants highlighted the aspects of the guidelines that could be improved and modified. The **Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea** with the comments of the participants are provided in *Track Change* in Appendix C.

CLOSURE OF THE MEETING

23. Ms Hernández closed the meeting recalling that a final draft of the guidelines should be presented to the Subcommittee on Marine Environment and Ecosystem in February 2014. To this aim participants would be given two weeks from 2 October 2013 to provide the GFCM Secretariat with further comments and sections as agreed during the discussion held during the workshop.

24. Ms Hernández thanked again all the participants for the fruitful meeting and debate and again the Turkish organizers for the excellent support provided in organizing and hosting the GFCM Workshop.

25. Mr Altan Lök closed the conference thanking all the participants for their contributions, the Scientific Committee of the 10th CARAH, the organizers of the Ege University, the volunteers, the sponsors and the GFCM for the support and fruitful collaboration.

26. The final report of the workshop was endorsed via email after a period of two weeks from 2 October 2013.

Appendix A

Agenda

Friday, 27 September

Opening of the Workshop (GFCM Secretariat and Chair)

1) Review the status of artificial reefs the Mediterranean and Black Sea

Objectives of artificial reefs

- **Greek artificial reefs: A tool for the management of biological marine resources** (by A. Kallianiotis*, P. Vidoris and G. Ghitarakos)
- **Artificial reef demand and perception of relevant local groups in Altınoluk (Turkey)** (by S. Tunca, B. Miran and *V. Ünal)
- **Artificial Reefs in Cyprus: an alternative fisheries management tool** (by G. Bayadas)

Evidences of the effectiveness of artificial reefs in enhancing fisheries and management strategies for artificial reefs

- **Time series analyses of fish abundance from an artificial reef and a reference area in the middle Adriatic Sea** (by G. Scarcella*, F. Grati, F. Domenichetti, L Bolognini, P. Polidori, S. Manoukian and G. Fabi)
- **Fish detection around artificial structures in the Adriatic Sea** (by E. Punzo, S. Malaspina*, F. Domenichetti, P. Polidori, G. Scarcella and G. Fabi)
- **Bluefish fishery around artificial reefs** (by B. Gül)

Other interventions:

- **Lack of artificial reefs in Libyan coasts** (by S. Ashor)
- **Artificial reefs in Lebanon** (by M. Fakhri)
- **Artificial reefs monitoring in Tunisia** (by N. Ben Hadj Hamida)

2) Roundtable discussion on the Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea

- ***Objectives of artificial reefs***
  - Habitat protection and restoration
  - Artificial reefs as potential nodes between networks of MPAs (understanding connectivity and recruitment enhancement)
  - Enhancing professional and recreational fisheries
  - Management of activities in coastal areas
  - Aquaculture
  - Artificial reefs as ecosystem services
- ***Dimensions, scales and typologies of artificial reefs according to different objectives***

2) Roundtable discussion on the Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea (Cont.)

- ***Methodologies to assess artificial reefs effectiveness and standardized monitoring procedures***
- ***Plans for the creation and management of new artificial reefs***

Appendix B

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Appendix C

Draft Guidelines for artificial reefs applications in the context of an integrated maritime approach in the Mediterranean and Black Sea

NB. The document provided here below includes the changes done by the participants during the Workshop.

PRACTICAL GUIDELINES FOR THE ~~PLACEMENT~~ ESTABLISHMENT OF ARTIFICIAL REEFS IN THE MEDITERRANEAN AND BLACK SEA

DRAFT

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1. INTRODUCTION

Artificial reefs have been used around the world since long time to attract fish at certain fishing grounds and facilitate captures for human consumption. There is evidence that in the Mediterranean sea the first ARs were unconsciously created in 1500s. At that time the rocks utilised to anchor the tuna fishery were left on the seabed at the end of each fishing season, accumulated over time and made new rocky habitats inhabited by fish which were exploited by local fishermen in the periods between the tuna fishing seasons (Riggio et al., 2000). It is likely that at the same time similar practices were employed by artisanal fishermen across the world (Simard, 1995). The modern concept of "artificial reef" was born in Japan in the 18th century and was adopted in the Mediterranean sea in second half of 1900s.

The increasing interest for artificial reefs has given rise to some concerns regarding the possible negative impacts due to the use of unsuitable materials and dumping of waste. Therefore some guidelines have been produced in the last fifteen years to support managers and scientists in the placement of artificial reefs in the European seas (OSPAR, 1999; UNEP-MAP, 2005; IMO-UNEP, 2008; OSPAR, 2009).

In 2009 FAO General Fisheries Commission for the Mediterranean (GFCM) started to debate on the use of ARs in the Mediterranean sea especially as means for enhancement and management of fisheries and fishing resources. This issue has been addressed during the annual meetings of the Sub-Committee on the Marine Environment and Ecosystem (SCMEE) leading to an *had hoc* workshop in January 2011. Acknowledging the increasing interest of several Mediterranean countries towards ARs, one of the outputs of the workshop was the need of updated guidelines to support potential developers in the establishment and monitoring of ARs in the coastal waters of the Mediterranean and Black seas. The purposes of these guidelines are to:

- update the information reported in the former guidelines;
- assist the countries in the deployment of ARs on the basis of scientific criteria:
- avoid pollution or degradation of the aquatic ecosystem due to the deployment of unsuitable materials as well as dumping of waste;
- prevent negative impacts due to the deployment of ARs
- provide information on the different scopes and types of artificial reefs, as well as on their potential effects;
- provide technical information on the deployment, monitoring, on-going management and socio-economic effects of artificial reefs.

They will address materials, design, placement at sea of the artificial structures, possible negative impacts generated by the deployment of ARs, monitoring methodologies to be applied to assess the effectiveness of ARs in order to standardize the results and to make them comparable with those obtained in other areas, and management measures to be applied to ARs in order to get and maintain over the time the expected results reporting, whenever possible, examples of already established ARs either in the Mediterranean and in other seas.

2. DEFINITION OF ARTIFICIAL REEF

For the purposes of these guidelines the following definition has been adopted, in order to promote a common understanding of the term, and to serve as standard definition. The definition has been derived from the UNEP-MAP Guidelines for the Placement at Sea of Matter for Purpose other than mere Disposal (Construction of Artificial Reef) (2005), the London Convention and Protocol / UNEP Guidelines for the placement of Artificial Reefs (2009), and the OSPAR Commission - Assessment of construction or placement of artificial reefs (2009).

~~London Convention and Protocol / UNEP guidelines for the placement of Artificial Reefs~~

~~An artificial reef is a submerged structure deliberately constructed or placed on the seabed to emulate some functions of a natural reef such as protecting, regenerating, concentrating, and/or enhancing populations of living marine resources.~~

~~Objectives of an artificial reef may also include the protection, restoration and regeneration of aquatic~~

~~habitats, and the promotion of research, recreational opportunities, and educational use of the area.~~

~~The term does not include submerged structures deliberately placed to perform functions not related to those of a natural reef - such as breakwaters, mooring, cables, pipelines, marine research devices or platforms even if they incidentally imitate some functions of a natural reef".~~

~~OSPAR~~

~~An artificial reef is a submerged structure placed on the seabed deliberately, to mimic some characteristics of a natural reef. It could be partly exposed at some stages of the tide….. it is understood that the definition excludes artificial islands, or structures, such as breakwaters, established for coastal defence purposes. (OSPAR Guidelines on Artificial Reefs in relation to Living Marine Resources, 1999; OSPAR Commission, 1009).~~

~~UNEP-MAP 2005 - Guidelines for the Placement at Sea of Matter for Purpose other than mere Disposal (Construction of Artificial Reefs)~~

~~An artificial reef is a submerged structure placed on the seabed deliberately, to mimic some characteristics of a natural reef. It could be partly exposed at some stages of the tide. These guidelines address those structures specifically built for protecting, regenerating, concentrating and/or increasing the production of living marine resources, whether for fisheries or nature conservation. This includes the protection and regeneration of habitats.~~

"An AR is a submerged structure deliberately placed on the seabed to mimic some functions of a natural reef, such as protecting, regenerating, concentrating and/or enhancing populations of living marine resources. It could be partly exposed at some stages of the tide. This includes the protection and regeneration of habitats.
The term excludes artificial islands, cables, pipelines, platforms, mooring, and other structures for coastal defence (e.g. breakwaters, dikes, etc.) which are primarily constructed for other purposes, as well as the Fish Aggregation Devices (FADs) employed to merely attract fish in certain fishing areas".

3. OBJECTIVES OF ARTIFICIAL REEFS

The artificial reefs can be considered as interventions of marine technology aimed to recover and/or improve the natural habitat in order to increase productivity and manage aquatic resources.
In this context, ARs are used in coastal waters worldwide for many applications, e.g.:

- Protecting sensitive habitats from fishing activities;
- Restoring depleted habitats;
- Mitigating habitat loss due to human activities;
- Improving populations of aquatic organisms providing shelter for juveniles and adults in delicate life stages (e.g. moult for crustaceans);
- Providing new substrates for algae and mollusc culture;
- Enhancing professional and recreational fisheries;
- Creating suitable areas for diving;
- Providing a mean to manage coastal activities and reduce conflicts;
- Research and educational activities
- Creating potential networks of MPAs to manage the life cycles of fish.

ARs are often created for more than one purpose (e.g. protection from fishing and finfish enhancement) and in this case they are defined as "multipurpose artificial reefs".

4. TERMINOLOGY

The use of a standard terminology regarding the different components of an artificial reef is essential in order to avoid confusion. In this documents the hierarchy used for Japanese reefs has been adopted (Grove and Sonu, 1991; Fig. XX):
Reef unit or *module*: the smallest element constituting an AR. The modules can be placed singly on the seabed or assembled.
Reef set: structure formed by the assemblage of reef units.
Reef group ~~or *oasis*~~: area constituted by more modules and/or reef sets more than one groups can be used to reef complex: complex formed by more than one reef group.
The term of "artificial reef" is referred a reef group or a reef complex.
The term of "structure" is referred to either a module and to a reef set.

Fig. XX – Hierarchy of the different components an AR (from Grove and Sonu, 1983)

5.

SITING, DESIGN AND CONSTRUCTION OF ARTIFICIAL REEFS

5.1 SITING

The location of an AR is essential for its ecological features and can strongly influence the expected effects from its establishment.
Environmental features such as sediment type, depth/bathymetry, currents, sedimentation rate, water turbidity, nutrients and surrounding habitats should be taken into account in the identification of the reef location (ecological features).

The stability of a reef is related to the characteristics of the reef (, weight, density and design), sediment type, current intensity, and wave motion. On muddy bottoms strong currents and wave action can cause sediment motion leading to sinking and scouring, with consequent rupture and displacement of the structures. Waves and currents can also cause sliding, toppling and displacement due to excessive lateral forces as well as deposit of re-suspended fine material on the horizontal surfaces of the substrates. This mud may be frequently removed by current and wave action, with consequent loss of sessile organisms just settled. For the same reason areas characterized by strong sedimentation, such as close to rivers' mouth, should be avoided.
Depth and water turbidity affect the light penetration into the water influencing the colonization of the artificial substrates by algae and other photophylous organisms and, consequently, the fish assemblage that will inhabit the reef. Water temperature is also strictly related to depth as warm waters tend to stratify above the colder ones creating a thermocline that can represent a sort of barrier for some organisms.
The typology of surrounding habitats can affect the benthic community and fish assemblage in terms of recruitment, composition and abundance.
Usually, the proximity of sea grass meadows and natural reefs may facilitate the recruitment rate at the reef by fish as result of movements from the surroundings (Bombace et al., 1994). On the other hand, the level of isolation of ARs has been linked to top-down predator control of the community structure with a higher predation pressure on larger reefs or reefs close to natural reefs in respect to small isolated ones (Shulman, 1985; Connell, 1998; Belmaker et al., 2005). Hence, it is expected that same structures will be colonized by different assemblages when placed at different distances from similar habitats.
Finally, in order to avoid conflicts, the placement of an AR should be taken into account the other activities already existing or foreseen in the area, such as navigation, recreation, fishing, aquaculture, MPAs, etc. and, especially in the case of large scale ARs, prior the construction the different users of the area should be adequately informed on the reef project in order to get their views.

5.2 MATERIAL

The material used for AR construction can affect the colonization of the artificial substrates by benthic organisms and, consequently, the composition of the fish assemblage that will inhabit the reef.
First of all, the materials should be inert in order to avoid pollution and bioaccumulation of contaminants in the environment and in the aquatic organisms.

The choice of the material should also consider the resistance to the chemical and physical forces in constant action in the marine waters, the time-life, and the suitability for colonization by benthic communities.
As regards the stability (see also point 5.1), a general rule is that the weight of the material used for the construction of the reef units should be at least double than that of the specific gravity of seawater or, alternatively, that the structure is actually anchored to the seabed (OSPAR, 1999).
For durability, the material should assure a minimum life time of 30 years; for functionality, it should demonstrate benthic colonization capability based on field verification carried out for a minimum of 1 year and finally, for economy, it should be cost-effective (Grove et al., 1991).
A wide range of natural and man-made materials have been used for AR construction. Natural materials include rocks, shells and wood, the latter being less durable over time due to the action of borrowing organisms. Rocks can be placed scattered on the seabed or assembled inside frames made of steel, iron, plastic or wood. Concrete, iron, steel, plastic are the most used artificial materials worldwide. Fiber-glass, ash byproducts, ceramic, and ferro-cement have been also utilised. These materials facilitate the building up of specifically designed modules which are usually pre-fabricated on land.
From the ecological aspect, it has to be also taken into account that some materials can be selective towards benthic organisms. For example, greater abundance of benthic species was recorded on concrete and plywood than on fiberglass or aluminium (Anderson and Underwood, 1994). Bombace et al. (1997) found a selective settlement of the burrowing bivalve *Pholas dactylus* on the horizontal surfaces of coal-ash blocks.

List of materials with features, advantages, disadvantage, objectives

5.3 TYPOLOGY OF REEF STRUCTURES

The typology of structures to be employed for the construction of an AR is a key element for its success both in terms of stability over time and of achievement of the expected ecological results.
The reef units can range from very simple modules such as rocks or manmade cubes placed singly on the seabed to sophisticate structures made of different materials (e.g. steel and concrete, steel and fiberglass) which can extend along the water column so to be effective on fish from the bottom to the surface.
Simple reef units can be assembled in reef sets to increase the three-dimensional complexity of the reef, hence enhancing its potential in the recruitment of larvae of benthic organisms and fish species. For the same scope different typologies of reef units and/or reef sets can be used to create an AR.
Shape and weight of the reef units and reef sets is crucial for their stability and durability. It often happens that structures completely sink in muddy bottoms because they are not provided with a base adequate to their weight. Complex modules may collapse due to the forces of currents and waves.
Nevertheless, structures of opportunity such as waste material are still largely employed. These structures include, for example, old ships, aircrafts, old vehicles such as cars, bus, train carriages, tracks, car tires, debris from demolition projects, and parts of obsolete offshore platforms. In the Mediterranean countries the use of these materials is strictly regulated by national laws according to the Barcelona Convention (1995) in order to avoid dumping of waste at sea. It is to underline the need of cleaning up these structures prior deployment in

order to avoid the release of hydrocarbons, anti-fouling and heavy metal pollutants in the surrounding environment and the costs related to these operations (more specific information on the procedures to be followed are reported in UNEP(DEC)/MED IG.16/8, 2005).
Moreover, fiber-glass vessels have a low density and need to be appropriately loaded with other materials to avoid the drifting on the sea surface. Car tires are highly unstable over time, do not achieve their purpose, and may contribute to degradation of the marine environment. The sinking of car bodies causes both dispersion of harmful substances to the environment and disintegration of the metal parts with consequent loss of fouling settled on them (Relini and Orsi Relini, 1971). It has been estimated that car bodies may have about three years of useful life as an artificial reef (Gulf States Marine Fisheries Commission, 2004). A life time of around 15 years is expected for subway carbon steel carriages and of 7 years for steel carriages (Sheely, CARAH 2013).
Different approaches are required when using newly constructed modules or recycled materials. In the former particular attention should be addressed to design and spatial arrangement of the structures, while in the latter, especially in case of old ships and similar structures of opportunity, cleaning and siting of the structures should be the primary issues to be taken into account. As precautionary approach, structures of opportunity should not be placed close to sensitive habitats (Goutayer, pers. comm.). **To be expanded**

5.4 PLACEMENT OF THE ARTIFICIAL STRUCTURES

The disposal of reef units and/or reef sets inside an AR needs to be planned on the basis of a range of criteria depending of the purposes of the reef.
In the case of reefs constructed as deterrent against fishing, the typology of the vessels to be stopped and the gears used have to be taken into account when calculating the distance between the reef structures and their spatial disposal.
In the ARs deployed for stock and fisheries enhancement the spatial disposal of the reef units and/or reef sets should be planned on the basis of their individual area of influence towards the different fish species been targeted in order to optimize the reef effects on them.
More detailed information on the spatial disposal of the reef units and reef sets are given in Section 6.

5.5 Reef DIMENSIONS

Reef dimensions include total volume of material, bottom coverage and surface area. The reef bulk volume is the space enclosed within the external envelop of the reef including both the reef structures and the free space between them (Grove et al., 1991).
Also in this case the optimal dimensions of an AR strictly depends on its purposes. Protection and restoration artificial reefs should have and extension linked to the area to be protected or restored. The former should be able to totally impede the passage of the fishing vessels while the latter should have a recovery potential proportional to the total surface of the habitat to be restored.
As regards the artificial reefs for stock and fishery enhancement, according with the Japanese experience a reef set should have a minimum bulk volume of 400 m^3 while the optimal reef size would be 3000 m^3/km^2 of bulk volume (Sato, 1985). Generally small reefs may not be able to sustain permanent populations of some species due to insufficient food availability. However, given a same amount of immersed material, higher density of fish are usually reported at smaller reefs in respect to larger ones

because the former have higher perimeter and can attract fish from larger areas (Bohnsack et al., 1991).

6. FUNCTION-SPECIFIC CRITERIA

The aim of this section is to provide more detailed information on the criteria to be used in the construction of artificial reefs on the basis of their purposes. Five categories of reefs have been taken into account: 1) protection artificial reefs; 2) production artificial reefs; 3) recreational artificial reefs; 4) restoration artificial reefs; and 5) multi-purpose ARs.

6.1 PROTECTION ARS

6.1.1 Objective

This application of the ARs is usually employed to protect habitat of ecological interest (e.g. Posidonia beds, reproduction and nursery areas, biogenic reefs, etc.) from illegal trawling/dredging that can damage either the habitat and the resources. The use of adequate ARs may definitely solve the problem saving man-time employed for control and reducing conflict between trawling and coastal small-scale fisheries.

6.1.2 Design and Material

Protection reefs should be specifically designed to be able to withstand the power of fishing vessels in the area and to either hook nets or tear them up. Therefore, they should be built using dense, relatively plain units, usually consisting of concrete blocks with deterrent arms. Several ARs have failed because the units were not heavy enough and were shifted or drawn up by the fishing vessels.

Fig. XX -

6.1.3 Siting

Planning the location of the units on the seabed requires knowledge on the fishing routes in the area in order to place the modules along lines perpendicular to them. The distances between modules should be less than the otter-board / dredge openings, hence of the free space needed by the vessel to pass between one module and the other. Usually, these modules are placed alternate along two or three paralleled lines.

When protection reefs are deployed with the aim of creating suitable grounds for selective small-scale fisheries and protecting them from other less-selective fishing activities, the reef units should be placed only along the perimeter of the area to be protected in order to allow the use of set gears within the area.

Several protection reefs have failed in the purpose because the units were freely dropped from the sea surface, hence randomly scattered on the seabed without following a specific design.

Block Weight Trawl power (AP): available power of the vessel for trawling

Total trawl resistance (TR): the product between the available power and the resistance from fishing gear, catch, objects, etc.(GR)

Gear resistance (GR) : derived from otter-trawl resistance which is related to sea water density, trawl speed and otter board trawl surface

→

Block Weight: calculated as a function of trawl power and factors favouring trawling (calm sea, maximum power, minimum depth and trawl speed)

Block resistance (BR): it depends on the block weight in water and is considered to be equal to or greater than TR less GR (BR ≥ TR – GR)

Otter-board opening: estimated by horizontal net opening, net length and sweepline length

Fishing routes: usually parallel or perpendicular to the coastline

→

Spatial Block arrangement

Fig. XX. Parameters to be considered in designing anti-trawling reef units.

6.1.4 Practical applications

Several examples of this application exist in the Mediterranean Sea (e.g. Spain, Tunisia).

6.1.4.1 Spain *To be completed*

Fig. XX – Spain: scheme of a protection artificial reef (courtesy of J.J. Goutayer Garcia)

6.2 Production ARs

6.2.1 Objectives

The overall objective of the protection ARs is to increase the productivity of the aquatic environment and promote sustainable utilisation of the resources.

Artificial reefs may increase the biomass, hence the availability for human consumption, of a variety of aquatic organisms (algae, molluscs, sea-urchins, fish) by enhancing their survival, growth and reproduction providing them suitable habitats.

When opportunely designed, this type of ARs can be used to create potential networks of MPAs to manage the life stages of the targeted species favouring their aggregation in certain areas in order to protect juveniles and gather the adults at suitable fishing grounds.

The specific applications of this type of ARs include:

- recovery of depleted stocks, by increasing survival of juveniles providing shelter and additional food;
- enhancement of local fisheries, by aggregating and establishing permanent populations of fish at suitable fishing grounds;
- shifting the fishing effort from an overexploited resource to other resources; e.g. if the soft bottom species in an area are overexploited the ARs can serve to shift a part of the fishing effort to pelagic or reef-dwelling species;

- compensation for a reduction of fishing effort; when there is the need of reducing fishing effort of trawling in an area, ARs can be used in negotiation to create new fishing grounds allowing fishermen to shift towards more selective fishing activities;
- development of extensive aquaculture of algae and molluscs, providing suitable substrates for settlement.

6.2.2 Design and Material

The modules generally used for the production ARs should be alveolar, of various shapes, and should have an appropriate amount of surface area and niches of various shape and size available for the establishment of settling organisms. Rough surface texture enhances benthic settlement providing refuge and supporting greater diversity (Harlin and Lindbergh, 1977; Hixon and Brostoff, 1985; Beserra Azevedo, et al. 2006). Consequently it also affects the fish assemblage attracting fish grazing.

Besides food availability, composition, diversity as well as abundance of the reef fish assemblage are strongly affected by the occurrence of adequate refuges and by the shape of the structures and, in order to host a permanent community, the AR must provide adequate habitats to juveniles and adults. Habitat quality affects habitat selection by fish and consequently, influences demography and population dynamics of the reef fish assemblage (Lindberg, CARAH 2013), On the basis of the fractal crevices theory in structurally complex natural or artificial environments large crevices are much rarer than the smaller ones. Consequently, the reefs can host more small and medium-sized than large organisms which tend to migrate outside. Therefore, the placement of large-holed reef units (especially in MPAs?) could avoid depletion of broodstock by fishing and enhance the reproductive capacity of reef fish (Caddy, 2011).

Other factors that should be taken into account in planning the reef structures are:

- independently from the size and the life stage, in general fish prefer cavities where there is light and with many openings to enable them escaping from predators;
- size, number and orientation of cavities should match with the behavioural features of the target species, such as whether they are territorial or gregarious;
- the overall design of reef structures should assure adequate water circulation.

With regard to the shape of the reef units/reef sets, it is well known that the affinity of several aquatic organisms towards the artificial substrates vary widely depending on the species and the life stage.

Three categories of organisms can be recognised basing on their reefiness (or reef affinity) (Nakamura, 1985; Grove et al., 1991):

- *Type A*: benthic, reef-dweller organisms (fish, crustaceans, cephalopods) that prefer to live at strict contact with the substrates (e.g. gobids, blennids, scorpenids, octopus, lobsters);
- *Type B*: nekto-benthic, reef-dweller fish that swim around the structures but are linked to them by the occurrence of shelter and/or prey availability (e.g., sparids, scienids, seabass);
- *Type C*: pelagic fish swimming in the middle and surface layers of the water column; they usually maintain a certain distance from the artificial structures but are likely linked to them by vision and sounds (e.g., mugilids, lamberjacks, dolphin).

For attracting Type A organisms the reef structures do not need to extend along the water column but have to be provided with internal spaces matching with the size of the target species, while for Type B fish the holes should be larger and the reef structures must reach at least a height of 2 m. For aggregating Type C species the reef should extend along the water column and the structures should have wide open spaces to favour the water flow.
Simple units can be also used for particular species, e.g. clay jars for octopus.
It derives that the complexity and diversity of the fish assemblage associated to an AR strictly depends on the complexity of the reef.
Fig. XX – Examples of production modules

6.2.3 Siting

The displacement of the reef structures within an AR may affect its influence on fish. Great distances between the reef units / reef sets may increase the total bulk volume of the reef but its effects on fish may be reduced if the structures are placed too widely from each other.
In general, the criterion to be applied in positioning the reef structures within a reef group is that the areas of influence of individual reef units and/or reef sets should overlap with each other (Grove et al., 1991). The reef groups do not need to interact each other when included inside a reef complex (Fig. XX).

Fig. XX – Spatial arrangement of of reef units/reef sets in a reef complex (from Grove and Sonu, 1985)

Production reefs should be placed in areas where already exist stock of the target species and that match with the ecological requirement of those species.
Usually in the Mediterranean sea this type of reef is placed in coastal waters up to 30 m depth, but the range depth noticeably increases in other seas (e.g. Japan) where high relief reefs are placed up to 80 m depth.
In the case of production ARs realized for enhancing the local small-scale fisheries, shifting the fishing effort or to compensate the loss of fishing grounds. although respecting the above mentioned criteria to assure stability and ecological effects, the reefs should be placed as close as possible to the fishing harbours allowing to reduce travel and search time, save fuel and increase fishermen' safety.
When ARs are constructed for localising and managing the entire life-cycle of migratory fish, different reefs, each matching with the ecological requirements of a certain life-stage of the target species, should be deployed along the migratory route.

6.2.4 Practical applications

6.2.4.1 Portugal

To be completed

6.2.4.2 Japan

ARs aimed to manage the life-cycle of migratory fish were constructed in a bay of Iki Islands (Sea of Japan), where schools of snapper were observed to follow a migratory route coinciding with the propagation of waves inside the bay. The strategy adopted was to place an induction reef at the entrance of the bay, a spawning reef where the waves converged and a nursery reef to improve the survival of juveniles (Fig. XX). This allowed to confine the life-cycle of snapper into the bay, to considerably improve their survival, and their catches to be managed by the local fishing communities (Nakamura, 1985).

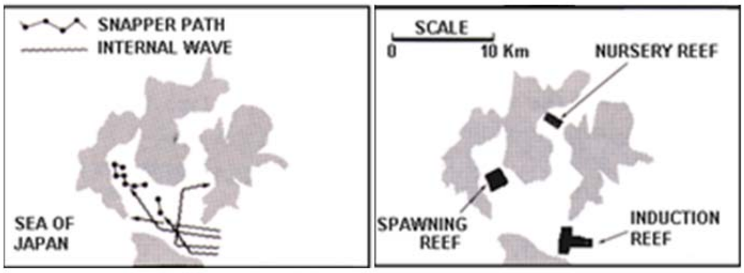


Fig. XX- Deployment of artificial reefs aimed to manage the entire life-cycle of snapper (from Nakamura, 1985).

Similar applications could be adopted in the Mediterranean sea to manage the life-cycle of some commercially important species whose juveniles, for example, prefer low depth and migrate towards offshore as they growth. A restocking experiment conducted with juveniles sea bass (*Dicentrarchus labrax*; 15 cm TL) released at an artificial reef located at 11 m depth in the northern Adriatic sea demonstrated that, just after release, the fish migrates inshore, especially close to estuarine areas. In the subsequent months, as they grew, they migrated again to the artificial reef and the mussel cultures located between 10 and 13 m depth. In this case, the placement of suitable reefs between the coast and the 13 m bathymetry could allow to partially confine released sea bass (Grati et al., 2011).

6.3. RECREATIONAL ARTIFICIAL REEFS

6.3.1 Objectives

These ARs are constructed to create adequate zones for recreational fishing and diving. The main purposes of these reefs are:

- to increase the offer to tourists in areas where natural rocky habitat are lacking;
- to reduce the human pressure on natural sensitive habitats;
- to reduce conflicts between professional and recreational fisheries in coastal zones.

6.3.2 Design and Material

There is a common tendency to use ship wrecks that usually encounter the needs of users (divers and recreational fishermen). Otherwise, to create a reef site of ecological interest and able to sustain, the same approach as for the production ARs should be applied.

6.3.3 Siting

These reefs should be placed in areas easily accessible from the local harbours and /or from the beach, possible in a sheltered position so diving is possible in poor weather conditions.

6.3.4 Practical applications

6.3.4.1 Albania

The southern Albanian coastline hosts diverse and valuable marine habitats threatened by rapidly increasing coastal development and tourism. A diving survey conducted in the last decade indicated a great potential for diving tourism in Karaburuni Peninsula. To protect the natural habitats from excessive pressure and improve the variety of diving opportunities the immersion of a number of ex-naval vessels has been forecasted within the Pilot Fishery Development Project (Government of Albania & World Bank, 2006). Five decommissioned Albanian Navy vessels were purposely sunk in 2010 in Ksamil Bay with the support of the United States Naval Ship Grapple.

Fig. XX- http://www.albaniamarinecenter.org/pages/waittroc.html

6.4. RESTORATION ARs

6.4.1 Objectives

This kind of ARs can be used to:

- recover degraded habitats and ecosystems where the interventions aimed to reduce the human pressure causing the degradation have failed;
- compensate the loss of ecologically habitats caused by some human activities linked, for example, to coastal development and energy production (wind mills, offshore platforms, etc.)

Particular attention has required in the use of ARs for the rehabilitation of natural coral reefs. In this case artificial reefs may represent a solution for coral reefs of particular economic value damaged through shipping accidents or at damaged sites used by tourist operators. However, the use of ARs techniques is recommended only to repair damaged reef areas of a few square meters, while such methods is not considered viable or feasible for coral reef rehabilitation on the scale of square kilometres due to the potential damage that the installation operations can cause to adjacent coral reefs and associated ecosystems (ICRI, 2009).

6.4.2 Design

In this case, natural materials as far as possible to the original ones (boulders, stones, etc.) should be employed. In coral reef rehabilitation boulders or concrete modules are usually employed.

6.4.3 Practical applications

6.4.3.1 Denmark

An example of restoration reef comes from Denmark where natural cavernous boulder reefs have been extensively exploited for their high concentration of easy-to-excavate large boulders suitable for constructing sea defences and harbour jetties. In 2008 the Danish Forest and Nature Agency constructed the Laeso Trindel artificial reef (Kattegat) in order to restore and maintain the local cavernous boulder reef habitat, a site of importance to the EU community and designated as a Natura 2000 Site in accordance with the EU Habitats Directive. The project consisted of the immersion of around 60,000 m^3 of boulders of various sizes and weights (1-6 t; Fig. XX).

Fig. XX - Laeso trindel artificial reef.

6.5 MULTIPURPOSE ARs

6.5.1 Objectives

In order to maximise the benefits from the construction of an AR and reduce costs the reef is often planned to achieve more than one purpose. In this case it is called "multipurpose AR".
Not all the functions of ARs described above are compatible each other. The most common application of multipurpose ARs in the Mediterranean sea joints together the functions of protection and production.

6.5.2 Design

A multipurpose AR will include modules of different type or, alternatively, reef units/reef sets adequately designed to achieve the functions of the reef. For example, an AR for protection and production include both units that act as deterrents to illegal fishing and structures (units and/or sets) aimed to increase the biomass in the area. Alternatively it can be constructed with modules/sets that perform both the functions.
Similarly, a production and recreational AR can include structures to increase the biomass and ship wrecks.
Fig. XX – Examples of multipurpose modules

6.5.3 Siting

The arrangement of the structures inside a multipurpose AR depends on the purposes of the reef. In protection and production reefs the protection units should be placed along the perimeter of the reef area with the production structures in the centre.
The same should be in the case of ARs created for protection, production and recreational.

6.5.4 Practical applications

Examples of multipurpose ARs are common in Italy, Greece, and Spain.

6.5.4.1 Protection and production

Italy - Since the 1907s ARs have been deployed along the Italian coastal areas to protect coastal habitats and fishing communities against illegal trawling as well as to enhance small-scale fisheries Moreover, along the Adriatic Sea, where an important fishery of clams (*Chamelea gallina*) is carried out with hydraulic dredges on the sandy-mud bottoms located in shallow water up to about 11 m depth, small-scale fisheries have conflicts both with illegal trawling for resources competition and damages to the set gears and with hydraulic dredges for space competition and, again, damages to the gears.
The strategy adopted to reduce these conflicts was to allocate spaces and resources by constructing large scale multipurpose (anti-trawling and production) ARs at around 3 nm offohore. The employed modules can be gathered into three main groups: protection module, b) production module, and c) mixed module (Fig. XX).
Anti-trawling structures associated with production structures or mixed modules (Fig. XX) were employed (Bombace et al., 2000; Fabi et al., 2001; Fabi, 2006). As trawlers are

used to begin their hauls outside the 3-mile zone and to enter inside the prohibited area perpendicularly to the shoreline, these reefs consisted of rectangular zones, as longer as possible, placed horizontally in respect to the coast and the distances between modules were calculated on basis of otter-board openings (Fig. XX). These ARs led to a reduction in conflict between fishers as they created suitable areas where small-scale fishermen can carry out their seasonal activity on the basis of the eco-ethology of the different species inhabiting the reef, often joining co-operatives which manage the reef areas and their resources.

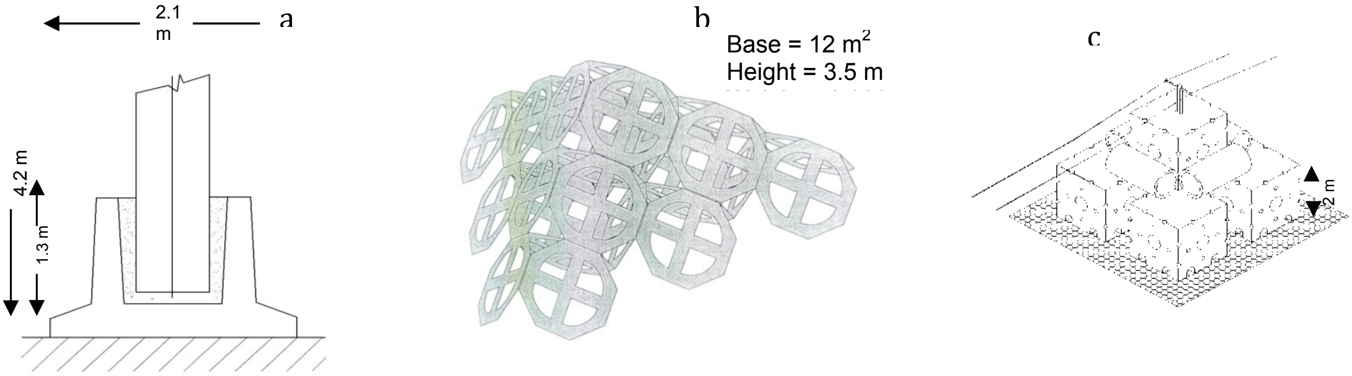
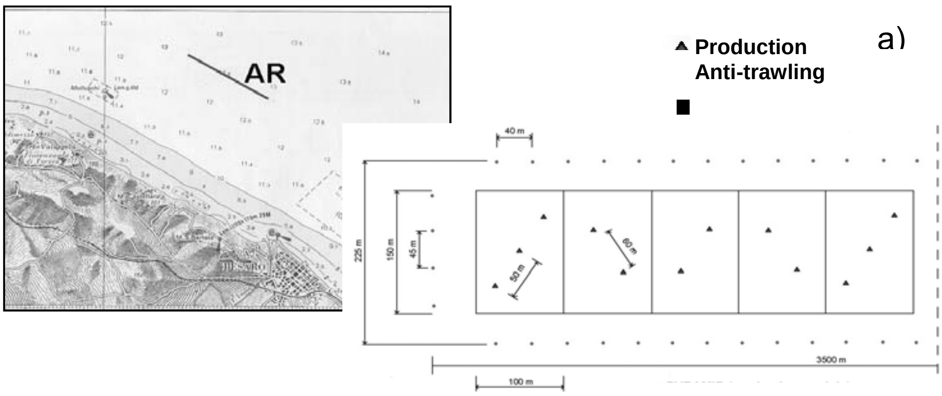
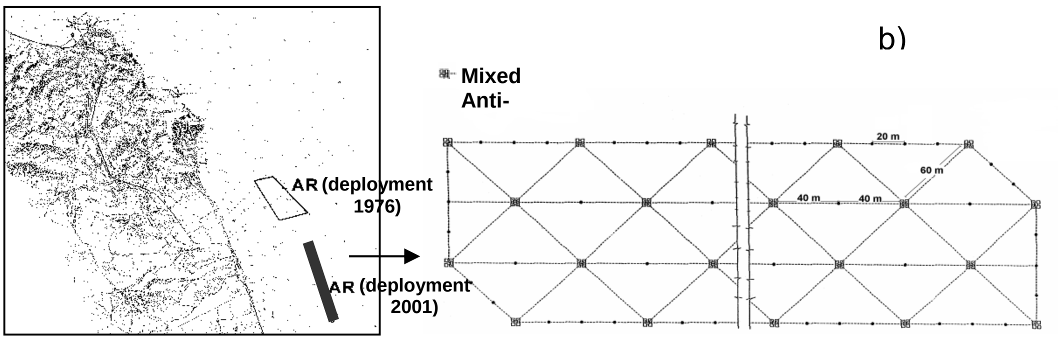


Fig. XX - Examples of artificial modules used in Italy: a) anti-trawling; b) production; c)





mixed (anti-trawling and production).

Fig. XX - Examples of anti-trawling artificial reefs deployed in the northern and central Adriatic Sea: a) anti-trawling and production modules; b) anti-trawling and mixed modules.

***Greece* -** Four multipurpose artificial reefs for protection and management of the marine resources were constructed in the period 2000-2006. The reefs, each having a surface area of 8-10 km^2, were made of different concrete modules: mixed modules, consisting of concrete cubic blocks provided with holes and deployed one by one on the seabed or assembled in pyramids were the commonest units., and production modules, such as bulky cement-bricks on a concrete base and concrete pipes assembled in pyramids were also employed (Fig. XX).

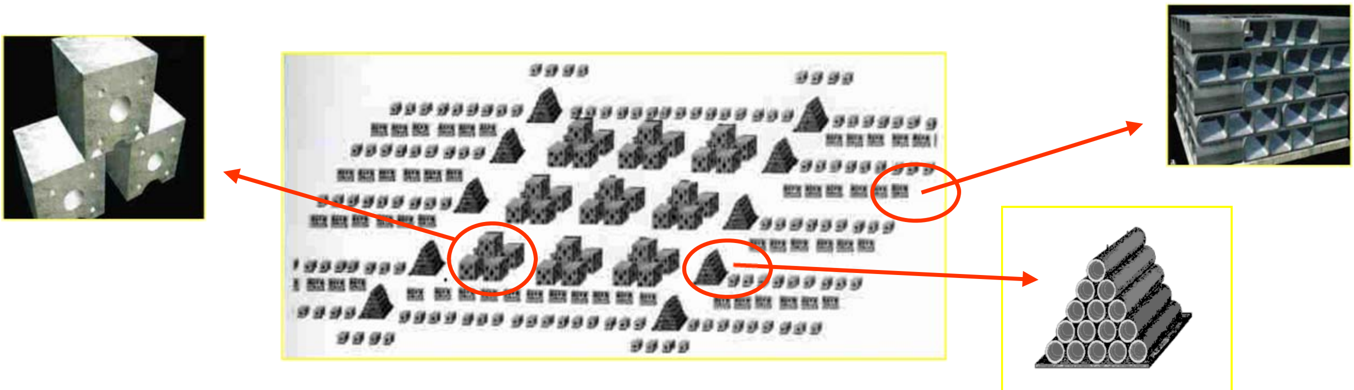


Fig. XX - Greece. An artificial reef plan using four different types of modules in order to increase the reef complexity (modified from and courtesy of A. Kallianotis).

***Spain* -** Similar strategies were adopted along the Spanish Mediterranean coast since the late 1980s with the aim of creating suitable grounds for selective small-scale fisheries and protecting them from other less-selective fishing activities (trawling and seines), improving marine communities, and preventing conflicts between fisheries. Also in this case protection, production and mixed modules were used (Fig. XX) and displaced to prevent trawling regardless their course (Fig. XX) (Moreno, 2000; Ramos-Esplá et al., 2000).

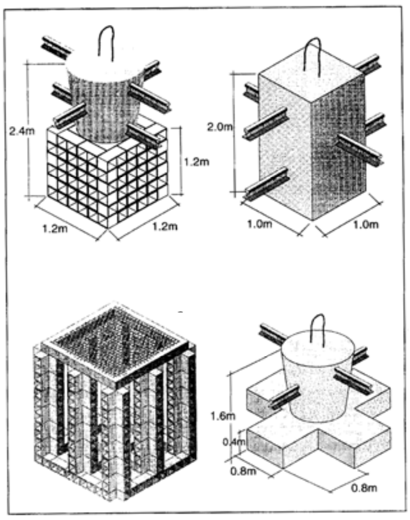


Fig. 7 - Examples of modules used in Spain for the construction of artificial reefs: a) mixed: b) anti-trawling; c) production (from Moreno, 2000).

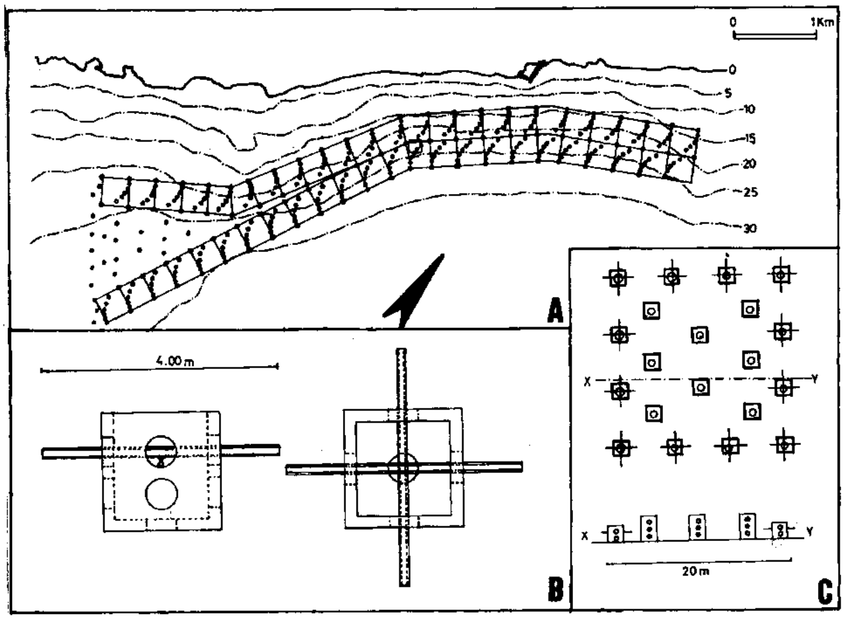


Fig. XX - Example of a Spanish protection and production artificial reef (El Campello) realised with anti-trawling and mixed modules: a) plan of the AR; b) protection block; c) attraction/concentration set and displacement of the units inside a reef set (from Ramos-Esplá et al., 2000).

6.5.4.2 Protection, production and extensive aquaculture *To be completed*

Italy - ARs were deployed within the coastal area of the northern Adriatic sea by local small-scale fishermen associations to improve their activity by creating suitable habitats for reef-dwelling fish and macroinvertebrates and favour the development of mussel wild population. In this case the reef sets were composed by two types of mixed modules: a) protection and production; b) production and aquaculture. (Fig. XX).

7. POSSIBLE NEGATIVE IMPACTS

Artificial reef deployment may cause negative impacts in the environment, either during the construction and once the reef has been established. These potential negative impacts should be considered in reef planning.

During reef installation, the presence of work vessels and other mechanical equipment can cause release of pollutants in the environment that might accumulate in the sediments. Moreover, the immersion of the artificial substrates may induce a short term increase of turbidity due to sediment disturbance temporarily altering photosynthesis of algae, sea-grasses and corals.

Sediments suspended during construction can also settle out the surrounding locations where they may smother existing communities. The extent of the problem will depend on the volume of sediment which is disturbed and by local currents.

Once that an artificial reef has been deployed, it might cause some long-term environmental changes. These can consist of the modification of bottom currents leading to subsequent variations in the grain-size distribution and eventual localised sediment scour close to reef modules (Fig. XX). A further effect might be the change of sediment organic content due to the metabolic activity of benthic and fish assemblages associated to the reef. These effects will likely modify the original soft bottom community inhabiting the surroundings.

Fig. XX – Adriatic sea: acoustic images of an AR showing the modifications of sediment distribution induced by the artificial substrates. The strong current down scoring eroded the sea bottom at South of the reef sets raising each of them on a sediment pile

Artificial reefs may also cause negative impacts on the fish resources, especially in cases where the reefs change the spatial redistribution of exploitable biomass simply aggregating it without increasing the total stock. In the absence of adequate management measures, higher density at the reef increases the catchability of the fishing gears. The grater accessibility to the resource/s increases the fishing effort potentially causing an increase of fishing mortality and, consequently, a decrease of the exploitable biomass in the area (Polovina, 1991).

A further concern regards the potential impact of ARs in the introduction and expansion of non-indigenous species providing them with suitable habitats. Analysis of risks should be performed prior the deployment an AR to evaluate the vulnerability of the AR area towards invasive non-indigenous species.

List of possible negative impacts of ARs …

8. METHODOLOGIES TO ASSESS EFFECTIVENESS AND IMPACTS OF ARS AND STANDARDIZED MONITORING PROCEDURES

A critical element in understanding how artificial reefs can be integrated into a more general marine resource management framework consists on the ability to evaluate their performance. Despite significant developments in construction and design, artificial reef projects have been criticized for a lack of planning in the development of adequate monitoring programs that will provide fisheries scientists and managers the information required to test objectives (Claudet and Pelletier, 2004). Artificial structures, particularly in the initial phase following deployment, demonstrate an ability to support greater fish abundance, diversity and biomass than similar naturally occurring habitats (Pickering and Whitmarsh, 1997; Wantiez and Thollot, 2000; Chou et al., 2002; Arena et al., 2007; Relini et al., 2007). Differences in the assemblage structure and recruitment patterns are further complicated by the relatively small size and isolated nature of many artificial reefs. In the present chapter elements helping in clarify a Mediterranean standardization of monitoring programs for the ARs are provided.

8.1 CRITICAL ASPECTS IN THE MONITORING PLANS

Scientific research into artificial reefs has gathered pace internationally since the 1950s. Many researchers have attempted to demonstrate the effects of anthropogenic manipulation of habitat complexity, but much of the research has been compromised by associated legal or financial constraints that limit the ability to develop formal hypothesis testing (Bortone, 2006), provide acceptable levels of replication (Kock, 1982; Fabi and Fiorentini, 1994; Fujita et al., 1996; Charbonnel et al., 2002), and/or avoid pseudoreplication, defined as the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent (Kock, 1982; Bortone et al., 1994; Jensen et al., 1994).

8.2. THE SAMPLING METHODS

Sampling methods used in studies associated with artificial reefs fall into two broad categories, non-destructive methods and destructive ones.

8.2.1 Benthic communities

The deployment of new hard substrates may induce changes in the communities of the natural habitats as well as the development of new epibenthic communities (fauna and algae) which will colonize the artificial structures.

8.2.1.1 Soft-benthic communities

Most of the researches on infauna surrounding artificial reefs dealt with the macrofauna group-size components, but meiofauna should be also considered, being an important component of the interstitial infauna of the sublittoral sand sediments (Fenchel, 1978) that may significantly affect the structure of the macrofauna communities (Watzin, 1983).

As a primary aim is to assess the radius of influence of an artificial reef on the surrounding seabed community, samples should be collected as close as possible to the reef edge and at increasing distances from it. The same should be done inside the reef in order to verify the influence of the different modules employed.

8.2.1.2 Epibenthic and algal communities

The technical features of the reef, such as material, shape, size, and surface rugosity should be taken into account in evaluating the epibenthic communities. Beside the animal component, the study on macroalgae is also important to assess the ecological role of an artificial reef, for example in terms of increasing oxygen production, trapping of sediments thus increasing food supply for detritivores, and creation on nurseries and food sources for herbivorous fishes (Falace and Bressan, 1996). Three main aspects should be assessed: presence/absence, luxuriance and fertility.
As in the case of soft-bottom communities, adequate spatial and temporal sampling is required as well as enough replicates in space and time. The number and size of samples depend on the spatial variability: the most variability requires more and larger samples (Moreno, 1996). Sampling must be simple and fast, because they must be carried out by SCUBA divers. For this reason, it is important that the protocol is standardised and well defined.

8.2.1.3 Sampling methods

Non-destructive methods

Underwater observations: It represents a qualitative and quantitative method to establish lists and zonation patterns and includes observations or photographic techniques. The latter may be used to estimate fauna and flora species composition, number of organisms, percent cover and relative density of the sessile community. Such methods are useful for dominant and large organisms, but are likely to underestimate small or understory components of the community.
These techniques can be used for soft- and hard-bottom communities, both animals and algae.
Both underwater observations and photographic techniques are non-destructive and repeatability methods. Photographic techniques allow an objective evaluation and the creation of a reference collection.
Nevertheless, the records obtained through these techniques can be affected by low taxonomic precision, especially for small-sized organisms and algae. In addition, these methods require for a good water transparency and in temperate waters may be difficult to be applied in all seasons

Destructive methods

Grab and box-corer samplers: these instruments are usually employed to sample the communities inhabiting the soft bottoms outside an AR and between the structures constituting the reef. Grab samplers and box-corers have a known volume and can be appropriate in quantitative studies. Moreover, they are operated on board and do not require underwater work but, at the same time, their positioning on the seabed is not precise. In addition, the penetration of these instruments inside sandy bottoms may be difficult. Box corers have a smaller capacity than grabs and it is usually required a high number of samples to obtain an adequate sediment volume.
Dredges: they can be used to sample soft-bottom communities outside the reef but not inside because of the presence of the structures. Dredges do not work on defined quantities of sediment and hence they are unable in the case of quantitative studies (Castelli et al., 2003).

Suction samplers: this method is utilized to sample soft-benthic communities, but it may be useful also for interstitial fauna living on the horizontal walls of the hard substrates. It allows to sample on the exact sampling point because these instruments are directly operated by SCUBA divers but may require for a great sampling effort to collect samples of adequate size and/or a sufficient number of replicates.
Scraping technique: this technique is commonly employed to sample hard-bottom communities (animals and algae). Similarly to the suction sampling, it has the advantage to sample on the sampling point but may require for a great effort by divers. In addition, it may be possible to loose part of the sample, especially small-sized organisms, due to underwater currents.

8.2.2. Fish assemblage

8.2.2.1 Sampling methods

Non-destructive methods

Visual census (UVC): Visual census by divers is historically the most common non-destructive method used and a range of techniques to monitor fish assemblages in a variety of shallow marine habitats has been developed (Bortone and Kimmel, 1991). The most common are:

- *Strip transect:* the diver swims along a transect of pre-established length in a pre-established time interval listing and the species encountered.
- *Point count*: the diver stand at a fixed point and enumerates the organisms observed within a prescribed area or volume in a pre-established time interval.
- *Species-time random count*: this method is based on the principle that abundant specie are likely to encountered first than the rarer ones. The observer swims randomly over the survey area for a predefined time period either simply recording the species encountered or listing them in the order in which they were initially seen.
- *Combinations of methods.*

In situ visual methods are relatively rapid, provide adequate levels of replication and are capable of recording a broad suite of variables, e.g. relative abundance, density size structure species composition and habitat characteristics (Bortone et al., 2000; Samoilys and Carlos, 2000). However, the limitations of diver based methodologies have been well documented (Thresher; Gunn, 1986; Smith, 1988; Lincoln Smith, 1989; Thompson; Mapstone, 1997; Kulbicki, 1998) and relate to the physical limitations (e.g. water depth and visibility) and species specific sources of "detection heterogeneity" (Macneil et al., 2008; Kulbicki, 1998) which can be summarized as the ability of the diver to see fishes accurately and record their presence under variable conditions (Sale, 1997).
Baited remote underwater video (BRUV): recent innovations in the development of video technology have resulted in the widespread use of baited remote underwater video as a means of monitoring fish populations in a variety of habitats (Cappo et al., 2006). BRUV systems have however inherent biases such as difficulties in determining the area sampled due to variables associated with the dispersion of bait (Bailey and Priede, 2002; Priede and Merrett, 1996; 1998), conservative relative abundance estimation (Farnsworth et al., 2007), reliance on acceptable visibility and an inability to detect more cryptic reef associated species (Watson et al., 2005).

Hydroacoustic tecniques: the most recent advancement in ARs research involves using stationary or mobile hydroacoustic technology (e.g. echosounders for fish, multibeam echosounder) to study fish abundance, distribution, and behaviour in specific areas.
Echosounders for fish have been successfully employed in surveying fish assemblages at hydroelectric facilities in riverine environments, around oil and gas platforms (Thorne et al., 1990; Thorne, 1994; Stanley et al., 1994; Stanley and Wilson, 1998; Soldal et al., 2002; Myounghee et al., 2011); however, thus far applying this technique to artificial reefs has been very limited (Thorne et al., 1989; Fabi et al., 2007; Kang et al., 2011). The advantage of the stationary hydroacoustic methods in respect to the mobile one is that in the former, when strategically placed and combined with computerised data records, the transducer arrays allow to collect long-term, time-series data along the entire water column or at specific depths.
The newer generation of multibeam echosounder (MBES) is able to detect at the same time the seafloor and the water column. An aspect that is commonly ignored when assessing the fish assemblage at an artificial reef is the current state of the structures. Studies usually refer to the initial arrangement of the artificial substrates but do not take into account movements and alterations that may occur over time due to environmental and anthropic factors although arrangement, distance, shape and dimensions of reef units and/or reef sets can strongly affect the composition and behaviour of the reef fish assemblage (Nakamura, 1985; Bombace, 1989; Okamoto, 1991). Relief imagery produced from multibeam bathymetric data can provide valuable and detailed base maps for seafloor investigation and interpretation (Todd et al., 1999; Mosher and Thomson, 2002) helping to better understand the evolution of the fish assemblage associate to an AR in respect to status of the substrates. These data associated to the data recorded along the water column allow to detect the behaviour of fish inside the reef and to map the spatial distribution and abundance of fish in respect to the reef structures (Fig. XX).

Fig. XXX – MBES images of fish schools around artificial structures in the Adriatic sea.

In general, the main disadvantage of hydroacoustic techniques is the difficulty of identifying the species, especially in a mixed-species assemblage like that typically inhabiting an artificial reef.

Destructive methods

These methods include adaptations of commercial fishing techniques such as traps, long-lining and set netting (Gannon et al., 1985; Kelch et al., 1999) as well as trawling.
Trawling is the less suitable technique because, due the physical presence of the reef structures, it must be performed at a certain distance from the reef. Consequently, as the radius of influence of an AR on the different species changes at increasing distances from it, trawling cannot allow to fully investigate the assemblage inhabiting at the reef.
The advantages related the use of fishing gears are represented by the availability of specimens to study the effect of the reef on growth, diet and sexual reproduction. Moreover, the possibility to sample day and night as well as in each season over the year independently from the water transparency allows to study the daily behaviour of species assemblages and the seasonal changes of the reef fish community.

On the other side, the potential habitat degradation due to the use of fishing gears, the unfeasibility to observe the behavioural aspect of the species associated with the ARs, and the possible underestimation in terms of both size and species due to the selectivity of the gear employed are clear weaknesses of such approaches. Moreover, these methodologies are often prohibited in sensitive areas such as marine parks (Lipej et al., 2003; Willis et al., 2003; Cappo et al., 2004).
However, the crucial aspect in the investigation of the biological assemblages associated with ARs is represented by the capacity to standardize the results of the different study methodologies, such as for example visual census and experimental fishing surveys.
The new perspectives monitoring to assess the effects of an AR refer to two critic points:

- No single technique is able to completely describe the communities associated to an AR.
- A combination of techniques should be employed and adjusted according to the morphological and geographical characteristics of the areas.

8.3. THE STATISTICAL FRAMEWORK

Surveys must be designed taking into account that fish assemblages and sessile resources associated with ARs are extremely patchy in distribution and abundance and variable in time. Patchiness and temporal variation are caused by processes external to the assemblage, particularly disturbances, changes of the environmental factors (e.g. temperature) and recruitment, in addition to processes operating within the existing assemblage. The statistical framework that have to be developed in order to better evaluate the biomass associated with ARs, thus determining the effectiveness of ARs for stock enhancement and fishery management, need to be related to the following new and comprehensive statistical ~~approaches:~~methods:

- BACI/ACI design (ARs considered as pulse or press influence)
- ANOVA; MANOVA desings
- Non parametric methods (give examples)
- Time series analyses.

Explain why and when ...

8.3.1 Spatial and temporal replication

The temporal and spatial scale of sampling is essential to separate reef effects from background variability. While some studies have examined how the distribution of reefs relates to habitat use and development of prey resources for resident species, few have explicitly attempted to isolate reef effects. Absence of background pre-deployment data (Clark and Edwards, 1999), erroneous and inappropriate experimental design (ALEVIZON and GORHAM, 1989), as well as infrequent sampling, e.g. only once per season (Santos and Monteiro, 1998) have also cast doubt over recorded changes in fish abundances.
The spatial extent of sampling depends on the size of the area designated for placement. Obviously, a number of reference~~control~~ sites without any artificial reef and having the same environmental characteristics (e.g., grain-size, depth) should be sampled at the same time, in order to assess the effects of the reef.(indicate better the reference sites to be considered 5-10, etc).
In studies with frequent sampling, high variability in abundances of individual species is evidence of key events such as settlement, migration and mortality. The same

experimental design sampled at less frequent intervals will fail to detect these events, which are fundamental to distinguishing between attraction and production. Artificial reefs and controls should be visited at intervals relevant to life history events, e.g. every 1–2 months to permit comparisons between and within seasons and detect abundance changes related to recruitment and mortality.

Whatever the typology of the study and the hypothesis to be being tested and the ultimate use of the data from sampling, spatial replication is a mandatory component of any kind of investigation. The large variability in numbers and varieties of species from place to place at many spatial scales creates fundamental problems for determining at which scale of replication is necessary. When in doubt about the relevant spatial scale, it is suggested to use a design that can detect changes or differences at one or more of several of the possible scales.

To test for seasonal (or other a priori selected scales of temporal variation), temporal variation among the factors of interest must be compared to temporal variation within each factor of interest. In other words, The temporal variation among seasons must be compared to the magnitudes of variation that occur in each season. To measure such variability, it is essential to collect samples at an adequate number of times within each season. With two or more scales of temporal sampling, seasonal or other long-term trends can be identified against background noise. Where there is no measure of shorter-term temporal variation and such variation is large, quite spurious seasonal (or other temporal) patterns will be seen in the data. Moreover, at a shorter temporal time scale, the variability due to the photoperiod needs to be considered in study the horizontal and vertical movement of reef fishes through the water column. Different scales of temporal sampling are extremely important for identifying environmental impacts. Disturbances to the environment may either be short-lived (pulse disturbances) or persist for long periods of time (press disturbances) (BENDER et al., 1984). The responses of organisms to either type of disturbance may be relatively short-term (i.e. a pulse response), for example, abundances may rapidly increase, but soon drop to normal levels, irrespective of whether the disturbance persists or ceases. Alternatively, populations may show long-term responses (i.e. press responses) to continuing disturbances (because the disturbance continues to exert an effect) or to pulse disturbances (because the disturbance, although ended long ago, caused long-term changes to some other environmental or biological variables).

9. SOCIO-ECONOMIC EFFECTS OF ARTIFICIAL REEFS *To be completed*

The primary reason for artificial reef deployment is to serve to human uses, such as commercial and recreational fishing and scuba diving. Even though the need of evaluating the socio-economic effects associated to the AR deployment has been highlighted since the beginning of 1980s (………) there is still a general lack of studies dealing on this issue and most of them focus on areas with the greatest concentration of ARs such as Japan and USA (Milon, 1988; Rhodes et al., 1994; Ditton et al., 1995; Simard, 1997; Bell et al., 1998; Milon et al., 2000). Independently from the purpose of an AR, usually its performance and efficacy is judged on the basis of the public satisfaction. Collection and evaluation off socio-economic data is useful to quantify the usage and public benefits of a reef helping to justify costs for the construction, maintenance and providing information for a successful management of the reef (Milon et al., 2000).

Socio-economic assessment of artificial reefs should be conducted by experts in social and economic sciences prior the reef construction or on already existing ARs. It involves the following phases (Milon, 2000):

a) Objective identification
b) Development of survey instruments
c) Collection and analysis of data

Socio-economic objectives are very broad and include a number of more specific goals, such as the ecological and the environmental issues.

The typology and quantity of data to be collected depend on the objectives of the AR and the kind of questions to be answered. The data collection phase includes three steps: (Table XX)

b) a) monitoring of utilization patterns: it serves to evaluate the broad goals of the reef project, e.g. increase of the number of sites suitable for divers and or recreational fishing, increase of nearshore grounds for local fisheries, replace or restore damaged natural habitats. The techniques for data collection and evaluation to be used in this step are: 1) direct observation of activities in the area; 2) on-site interviews; 3) mail or phone surveys. These techniques can be applied individually or in combination. Data collection should not be conducted on a one-time basis or in short time period as the perception of stakeholders may be easily influenced by events and change in a few days.Impact assessment: it includes social assessment and economic assessment and is aimed to understand the social and economic importance of an AR for the local communities assessing the changes induced by the project and evaluating whether these changes fit with the specific objectives. For example, if a goal of a reef project was to increase the local economy by XX% improving recreational fishing and attracting non-resident fishermen, the achievement of this goal could be evaluated through an economic analysis that compares the non-resident recreational activity before and after the reef deployment. In order to assess the social and economic changes produced by the deployment of an AR it is necessary to know the previous conditions taking into account different dimensions: historical, cultural, demographic, social, economic and ecological.

c) B) Efficiency analysis to evaluate the economic performance or net benefits of the reef: efficiency analysis can be classifies as either cost-effectiveness or cost-benefit evaluations. The former is aimed to determine whether a project can produce or has produced the expected benefits at the least cost, while the latter evaluated whether the benefits of the project exceed the costs. Both analysis provide information on whether the reef project if economically sustainable. They can be also used to compare the efficiency of different reef projects or to compare the economic performance of the reef project with other types of initiatives.

Table XX: Types of socio-economic assessment (from Milon et al., 2000)

Step 1 – Monitoring

Questions to ask:
- Who uses the artificial reef and its resources?
- When does use occur?
- Where does use occur?
- Why does use occur?

Techniques to be used:
- Data collection and analysis from site observations, interviews, mail and/or phone surveys

Step 2 – Impact Assessment

Questions to ask:
- Which changes, if any, are measurable in social or economic activities due to the development and usage
- Where do changes occur?
- Why do changes occur?

Techniques to be used:
- Economic analysis, input/output analysis, social impact analysis

Step 3 – Efficiency analysis

Questions to ask:
- Are the objectives of the projects being met at the least possible cost?
- Does the monetized value of project benefits exceed the project costs?

Techniques to be used:
- Cost-effectiveness analysis
- Cost-benefit analysis

9.1 STAKEHOLDER ANALYSIS

The deployment of an AR can affect many human activities, hence a variety of stakeholders. Possible stakeholder groups are: recreational fishermen, recreational divers, professional fishermen, professional divers, resource managers, scientists, environmental groups (MIlon, 2000). In several countries the majority of ARs are public resources developed and managed by public authorities and several users can get benefit from them. However, in such situation it is often difficult to manage the usage of the reef and congestion may likely occur with negative impacts on the reefs effects (see Section 10). It is also important to note that the term "stakeholder" does not only refer to groups the can get benefits from the AR deployment but also to those which oppose to the reef project (e.g. environmental groups).
Stakeholder analysis can be useful to either identify the most relevant stakeholder groups and to understand their position towards the reef project. It also helps to identify incompatible uses of the reefs and potential sources of conflicts. Such information may support managers to evaluate the importance of each group in the development of the reef project and, once the reef has been constructed, to plan adequate management measures to avoid or reduce conflicts.

10. ARTIFICIAL REEF MANAGEMENT, CONTROL AND SURVEILLANCE

Similarly to other types of aquatic environments, ARs may require some degree of management control to assure that they provide the desired outcomes for both the biological resources and users. Given the lack of literature concerning the management of artificial reefs, one of the purpose of these guidelines is to provide management strategies for the different types of ARs. The involvement of stakeholders, and especially fishermen (small-scale or recreational fishermen depending on the purposes of the AR) in the AR management is fundamental.

10.1 PROTECTION ARS
These reefs do not need to be subjected to any control measures as act by themselves as a means of control impeding the illegal trawling/dredging in sensitive habitats.

10.2 RESTORATION ARS
Considering that the main purpose for the placement of this type of ARs is the recovery of depleted habitats and ecosystems of ecological relevance, access to them should be totally forbidden to any kind of activity except for research.

10.3 PRODUCTION, RECREATIONAL, AND MULTIPURPOSE ARS
There is evidence that the deployment of these types of ARs cannot be successful if it is not associated to site-specific management plans which regulate the exploitation of the reefs (Milon, 1991; Grossman et al., 1997). The open-access may lead to overexploitation and rapid depletion of the reef resources and conflicts within and between user groups. This usually happens where the ARs are created by public agencies in public waters without effective restrictions on access by the different user groups (Milon, 1991) or where there is a lack of control to assure that the restrictions are respected.
User conflicts can be generated by stock effects and congestion effects. The former may occur from overexploitation of all species or particular species at a reef site. The latter occurs when the activities of different users interfere each other and may result from

either incompatible uses (e.g. recreational and commercial fishing), incompatible fishing gears or too many users in a limited site. Stock and congestion effects are not mutually exclusive (Samples, 1989).

Some basic options for reef management can be identified:

1) selective access control: it may consists in the establishment of property or user rights in which local fishermen communities or recreational associations would be co-responsible with government agencies for regulating access and monitoring the activities which are carried out at the reef. It is often not feasible due to political and institutional constrains which explicitly forbid to discriminate between different groups of users (Whitmarsh et al., 2008). This measure is efficiently applied in Japan, where fishermen cooperatives are granted exclusive commercial rights to regions of coast line, thus prohibiting other user groups from harvesting from ARs (Polovina and Sakai, 1989; Simard, 1997).

2) Gear and catch restrictions: this measure is aimed to orient harvesting strategies at the reef through the use of selective fishing gears in order to allow optimal fishing yields and avoid the disruption of the natural succession of the ARs and associated assemblages; the exploitation strategies should include different fishing gears to diversify the catches and exploit all the reef resources in order to avoid alterations in the equilibrium among the functional groups of fish and macroinverterbrates inhabiting the reef. Gear restriction has been successfully adopted to manage ARs in USA (Mcgurrin, 1989; National Marine Fisheries Service, 1990).

3) Temporal closure: it can be adopted to avoid exploitation of the reef resources in particular seasons of the year, for example to favour the reproduction and/or the early growth of juveniles at the reef but this measure may increase congestion and overexploitation in the remaining periods.

4) Temporal segregation of users: it is aimed to separate user groups allocating specific periods of time when each group is permitted access. Times may be chosen on the basis of various factors such as stock availability, weather conditions, market prices, etc. In this way the different user groups can continue to use the artificial reef without interaction between them, but this management measure is easily enforceable only when the different user groups (e.g. recreational and professional fishermen) are easily distinguishable. In addition, similarly to closed seasons, it may increase congestion within user groups because access opportunities for each of them are compressed into shorter time periods.

5) Spatial segregation of users: it consists of creating separate reef sites for each user group. Nevertheless, creating and maintaining multiple ARs are much more expensive than the other control options.

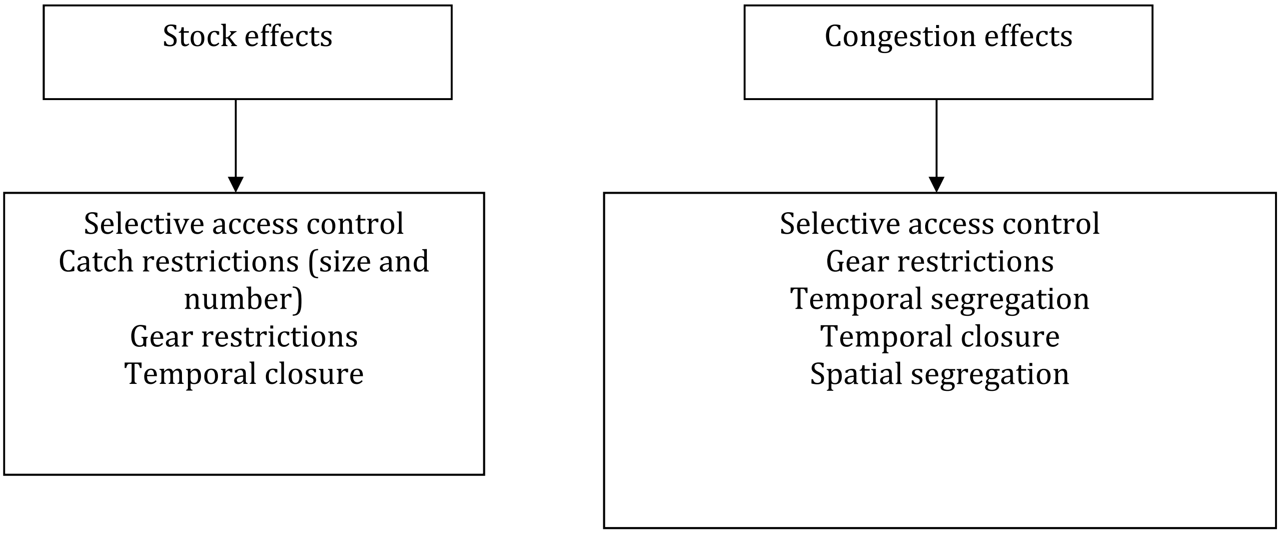
The first four options are applicable where only one habitat exists, while all five strategies are feasible in multiple site environments.

Stock effects can be reduced by regulating harvesting. This can be attained by selective access control, setting catch limits (size and number), by limiting fishing gears and selectivity, and by setting temporal catch limits (temporal closure for fishing).

Congestion effects can be reduced by selective access controls, by gear restrictions, and by temporal or spatial segregation of users.

However, no single management control can be optimal for all situations and the choice of one or more options must be based on an evaluation to determine the nature of the conflicts and the effectiveness of the management options adopted.

The involvement of stakeholders, and especially fishermen (small-scale or recreational fishermen depending on the purposes of the AR) in the AR management is fundamental.~~The involvement of stakeholders, and especially fishermen (small-scale or recreational fishermen depending on the purposes of the AR) in the AR management is fundamental.~~ Applied research is another key element in artificial reef management



programs providing assistance in monitoring the activities carried out at the reef and evaluating the efficacy of the adopted management measures.

Fig. XX. Habitat management controls to reduce users conflicts (adapted from Samples, 1989).

Flexible adaptive management

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