Funded by the European Union
بتمويل من الاتحاد الأوروبي

Management and Monitoring Plan for Artificial Reefs

"This Artificial Reef was built with the financial support of the European Union"

This plan was developed through the project "Promoting marine biodiversity and improving fishery potential and marine ecotourism activities through the deployment of Artificial Reefs off the Lebanese coast" implemented by the Marine and Coastal Resources Program (MCR), Institute of the Environment (IOE), University of Balamand (UOB)

Authors

MANAL NADER, Ph.D. – Director – IOE-UOB

SHADI EL INDARY, M.Sc. – Instructor – MCR-IOE-UOB

RANIM TAHHAN, M.SC. – Research Assistant – MCR-IOE-UOB

Disclaimer

"This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of the University of Balamand and do not necessarily reflect the views of the European Union"

Table of Contents

TABLE OF FIGURES

LIST OF TABLES

Executive summary

The intended purpose of the Artificial Reef (AR) was to enhance the protection and sustainability of maritime resources of the Lebanese coastal zone through the design and deployment of a model AR based on international environmental criteria, and through capacity building and increased community and public awareness. This is a long term goal that could take decades to achieve, and is not always guaranteed to occur. It is therefore necessary to develop criteria and indicators that can be measured to assess progress toward the desired goal.

In order to assess the success of the AR in terms of fulfilling its intended objectives, management measures must be developed and monitoring schemes for species colonization should be conducted. The colonization methodology must be implemented over a minimum period of one year to assess fish assemblages, benthic communities and other species groups covering early settlements.

The reef was deployed in July 2020 in front of the town of Barbara, Mount Lebanon. The gained experience from a previously deployed AR in Al-Aabdeh in 2012 and throughout the phases of the current project offered a benchmark for developing future science-based guidance for the placement of artificial reefs in marine waters. This report provides guidelines for management and monitoring of ARs based on experience gained from the AR2020 project implemented by the Marine and Coastal Resources Program at the Institute of the Environment – University of Balamand (MCR-IOE-UOB).

Introduction

One of the main aims of constructing ARs is usually to create habitats for marine life and increase biodiversity. Other reasons for developing ARs include supporting the fisheries sector and promoting recreational activities such as scuba diving to help the tourism sector (Dubois, 2012; FAO, 2015; Achilleos et al., 2018). ARs provide attachment substrate for habitat-limited sessile invertebrates and algae. This resultant biofouling community in turn supports trophically-related motile invertebrate and fish species, eventually creating a dynamic environment that increases biomass at the site (Hicks et al., 2016). No matter what the reasons are for developing an AR, it is an established fact that as soon as it is created, fish and many other aquatic organisms begin to use it as a habitat for feeding and shelter amongst others (Seaman & Sprague, 1991; D'Itri, 2018; Glarou et al., 2020).

For more than 30 years, the Mediterranean Sea has been a target location for the deployment of many ARs especially by European countries such as France, Germany, Italy and Spain. Previously, such reefs were established locally without national collaboration. However today, most are established with national collaboration and in many cases with international collaboration (Jensen, 2002; Bortone et al., 2011; FAO, 2015).

01 The Action

The Lebanese marine environment is under an increasing series of diverse and complex stresses (natural and anthropogenic) that have led to serious detrimental changes in the health of this ecosystem resulting in habitat destruction and a tremendous decrease in its marine biological resources. One proven positive step towards turning the tide is to create stable and sustaining habitats in the form of human made ARs, based on international environmental criteria. Within this context, the European Union (EU) funded the Marine and Coastal Resources Zone Program - Institute of the Environment, University of Balamand (MCR-IOE-UOB) to implement the “Promoting marine biodiversity and improving fishery potential and marine ecotourism activities through the deployment of ARs off the Lebanese coast (AR2020)” project (Ref.: ENI/2018/395-777). This action aims at enhancing the protection and sustainability of maritime resources of the Lebanese coastal zone through the design and deployment of model ARs, the AR2020, based on international environmental criteria, and through capacity building and increased community and public awareness. The AR was deployed in July 2020 1km off the shore of Barbara, Mount Lebanon (Figure 1). Forty-seven concrete and metallic structures were placed at an average depth of 25m. These structures varied in shape between 12 houses, 15 trees, 15 towers, and five tunnels covering an area of 1225m^2 among which some contain limestone boulders and pottery jars within their concrete bases.

This document has been prepared based on experience gained from two deployed artificial reefs, the Al-Aabdeh Artificial Reef and the current AR2020, with the bulk of the information included based on the latter.

Figure 1.
Location of the Artificial Reef in Barbara, North of Lebanon

02 Aim of the report

The aim of the report is to set scientific methodologies for management and monitoring of AR’s based on activities implemented at the AR2020.

03 Literature Review

To evaluate the success and benefit of any deployed AR, it is fundamental to sustainably manage and monitor the AR to record any changes that occur after deployment. There are various methodologies for reef evaluation but the choice of which methodology to use depends on the study area and the objective of the study. Monitoring programs should be part of management plans aimed to ensure that the AR is sustainably managed and that its operation does not have negative impacts on the marine environment and surrounding fish communities (FAO, 2015).

A Management plans

ARs may require post-installation management to make sure that they provide the desired outcomes for both biological resources and users. Additionally, effective management can help reduce potential risks such as damage to fishing gear, injuries to recreational divers visiting the reef, decomposed materials or movement of the reef units off-site. The objectives of management plans are to ensure that the AR is sustainably managed and that its operation does not have a significant impact on the marine environment or surrounding society. The management plan should therefore guarantee that the commitments made in pre-planning assessments (such as environmental assessments) and any approval or license conditions are fully implemented. These plans should clearly cover sub-management plans, research and monitoring programs, and protocols that address any identified potential environmental impact (Bortone et al., 2011; FAO, 2015) and should be developed using participatory approaches.

B Monitoring Colonization

Specialized scientific methods are required to quantitatively assess and monitor habitats to determine if objectives of the deployment of the AR are being met. Assessments that are not goal-oriented can be costly in view of expenses for personnel and operating costs. Further, poorly designed studies can provide misleading and irrelevant information that may lead to inaccurate conclusions (Seaman & Sprague, 1991) and undermine the obvious benefits of the AR.

1. Fish Assemblages and Motile Species by UVC

In colonization studies of ARs, two broad categories of sampling techniques have been used for studying fish assemblages::

a. Capture Methods

Capture methods involve removal of the fish or aquatic organisms from the marine environment and mainly include:

- Trapping.
- Trawling/Netting (using gill, trammel, drift nets or trawls).
- Hook and Line (using drop-lines, long-lines or handlines).
- The use of explosives or icthyocides (such as rotenone or clove oil).

It is recommended to avoid using capture methods since they rely on removing the organisms (killing) and are therefore considered destructive as they may cause irreversible damage to the aquatic ecosystem. For example, capture methods are prohibited in Marine Protected Areas (MPA) due to such reasons (Bodilis et al., 2011; Hicks et al., 2016). .

b. Observational Methods

Observational methods involve the observation of the fish or aquatic organism in the marine environment itself (in situ) (Watson, 2004). They are relatively rapid, provide adequate levels of replication and at the same time provide a wide range of variables such as relative abundance, density, size structure and species composition (Michael Lowry, 2012; Hicks et al., 2016; Zarco-Perello, & Enríquez, 2019). Unlike capture methods, observational methods are non-destructive and are therefore more preferable for studies on fish assemblages especially in MPAs making them extremely adequate for monitoring ARs. The following are the main observational methods used today (Hicks et al., 2016; Zarco-Perello, & Enríquez, 2019):

- Hydro-acoustics: mainly used in studying and locating fish aggregations for ARs intended to help fisheries. They involve the detection of acoustic signals produced by different motile species in the study area.
- Video cameras: with the advancement of technology, the use of video cameras underwater to capture footage of the motile species colonizing the reef is becoming more widespread. Cameras can be used by divers or remotely operated underwater vehicles (ROVs) allowing the collection of footage of the different species in the study area. The footage would then be reviewed in laboratories which would minimize the chance of missing or misidentifying some individuals, and would provide a better algorithm for the determination of dimensions of recorded organisms.
- Underwater Visual Census (UVC): involves the use of scuba diving to survey motile species distribution and is the most popular method for studying the distribution of motile species assemblages and the most recommended. Many studies of colonization on ARs have been conducted through surveys with scuba equipment (Herrera, 2002; Thanapoulou et al., 2018). There are various different UVC techniques used to survey motile species populations *(Table 1)*. Some examples are:
  - Strip transect.
  - Stationary point count.
  - Line transect.
  - Interval Counts (or Rapid Visual Censuses).
  - UVC with audio and/or visual devices.

Table 1: UVC Sampling Techniques

UVC sampling technique	Description of method
Strip transect	The strip transect method involves a diver swimming along lanes (usually marked with measuring tape, lines or fixed stakes) while recording the number, size and sometimes position or activity of the motile species.
Stationary point count	Diver counts motile species in a circular space up to 10m distance from a stationary point for a duration of 5-10 minutes.
Line transect	A diver records information on the sighting angle and the distance of individual motile organism from themselves allowing for calculation of the perpendicular distance between the subject and the line. Length is its only dimension.
Interval counts (or Rapid Visual Censuses)	Also known as "timed scuba swims" where a diver records all fish seen while swimming for a specified time. Often area is not known.
Audiotape	A diver records fish observed on an underwater tape recorder.
Audiotape + video	Using a stereo-video set-up, divers can record the motile species of the region on tape and collect acoustic data while moving through the specified transect. This may be done with two divers, one operating the video positioned behind and below while the other would be collecting audio observation.

However, among all these, the strip transect method is the most commonly used UVC sampling technique. The ease and efficiency associated with conducting strip transects has played a role in promoting their widespread application.

2. Benthic Communities

a. Non-destructive methods:

Two commonly used non-destructive methods in the Mediterranean Sea to study benthic communities are "visual inventory quadrats" and "still photography". In "visual inventory quadrats" the diver observes and identifies the various organisms found within the limits of a defined quadrat whereas in "still photography", a photograph is taken of these organisms. There are many advantages and disadvantages associated with each of these two methods. "Still photography" provides permanent records, allows software image analyses, reduces the time spent underwater and does not require divers with a lot of experience in species identification as organism are identified in the laboratory. However, the analysis of images is very time consuming, and may depend on the quality of the photos. Visual inventories on the other hand through the "visual inventory quadrats" technique require longer underwater time, need divers skilled with species identification and may be more affected by observer subjectivity (Sheehan et al., 2010; Jimenez et al., 2017). Nonetheless, this method is insufficient when dealing with sessile organisms, those that attach themselves to substrates. These species, like some bivalves, and algae cannot be identified with visual observation alone, they require scientific approaches that demand a more intrusive approach collecting the individuals for in-lab classification, therefore destructive methods need to be applied. .

b. Destructive methods

Simple random sampling is the most basic form of sampling, and is considered an effective method for sampling populations. A systematic series of dives held by a group of two divers can collect a few samples per morphospecies to minimize environmental impact and identify some other species on site (sponges, corals, echinoderms, …). The samples are later sorted in the laboratory and classified into functional groups with the aid of a stereomicroscope and relevant bibliography or sent to specialists. This technique is commonly employed to sample hard-bottom communities (animals and algae) but it may require a greater effort by divers. In addition, part of the sample is likely to be lost, especially small-sized organisms, due to underwater currents (Lira et al., 2010; FAO, 2015; Achilleos et al., 2018; Noble-James et al., 2018).

04 Management of the Artificial Reef

An adequate management plan should be developed for an AR. Physical, biological and socio-economic monitoring are key elements of the management plan as it allows assessing the structural performance of the AR over time and whether the AR provides the expected benefits. The involvement of stakeholders in AR management is crucial. Professional and recreational fishers as well as divers can provide support in reef monitoring and evaluation. Applied research is another key element in AR management programs because it provides assistance in monitoring the activities carried out at the reef, in evaluating the efficacy of the adopted management measures and, where necessary, in identifying actions to be undertaken as well as alternative management options.

A Environmental considerations

Management plans must emphasize the importance of continuous monitoring activities of species. Such activities are usually held by experienced marine scientists and may be challenging where no funds are available. Nevertheless, and according to Haklay et al. 2021, "Citizen Based Science", a recent concept is being promoted as an alternative to costly monitoring activities. "Citizen Based Science" is defined as "the practice of public participation and collaboration in scientific research to increase scientific knowledge". Such concept bridges the gap between scientists and the wider public or users of the AR, thus people can share and contribute to data monitoring and collection programs (Haklay et al., 2021).

As an AR is usually deployed for multipurpose functions, its access cannot be prohibited to any kind of activity. Nevertheless, technical measures must be established to regulate access and exploitation at the reef site. Unregulated access may lead to overexploitation and to a rapid depletion of reef resources as well as to conflicts within and between user groups. This usually happens when

ARs are created by public agencies in public waters without effective restrictions regarding access by different user groups or where there is a lack of control to assure that the restrictions are respected (FAO, 2015).

B Socioeconomic considerations

The fisheries sector in Lebanon is an artisanal small scale sector where most of the fishing effort occurs in relatively shallow waters and is fairly regulated by the Ministry of Agriculture. On the other hand, recreational fishery is not clearly regulated nor monitored. These regulations are limited to: :

- Rod and line: with a maximum of two hooks per rod.
- Underwater fishing for amateurs with spear-guns without the use of scuba gear.
- Riverine fishing.

ARs are usually accessed by artisanal commercial fishing vessels from nearby ports due to trip expenditures that are attributed to the action of fishing (tackle, bait, loss of fishing gear, travel, boat fuel,...). As for recreational fishing vessels, they may access the reef from distant ports while still contributing to the blue economy sectors through purchasing fishing gear, dining on shore, and by participating in other leisure activities thereby benefiting to the local economy of coastal communities.

As previously mentioned, ARs can be aggregating spots for various marine organisms which would create a site of intrigue to people from different parts of the country and the world to participate in the different recreational activities that might be offered. Such reefs would promote ecotourism by creating new diving sites increasing the number of customers of diving clubs therefor imparting a stronger socio-economic vantage to marine ecotourism sectors.

C Safety considerations

These usually include simple actions, such as indicating the reef's location on nautical charts in order to avoid damages to navigating ships and to providing user guidelines (e.g. diver best practices) to prevent injuries to people diving at the AR or any other safety considerations specifically related to the area of deployment or to the site itself.

For all the above considerations, several overlapping basic options can be identified for AR management:

1. Selective access control: it may consist in the establishment of property or user rights whereby local fisher communities or recreational associations (recreational fishing service providers, scuba diving clubs, ...) would be co-responsible with government agencies for regulating access and monitoring both the activities which are carried out at the AR and the physical performance of the reef structures (Lindberg, 2011; FAO, 2015)..

2. Gear and catch restrictions:

   This measure is applied to manage and control the various methods used for harvesting resources at the AR by enforcing rules that specify approved fishing gear to allow optimal fishing yields and avoid disruption of the natural succession of ARs species and associated assemblages (FAO, 2015; NSW, 2021).

3. Temporal closure: it can be adopted to avoid the exploitation of AR resources in particular seasons of the year, for example to favor the reproduction and/or the early growth of juveniles at the reef (FAO, 2015; NSW, 2021).
4. Temporal segregation of users: aims at separating user groups allocating specific periods of time when each group is permitted access.

However, no single management control approach 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. In this case, a participatory approach involving all stakeholders like fishers (small-scale or recreational fishers), recreational divers, research bodies and public institutions in AR management is fundamental.

05 Monitoring Methodology of the Artificial Reef

Monitoring programs are usually designed by teams with appropriate marine science background in collaboration with all stakeholders (fishers, diving community, public authorities...). The program can be designed to be highly cost effective through the pooling of resources and will produce a sense of ownership and empowerment for managing the AR. On the other hand, and as a result of species community succession processes, the monitoring focus is likely to change over time as the AR community develops, thus the program requires continuous updates by experts. Accordingly, the monitoring methodologies applied are divided into two main methods; pre and post deployment techniques.

A Pre deployment monitoring

One of the first steps is to review available bathymetric and topographic maps to identify potential sites for evaluation for AR deployment based on scientific criteria like water depth, flat seafloor, distance from pollution sources, distance from main urban areas, distance from river estuaries, and distance from navigational routes (for proper siting of an AR, please refer to the "Replicability Guidelines and Methodological Approaches for ARs in Lebanon" http://www.balamand.edu.lb/IOE/ArtificialReef/). Pre-deployment monitoring usually involves:

- Bathymetrical surveys: Acoustic systems ***(Figure 2)*** provide a detailed bathymetric chart of the sea floor ***(Figure 3)*** , whereas dives and remotely operated vehicle inspections provide visual representation of the natural environment in the selected area. The appropriate methodology using the most recent advances in the field should be selected and applied to meet set objectives. Such surveys should result in a detailed description of the characteristics of the sea floor within the proposed reef deployment area, highlighting the presence of suitable flat areas at suitable depths. Flat areas are important to prevent the units from sliding due to sloping sea bottoms, while clearance depth over the AR post deployment should be > 20 m to avoid creating a navigational hazard for ships.

Figure 2.
(a) ELAC Hydrostar 4300 Single Beam Echo Sounder
(b) Bathymetrical survey of the seafloor. (Source: MCR-IOE-UOB)

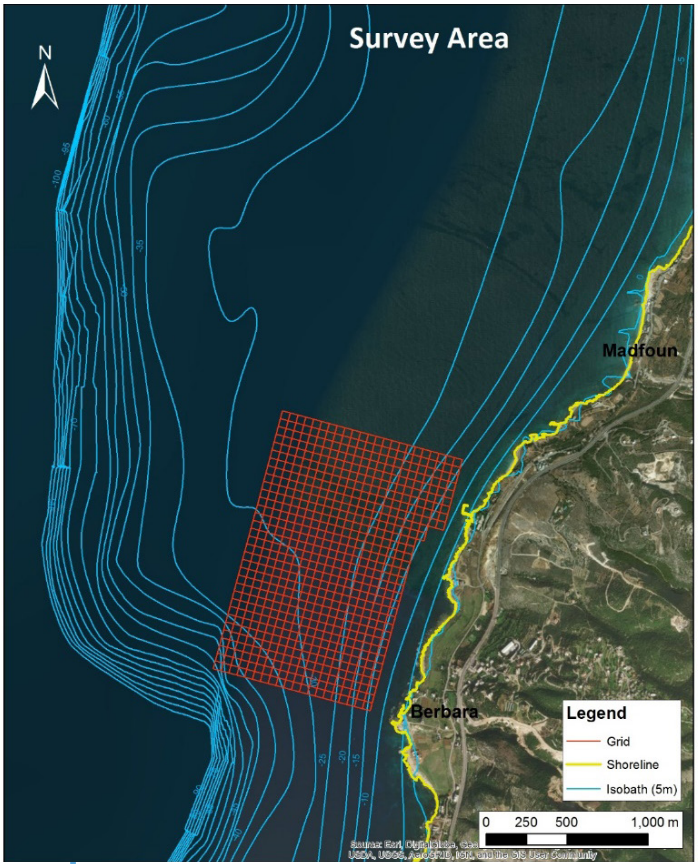

Figure 3.
Surveying grid of 50x50m. (Source: MCR-IOE-UOB)

- Granulometry: Sediment types found on the seafloor are essential and may be used as an indicator of wave action and water movement, especially that ARs are known to scour the sea bottom with units ending up being buried. Knowledge of grain size distribution is a variable required for site selection. As a rule of thumb, the larger the grain size, the higher the energy needed to transport it. Relatively high energy environments are suitable for ARs due to the continuous mixing of nutrients in the water column. Such positive factors though should be weighed against wave action that may displace or even destroy the units. The appropriate methodology using the most recent advances in the field should be selected and applied to meet set objectives.

- Hydrometric description of the water column: Certain parameters are essential for the optimal productivity at ARs. For example, depth and turbidity affect light penetration into the water, thus influencing the colonization of artificial substrates by algae and other photophylous organisms. This can in turn affect the fish assemblage that will inhabit the reef. On-site, continuous readings of physical parameters (preferably for a full year) using an advanced, accurate hydrometer ***(Figure 4)*** should be undertaken for the following, but limited to: water parameters (Temperature (°C), conductivity (mS), Salinity (SAL), Dissolved Oxygen (DO), Total Dissolved Solids (TDS, g/l), Total Suspended Solids (TSS, g/l), Water density (g/l), pH, and Turbidity (NTU)).

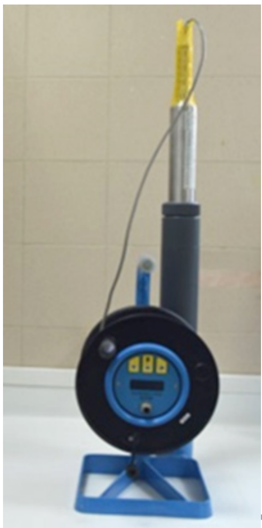

Figure 4.
SEBA KLLQ2 device.
(Source: MCR-IOE-UOB)

- Current and wave profiles: Reef structures alter currents differently in deep waters. As water driven by currents flows into vertical reef surfaces, it veers upward creating localized upwelling, mixing nutrient-rich bottom water with less rich but more biologically active surface layers. The exchange of surface and bottom water takes a fresh food supply down to filter-feeders and other reef inhabitants. It also takes highly oxygenated surface water to the bottom (Lindberg and Seaman, 2011). Even though currents are essential to carry nutrients onto the AR, very strong currents may not be desirable if one of the aims is to provide recreational diving opportunities.

  Regarding waves, areas of consistently high wave energy may not be suitable as AR deployment sites. High wave energy will decrease the durability and stability of AR material due to constant exposure to wave surge. The wave-energy may also limit the settlement potential of sessile organisms if water is too turbulent.

  Currents and wave profiles are usually described through the deployment of acoustic wave and current profilers in the potential deployment site (*Figure 5*) for at least a period of 12 months to capture seasonal variations. Results, especially wave profiles, will provide essential information on site suitability and the type of structure to be deployed.

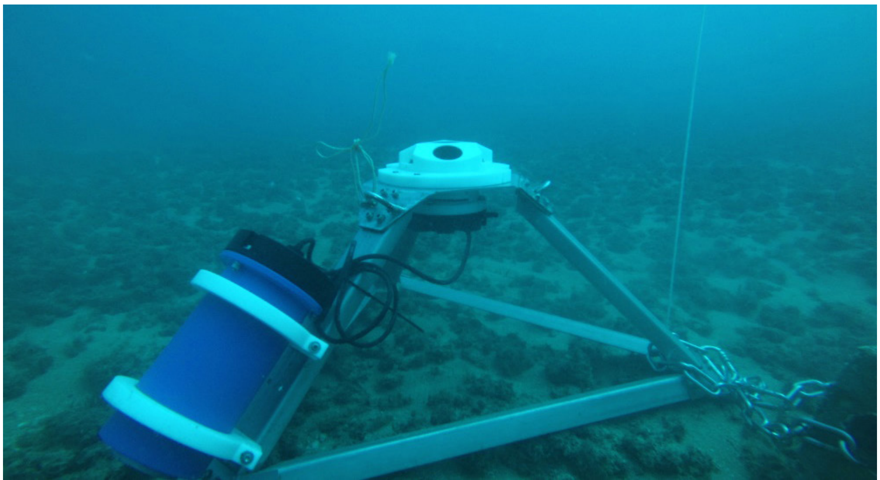

Figure 5.
Accoustic Wave and Current Profiler (AWAC). (Source: MCR-IOE-UOB)

- Biodiversity assessment/species richness: The appropriate methodology using the most recent advances in the field should be selected and applied to meet set objectives. The method nevertheless should foresee diving missions to assess biodiversity over a period of at least 12 months to capture to the extent possible seasonal variation. Such missions also report on any existing archeological remains, artifacts or shipwrecks that may be of high cultural value.

  Supported by video footage and photographs, scientific divers usually collect specimens and document both benthic and motile species observed in the study area. Main variables recorded for motile species include name, count, and size. Sessile species are usually scrapped, collected and preserved for identification in the laboratory. Such information is essential as a baseline for future comparison with biodiversity/species richness data to evaluate the success of the AR post-deployment.

B Post deployment monitoring

Deployment site

Once the AR has been deployed in the selected site, a detailed map with coordinates for the AR and for each deployed unit should be generated *(Figure 6)*. Such a map will facilitate the planning and undertaking of all set activities ranging from scientific assessment, to commercial and recreational fishing to scuba diving.

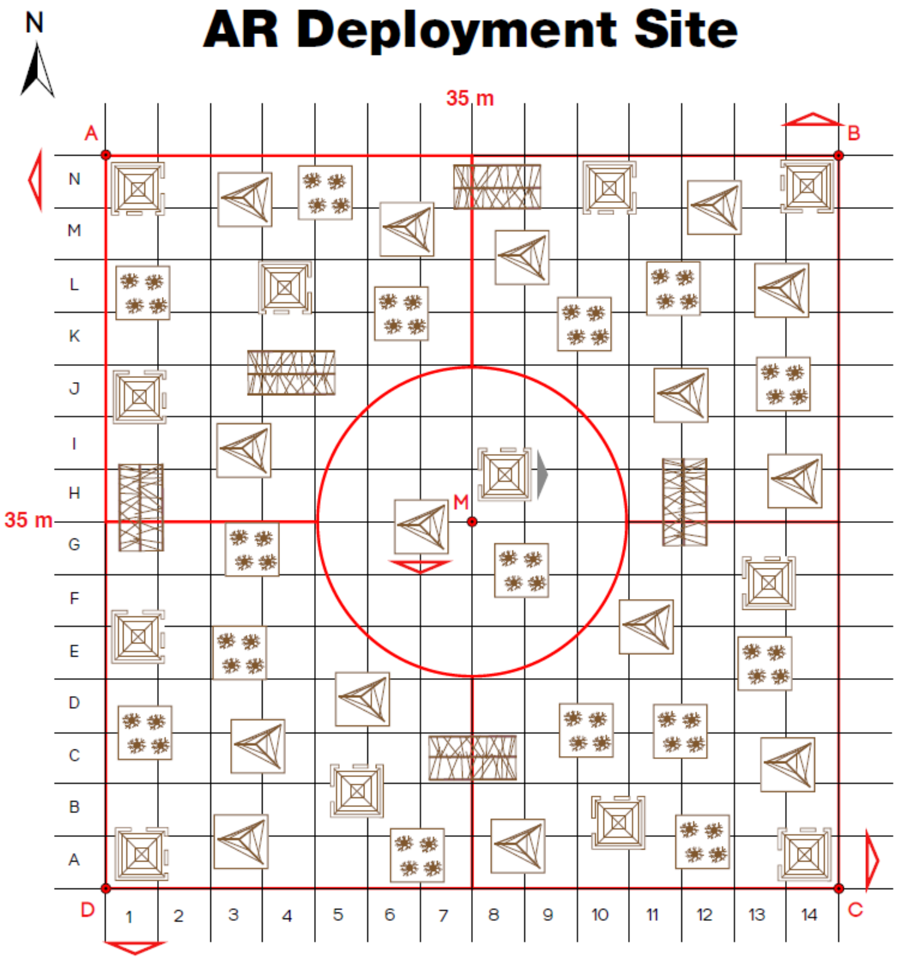

Figure 6.
Artificial reef design.
(Source: MCR-IOE-UOB)

Monitoring the colonization of motile species assemblages

The methodology applied for monitoring during the pre-deployment is usually not suitable for post deployment since organisms are exposed to different sets of sea floor morphology and substrate types (vertical structures, cement, metal, etc...). Accordingly, the appropriate methodology using the most recent advances in the field should be selected and applied to meet set objectives.

Nevertheless, surveys should be carried out at least over a period of 12 months to capture to the extent possible seasonal variation. As previously discussed, the UVC is the most adopted with improvements continuously being introduced (Ribeiro et al., 2006; Harmelin, 1987; SPA/RAC–UN Environment/MAP, 2017; *Figure 7*). In brief, divers estimate the number and size of all observed individuals and record information on pre-organized slates that include the most common and expected species.

Figure 7.
Fish count by divers. (Source: MCR-IOE-UOB)

Figure 8.
Benthic species sampling. (Source: MCR-IOE-UOB)

Monitoring the colonization of benthic communities

The appropriate methodology using the most recent advances in the field should be selected and applied to meet set objectives. Surveys should be carried out at least over a period of 12 months to capture to the extent possible seasonal variation. Several methods may be implemented to investigate benthic communities, most of which involve scraping organisms attached to selected surfaces (i.e. concrete, metal,...; *Figure 8*). Samples are collected in labeled plastic bags with sea water and placed in coolers containing ice to be identified in the laboratory to the lowest taxonomic level.

06 Expected challenges

The main expected challenges for monitoring colonization of ARs may include but are not limited to the following:

- Weather conditions might limit ability to carry-out missions at sea as weather reports are usually extremely inaccurate.
- Underwater visibility may hamper the successful implementation of the monitoring methodology.
- Limitations and biases associated with scuba diving and scuba divers. The magnitude of these challenges depends on the diver's experience, speed, ability to differentiate between various marine species and ability to notice marine species during underwater observations.
- During scraping, part of the sample is likely to be lost, especially small-sized organisms, due to suspension and underwater currents.
- Identification of sessile species to the lowest taxonomic level may prove extremely challenging given their complexity.
- Equipment and gear malfunction may force the mission to be aborted.

References

Achilleos, K., Patsalidou, M., Jimenez, C., Kamidis, N., Georgiou, A., Petrou, A. & Kallianiotis, A. (2018). Epibenthic Communities on Artificial Reefs in Greece, Mediterranean Sea. Water 2018, 10, 347; doi:10.3390/w10040347.

Bodilis, P., Seytre, C., Charbonnel, E. & Francour, P. (2011). Monitoring of the Artificial Reef Fish Assemblages of Golfe Juan Marine Protected Area (France, North-Western Mediterranean). Brazilian Journal of Oceanography. 59(spe1):167-176 DOI: 10.1590/S1679-87592011000300018

Bortone, S., Brandini, F., Fabi, G. & Otake, S. (2011). Artificial Reefs in Fisheries Management. CRC Press.

D'Itri, M. (2018). Artificial Reefs: Marine and Freshwater Applications. CRC Press.

Dubois, M., Bellan-Santini, D., Bentahar, I., Chevaldonne, P., Perez, T., Vacelet, J. & Bellan, G. (2012). Artificial reefs deployed in the bay of Marseilles : (nord-western Mediterranean Sea): originality and first benthic faunal stages. Biologia Marina 19(1):200-201.

FAO. (2015). Practical guidelines for the use of artificial reefs in the Mediterranean and the Black Sea, by Gianna Fabi, Giuseppe Scarcella, Alessandra Spagnolo, Stephen A. Bortone, Eric Charbonnel, Juan J. Goutayer, Naoufel Haddad, Altan Lök, and Michel Trommelen. Studies and Reviews. General Fisheries Commission for the Mediterranean. No. 96. Rome, Italy.

Haklay M.., Dörler D., Heigl F., Manzoni M., Hecker S. & Vohland K. (2021) What Is Citizen Science? The Challenges of Definition. In: Vohland K. et al. (eds) The Science of Citizen Science. Springer, Cham. https://doi.org/10.1007/978-3-030-58278-4_2.

Jensen, A. (2002). Artificial reefs of Europe: perspective and future. Journal of Marine Science.

Jimenez C, Andreou V, Evriviadou M, Munkes B, Hadjioannou L, Petrou A, et al. (2017) Epibenthic communities associated with unintentional artificial reefs (modern shipwrecks) under contrasting regimes of nutrients in the Levantine Sea (Cyprus and Lebanon). PLoS ONE 12(8): e0182486. https://doi.org/10.1371/journal. pone.0182486.

Lelli, S. (2017). Contribution to a better knowledge of biology, distribution and diversity of demersal species along the Lebanese coast, eastern Mediterranean: a focus on Lessepsian fish species. Ocean, Atmosphere. Université de Perpignan, 2017. English. NNT : 2017PERP0051.

Lindberg, W.J. & Seaman, W. (editors). (2011). Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida. Florida Department of Environmental Protection. Miami, FL. xi and 150 pages.

Lira, S.M.A., Farrapeira, C.M.R., Amaral, F.M.D. & Ramos, C.A.C. (2010). Sessile and sedentary macrofauna from the Pirapama Shipwreck, Pernambuco, Brazil. Biota Neotrop. 10(4): http://www.biotaneotropica.org.br/v10n4/en/abstract?article+bn03310042010.

Michael Lowry, H. F. (2012). Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. Journal of Experimental Marine Biology and Ecology.

Noble-James, T., Jesus, A. & McBreen, F. 2018. Monitoring guidance for marine benthic habitats (Revised 2018). JNCC Report No. 598. JNCC, Peterborough.

NSW. (2021). Long Term Management Plan - Batemans offshore artificial reef. www.dpi.nsw.gov.au Papadopoulou KN, M. V. (2011). Options for Delivering Ecosystem-based Marine Management. Retrieved 12 22, 2012, from www.liv.ac.uk: http://www.liv.ac.uk/media/livacuk/odemm/images/Mediterranean_Sea_Background.pdf

Seaman, W., & Sprague, L. (1991). Artificial Habitats for Marine and Freshwater Fisheries. Academic Press, Inc.

Funded by the European Union

بتمويل من الاتحاد الأوروبي

Institute of the Environment - University of Balamand

'This Artificial Reef was built with the financial support of the European Union'

www.balamand.edu.lb