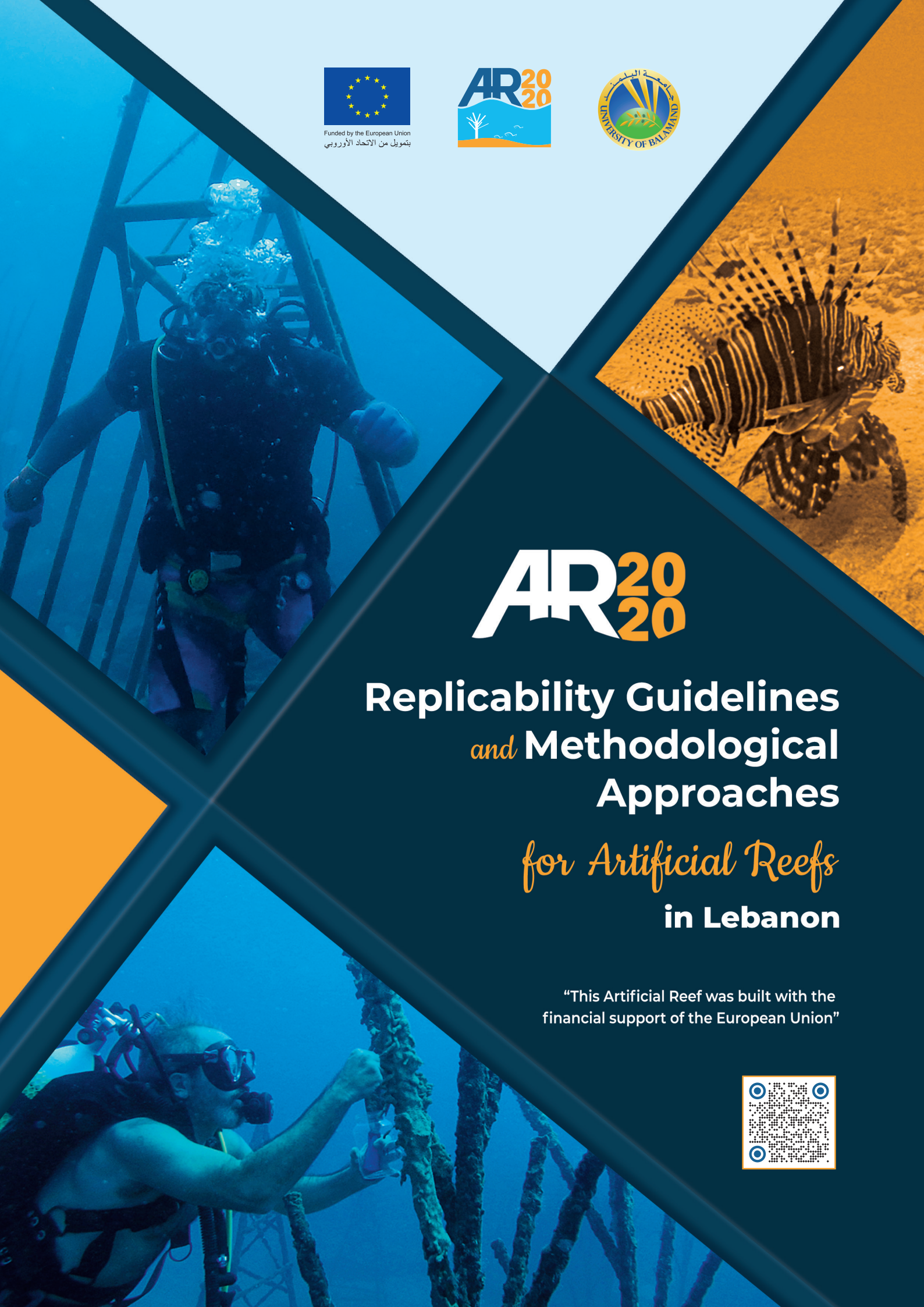

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Replicability Guidelines and Methodological Approaches for Artificial Reefs in Lebanon

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

“This guide 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

RAWAN EL JAMAL, B. Sc. – Research Assistant – MCR-IOE-UOB

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AR: Artificial Reef
MCR: Marine and coastal resources program
IOE: Institute of the Environment
UOB: University of Balamand
TORs: Terms of References
MPA: Marine Protected Area
FAO: Food and Agriculture Organization of the United Nations
PCB: Polychlorinated Biphenyl
FRP: Fiberglass reinforced plastic
PVC: Polyvinyl chloride
Ppm: Parts per million
LAF: Lebanese Army Forces
MOE: Ministry of Environment
MOPWT: Ministry of Public Works and Transport
FON: Friends of Nature
NGO: Non-governmental organization
EU: European Union
EIA: Environmental Impact Assessments
MOD: Ministry of Defense
MIM: Ministry of Interior and Municipalities
MOT: Ministry of Tourism
ISF: International Security Forces

Executive Summary

The Eastern Mediterranean region has been subjected to many anthropogenic threats for a long time ranging from pollution to significant decrease in fish stocks, to an unstable blue economy. These threats that have led to fundamental alterations in its natural environment resulting in habitat destruction and a tremendous decrease in marine biological resources. One of the proven means to remedy such risks is the deployment of Artificial Reefs (AR) as they have been recorded to improve the state of marine coastal environments from both ecological and socio-economic perspectives. This document has been developed to share the knowledge gained by the Institute of the Environment, University of Balamand from the AR deployed in Al-Aabdeh, North Lebanon in 2012 and the current AR2020 deployed off the coast of Al-Berbara village in Mount Lebanon therefore providing a roadmap for the replication of such initiatives in Lebanon in the future.

After providing an overview of definitions, objectives and functions of ARs, this document highlights the different steps required to successfully deploy an AR in Lebanon. This includes background research, understanding of the most recent technologies applied for AR site selection, construction material and unit design, legislation and permitting requirements, procurement and commissioning, monitoring, assessment and management, capacity building, and finally importance of awareness raising to target groups and beneficiaries.

Introduction

The Lebanese marine ecosystem is a host for many faunal species with commercial importance. This ecosystem has come under an increasing series of diverse and complex stresses (natural and anthropogenic) that have led to serious detrimental changes in its natural environment resulting in habitat destruction and a tremendous decrease in marine biological resources. One proven positive step towards turning the tide is to create stable and sustainable habitats in the form of Artificial Reefs (ARs). ARs support marine life in areas where there is a lack of stable substrate and provide an added value to fisheries, ecotourism and education. In addition, ARs create suitable shelters and feeding and spawning habitats for marine organisms enhancing fishing success in addition to providing scuba-diving attractions. Within this context, the Marine and Coastal Resources Program, at the Institute of the Environment, University of Balamand (MCR- IOE- UOB), deployed the AR2020 in the coastal waters of Al-Berbara village at an average depth of 25m on an area over 1225m^2 ***(Figure 1)***. AR2020 consists of 47 concrete and metallic structures populated with limestone boulders, and pottery jars including 12 houses, 15 trees, 15 towers and 15 tunnels ***(Annex 1: Drawings of the AR2020 units)***. In addition to the permitting process, the approach of deploying the Reef was based on an extensive bibliographic search where the most recent methodologies were adopted for site selection, development of the Terms of References (TORs), evaluation of offers and contract awards, design and construction, transport and deployment, pre and post-deployment assessment and finally capacity building and awareness raising activities (http://www.balamand.edu.lb/IOE/ArtificialReef/).

The current document aims at providing general guidelines for the establishment of ARs based on field practices and experience gained. It also provides insights in overcoming challenges and highlights the importance and the best means to disseminate scientific approaches and results and to raise awareness about ARs at all levels.

Figure 1. AR2020 location (Source: MCR-IOE-UOB)

01 Artificial reefs

1 Definition and objectives

ARs are man-made or natural structures deployed in specific areas of aquatic environments to mimic some of the functions of natural reefs. They serve many purposes from protecting sensitive habitats, thus enhancing marine populations, to supporting fisheries, to establishing new scuba-diving locations amongst many other objectives therefore creating new opportunities to strengthen blue economy sectors.

2 Functions

ARs are widely distributed around the world and have been adopted as an effective mean to mitigate ecological challenges, protect and help the propagation of biodiversity and enhance coastal economies. In the Mediterranean, more than 15 countries have deployed ARs to protect and enhance the propagation of marine biodiversity and to support their blue economies. The Food and Agriculture Organization of the United Nations (FAO) identified five main types of ARs with each serving a certain purpose and are thus distinguished according to their function:

i. Protection Artificial Reefs

Deployed to protect marine resources and fisheries from illegal fishing techniques such as trawling that can damage both aquatic habitats and related resources.

ii. Production Artificial Reefs

Deployed to increase the productivity of the marine environment thus the availability of biological resources for human consumption, and to promote the sustainable utilization of such resources.

iii. Recreational Artificial Reefs

Deployed to attract tourists by creating sites for recreational fishing and diving.

iv. Restoration Artificial Reefs

Deployed for the recovery of degraded habitats and ecosystems and to compensate the loss of ecologically important habitats caused by anthropogenic activities.

v. Multi-purpose Artificial Reefs

Deployed to achieve more than one purpose therefore ensuring maximum benefit both on ecosystem and socio-economic levels. However, one artificial reef cannot combine all the functions described above. The most common combination of functions used for multipurpose ARs in the Mediterranean Sea is the protection and production functions.

02 Construction Materials

The type of material chosen for the construction of structures for ARs play essential roles in their success. Unit construction material can range from structures of opportunity (waste objects like old ships, aircraft, train carriages...) to very complex structures made of several different materials designed to create three dimensional environments providing large surface areas for organisms to attach (combination of metal, concrete, pottery jars, boulders...) *(Figure 2).* Depending on availability, cost and reef objectives, the type of material should be chosen. Regardless, all AR material should be devoid of any type of pollutants and should resist to the maximum extent possible the chemical and physical forces that are constantly acting in marine waters.

Figure 2. AR2020 units under construction (Source: MCR-IOE-UOB)

Even though many material types were used for constructing artificial reefs, concrete, metals and plastics dominate. It is highly recommended to avoid any material for construction of the units that are not mentioned in this report.

1 Steel and Metal

One of the main advantages of steel and metal is the possibility to develop large, complex prefabricated units therefore providing large surface areas for the attachment of organisms. It is highly recommended that scrap metal be used for the construction of AR units according to national environmental criteria as not to pollute marine waters. Metallic material should exclude aluminum, painted metal, galvanized products and any objects covered with polychlorinated biphenyls (PCBs) since they can accumulate and persist in the environment eventually becoming toxic to organisms. Regarding stability of the units, the weight of the units should be at least twice the specific gravity of seawater.

2 Vessels

Due to their high vertical profile, vessels (commercial and military) attract species from different depth of the water column when deployed as ARs. Capability of vessels to create upwelling conditions and alter current direction and speed as well as reduce wave impacts makes them attractive to fish schooling. In the case of vessels, and since they contain PCBs, lead in paints and in ballast in addition to other contaminants and hazardous wastes, the permitted levels of pollutants to be released in marine waters should be adhered to according to national rules and regulations. Petroleum products need to be carefully cleaned from ships prior to deployment.

3 Military Hardware

Occasionally, military hardware may be available for deployment as ARs. Usually, such units are obsolete, multi-ton, mobile, armored equipment of high durability and stability. As for vessels, they should be cleaned of contaminants. Military hardware equipment is typically of high quality and outlasts most artificial reef material as they are constructed of heavy gauge steel, extremely durable, very heavy, and, therefore, expected to be stable on the ocean bottom, even under severe weather conditions. They tend to be colonized in very short periods of time and to provide suitable habitats.

4 Concrete

Concrete materials are extremely compatible with the marine environment, highly durable, stable, and readily available. Furthermore, the capability to cast concrete into a great variety of forms makes the material ideal for developing prefabricated units. In addition, concrete provides excellent surfaces and habitats for the settlement and growth of encrusting or fouling organisms, which in turn provide forage and refuge for other invertebrates and fish. Concrete slabs can be populated limestone boulders and pottery jars and other material that help meet the objectives of the reef. For example, boulders provide larger and rougher surface areas for colonization while pottery jars provide habitats for species like octopus and lobsters. It is nevertheless highly recommended to use reinforced concrete mix certified for marine environments to ensure durability of the structures Cement types II-V are resistant to the sulfates and other chemicals in sea water which can attack and break down concrete made with Type I concrete. *(Table 1)*

Table 1: AR2020 concrete characteristics (Source: MCR-IOE-UOB)

High Sulfate Resistant Portland Cement (Grade V); British Standard BS 5328
Water/Cement ≤ 0.45
Minimum Resistance 35 MPa (C35)
Nominal reinforcement cover greater than 35mm

5 Rocks and pottery jars

Rocks can be scattered on the seabed, deployed in disordered piles or assembled inside frames that are made of steel, iron, plastic or wood. Additionally, limestone boulders and pottery jars can be added to concrete slab foundations.

Finally, it is important to highlight that it is necessary to supervise construction work in order to ensure the proper execution of designs and the proper usage of materials, thus work supervision based on the TORs should be a main component of all awarded contracts.

03 Artificial Reef Legislation

To date, no specific regulations govern the deployment of ARs in Lebanon. However, a permit from the Ministry of Public Works and Transport (MOPWT) is required for conducting research and/or the use of the maritime public domain. Approval is then sent to the Ministry of Interior and Municipalities (MOIM), that in turn informs the Coastal Brigade of the Internal Security Forces (ISF) to allow the beginning of works and to oversee the proper adherence to the permits. Coordination is also highly recommended with the Lebanese Navy of the Lebanese Army Forces (LAF) and the Ministries of Environment (MOE) and Agriculture (MOA). Nevertheless, AR deployment is covered by several international laws and conventions:

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, which does not include Lebanon as a signatory party. Map of Parties 2022.pdf (imo.org)
- United Nations Convention on the Law of the Sea, where Lebanon is a signatory. United Nations Convention on the Law of the Sea (imo.org)
- Convention on the Protection of the Black Sea against Pollution, which Lebanon does not take a part in. Commission on the Protection of the Black Sea Against Pollution (blacksea-commission.org)
- Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, where Lebanon is a contracting party. Barcelona Convention - Marine - Environment - European Commission (europa.eu)
- FAO Code of Conduct for Responsible Fisheries where Lebanon abides by its principles and standard behaviors. Code of Conduct for Responsible Fisheries | Illegal, Unreported and Unregulated (IUU) fishing | Food and Agriculture Organization of the United Nations (fao.org)

04 Standard practice for the establishment of Artificial Reefs

From the experience gained by the MCR-IOE-UOB from establishing Al- Aabdeh and the AR2020 reefs, deploying an AR includes several generic phases with specificities for the country of Lebanon that can be summarized in the following: background research, understanding of the most recent technologies applied for AR site selection, construction material and unit design, permitting, procurement and commissioning, monitoring, assessment and management, capacity building, and finally awareness raising to target groups and beneficiaries.

Before launching activities for the deployment of an AR, it is imperative to secure the support of the MOTPW either by inviting them to be full partners or at least supporters of the project.

1 Literature review

In order to deploy a successful AR, all information must be acquired and analyzed to benefit from new techniques and information to ensure the success of the project. Such review should include, but is not limited to knowledge on the type of reef to be established, successful case studies, scientific advances and monitoring plans (pre and post), new structural designs, and deployment techniques. Most importantly, constant review of legislative requirements should be carried-out in

order to adhere to applicable laws. Failure to comply with enacted legislation will lead to halting the project. As previously stated, there are no specific laws in Lebanon that specifically regulate the establishment of ARs except legislation related to the occupation of maritime domain that falls under the mandate of the MOPWT.

2 Preliminary Site identification and adoption

For preliminary site identification, the potential deployment site *(Figure 3)* should be evaluated in-house according to information acquired through the Literature Review and available:

- Bathymetric maps showing sea bottoms, slope, habitat types and sedimentation rates where muddy bottoms in addition to clay, fine silts or loosely packed sand and areas close to river mouths and coastal areas with limited water flow, should be avoided since they are subjected to high sedimentation rates and to the units sinking and scouring.
- Topographic maps (closeness to estuaries, marine protected areas (MPAs), archeological sites, closeness to urban areas, closeness to pollution sources).
- Blue socio-economic activities (commercial ports, fisher ports and communities, fishing grounds, tourism, scuba diving).
- Nutrients availability and concentration can deeply affect the composition of the community colonizing the reef. In oligotrophic water, marine sessile organisms mainly depend on the light gradient, hence on the depth, in eutrophic waters instead, light is less important. Therefore, it is important to study depth, light penetration and nutrient availability.
- The surrounding natural environment where habitats at the reef site and its surroundings and life history of target species should all be taken into consideration before adopting the deployment site with special attention given to threatened and protected species.

Once located, a permit from the MOPWT is required to carry-out field assessments (preferably for one year to establish robust baseline data sets) for the adoption or the rejection of the preliminary identified site. Field assessments may include but are not limited to: detailed bathymetric mapping, current and wave profiling, physical and chemical variables, species richness/ biodiversity, and granulometry, water turbidity and nutrients. Based on the results of the field assessments combined with the preliminary site identification data, the site will either be adopted or rejected. In case of rejection, the process is to be repeated for a different site. It is therefore best to give the preliminary site identification exercise the outmost importance in order to conserve time and resources.

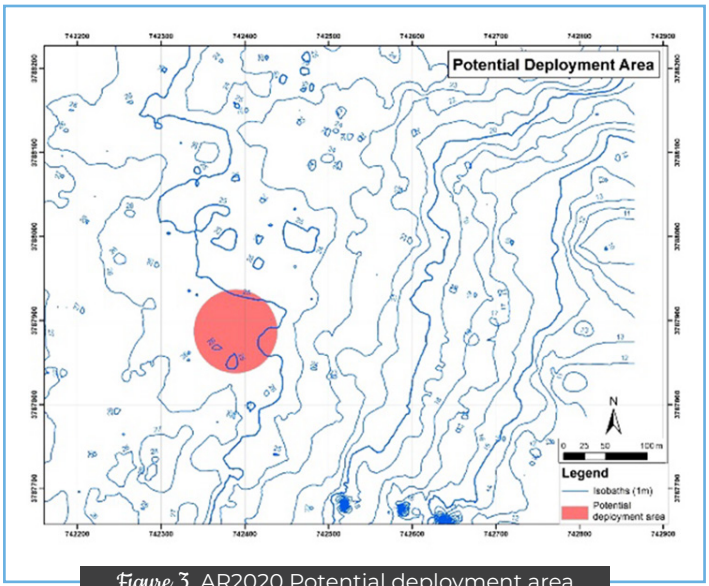

Figure 3. AR2020 Potential deployment area (Source: MCR-IOE-UOB)

3 Permit-I for site evaluation studies

The scientific assessment pre deployment of any AR requires a permit from the MOPWT, and a go-ahead from the ISF (Refer to section III. Artificial Reef Legislation).

4 Procurement and commissionin

A tender dossier with a clear set of Terms of Reference (TORs), including tender evaluation criteria must be developed and published for the design and construction of the units. It is highly recommended that at least three offers be received for evaluation and the contract be awarded to the party with the combination of the most economically advantageous and technically compliant tender. It is important for the awardee to take into consideration the location for constructing the units as they will have to be transferred to the port for loading on barges for deployment.

5 Permit-II for deployment

A second permit for deploying the AR units must be obtained from the MOPWT defining the exact site for deployment during a specific period. Even though the permit from the MOPWT may be generated in a reasonable time period, it will still have to go through the MOIM for processing. Experience has shown that this step is quite time consuming and should be allocated for by the project. In brief, and after the approval of the MOPWT, the permit is sent to the MOIM for processing as the ISF is the party responsible for the monitoring of works on the maritime public domain through the Coastal Brigade. In parallel, the Lebanese Navy of the LAF is to also be informed early on in the process as they are mandated for security matters in territorial waters. Even though time consuming, these procedures are easily completed through close cooperation and follow-up from the project team with all the parties concerned. Work supervision based on the TORs should be a component of the contract awards since it is necessary to ensure a proper AR deployment process without delays and other possible complications *(Figure 4).*

Figure 4. AR2020 units (a): Transport
(b): Deployment (Source: MCR-IOE-UOB)

6 Management and Monitoring

It is necessary to monitor the success of the reef post-deployment in terms of both enhancement of biodiversity and socio-economic contributions through a well detailed monitoring plan. The Literature Review should include the most recent monitoring and assessment methodologies for ARs at all levels. Depending on availability of resources, the monitoring plan is best carried-out for at least 3-5 years therefore providing the reef enough time to mature. Another approach is to introduce "citizen based monitoring" methods in collaboration with reef users like fisher cooperatives, recreational fishers, and scuba-divers. Information collected from such beneficiaries over the long-term will provide essential data on the performance of the reef and its contribution to both marine biodiversity enhancement and blue economy. (Refer to "Management and Monitoring plan of Artificial Reefs" on http://www.balamand.edu.lb/IOE/ArtificialReef/).

7 Capacity building and awareness raising

The development of a successful AR as well as the implementation of good practices by the concerned authorities requires building capacities among the fisher communities since the AR enhances marine biodiversity and increases fishing yield therefore positively contributing to the socio-economic situation of fishermen and recreational fishing opportunities, creating permanent and/or part-time employment to fishermen. Scuba-divers are also an important component of capacity building as the AR also creates a new diving site as well as increases the chances of divers to encounter an array of sessile and motile marine organisms increasing the income of diving clubs, creating new jobs, and further promote marine ecotourism and awareness on the importance and beauty of marine ecosystems. Thus, capacity building workshops must ensure the presence of national and local public authorities in order to take initiatives to deploy new ARs as they are required to mitigate the stresses on coastal resources by coastal communities *(Figure 5.a)*. Public authorities/ministries that should be included in any AR deployment are:

- Municipalities in the vicinity of the deployment site.
- Ministry of the Environment (MOE; responsible for protection of biodiversity, pollution).
- Environmental Impact Assessments (EIA's) and protected areas).
- MOPWT; mandated over the maritime public domain and marine waters).
- Ministry of Agriculture (MOA; manages the fisheries sector, issues fishing and diving permits).
- Ministry of Defense and the LAF (MOD; provision of derelict military material for deployment as AR and enforcing maritime laws through the Lebanese Navy).
- Ministry of Interior and Municipalities (MOIM; responsible for enforcing applicable laws; mandated over municipalities).
- Ministry of Tourism (MOT; promoting all types of tourism activities including ecotourism).

Awareness raising campaigns should also be held for schools and universities as they are involved in environmental education, research and the academic spreading of environmental awareness and knowledge. Coastal communities should also be engaged in these campaigns due to their lack of proper knowledge and awareness about the benefits of ARs in coastal blue economy from the creation of blue jobs to increasing the yield of marine products. Finally, Non Governmental Organizations (NGOs) and MPAs are advocacy groups and representatives of communities greatly involved in awareness raising as well as activism to protect the natural environment and its associated resources *(Figure 5.b)*.

Figure 5. Capacity building (a): Workshop for stakeholder and experts
(b): Presentations for schools (Source: MCR-IOE-UOB)

05 Safety regulations

Regardless of the designation of the AR (MPA, no fishing zone...), the main safety regulations and best practices that should apply include, but are not limited to the following:

- Do not throw your anchor on the AR site, use the AR buoys *(Figure 6)*.
- Respect fishing laws and regulations, and report any violation to the authorities.
- Do not crowd boats.
- Keep an eye out for diver-down flags.
- Do not throw trash overboard.
- Be aware of your surroundings.
- Be aware of certain species that may pose certain harm to you.
- Respect marine life.
- Do not fish within the Reef but around it to allow marine organisms to reproduce and mature.
- Do not practice spearfishing within the Reef.
- Do not touch, chase or feed marine organisms.
- Practice catch and release especially for juveniles by returning them quickly and humanely to the water.
- Avoid touching Reef structures and do not disturb sediments.

Figure 6. AR2020 Buoy (Source: MCR-IOE-UOB)

06 Artificial Reefs in Lebanon

The significant potential benefits of ARs have been firstly reported in the "Economic Assessment to Convert 100 Derelict Buses to Artificial Reefs" that was conducted in 2005 through a fund provided by the United Nations Development Program in Lebanon (UNDP). It clearly showed that deployment of ARs has the potential to improve fishing yields therefore enhancing the living standards for fishermen, and to boost marine ecotourism through the creation of new diving sites. Since then, four official ARs of different purposes have been deployed off the Lebanese coast *(Figure 7)*.

Figure 7. Map of different Artificial Reefs in Lebanon (Source: MCR-IOE-UOB)

1 Al-Aabdeh Artificial Reef - North Lebanon

In 2011, and to practically mitigate some of the impacts that are negatively affecting Lebanese marine waters and their biological resources, the Lions & Rotary Clubs, in coordination with the Ministry of Environment (MOE), MOPWT, MOD, the LAF and in partnership with the MCR-IOE-UOB funded the deployment of the first official AR in Lebanon in June 2012 in Aabdeh, North Lebanon *(Figure 7)*. Twelve vehicles and three tanks that were donated by the LAF were sunk 5km off the coast at an average depth of 25m *(Figure 8)*. A Master Thesis at the Department of Environmental Sciences at the Faculty of Arts and Sciences, University of Balamand and in collaboration with the MCR-IOE-UOB in early September 2017 assessed species richness of the AR after five years of deployment. It resulted in the identification of a total of 93 species of fauna and flora (with many more collected and still require identification) further showing the importance of ARs in enhancing marine ecosystems. Colonization has exceeded expectations and the AR is fulfilling its role of providing substrates for the settling of many marine species and for providing refuge to juveniles and adults alike therefore enriching marine biodiversity in the region *(Figure 9)*.

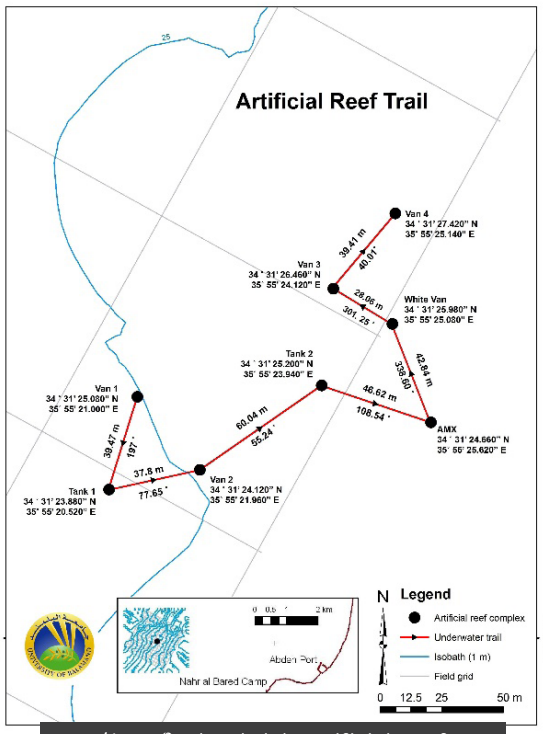

Figure 8. Al-Aabdeh Artificial Reef (Source: MCR-IOE-UOB)

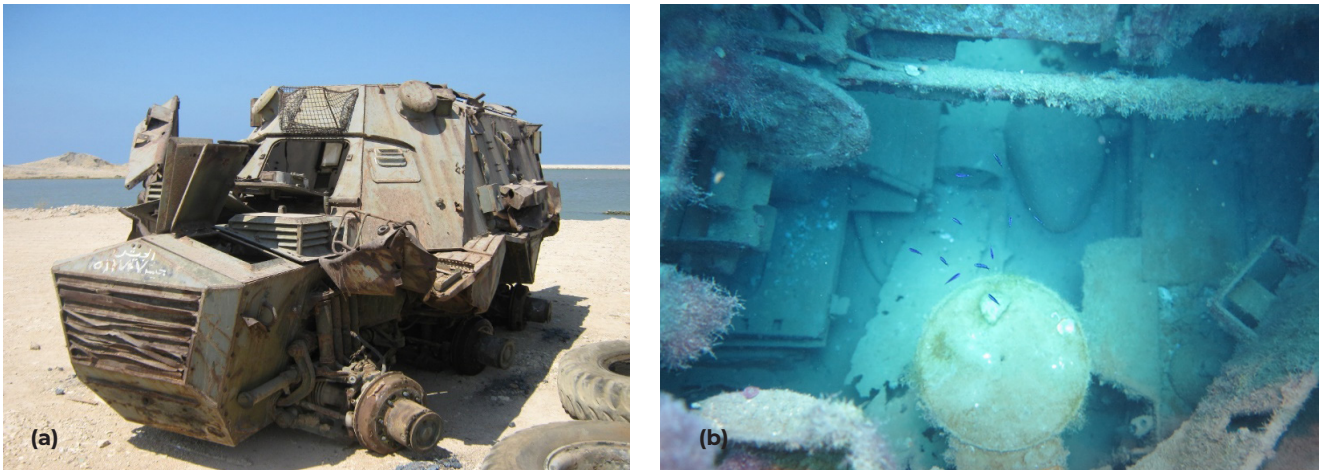

Figure 9. Al- Aabdeh Artificial Reef (a): Military machinery ready for deployment (b): Tank colonized by algae and fish after deployment (Source: MCR-IOE-UOB)

2 El Zireh Underwater Garden, Saida – South Lebanon

On 28 July 2018, in the vicinity of the city of Saida, six old tanks and four other military hardware were donated by the LAF and submerged at a depth of 14, 17 and 18m about 6 to 40m apart from one another, within an area of 150m^2 near Al Zireh Island *(Figure 10)*. This AR was purposefully built for recreational purposes, more specifically scuba diving and snorkeling activities *(Figure 7)*.

Figure 10. Saida underwater garden (a): Military vehicles transported on barge (b): Military vehicle deployment (Source: arabianbusiness.com)

3 Concrete Artificial Reef Garden of Jounieh Bay – Mount Lebanon

Friends of Nature (FON; Friends of Nature - Home (f-o-n.org)), NGO, took the initiative to deploy a AR in Jounieh Bay that aimed not only to restore marine biodiversity and productivity of the sea, but also to promote marine ecotourism *(Figure 7)*. The action was funded by the PROMARE Project which is implemented by the European Union (EU) in partnership with the MoE while the approvals for the project and the location were provided by the MOA and the MOPWT. Deployment took place between 15 and 30 December 2020 in four installations based on weather convenience. One complex was built, composed of five groups integrating 26 sets with 206 concrete units at a depth ranging from 12 to 35m, and extending over an area of 260,000m2 *(Figure 11)*. Close collaboration between

FON, local authorities, civil society, fishermen as well as beneficiaries was essential to comprehend the value of the "Concrete Artificial Reef Garden of Jounieh Bay" to enhance marine biodiversity and eventually productivity, which will help improve their livelihood.

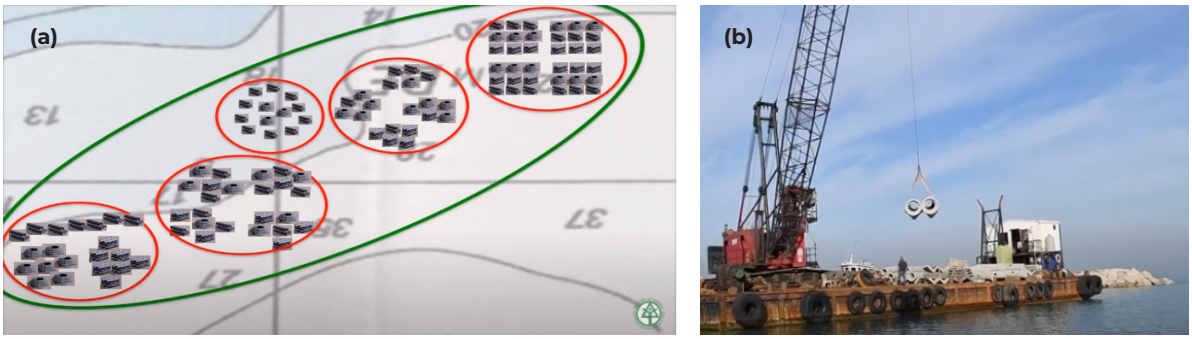

Figure 11. Concrete Artificial Reef Garden of Jounieh Bay (a): Structures and units (b): Deployment of structure (Source: Friends of Nature)

4 AR2020 Al-Berbara Artificial Reef – Mount Lebanon

The AR2020 project is funded by the PROMARE Project implemented by the EU and executed by the MCR-IOE-UOB. It aims at enhancing the protection and sustainability of marine biological resources in Lebanon through the design and deployment of a model AR and through capacity building and increased community and public awareness. AR2020 was deployed 1km offshore the village of Al-Berbara in Mount Lebanon on July 28 & 29, 2020 at an average depth of 25m to promote marine biodiversity, improve fishery potential, and increase marine ecotourism activities like scuba diving and recreational fishing *(Figure 7)*. Its 47 concrete and metallic structures are distributed over 12 Houses, 15 Trees, 15 Towers, and five Tunnels populated with limestone boulders and pottery jars and stretches over an area of 1225m2. The process included: 1) Selection of deployment site that included assessment of biodiversity; 2) Construction of the 47 units; 3) Deployment and; 4) Monitoring. Two years post deployment, biodiversity assessment resulted in the increase of 35% in motile species and 115.3% in sessile species colonizing the reef with samples still not yet identified *(Figure 12)*. It is important to mention that the numbers mentioned are expected to increase considering that maturation of an AR is reached after five to ten years of deployment. The AR2020 has started to create employment opportunities for an array of sectors such as fishermen where they are targeting directly the areas next to the reef for fishing and by transporting scuba divers. In addition, scuba-diving clubs are already visiting the reef and restaurants are benefiting from the increased fish yield of the AR2020.

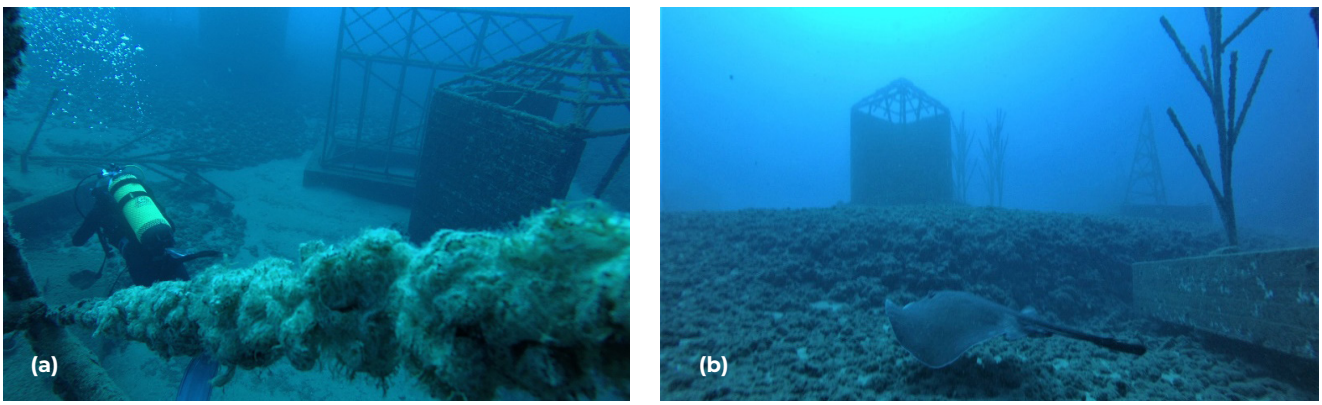

Figure 12. AR2020 (a): Diver exploring the AR units (b): Stingray swimming within the AR (Source: MCR-IOE-UOB)

Conclusion

As shown, several initiatives have been formerly launched to promote the sustainable use of marine resources through ARs while taking into consideration the well-being of fishermen communities. However, due to the absence of financial funding and the lack of prioritization at political level of marine conservation and the sustainable management of marine resources, it is highly recommended that AR deployment be accompanied by proper legislative framework and the proper application of laws to stop all activities damaging the marine environment.

The assessment of the colonization of the Al-Aabdeh AR five years after deployment and the monitoring of the AR2020 over a period of one year have clearly shown that such interventions, if conducted based on scientifically approved criteria, do enhance marine biodiversity, increase fishing yield and provide an array of opportunities for blue economies. It is therefore recommended that AR initiatives be increased based on clearly set guidelines as forwarded in the current Replicability Guidelines.

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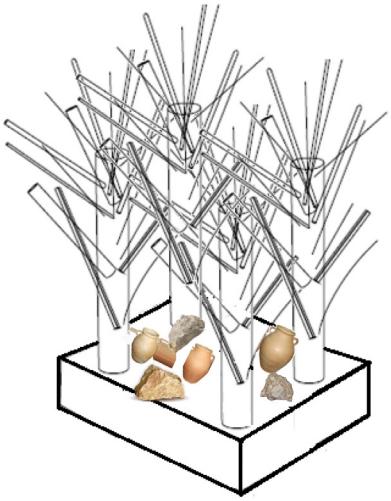
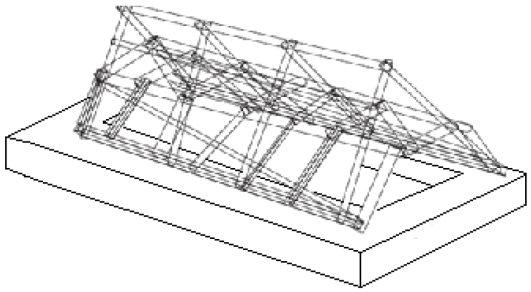
Annexes

Annex I. Drawings of the AR2020 units

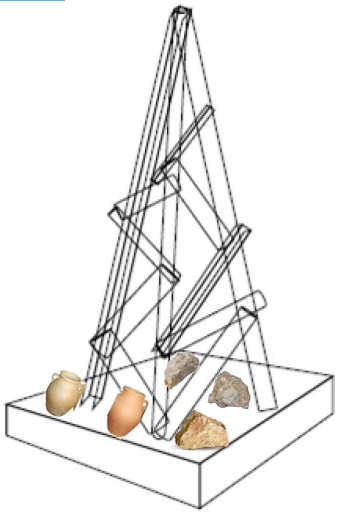
A. TREE



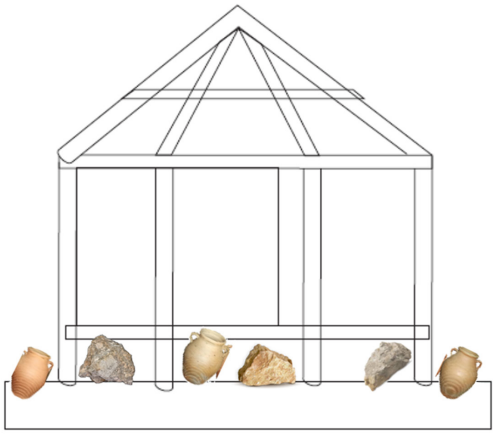
B. TUNNEL



C. TOWER



D. HOUSE



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