DOI: 10.31398/tpjf/29.2.2021-0030

POLICY BRIEF

Deployment of Artificial Habitats Alone Cannot Make up for the Degradation of Coral Reefs

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KEY POINTS

- Artificial habitat projects are expensive endeavors that should be carefully designed and planned to be sustainable and effective.
- Artificial habitats must be implemented with other fisheries enhancement and management measures and be monitored to allow for future improvements in site selection criteria and design.
- Coral reef rehabilitation is much more expensive than protection.
- Given the considerable cost and effort involved, artificial habitat deployments are justified in only a few situations. The lessons shared in this brief contain recommendations for the review and amendment of the joint memorandum concerning the use and management of artificial reefs.

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Received: *October 6, 2021*
Accepted: *June 20, 2022*

Keywords: *artificial habitats, coral reefs, fisheriesmanagement, fish recruitment, coral settlement*

Introduction to the artificial habitat project

Artificial habitats (AH, formerly known as artificial reefs) are again being deployed to improve the catch of coastal fishers by mitigating the degradation of coral reefs in the Philippines. AH are human-made structures deployed underwater to mimic the structural complexity of coral reefs to provide living space for fish and other marine organisms. AH can also serve as firm substrates for coral growth. However, like coral propagation and mangrove reforestation, AH deployment is not a "magic bullet" panacea for the depletion and degradation of Philippine coastal resources. The DLSU Shields Ocean Research (SHORE) Center spearheaded a project wherein different AH modules (i.e., open-frame cube, truncated pyramid, and jackstone modules) were deployed to evaluate their suitability for enhancing coral settlement and fish recruitment. This project was designed to enhance the coastal environment and provide livelihoods for fishers. Several challenges were encountered during the implementation of the project despite it having a clear set of objectives, well-planned activities, and the vigorous effort of the people involved. This policy brief seeks to share the lessons learned from the project. It includes recommendations for improving Joint DENR-DA-DILG-DND Memorandum Order No. 2000-01, the relevant policy, to guide future deployments of AH around the Philippines.

Lesson 1: Site selection is critical

Site selection is critical to a successful AH undertaking because its effectiveness is determined mainly by the bottom composition, depth, wave, current action, and sedimentation level (Table 1; Spieler et al. 2001; Barber et al. 2009; Fabi et al. 2015; Salleh et al. 2018). AH are best deployed on broad flat areas covered by compact sand and rubble with a depth of between 5–10 meters. The bottom should be firm and stable enough to prevent the concrete AH modules from getting buried. The AH should be below the reach of large waves created by storms and

Table 1. Best practices for the site selection of artificial habitats (AH).

Criterion	Best Practices
Site of Deployment	Deploy on broad areas of the reef but not on the reef flat, which is the shallow part of the reef exposed during low tides.
Bottom Composition	Compact sand and rubble prevent AH from getting buried. Avoid silty bottoms.
Depth	A depth of 5-10 m is deep enough to avoid large waves but shallow enough to allow for monitoring without scuba.
Distance	AH should be more than 1 km away from natural reefs to avoid attracting fish and depleting reef stocks.
Sedimentation Level	The site of deployment must be far from rivers and streams to avoid high sedimentation levels that negatively influence corals and fish.

typhoons but sufficiently shallow to monitor without scuba. AH deployments that are too shallow may be quickly overgrown by barnacles and seaweeds, hindering coral growth. These shallow AH modules may also be displaced by strong currents and heavy wave action, damaging nearby coral reefs (Düzbastilar et al. 2006). AH should not be deployed on reef flats (i.e., the shallow part of the reef composed of rubble and loose sand that is usually exposed during low tides) and in channels through reefs. The AH deployment areas should be more than 1 km away from the surrounding natural reefs and 500 m from the existing AH (DENR-DA-DILG-DND, 2000). This requirement prevents AH from attracting and depleting fish from the natural reefs and potentially making these fish easier to catch, leading to the risk of overfishing in the area. Several studies have reported impacts of AH on the species composition and abundance of fish in adjacent natural reefs, such as the strong attraction of large predators or target species that can lead to adverse shifts in predation, competition, or nutrient output (Rilov and Benayahu 2000; Walker and Schlacher 2014; Simon et al. 2011). The water quality around the deployment area should also be favorable for coral growth. Hence, the AH should be far from rivers and streams and associated development involving reclamation, mining, and deforestation. These are critical drivers of water clarity and the rapid accumulation of sediments that influence the settlement of benthic invertebrates, including coral and fish assemblages on and around AH.

Lesson 2: Some designs work better than others

The design of AH modules (Figure 1) must be appropriate to the specific purpose of the AH deployment. Our experience in western Batangas indicates there are no good, general-purpose designs for modules. The growth of micro-fragments from three coral species attached to AH differed significantly, with results showing the higher cover on the jackstone and pyramid modules (Mostrales 2021). The jackstone modules had more juvenile corals settling on them than the open-framed cube and truncated pyramid. The apparent preference for this surface by recruits may be due to fewer sediments accumulating on the more steeply inclined and

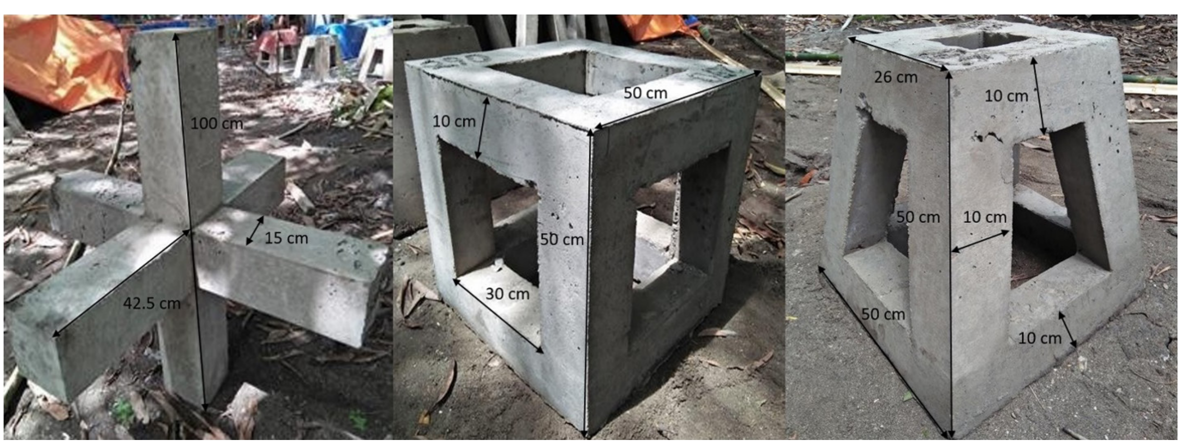

Figure 1. The three AH designs with dimensions. From L to R: jackstone, open-frame cube, and truncated pyramid.

vertical surfaces (Clark and Edwards 1999; Perkol-Finkel and Benayahu 2004; Mizrahi et al. 2014). Fewer corals were recruited onto the open-framed cube's vertical surfaces and the truncated pyramid modules. The lower coral recruitment in the latter modules may be due to competing organisms such as sponges, tunicates, and the activity of sea urchins and sea cucumbers that preferred the cavities of the AH (Blakeway et al. 2013).

Fish surveys of the AH modules were conducted almost three years after deployment. Although the three designs had a similar mean number of individuals, the open-framed cube and the truncated pyramid modules had at least five times more associated fish biomass than the jackstone modules (Figure 2). For fisheries stock assessments, biomass is a more useful parameter because the length estimates in visual censuses provide a size-frequency distribution (Samoilys 1997). The higher biomass values of the open-framed cube and the truncated pyramid modules were due to the presence of larger target fish which favored the shelter provided by the proximity of these modules to one another. On the other hand, the jackstone modules had larger open spaces between them, presenting less structural complexity and fewer hiding places from predators. As such, fewer fish were seen swimming and hiding near these modules.

Lesson 3: Artificial habitats are not as cost-effective in covering large areas

AH projects cost millions of pesos and yet cover only small areas. Three different concrete AH modules—jackstone (100 cm x 100 cm x 100 cm), open-frame cube (50 cm x 50 cm x 50 cm), and truncated pyramid (50 cm x 50 cm x 30 cm; see Figure 1) were used and studied in the three western Batangas towns. The materials for 1020 AH modules covering only 0.00186 km^2 cost about PHsxP 505,095. Factoring in the labor and deployment costs of PHP 623,500 and PHP 255,950, the total cost of deployment is PHP 1,384,545. This figure roughly translates to PHP 744.4 million to make and deploy enough AH to cover a square kilometer.

The Philippines has over 22,500 square kilometers of natural coral reefs (Burke et al. 2011). It would thus cost at least PHP 16.7 trillion to replace our coral reefs with artificial versions, assuming there are enough suitable places for all this concrete to be deployed in the sea. In contrast, it costs about PHP 1 million to adequately manage a square kilometer of a marine protected area (White et al. 2000). The Tubbataha Management Office, which oversees 970.3 square kilometers of the largest and best-managed marine protected area in the Philippines, spent an estimated PHP 10 million from 2000 to 2005 to implement a management plan, which translates to a cost of about PHP 10,306 to protect a square kilometer area (Dygico 2006). Economic analyses done by Haisfield et al. (2010) show that for every square kilometer of a marine park, enforcement would only cost PHP 3.3 million compared to a PHP 241 million cost of rehabilitating the same area. These computations show that rehabilitation is approximately 70 times more expensive than protection. Further, it is estimated that costs for the most commonly used methods in coral reef restoration range from about PHP 367,000 to PHP 244.7 million per hectare, while the establishment and management of marine protected areas average to about PHP 14,000 per hectare (Butardo-Turibio et al. 2009; Bayraktarov et al. 2019). Consequently, these studies, as well as cost projections made from our own, show that coral reef rehabilitation is much more costly than protection.

Ideally, marine protected areas encompass coral, mangrove, and seagrass habitats to support a greater variety of fishes and other organisms (Honda et al. 2013; Ramos et al. 2015). This setup

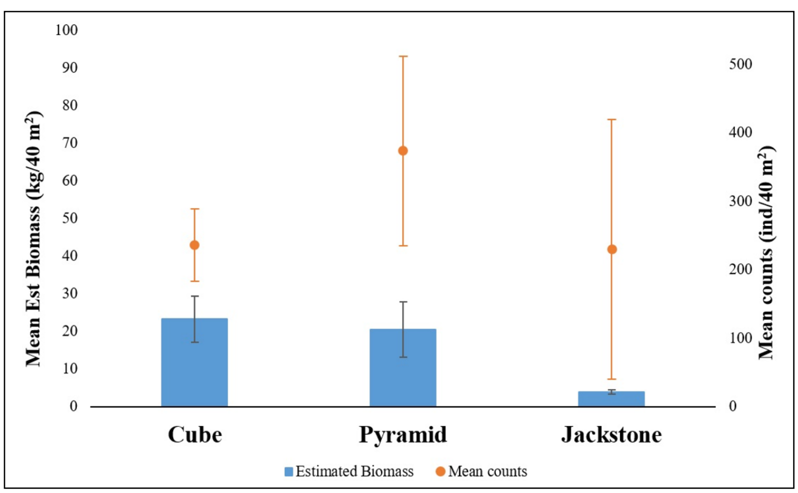

Figure 2. Mean fish estimated biomass (the blue columns) and mean fish counts (orange circles) in each type of AH (Talim Bay, Lian, Batangas, October 7-9, 2020). Error bars = ±1SE.

is also more cost-effective and sustainable. Both marine protected areas and AH deployments must be large enough to provide habitat space for enough organisms to improve the catch of local fishers. As a rule of thumb, 10% of the biomass (i.e., the total living weight of organisms) inside protected areas and AH deployments spill over into adjacent areas where they can be caught (Licuanan et al. 2006). This spillover is like interest on a bank deposit. The larger the deposit, the bigger the interest income. Thus, the protection and conservation of reefs by eliminating the anthropogenic stressors and allowing natural coral recovery appear far more cost-effective than restoration efforts like artificial habitats (Jokiel and Naughton 2001; Naughton and Jokiel 2001; Mayuga 2017).

Lesson 4: All AH must be monitored and fishing around them regulated

In the Philippines, stakeholders from local government to the private sector and non-governmental organizations engage in AH projects to increase fish catch (Mayuga 2017). However, if not done properly, AH become fish-aggregating devices which may lead to overfishing. Therefore, the AH activity should be part of a broader fisheries management plan that involves sustained monitoring and regulating the number of fishers, the kinds of gears they use, and where and when they should and shouldn't be fishing. In addition, the fisheries management plan needs clear, specific, and realistic objectives. Further, all concerned stakeholder groups (e.g., scientists, government and non-government organizations and units, and the local communities and fishers) should be involved in conceptualizing, designing, developing, and implementing this plan.

The local fishing community must get a sense of ownership over the plan and the whole project. The community must monitor the project, with specific measures of success for each of the project objectives. Few artificial habitat projects have conducted monitoring beyond a few months after deployment. Fewer still involved the local community in the management and protection of the AH (see "Recent inspections…" 2016; "BFAR Gives 40…" 2018 as examples). Most efforts are part of marine conservation projects and end with the deployment of AH, not their monitoring (see Garcia 2019; Requejo 2019). Monitoring allows the AH project to generate greater involvement and awareness and provide baseline data for succeeding monitoring visits and the basis for assessing performance and effectiveness. These, in turn, allow improvements in the design and implementation of future AH deployments. Citizen science methods can make this monitoring more participatory, involving non-swimmers, the local youth, and even the elderly (see Licuanan and Mordeno 2021; Licuanan et al. 2021; also https://cfiusa.knack.com/mpa-fishmapp#home/).

Many fishery managers see the potential of using AH to enhance fish stock and production. However, AH deployments that are too small act more as fish aggregating devices than habitats, leading to overharvesting if fishing is allowed near these structures. AH deployments must be large enough to provide habitat space for enough organisms to improve the catch of local fishers. Recovery of fish stocks can take a few years, even if the AH effort is large enough. This recovery can be faster if no fishing is allowed over and near the AH module clusters. Hence, for fish stocks to recover, AH must be part of no-take protected areas. Enhancement of inshore fisheries resources using AH should incorporate sustainability and fisheries management with the local community being involved, like in patrolling the AH deployments.

CONCLUSIONS AND POLICY RECOMMENDATION

A successful artificial habitat project must have an appropriate, community-based management system with clearly defined objectives, whether related to enhancing fisheries or facilitating the restoration of coral growth. As such, the following are recommended to amend the Joint DENR-DA-DILG-DND Memorandum Order No. 2000-01 to not only better facilitate future AH projects, but hopefully realign current and future AH projects to the memorandum's original objectives, one of which is to ensure the sustainable development of the country's fishery and aquatic resources.

First, Section 9 of the joint memorandum should be updated to include a site selection requirement to ensure that the environmental and ecological features of the target site (e.g., how far the site is from rivers, streams, and associated development) are considered for the proper structural design and construction of AH before starting any project. In addition, human impacts, including destructive and overfishing, reclamation, land-based and coastal development, mining, and deforestation, must be managed with the appropriate strategies and institutional arrangements.

Second, under Section 11, AH deployments must always be implemented as part of broader coastal protection, conservation, and management programs involving fisheries regulation and a network of marine protected areas. Using AH alone to stop or reverse the decline of coral reefs in the Philippines would be prohibitive, considering the considerable cost and massive effort involved in covering a small area with AH. Consequently, their deployments are justified only in a few situations (e.g., tourist dive spots in isolated regions, deter the use of nets, serving as submerged breakwaters to protect shoreline).

Third, under Section 12, annual monitoring (may also be quarterly or biannual monitoring if budget allows) must be included, and socioeconomic evaluation of AH must be strictly accomplished. Under the current memorandum, monitoring is only required six months after installation, while socioeconomic evaluations are rarely done. Data gathered from regular monitoring would be helpful for the improvement and development of both current and future projects. Given the expenses needed for monitoring, this reinforces the recommended requirement that AH deployments must always be part of a broader management plan to be more sustainable and cost-effective.

ACKNOWLEDGMENTS

We thank the Department of Environment and Natural Resources for funding this project in collaboration with Pusod Inc., the local governments of Lian, Calatagan, and Nasugbu in western Batangas. The Commission on Higher Education DARE-TO Collaboration on Resource Management among Academe and Local Communities (CORAL) Project funded the subsequent fieldwork related to this work. We also thank the current and past members of DLSU SHORE that implemented this project.

AUTHOR CONTRIBUTIONS

Bahinting SED: Conceptualization, Investigation, Writing - Original Draft. Mostrales TPI: Conceptualization, Investigation, Writing - Original Draft. Principe AS: Investigation, Visualization, Writing - Original Draft. Licuanan WY: Conceptualization, Writing - Review and Editing, Supervision.

CONFLICTS OF INTEREST

The authors reported no potential conflict of interest.

ETHICS STATEMENT

The authors carried out no harmful animal or human studies.

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