CONTRIBUTION 6.9

Utilization of Artificial Reefs for Enhancement of Spiny Lobster Resource

Hiroaki Terashima*[1], Saori Imamura*[1], Monique Calderon*[2] and Makeba Felix*[2]

IC Net Limited. Member for the Project for Strengthening Sustainable Use and Management of Coastal Fisheries Resources in the CARICOM Countries (COASTFISH)[1]*
LA Tower 27 F., 11-2 Shintoshin, Chuo-ku, Saitama-shi, 3306027, Japan.
E-mail: terashima@icnet.co.jp.com
Department of Fisheries, Saint Lucia[2]*
Pointe Seraphine Castries Saint Lucia
monique.calderon@govt.lc, makeba.felix@govt.lc

Abstract

The Caribbean spiny lobster, *Panulirus argus* found in the western Atlantic Ocean, including the Caribbean Sea and the Gulf of Mexico is a highly valued commercially important species, which is considered a delicacy in the world. In order to manage and conserve the resource of this species, many countries in the region have legislated for fishing restrictions, including minimum size limits, closed seasons, and fishing quotas. However, in several countries, the resources have still faced significant declines owing to overfishing by poaching, habitat destruction and climate change. In order to improve this situation, Japanese aid agencies have implemented an artificial reef project as demonstration tests for development of the nursery ground to enhance the spiny lobster stock. The Overseas Fisheries Consultants Association (OFCA) implemented a model project at St. Vincent and the Grenadines from 2003 to 2005 with the aim of increasing the Caribbean Spiny Lobster stocks, providing technical guidance and lectures to the Fisheries Division through the installation and monitoring surveys of artificial reefs. Subsequent intermittent monitoring observed a large number of spiny lobsters aggregating on artificial reef designed to attract the spiny lobster. In 2020, Japan International Cooperation Agency (JICA) then launched the Project for Strengthening Sustainable Use and Management of Coastal Fisheries Resources in the CARICOM Countries - COASTFISH Project. One of the pilot activities is to deploy an artificial seaweed and an artificial reef combined for development of the nursery habitat for juvenile spiny lobster, and already juvenile spiny lobsters were found on the artificial reef. In this pilot project, local fisherfolks, MPA rangers and officers of the Fisheries Department worked together to develop and monitor the artificial reefs that are inexpensive and easy to install. Such efforts are being made with reference to the "satoumi activities" that are being carried out in coastal areas of Japan.

KEYWORDS: Artificial reef. Caribbean Spiny Lobster. Resource Enhancement. Sato-umi

CITATION: Terashima, H., M. Calderon and M. Felix, 2026. Utilization of Artificial Reefs for Enhancement of Spiny Lobster Resource. Contribution 6.9, p467-480 *IN* CRFM, 2026. Volume I: Technical Papers. Presented at the CRFM 20th Anniversary Scientific Conference, 28-31 August 2023. CRFM Special Publication No. 37, CRFM Secretariat https://www.crfm.int/index.php?option=com_k2&view=item&id=939

1. INTRODUCTION

The Caribbean spiny lobster, *Panulirus argus* found in the western Atlantic Ocean, including the Caribbean Sea and the Gulf of Mexico is one of the most sought-after species (Phillips and Melville-Smith, 2006). This species is a commercially important and is highly valued marine product (Ehrhardt et al., 2011). Although the status of *P. arugus* populations vary across different regions and countries within the Caribbean, some populations have faced significant declines due to overfishing, habitat destruction, and so on (e.g., Baisre 2000, Fonteles-Filho, 2000, Horsford et al., 2014). To manage and conserve *P. arugus* resources from overfishing, many countries have implemented regulations and fishing restrictions (Lovell, 2023). These include minimum size limits, closed seasons, and fishing quotas to help protect the species and allow populations to recover (e.g., Saint Lucia, 1987, Saint Vincent and the Grenadines, 1987). On the other hand, attempts are being made spiny lobster stocks. However, since it has a floating period of nearly one year, it is extremely difficult to make full-scale farming economically viable (Kittaka and Kimura, 1989, Goldstein et al. 2008).

For this reason, various attempts have been made to increase their habitats with artificial reefs in shallow water in order to increase the amount of natural resources (e.g. Eggleston et al., 1990, Butler and Herrnkind, 1997, Spanier et al., 2011). These attempts have been made enormously in Japan to increase coastal resources using artificial reefs (Sheehy, 1982, Ito, 2011). Artificial reefs play a major role in providing marine life habitat, especially in areas where the natural reef is limited or degraded. They serve as essential tools in enhancing biodiversity, promoting fisheries and supporting ecosystem conservation efforts (Spanier et al., 2011). Based on these considerations, Japan's Overseas Fisheries Consultants Association (currently Marino Forum 21) conducted a pilot project to install and monitor the artificial reefs in order to conserve and increase spiny lobster resources in cooperation with the Fisheries Division of St. Vincent and the Grenadines in 2004 (OFCA 2018). In addition, by supporting the holding of workshops conducted by staff of the Fisheries Division for fisherfolks, it aimed to raise the awareness of stakeholders regarding fisheries resource management and fisheries organisation.

After this activity, a pilot project to build out a juvenile spiny lobster habitat has been implemented as part of a technical cooperation project targeting six east Caribbean countries such as Antigua & Barbuda, Dominica, Grenada, St. Kitts & Nevis, Saint Lucia, and St. Vincent & the Grenadines, organized by Japan International Cooperation Agency (JICA) since 2020. In particular, in Saint Lucia from 2021, by installing artificial seaweed where post larva and juvenile spiny lobster gather, and inexpensive artificial reefs, we have been attempting to provide artificial habitat for it. In this paper, we will show the findings obtained from these activities and explain the effects on future spiny lobster stocks.

2. Survey Methods

2.1 St. Vincent and the Grenadines:

Locations and descriptions of target artificial reefs are as follows.
Preliminary surveys were conducted in July and October 2003 to determine the appropriate artificial reef sites, two sites were then selected (Fig. 1). Of these, Site 1 was near Isle a Quatre, off the coast of Bequia Island with a gentle slope with rocks and boulders interspersed on gravel bottoms in around 12 metres depth. The site 2 was on fine sandy bottom with small rocks and

boulders scattered near Mustique Island in around 15 metres depth. Both areas are marine management areas, especially the target area of Mustique Island is secured as marine protected area which has been managed by a non-profit organization.

As shown in Fig. 2, three types of artificial reefs, namely an assembled reef developed by a private Japanese manufacturer (truss reef), a terraced concrete reef developed for the purpose of attracting spiny lobsters as part of the New Fisheries Cooperation Development Promotion Project (terrace reef), and a gabion, were installed in September 2004. In terms of Terrace reef, 3-layered type was installed in site 1, but for site 2, 4-layered type was used in anticipation of burial at the bottom condition (Terrace reef in Fig. 2 is a 4-layered type in Site 2).

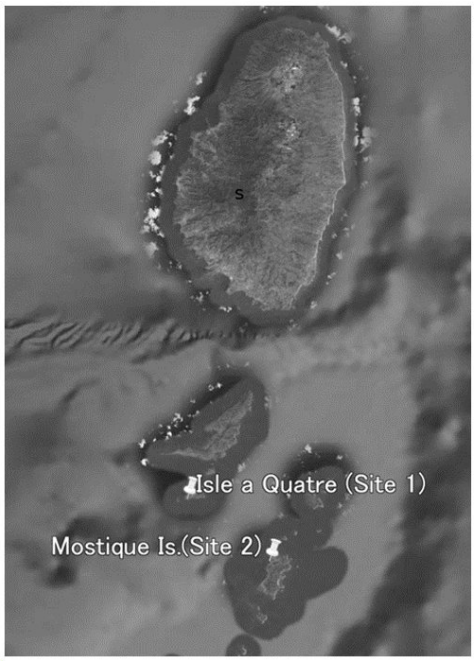
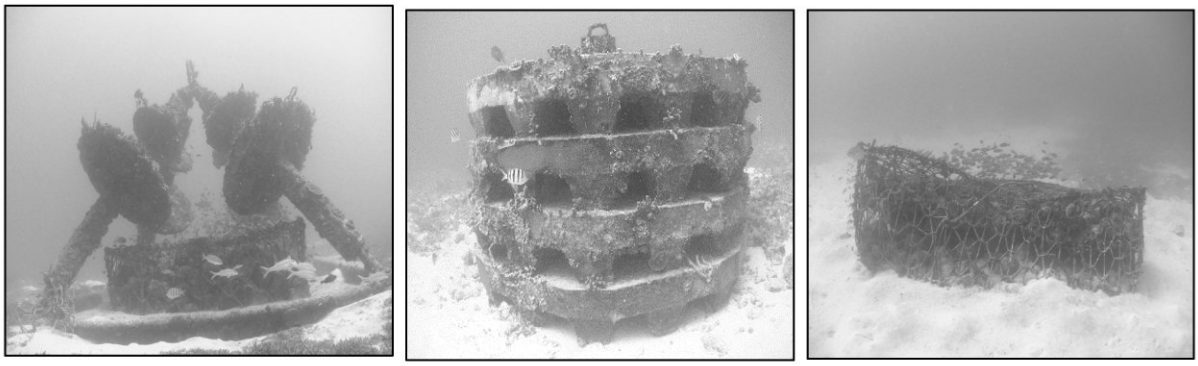


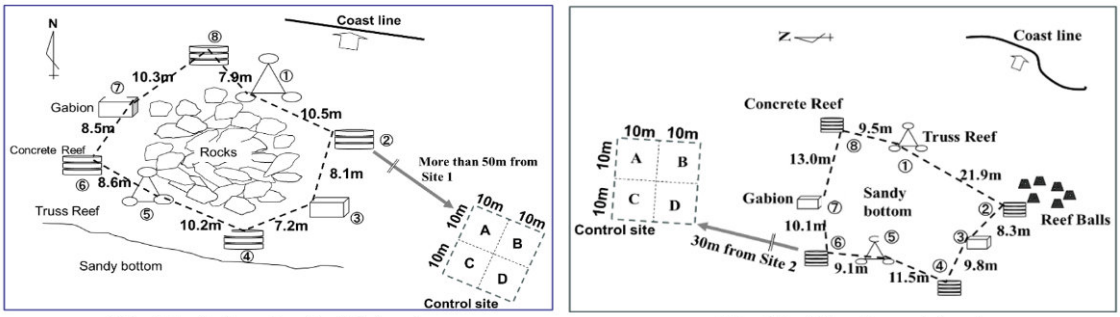
Figure 1. Artificial reef sites (Display on Google earth



Truss reef | Terrace reef | Gabion

Figure 2. Types of artificial reefs installed in the target area

After installing the artificial reefs, a layout map of them was made out. In addition, a 20 metres x 20 metres square control area was set up on the natural reef near these artificial reefs. The control area was divided into four areas of 10 metres x 10 metres, and the number of spiny lobsters inhabiting each area was examined by underwater visual observation. These layouts are as shown in the Fig. 3.



Site 1 in "Isle a Quatre" Island | Site 2 in "Mustique Island

①&⑤: Truss reef; ②, ④,⑥ & ⑧: Terras reef; ③ & ⑦: Gabion

Figure 3. Schematic layout of artificial reefs site in the Site 1 and Site 2

SCUBA divers carrying underwater cameras and waterproof paper dived into the survey areas and counted the number of spiny lobsters inhabiting each artificial reef and control area. In addition, the number of individuals was counted by divided into less than 9 inches (25 centimetres) which was catch limits of and more than 9 inches. The body length of each observed individual was determined visually by divers, but after completing the diving survey, each individual photographed was compared with the surrounding artificial reefs and natural rocks in an attempt to ascertain the body length as accurately as possible.

2.2 Saint Lucia:

Locations and descriptions of target artificial reefs are as follows.

The Japan International Cooperation Agency (JICA) has launched the "COASTFISH Project", a project to strengthen the sustainable use and management of coastal fisheries resources in six East Caribbean island countries. As one of the pilot activities, in Saint Lucia, with the aim of improving the coastal habitats of the target area, we managed to instal artificial reef using locally available materials that are easy to process and transport. In consultation with the Department of Fisheries in Saint Lucia, Laborie and Soufriere were chosen as pilot sites (Fig. 4).

Figure 4. Artificial reef sites in Saint Lucia (Display on Google Earth)

In Laborie, first of all, we conducetd a workshop with local fisherfolks in November 2021, and the Department of Fisheries explained to them the concept of installing an artificial reef for spiny lobster resources. The discussions were then held regarding the location site, materials and design of the artificial reef. In terms of the design of artificial reef, the first condition was inexpensive and easy to install. Since the conch shells collected by local fisherfolks have been discarded, gabions filled with conch shells were adopted (Fig. 5).

When installing this artificial reef (conch shell reef), a frame is made of reinforcing bars or PVC pipes, transported to the target area by a small boat with an outboard motor, and installed it on the seabed. We then dropped a batch of conch shells or concrete blocks from the boat toward the frame underwater. The SCUBA divers then threw these conch shells or concrete blocks, which are scattered around, in the frame so that the frame has sufficient dead weight. This made it possible to install an artificial reef without large equipment and budget.

In addition, when spiny lobsters transform from the planktonic stage to benthic life, they gather in seaweed and use it as hiding place. For this reason, in order to confirm the gathering status of the larvae and juveniles of spiny lobster, we installed artificial seaweed (Product name: MojaMoja, manufactured by Okabe Co. Ltd.) as a sampler and collected them after a certain period of time.

The artificial reefs and artificial seaweeds were installed at the location shown in Fig. 6 in November 2021. After installing them, the layout map was made out as shown in the Fig. 7. In addition, a 20-m square seafloor located about 50 m north of the northern end of this artificial reef site was used as a control site. In order to measure the amount of juvenile spiny lobsters gathered in the artificial seaweed installed in November 2021, two artificial seaweeds were retrieved in January 2022, and the number of juvenile spiny lobsters gathered in it was counted.

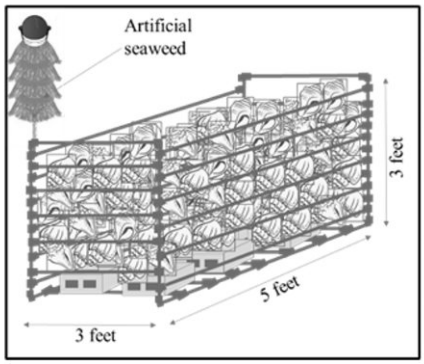


Figure 5. Prototype of an artificial reef with conch shells in a reinforced cage

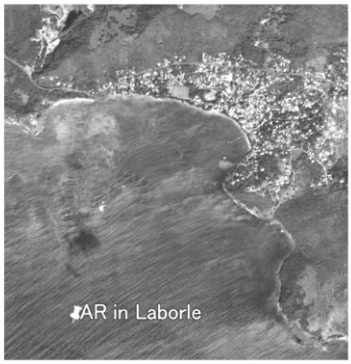


Figure 6. Artificial Reef site in Laborie

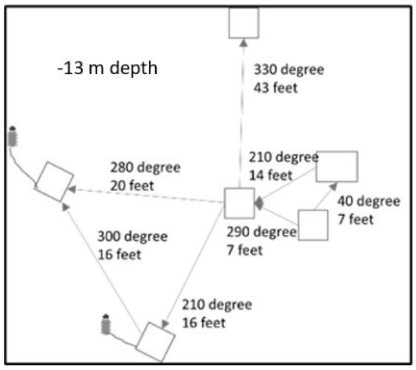


Figure 7. Schematic layout of artificial reefs site in Laborie

In Soufriere, seagrass beds of *Halophila* spp. extend on the off public beaches from the shoreline to 25–27 metres depth, as shown in Figure 8. This seagrass bed is suitable for juvenile *P. argus* and other reef fish to get fed. In addition, this is an area frequented by fisherfolks and serves as a fishing ground for seine net. Although juvenile spiny lobsters are occasionally caught in this seine net, fisherfolks are often seen releasing them that are smaller than the size allowed by law. This seagrass bed is however not seen below 27 metres depth, and the topography is a monotonous sandy bottom. There is almost no fishing activity due to few amounts of fish there. For this reason, we decided to set up a new conch shell reef with the aim of expanding the nursery grounds for juvenile spiny lobster and juvenile reef fish and confirm its effectiveness.

The artificial reef installed at Soufriere was made of 2-inch-diameter PVC VP pipes with wire mesh and randomly stacking concrete blocks inside as a prototype. It was installed on 24 September 2022 on the sandy bottom at 28 metres depth off the public beach of Soufriere as shown in Fig. 9. In addition, an area approximately 20 meters long along a reef located approximately 100 meters west-northwest of the artificial reef site was used as a control site.

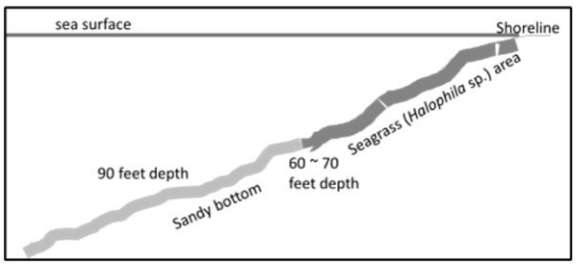


Figure 8. Schematic diagram of the bottom condition in Soufriere

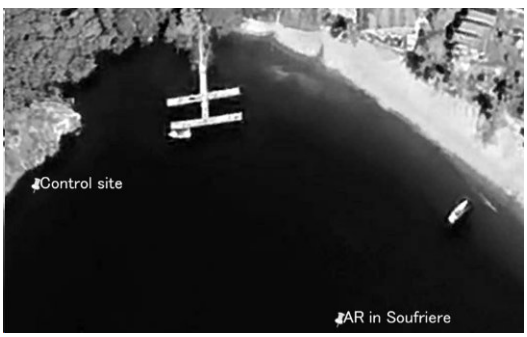


Figure 9. Location of artificial reef site in Soufriere

SCUBA divers with underwater cameras and waterproof paper monitored these sites to check upon the number of spiny lobsters in the artificial reef. We also took pictures and videos at the same time.

3. RESULTS

3.1 St. Vincent and the Grenadines:

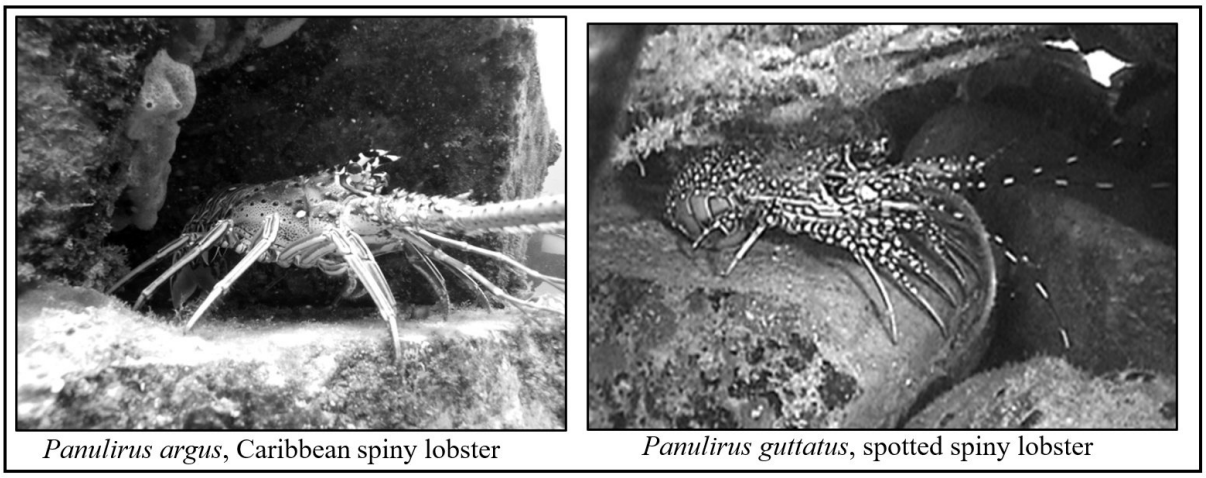
The dates of each monitoring survey conducted were as follows.

The first and second monitoring surveys were conducted in November 2004, and June 2005 respectively. However, thereafter, no monitoring survey was conducted in these two reef areas for long time, and the status of spiny lobster on the artificial reefs had not been figured out. The third monitoring survey was therefore, conducted in December 2014 to confirm the status at the two artificial reef sites. The fourth survey was then conducted Site 2 on February 4, 2018, though Site 1 survey had to be cancelled due to bad weather condition (Table 1).

Table 1. Date of each monitoring survey in St. Vincent and the Grenadines

1st monitoring survey		2nd monitoring survey		3rd monitoring survey		4th monitoring survey	
Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
13 & 16 November 2004	17 November 2004	21 & 26 June 2005	23 &24 June 2005	15 December 2014	16 December 2014	Survey cancelled due to bad weather	8 February 2018

In the survey, two species of spiny lobsters were observed around the survey areas (Fig. 10). They are *P. argus*, which is called Caribbean spiny lobster, and *P. guttatus*, which is called spotted spiny lobster. Of these, *P. argus* grows large and is traded at a high price in the market. On the other hand, relatively small *P. guttatus* has little market value and are rarely seen on the market. Therefore, we can say that the *P. argus* currently has high fishing pressure and high resource management requires.



Panulirus argus, Caribbean spiny lobster

Panulirus guttatus, spotted spiny lobster

Figure 10. Two species of spiny lobsters observed in the survey

The changes of total number of spiny lobsters observed in each survey site in time series are shown in Fig. 11 and 12. At Site 1, both populations of *P. argus* and *P. guttatus* have increased in artificial reef site over the years. However, such tendency could not be confirmed in the control site.

No *P. argus* was observed around the artificial reef in November 2004, but by December 2014, about 10 years later, more than 50 individuals of *P. argus* had been observed in total, with more than 70 individuals of *P. guttatus*, which might indicate that the artificial reefs have provided a suitable habitat for the spiny lobsters. On the other hand, at Site 2, almost no *P. argus* or *P. guttatus* was observed in November 2004 and June 2005 which were 3 to 5 months and 1 year after the installation of the artificial reef respectively. However, in December 2014 and February 2018, 71 and 40 individuals of *P. argus* were observed, respectively. On the other hand, *P. guttatus* was not observed there at all. In the control site, neither *P. argus* nor *P. guttatus* appeared on any of the survey days.

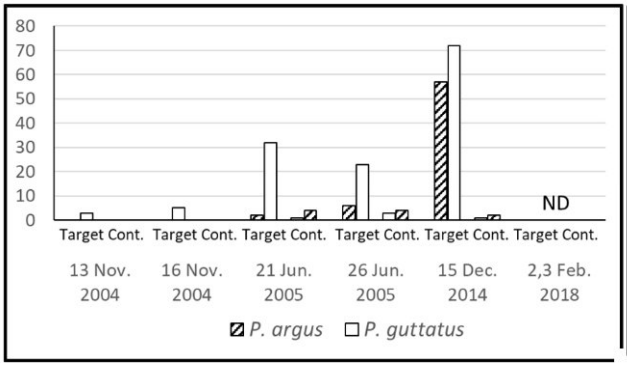


Figure 11. Total number of lobsters observed at in artificial reef at Site 1 in time series

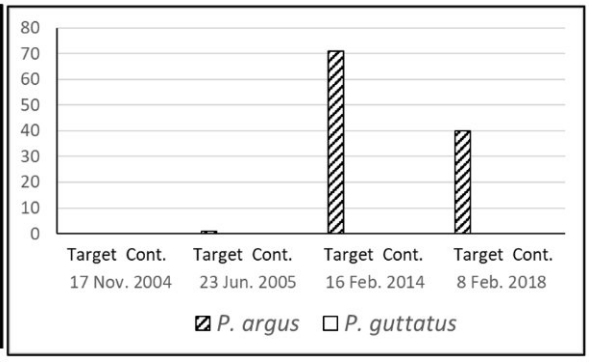


Figure 12. Total number of lobsters observed at in artificial reef at Site 2 in time series

Among the *P. argus* and *P. guttatus* observed at each survey, all individuals of *P. guttatus* were less than 9 inches, and no individuals larger than 9 inches appeared. In *P. argus* there were many individuals of 9 inches or more, but individuals of less than 9 inches were also seen (Fig. 13).

At the time of Site 1's survey on 21 Jun 2005, only 2 individuals of *P. argus* were observed, and both individuals were 9 inches or larger, making the occurrence rate of 9 inches or larger 100%. Conversely, at the time of the survey on 23 Jun 2005, only one individual of *P. argus* was observed, and that individual was less than 9 inches, making the occurrence rate of less than 9 inches 100%. In all other surveys in which *P. argus* appeared, more than 20 individuals observed. At that time, around 80% of individuals were 9 inches or more, and the frequency of individuals with less than 9 inches was low.

As mentioned above, the artificial reefs surveyed were truss reefs, gabions, and terrace reefs, but most of the spiny lobsters that gathered were observed inside the terrace reefs which was designed for spiny lobsters. Whereat, we compared the mean ± standard error of the number of *P. argus* observed on the terrace reef and the other 'truss reefs and gabions' at Site 1 and Site 2 as shown in Fig. 14 and 15 respectively. Similarly, Fig. 16 showed the mean ± standard error of the number of *P. guttatus* observed in “terrace reef” and “truss reef / gabion” at Site 1 (*P. guttatus* was not observed at Site 2).

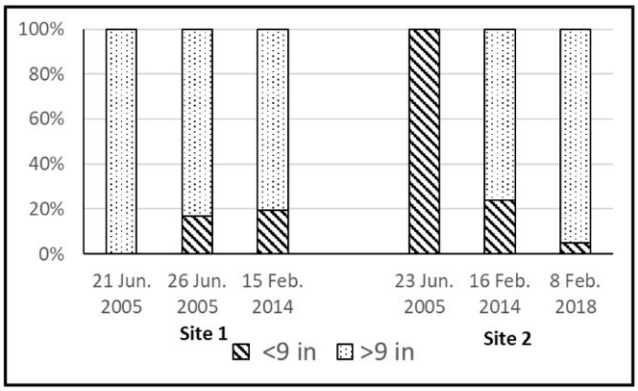


Figure 13. Percentage of P. argus individuals under and over 9 inches appeared at each survey.

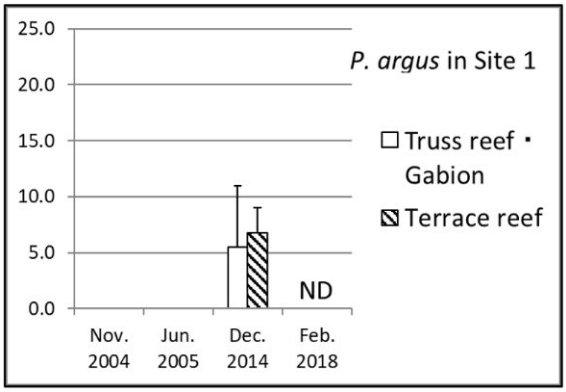


Figure 14. Mean ± standard error of the number of P. argus observed in "terrace reef" and "truss reef/gabion" in Site 1

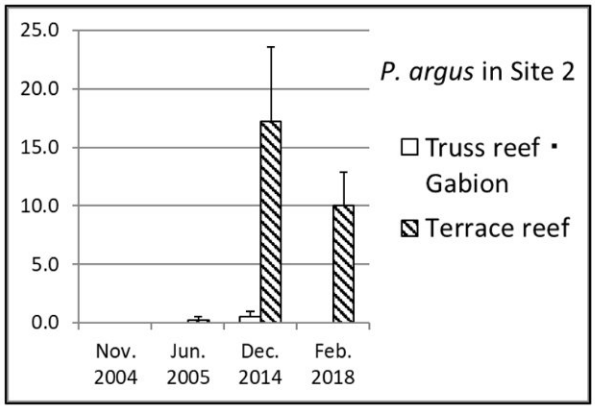


Figure 15. Mean ± standard error of the number of P. argus observed in "terrace reef" and "truss reef/gabion" in Site 2

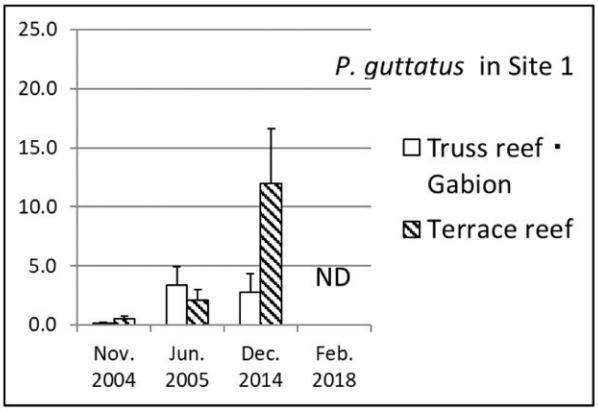


Figure 16. Mean ± standard error of the number of P. guttatus observed in "terrace reef" and "truss reef/gabion" at Site 1.

3.2 Saint Lucia:

Date of each monitoring survey undertaken is shown in Table 2.

Table 2. Date of each monitoring survey in Saint Lucia

Laborie					Soufriere
24, 29 November. 1 December 2021	13, 21 January 2022	21 August 2022	16 20 September 2022	17, 20 December 2022	15, 21 December 2022

In Laborie, the changes of total number of spiny lobsters observed in artificial reef site in time series are shown in Fig. 17. No spiny lobsters were observed in or around the artificial reefs during the survey in January 2022, two months after the installation. However, about nine months later, in August 2022, three juvenile *P. argus* with a total length of 2 to 4 inch were observed, and about ten months later, in September 2022, four juvenile *P. argus* were observed. In addition, about a year after the installation, in December 2022, 3 juvenile *P. argus* were observed as before, and 20 individuals of *P. argus* with a total length of 5 inch or more were observed in the artificial reef cite. On the other hand, no spiny lobster including *P. argus* and *P. guttatus* was observed in the control site. Through this monitoring, all spiny lobsters observed at artificial reef sites were *P. argus*, and no *P. guttatus* was observed.

In Soufriere three months after the installation in September 2022, a total of 20 individuals of spiny lobster were observed within the artificial reef site off the public beach, two of which were juveniles less than 4 inch in total length. All spiny lobsters observed were *P. argus* and *P. guttatus* was not recorded. On the other hand, no spiny lobsters were observed in the surrounding natural reefs, which were used as control sites.

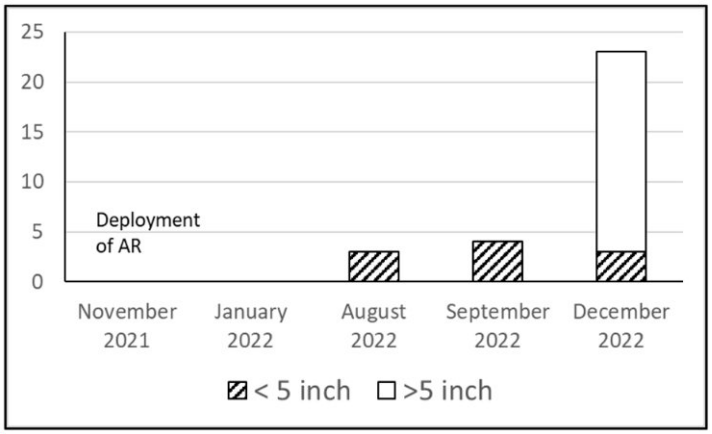


Figure 17. Total number of P. argus observed at in artificial reef Site in Laborie in time series

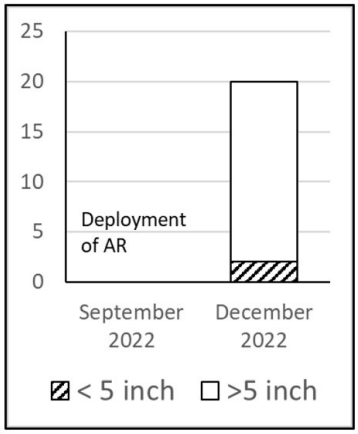


Figure 18. Total number of P. argus observed at in artificial reef Site in Soufriere in time series.

Regarding the juvenile spiny lobsters gathered in artificial seaweeds, two of those installed in November 2021 were retrieved after two months in January 2022, in order to check the number of juvenile spiny lobsters gathered in it. Consequently, 16 juvenile spiny lobsters were retrieved from one artificial seaweed and 2 from the other, for a total of 18. All individuals collected were *P. argus* (Fig. 16). The total lengths of these juvenile spiny lobsters (from top of carapace to end of tail) were as shown in Table 3.

Figure 19. Juvenile spiny lobsters collected from artificial seaweed

Table 3. Total lengths of spiny juvenile lobsters, P. argus collected from artificial seaweed.

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Total length (mm)	27	24	25	25	26	38	27	28	34	27	24	24	28	26	27	27	25	26

4. DISCUSSION

Based on the survey results that are mentioned above, it was clear that the artificial reefs have a much higher effect for attracting spiny lobster than that of natural reefs. Various studies have shown that artificial reefs promote the gathering fish by altering the seafloor (e.g., Bohnsack et al. 1991, Grove et al. 1991, Terashima et al. 2007-1, Hylkema et al., 2023). It is thought that the installation of such artificial structures will serve as suitable habitats for reef marine organisms including spiny lobster. Especially, it was clear that large numbers of *P. argus* and *P. guttatus* aggregated on the Terrace reef, which was designed specifically to attract spiny lobsters. The installation of well-designed artificial reefs within managed Marine Protected Areas (MPAs) is therefore expected to protect its stocks from overexploitation. In addition, by setting artificial reefs on sandy bottoms where there are not many reef-living organisms and therefore no use as fishing grounds, it would be possible to make out new management areas or MPAs in places different from existing fishing grounds. Efforts to avoid concentration of excessive fishing pressure on aquatic organisms have been made around the world (e.g., Terashima et al. 2007-2, 2012). It will be possible to manage the resources of spiny lobsters by taking such measures. However, it is clear that installing a large artificial reef requires not only the cost of materials, but also high costs for installation (OFCA. 2018). Appropriately designed artificial reefs can be installed as needed if there is sufficient budget, but in many cases it is not possible. The conch shell reef designed and used in St. Lucia would be suitable for projects in developing countries with limited budgets because it can be easily installed at low cost.

It should be noted that there are two species of spiny lobster in the eastern Caribbean region, *P. argus* and *P. guttatus*, but most of the individuals observed in this study were *P. argus*. It is not clear what caused this. *P. guttatus* resources may be low in the region, but we need to collect more data to draw clear conclusions.

Artificial seaweed ("Mojamoja" manufactured by Okabe Co., Ltd.) developed in Japan is known to be effective in attracting post larvae such as spiny lobsters and sea cucumbers (Harada, 2016). It can be said that this study confirmed that this artificial seaweed would be effective in attracting post larvae and juvenile of spiny lobster species not only in Japan but in the Caribbean Sea. If there is an inexpensive artificial reef to combine with this artificial seaweed, it is considered to be highly effective as a habitat for juvenile spiny lobsters settled on the bottom. The conch shell reef made in this activity is considered to have such an effect. However, while this artificial seaweed is effective in attracting spiny lobster larvae, it is also obvious to require costs. Around the eastern Caribbean, aquaculture of seaweed locally called Seamoss including *Gracilaria* spp. and *Eucheuma cottonnii* as well, which is used as nutritional food, is becoming popular (Bulbulia, 2022). Local community people farming this seaweed in the area are aware of large number of Post larvae of spiny lobster uniquely exist around the seaweed. For this reason, it is expected that marine resources including post larva and juvenile spiny lobster can be inexpensively enhanced on newly provided underwater habitats by combining the conch shell reef and the seaweed farming.

In the Caribbean region, lobster fishing using artificial reefs called Casitas as secondary fishing gear is popular. Along with this, several attempts have been made to increase the spiny lobster resource by deploying Casitas and increasing the habitats for it (e.g., Eggleston et al. 1990, Lipcius et al. 1998, Briones-Fourzán, p. and E. Lozano-Álvarez 2001). Based on the results of such activities, Briones-Fourzán et al. (2007) mentioned that the casitas could be used to create habitats for juvenile and young spiny lobster, which may enhance the resource. In contrast,

Gutzler, et al. (2015) pointed out that an aggregation of juvenile spiny lobster attracts its predators, and that Casitas used for fishing have wide openings that allow predators of juvenile spiny lobsters to easily enter. They then suggested consequently that the predation rate increases, which adversely affects the growth of spiny lobster stocks. Therefore, when considering the use of artificial reef for enhancement of the resource, it would be necessary to select an appropriate size and design to facilitate hiding places for juvenile spiny lobsters (Sosa-Cordero et al. 1998). The conch shell reef mentioned above has many openings and gaps in and between conch shells, which are too small for large spiny lobsters and predators to enter, but just suitable for juveniles one around 30 millimetres in length to hide. Therefore, it might be useful for establishing a spiny lobster nursery ground to deploy this type of artificial reefs beside a seagrass bed where provide abundant food for lobsters, and to set up the area as MMA or MPA. Such an activity is expected to contribute to the enhancement of the resource.

In order to effectively and sustainably disseminate resource breeding activities through the installation of artificial reefs, it is essential to have the local residents understand the purpose of the activity and obtain their active cooperation. In Japan, this strategy is called 'satoumi'. Mizuta and Vlachopoulou (2017) define this word as a status in which human activities and ecosystems interact to increase biodiversity and productivity, thereby improving ecosystem services. Incorporating such bottom-up efforts by fisherfolks into the Caribbean region is advocated to be an effective means for sustainable and competitive fisheries management. In the future, it will be necessary to encourage local fisherfolks to understand the concept of satoumi in Caribbean countries, and to manage coastal fisheries resources in cooperation with local fisherfolks, fisheries officials and researchers.

ACKNOWLEDGEMENT

Of these studies, the activities in Saint Vincent and the Grenadines were part of the New Fisheries Cooperation Promotion Project implemented by OFCA, and the activities in Saint Lucia were part of a technical cooperation project called COASTFISH implemented by JICA.

Special thanks go to Mr. Kris Isaacs, Senior Fisheries Officer, Mr. Jeremy Searles, Fisheries Officer, and Mr. Raynaldo Horald, Fisheries Assistant of Fisheries Division, Ministry of Agriculture, Forestry & Fisheries in Saint Vincent and the Grenadines due to their participation and assistance for the underwater activities in the country.

LITERATURE CITED

Baisre, J.A. 2000. The Cuban Spiny Lobster Fishery. Pages 135-152, in: B.F. Phillips and J. Kittaka, (eds) Spiny Lobsters: Fisheries and Culture. Blackwell Science Ltd. UK.

Bohnsack, J.A., D.L. Johnson and R.F. Ambrose. 1991. Ecology of Artificial Reef Habitats and Fishes. 61-107. in: W. Seaman Jr and L. M. Sprague (eds) Artificial Habitats for Marine and Freshwater Fisheries. Academic Press Inc. USA.

Briones-Fourzán, p. and E. Lozano-Álvarez 2001. Effects of artificial shelters (Casitas) on the abundance and biomass of juvenile spiny lobsters Panulirus argus in a habitat-limited tropical reef lagoon. Marine Ecology Progress Series, 221: 221–232.

Briones-Fourzán, P., E. Lozano-Álvarez, F. Negrete-Soto and C. Barradas-Ortiz. 2007. Enhancement of juvenile Caribbean spiny lobsters: an evaluation of changes in multiple response variables with the addition of large artificial shelters. Oecologia 151: 401–416.

Bulbulia, F., R. Alleyne, K. Moore and S. George. 2022. Unlocking the Potential of Aquaculture for Food Security and Climate Resilience in the Caribbean. FAO Aquaculture News Number 66: 16.

Butler, M.J. and W.F. Herrnkind. 1997. A test of recruitment limitation and the potential for artificial enhancement of spiny lobster (*Panulirus argus*) population in Florida. *Canadian Journ. Fish. Aquat. Sci.,* 54**:** 452-463.

Eggleston, D., Lipcius, R., Coba-Centina, L., & Miller, D. 1990. Shelter scaling regulates survival of juvenile spiny lobster, *Panulirus argus*. Marine Ecology Progress Series, 62, 79–88.

Ehrhardt, N., R. Puga and M. J. Butler IV. 2011. Implications of the Ecosystem Approach to Fisheries Management in Large Ecosystems. The Case of the Caribbean Spiny Lobster. Pages 157-175. in: L. Fanning, R. Mahon and P. McConney, (eds) Ecosystem-based Management in the Wider Caribbean. Amsterdam University Press. Amsterdam.

Fonteles-Filho, A.A. 2000. The State of the Lobster Fishery in North-east Brazil. Pages 121-134. in: B.F. Phillips and J. Kittaka, (eds) Spiny Lobsters: Fisheries and Culture. Blackwell Science Ltd. UK.

Goldstein, J.S., H. Matsuda, T. Takenouchi, and M. J. Butler IV. 2008. The Complete Development of Larval Caribbean Spiny Lobster Panulirus argus (Latreille, 1804) in culture. Journal of Crustacean Biology 28 (02): 306–327.

Grove, R. S., C. J. Sonu and M. Nakamura. 1991. Design and Engineering of Manufactured Habitats for Fisheries Enhancement. 109-152. in: S. A. Bortone, F. P. Brandini, G. Fabi and S. Otake (eds) Artificial Reefs in Fisheries Management. CRC Press, USA.

Gutzler, B. C., M. J. Butler-IV, and D. C. Behringer. 2015. Casitas: a location-dependent ecological trap for juvenile Caribbean spiny lobsters, *Panulirus argus*. ICES Journal of Marine Science 72(Supplement 1): i177–i184.

Harada, M. 2016. Introduction of Okabe Co., Ltd. Marine Division. Nippon Suisan Gakkaishi 82(2): 204-205. (in Japanese)

Horsford, I., H. Simon, M. Archibald, J. Webber and T. Joseph. 2014. Biology, Status, and Current Management of the Caribbean Spiny Lobster (*Panulirus argus*) in Antigua and Barbuda. Proceedings of the 66th Gulf and Caribbean Fisheries Institute November 4 – 8, 2013 Corpus Christi, Texas USA. 423-433.

Hylkema, A., A. O. Debrot, R. A.R. Cammenga, P. M. van der Laan, M. Pistor, A. J. Murk and R. Osinga. 2023. The effect of artificial reef design on the attraction of herbivorous fish and on coral recruitment, survival and growth. Ecological Engineering 188 (2023) 106882. 11 pp.

Ito, Y. 2011. Artificial Reef function in Fishing Grounds off Japan. 239-264. in: in: S. A. Bortone, F. P. Brandini, G. Fabi and S. Otake (eds) Artificial Reefs in Fisheries Management. CRC Press, USA.

Kittaka, J., and K. Kimura. 1989. Culture of the Japanese spiny lobster, *Panulirus japonicus* from egg to juvenile stage. Nippon Suisan Gakkaishi 55: 963-970.

Lipcius, R. N., D. B. Eggleston, D. L. Miller and T. C. Luhrs. 1998. The habitat-survival function for Caribbean spiny lobster: an inverted size effect and non-linearity in mixed algal and seagrass habitats. Marine and Freshwater Research 49(8): 807 - 816.

Lovell, T.A. 2023. Managing abandoned, lost and otherwise discarded fishing gear (Derelict Gear) in Eastern Caribbean small-scale fisheries: An assessment of legislative, regulatory and policy gaps. Marine Policy 148 (2023) 105432. 13 pp.

Mizuta, D. D. and E. I. Vlachopoulou. 2017. Satoumi concept illustrated by sustainable bottom-up initiatives of Japanese Fisheries Cooperative Associations. Marine Policy Vol. 78: 143-149.

OFCA. 2018. New Fisheries Cooperation Promotion Project, Education and Dissemination Aimed at Introducing Coastal Fisheries Resources Management and Stock Enhancement - Example of Artificial Fish Reef Experimental Projects in the Republic of Senegal & St. Vincent and the Grenadines- 20 pp. Overseas Fisheries Consultants Association, Tokyo.

Phillips, B. F. and R. Melville-Smith. 2006. *Panulirus* Species. Pages 359 384. in: B. F. Phillips, (ed.) Lobsters: Biology, Management, Aquaculture and Fisheries. Blackwell Publishing. UK.

Saint Lucia. 1987. Fisheries (Turtle, Lobster and Fish Protection) Regulations. Statutory Instruments No. 67: 161-163.

Saint Vincent and the Grenadines. 1987. Statutory Rules and Orders. 26 pp. St. Vincent and the Grenadines.

Sheehy, D. 1982. Japanese Artificial Reef Technology - Translations of Selected Japanese Literature and an Evaluation of Potential Applications in the U.S. Technical Report 604. Aquabio Inc. USA. 380 pp.

Sosa-Cordero、E., A.M Arce, W. Aguilar-Dávila and A. Ramírez-González. 1998. Artificial shelters for spiny lobster *Panulirus argus* (Latreille): an evaluation of occupancy in different benthic habitats. Journal of Experimental Marine Biology and Ecology. Vol. 229 (1): 1-18.

Spanier, E. K. L. Lavalli, and Dor Edelist. 2011. Artificial reefs for lobsters - An Overview of Their Application for Fisheries Enhancement, Management, and Conservation. 77-109. in: S. A. Bortone, F. P. Brandini, G. Fabi and S. Otake (eds) Artificial Reefs in Fisheries Management. CRC Press, USA.

Terashima, H,. K. Sakurai, M. Taniguchi, S. Sasaki, H. Noguchi, K. Asamidori and T. Hoshino. 2007. Effect of Hemispherical Steel net Covering Artificial Reef on Fish Aggregation. Recent Advances in Marine Science and Technology 2006: 11-22.

Terashima, H., M. Sato, H. Kawasaki and D. Thiam. 2007. Quantitative biological assessment of a newly installed artificial reef in Yenne, Senegal. Zoological Study. 46(1): 69-82.

Terashima, H., N. B. H. Hamida, O. B. Abdallah, N. L. Moatenri, H. Nanao, M. Sato, M. Tada, H. Missaoui and O. Jarboui. 2012. Temporal Variation in Fish Biomass on the Artificial Habitats Installed in Gabes Gulf, Southern Tunisia. Recent Advances in Marine Science and Technology 2012: 37-53.