**Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand**

# FISHERIES REFUGIA MANAGEMENT PLAN FOR MUD SPINY LOBSTER ON THE EAST COAST OF JOHOR

DEPARTMENT OF FISHERIES, MALAYSIA

**SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER**
TRAINING DEPARTMENT

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# FISHERIES REFUGIA MANAGEMENT PLAN FOR MUD SPINY LOBSTER ON THE EAST COAST OF JOHOR

2022

# FOREWORDS

The growing demand for seafood is putting a strain on fishery resources. The mud spiny lobster, scientifically known as Panulirus polyphagus is a popular seafood and luxurious delicacy enjoyed worldwide. Although the IUCN red list does not classify the mud spiny lobster as endangered, the captured fisheries statistic indicated a decline in the lobster landing in Malaysia (1988 - 2018). Therefore, a management plan is required to ensure the sustainability of the lobster fisheries, particularly on the east coast of Johor.

The management plan shall consider all issues and challenges, including the need to transform the current fishing practices into a sustainable business and to remain significant and iconic on the east coast of Johor. The transformation of lobster fisheries is anticipated to increase the value chain and create more employment opportunities on the east coast of Johor.

This lobster refugium management plan addresses many facets of lobster fisheries, including resource conservation, co-management, business development, engagement and communication with stakeholders, and a research plan. The management plan outlines eight strategies to promote sustainable lobster fisheries in Johor. Key strategies include discouraging the capture and export of juvenile lobster and egg-berried females. In addition, the Department will announce the closure of lobster season in the sensitive area deemed essential for lobster aggregation and reproduction. In addition to supporting the implementation of the SEAFDEC/UNEP/GEF Project on the Establishment and Operation of a Regional System of Fisheries Refugia In The South China Sea And Gulf Of Thailand, the development of this management plan is also consistent with the Department's goal of realizing the National Agrofood Policy 2.0 (DAN 2.0).

The Department of Fisheries Malaysia (DOFM) will continue prioritizing sustainable resource management and national food security. This management plan will be implemented within the allotted time frame. In the interim, the Department will periodically review and revise the strategies to achieve the sustainable goal.

The Sustainable fisheries plan will remain on paper if stakeholders remain passive in their support and adoption. The joint responsibility is essential to ensure the sustainability of the lobster fisheries as well as its ecosystem function. With the publication of this management plan, the Department hopes to simultaneously promote sustainable fishery and garner the support and cooperation of all parties in order to protect our fisheries resources.

# Ackwowledgement

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## DISCLAIMER

# FISHERIES REFUGIA MANAGEMENT PLAN FOR THE MUD SPINY LOBSTER ON THE EAST COAST OF JOHOR

## Executive Summary

The Department of Fisheries Malaysia (DOFM) endorsed the concept of fisheries refugia as one of its efforts to sustain the lobster fisheries, particularly the protection of the lobster stock on the east coast of Johor. The fisheries refugia are a complementary effort to the present management framework that filled gaps, particularly for the mud spiny lobster. Nonetheless, fisheries refugia are not a replica of a marine protected area (MPA). The fisheries refugia emphasize long-term viability of the fishing industry, specifically resource sustainability. Hence, the vision of the fisheries refugia is to develop sustainable lobster fisheries on the east coast of Johor via its mission of implementing good practices as outlined in the fisheries refugia plan. In the context of conserving the mud spiny lobster stock on the east coast of Johor, over-fishing is the primary threat. The fisheries refugia will not achieve its goals if the lobster refugium is limited to the surrounding area of Tanjung Leman. After considering critical habitats for lobster, the sea current circulation pattern, species distribution, and the present fisheries activities in the area, the boundary of the fisheries refugium was re-delineated to cover the coastal water on the east coast of Johor. In addition, an area of 1,717 $km^2$, located southward of Pulau Aur, was identified as the sensitive area for spawning within the lobster refugium. The fisheries refugia plan highlighted eight strategies to sustain the lobster fisheries in the designated refugium. **Strategy 1**: Conserving habitats of the mud spiny lobster through concerted efforts from various government agencies; **Strategy 2**: Deploying artificial reefs to create habitats for lobster, with the rigs-to-reefs program being one of the programs that could be capitalized upon; **Strategy 3**: Prohibiting catches of juvenile lobsters (carapace size < 6 cm) and berried females; **Strategy 4**: Announcing the closure of the lobster fishing season in the sensitive area from 15 December until the last day of February of the following year to allow spawning; **Strategy 5**: Research and development for lobster aquaculture. The lobster aquaculture could divert harvesting pressure and create job opportunities for the community; **Strategy 6:** Engaging the stakeholders in co-managing the refugium. Among the duties of the managing committee are establishing a lobster floor price and monitoring the current status of lobster stock within the refugium. The lobster floor price is intended to compensate fishermen for not catching the juvenile lobsters and berried females; **Strategy 7**: Modulating lobster demand chain and financially sustaining management of the lobster refugium. In order to prevent catching downsized lobsters, the current lobster fisheries in Johor shall be planned toward sustainable seafood markets where catches of juveniles and berried females are prohibited. Towards this end, a refugia endowment will be established to support the management

of the fisheries refugia. In the meantime, the Malaysian Seafood Council will be established to facilitate the transformation of the present lobster industry in Johor. Lastly, **Strategy 8**: Further research to improve the management of the fisheries refugia. The research should encompass three fundamental aspects: i.e., the biology of the mud spiny lobster, the socio-economic condition of the fishing community, and market strategies for high-end seafood. The performance of the fisheries refugia can be benchmarked via lobster size at stock landing, lobster carapace size, and puerulus watch program. The fisheries refugia plan shall be dynamic and data-driven. A periodic review and update of the management plan based on current changes and needs can help to ensure that best practices are followed. The endpoint of the refugium management plan relies on the shift of consumer markets toward sustainability. Implementing sustainable practices in the fisheries refugia shall begin with creating public awareness, improving the value chain of the lobster industry, and enforcing and penalising repeat offenders.

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# Abbreviation

| | |
|---|---|
| MPA | Marine Protected Area |
| NSC | Norweigian Seafood Council |
| SEAFDEC | Southeast Asian Fisheries Development Center |
| IUCN red list | The International Union for Conservation of Nature (IUCN) Red List of Threatened Species |
| SWOT | Strength-Weakness-Opportunity-Threat |
| DOFM | Jabatan Perikanan Malaysia |
| UNEP | United Nation Environment Programme |
| RTR | Rigs-to-reefs |
| SCUBA | Self-Contained Underwater Breathing Apparatus |
| GEF | Global Environment Facility |
| MSY | Maximum Sustainable Yield |
| NOAA | National Oceanic and Atmospheric Administration |
| MSC | Marine Stewardship Council |
| WRL | Western Rock Lobster |
| MSC | Malaysia Seafood Council |
| AR | Artificial Reefs |

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# 1.0 INTRODUCTION

The concept of wildlife refugia was introduced as early as 1939 to protect biological resources, particularly wildlife in nature (Elton, 1939). In the early stage, the refugia concept aims to shelter those species from predators temporarily. In this context, the wildlife refugia may not be the habitat for the targeted species per se. The concept of wildlife refugia was then adapted and used to manage biological resources, including fisheries. Nowadays, the refugia concept is used to complement the efforts to conserve and restore marine biological resources, particularly complementing the marine protected area (MPA). Keppel et al. (2015) highlighted the potential of the fisheries refugia to reduce the impact of climate change on fisheries resources. The concept of fisheries refugia, which provides spatial and temporal protection to a specific species, has been used in many countries under different terms and programs. For example, catches of blue swimming crabs in Perth and the southwestern area of Australia are prohibited throughout the close season, beginning 1 September until 30 November, protecting crab breeding stock. The closure order covers commercial and recreational purposes (Johnson et al., 2020). In Norway, the catch of undersize Skrei is prohibited from January to April every year to conserve the Skrei stock in the country (Tsiouvalas et al., 2022). The government of Norway and Russia has collaborated in protecting the migrating Skrei stock by introducing quota to limit Skrei catch in both countries since 2006 (Kvamsdal et al., 2016). Through its subsidiary company, the Norwegian Seafood Council (NSC), the government of Norway has upgraded the Skrei industries by introducing sustainable fisheries. The efforts were translated into a branding that successfully penetrated the international seafood market. The concept of fisheries refugia was reviewed thoroughly and was introduced to the ASEAN countries via SEAFDEC/GEF/UNEP program. The fisheries refugia are deemed to be the solution that could integrate fisheries and habitat management for small-scale fisheries in this region (Paterson, 2013). The SEAFDEC/GEF/UNEP program published information about the ASEAN refugia program via its website at http://fisheries-refugia.org.

In Malaysia, the concept of fisheries refugia is gaining momentum as it provides alternative protection to the MPA's no-take zone. The no-take zone, to some degree, affected the livelihood of the small-scale artisanal fishermen who could only harvest seafood from the nearby coastal water. In 2016, the DOFM intended to implement the fisheries refugia at Tanjung Leman for mud spiny lobster and Kuala Baram for tiger prawns. The mud spiny lobster and tiger prawns' stocks are facing a declining trend, as revealed in its twenty-year landing data (Mohd Ghazali et al., 2016). In principle, fisheries management depends on three integrated components, as demonstrated in Figure 1 (Lackey, 2005). Sustainable fisheries require the manager to investigate each component of fisheries management. Selwood and Zimmer (2020) reported key factors that should be considered in protecting an operational taxonomy unit (OUT) in a sustainable manner, and the key factors that have been identified are:

- Identification of intended species for protection
- Delineation of protection boundary
- Identified threats and challenges to the protection

After identifying the key components, each component shall have its corresponding strategies and action plan.

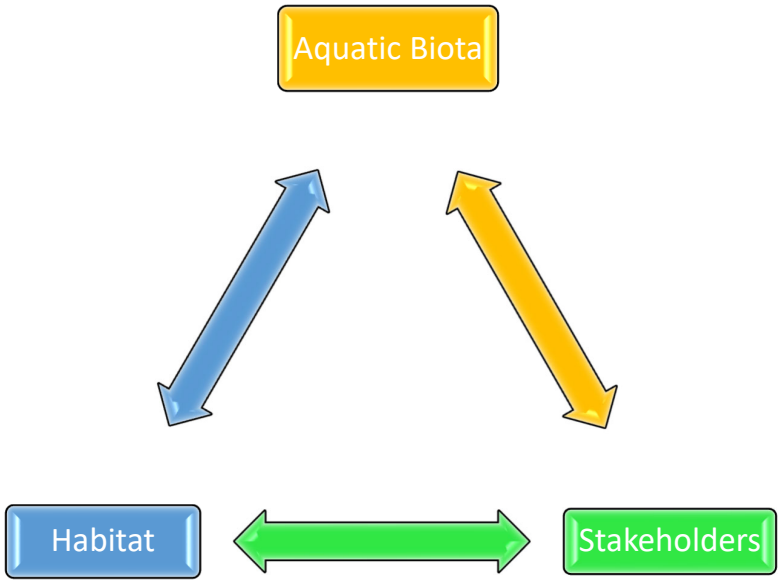



**Figure 1: Interactive components in fisheries management**

The mud spiny lobster (*Panulirus polyphagus*) is a popular commodity for export. However, many aspects of the lobster, including its distribution, life cycle, and reproductive behavior in Malaysia, are vastly unknown. Most information pertinent to lobster behavior is based on the findings from rock lobsters (*Jasus edwardsii*) and common spiny lobsters *(Panulirus vulgaris)*. However, based on the few studies on the mud spiny lobster (*Panulirus polyphagus*) in Malaysia, the mud spiny lobster is commonly found along the east coast of peninsular Malaysia, extending from the Kelantan in the north down to Johor in the south (Alias et al., 2000). Noor Hanis and Siow (2019) and Siow et al. (2020) again reported the declining lobster landing since 2010, most probably associated with overfishing (Figure 2).

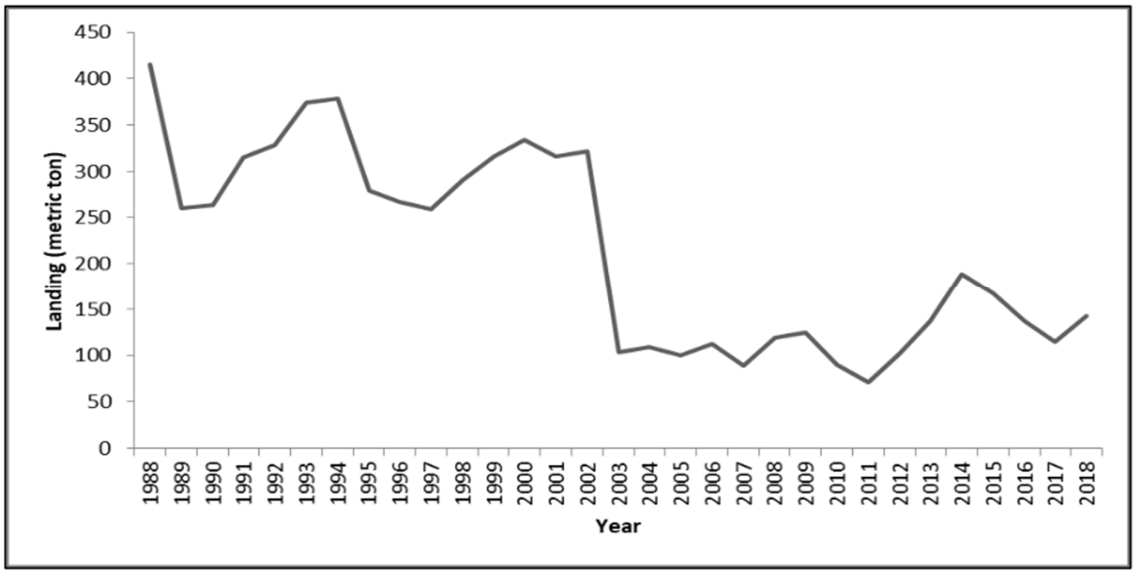



**Figure 2: Lobster landing trend on the east coast of Peninsular Malaysia 1988 - 2018 (Siow et al., 2020)**

Concluding the findings of various studies on the implementation of fisheries refugia in various countries, particularly in relation to establishing catch quota, seasonal closure, and other means of fisheries stock conservation, the following components are essential to a successful implementation of fisheries refugia:

- Sensitive areas that harbor a portion or the entire life cycle of the targeted species
- Sensitive period to a portion or the entire life cycle of the targeted species
- Impact assessment of the current fisheries practices; both fishing apparatus and fishing methods on the population of the targeted species; and the alternative to the destructive fishing apparatus and methods
- Stakeholders' engagement plan in the fisheries refugia
- Research plan as the basis for data-driven management. The management plan for the fisheries refugia management plan must be scientifically sound
- Financial sustainability. The financial aspect must be part of the management plan to ensure that all the necessary interventions could be properly implemented without the financial drawback.

All the above mentioned components form the basis for the fisheries refugium management plan for mud spiny lobster on the east coast of Johor. Although studies on the mud spiny lobster have been conducted by the Department of Fisheries Malaysia, specifically on the east coast of Peninsular Malaysia, the studies are one-offs and lack continuity. More data are required to formulate a good management plan for the mud spiny lobster on the east coast of Johor. Nonetheless, the lack of data shall not restrict the development of the management

plan; indeed, the management plan takes into consideration the precautionary principle on areas that lack information or are highly uncertain.

## 1.1 SWOT (STRENGTH-WEAKNESS-OPPORTUNITY-THREAT) ANALYSIS

Table 1 shows the matric of the SWOT analysis for implementing fisheries refugia on the east coast of Johor. The SWOT analysis has identified the gaps, which were subsequently fulfilled by the strategies in the management plan.

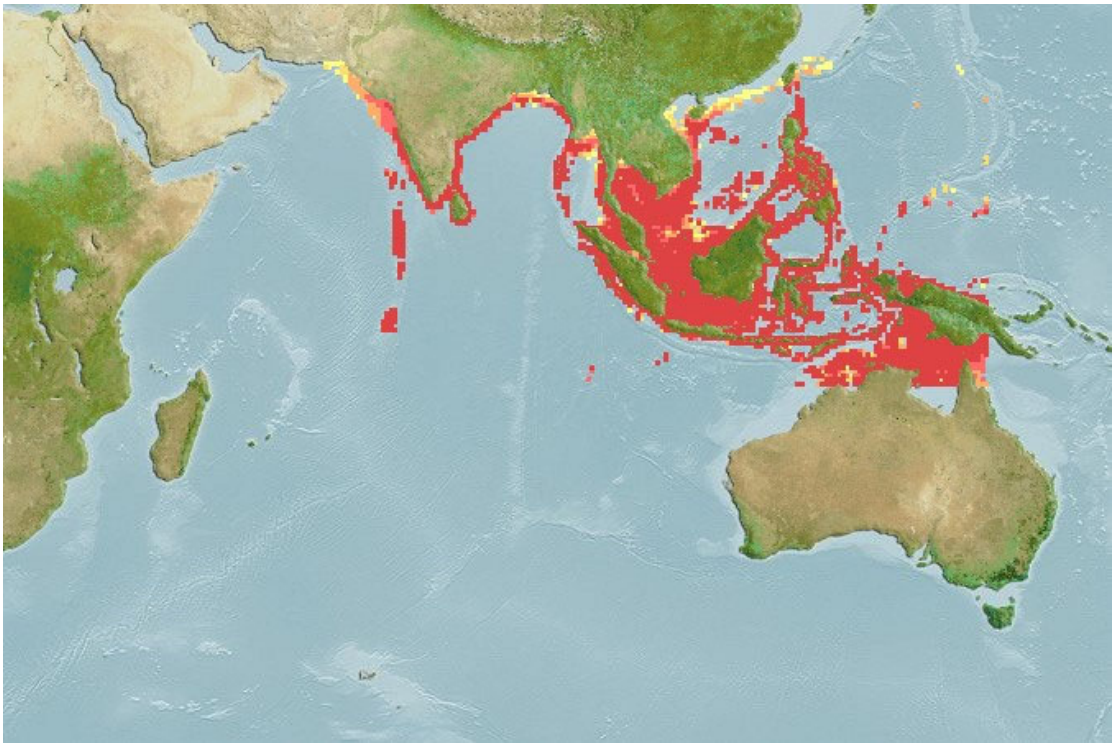
**Table 1: SWOT analysis for the lobster refugium on the east coast of Johor**

| STRENGTH | WEAKNESS |
|---|---|
| - DOFM has conducted scientific research on the mud spiny lobster.<br>- The data could be used as a guide for developing the management plan for the lobster refugium.<br>- Based on the research, the local community, particularly the artisanal fishers are in support of the fisheries refugium in Johor | - Lack of coordination and support from inter- and intra- agencies<br>- Lack of strategy to overcome the challenges and limitations in the fisheries refugium<br>- Lack of financial resources to support intervening activities in the fisheries refugium<br>- Lack of publicity. Public awareness of conserving fisheries resources is low. |
| **OPPORTUNITY** | **THREATS** |
| - The fisheries refugia is a regional program implemented in the ASEAN countries. The procedures and findings are published, providing a good reference for implementation.<br>- Successful implementation of the fisheries refugia will provide a good framework to protect other fisheries resources | - Objection and rejection of the refugium concept by the stakeholders<br>- Lack of political will |

# 2.0 LITERATURE REVIEW

## 2.1 BIOLOGY OF THE MUD SPINY LOBSTER

The mud spiny lobster (*Panulirus polyphagus)* is widely distributed across the Indo-Pacific region covering the Maldives and Bengal Bay in the Indian Ocean, Thailand, Malaysia, Indonesia, Vietnam, Philippines, Papua New Guinea, and extended to Australia (Figure 3). The mud spiny lobster is classified as the least concern in the IUCN red list. Even though the mud spiny lobster is of the least concern from the perspective of biodiversity conservation, the declining trend in Malaysia suggested the need to conserve the fisheries stock. The status of the mud spiny lobster in the IUCN red list does not reflect the need to manage the commodity in the country.



*(Source: IUCN Red list)*

**Figure 3: Distribution of the mud spiny lobster *Panulirus polyphagus***

The mud spiny-lobster *Panulirus polyphagus* is commonly found in the muddy area where the water is turbid. Occasionally, the mud spiny lobster could also be found on the rocky bottom near a river estuary (Holthuis, 1991). The mud spiny lobster is a carnivorous predator that preys on weak and inactive benthic organisms (Kanciruk, 1980). It is also a scavenging organism that feeds on carcasses (Diaz-Arredondo & Guzman-del-Proo, 1995; Briones-Fourzan et al., 2003). The juvenile mud spiny lobster is commonly found in shallow water, around 3 m water depth, while the adults can be found in 40 – 60 m water. Some reports encountered the lobster in approximately 90 m water depth (Holthuis, 1991; Ikhwanuddin et al., 2014). Except for the report published by

Kagwade (1988), no other publication elaborates life cycle of *Panulirus polyphagus* in greater detail. Most of the life cycle published on *Panulirus polyphagus* is extrapolated based on the life cycle of *Panulirus* spp., as demonstrated in Figure 4.

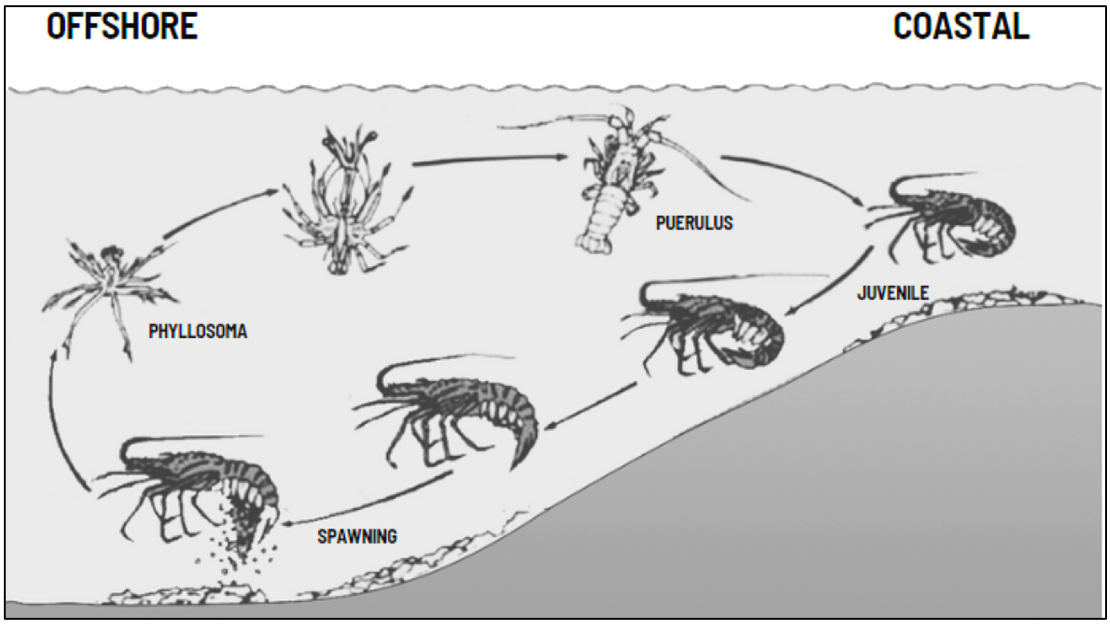



**Figure 4: Life cycle of Panulirus lobster (*Panulirus* spp.)**

The mud spiny lobster uses the r-strategy in its reproductive cycle. The mud spiny lobster has high fecundity yet low survival in an ever-changing environment. The planktonic stage of the lobster larvae is relatively long (from a few months up to about two years). The larvae drifted following the sea current circulation pattern (Lipcius & Eggleston, 2000). The *Panulirus* lobster is sexual dimorphism (i.e., the sexes of the lobster exhibit different morphological characteristics, particularly characteristics not directly involved in reproduction), and it reproduces throughout the year (Kagwade, 1988; Quackenbush, 1994; Pollock 1997). Although the lobster reproduced throughout the year, the spawning mainly happened from September until January (Kagwade, 1988). The size of the female lobster will determine the ovigerous frequency and the number of eggs released in a year. Bigger female lobsters could produce more than two million eggs per individual (Quackenbush, 1994; Chavez, 2019). The mature lobsters will migrate into deeper water (>40 m) for spawning. During the spawning process, the male lobster will stick its spermatophore on the abdomen of the female lobster, where external fertilization occurs (Cruz & Bertelson, 2009). The female lobster then carries the fertilized eggs. The larvae hatched from the eggs will be released into the water column and drift by the sea current.

Spawning of the *Panulirus cygnus* occurs after the female is molted. After molting, the hairy-like structure of the swimming legs provides better sticking on the eggs (Kittaka et al., 1994). Sperm is released from the spermatophore mass by scrapping the speculated end of the fifth leg (Kagwade, 1988). After embedding in the

ovary (external fertilization), the eggs are attached to the female pleopod filament and incubated by the female for 4 – 8 weeks for the embryos to develop before hatching.

While the females berried the eggs between their pleopods, they rarely came out of their hiding place and rarely fed during this stage. When the eggs are matured, the female lobster fans its pleopods to release the newly hatched larvae. This stage 1 phyllosoma is planktonic and often carried by the sea current offshore. The phyllosoma is transparent and dorso-ventrally compressed with a neatly formed prickly appendage that allows for a prolonged planktonic phase (Barret, 2019). Stage 1 phyllosoma begins to feed on zooplankton as soon as it hatches due to the absence of egg yolk in the phyllosoma. The phyllosoma metamorphosized multiple times before its puerulus stage. Soft gelatine zooplankton, including chaetognaths, ctenophores, salpa, and medusae, are lobster larvae's favorite food (Kittaka et al., 1994; Sawstrom et al., 2014). As this zooplankton occupied a higher trophic level resulting in uneven and scarce distribution, it significantly impacted the growth of the phyllosoma larvae (Sawstrom et al., 2014). The phyllosoma larvae then drifted by the ocean current for 8 -11 months (Barret, 2019), and in between, they molded 7 – 13 times (Lipcius & Eggleston, 2000). Depending on their food and nutritional level, this process may be extended beyond two years (Lipcius & Eggleston, 2000). This happens when the phyllosoma larvae are trapped in the open ocean circulation. Under such circumstances, the phyllosoma larvae will continue to grow and ecdysis to lengthen their planktonic phase (Lipcius & Eggleston, 2000).

The transition from the pelagic phase to the benthic phase begins with a major change from a transparent leaf-shaped phyllosoma carried by the current to a transparent puerulus stage that resembles a shrimp and can swim fast against the current. This metamorphosis involves a series of physiological, morphological, and behavioral transformations that occur when the current carries them into the shallow coastal waters (Barret, 2019). The last stage of ocean phyllosoma may last for 20-30 days, during which the entrail is pulled back from a cephalic shield that shrinks and folds down to achieve a prawn-like body shape (Ventura et al., 2015). When the phyllosoma stomach is completely retracted (this process lasts up to 24 hours), it will mold within three days into a transparent nektonic puerulus. At this time, the nektonic puerulus does not feed. A combination of complex stimuli such as salinity, turbidity, nutrients, tides, currents, and the complexity of the seabed topography (Priyambodo et al., 2017) will stimulate active movement, which triggers them to swim to the shallow coastal water, and eventually settle on the benthic environment. The late-stage puerulus will seek refuge in rock crevices or holes in mangroves, coral reefs, and other habitats, including seaweed and seagrass bed (Herrnkind, 1986; Dennis et al., 1997, Siow et al., 2018). As the puerulus swims into the shallow habitat, its digestive system will fully be developed and lead to staining of the hepatopancreas (phase-H puerulus) (Ventura et al., 2015). When the puerulus sought a suitable hiding place in the benthic environment, cuticle pigmentation (pigmented puerulus) applies to help disguise the puerulus from predators. After the subsequent ecdysis, the puerulus will grow into the juvenile lobster.

Alias and Rashidah (2000) reported a high density of juvenile lobster (~200 g/piece) found on the rocky bottom in turbid water, situated near river mouths at approximately 10 m water depth, while adults are found in deeper

waters, approximately 50 m water depth. The matured adult weighed more than 400 g/piece, spawning in deeper water. The mud spiny lobster is reported to be carnivorous. Other reports also pointed out the omnivorous and scavenging behavior of the lobster.

During the day, lobster hide in the crevices of the rocks. Lobster is nocturnal and will come out from the rock crevices for feeding at night. Their prey usually includes sea urchins, snails, crabs, sea moon leeches, clams, and bivalves (Kanciruk, 1980; Holthuis, 1991). Although cannibalism was reported in lobster aquaculture, there is no report of cannibalism among lobsters in the wild. Like other crustaceans, lobsters also navigate and hunt using their sense of smell and taste. The lobsters take four to six years for juveniles to grow and reach sexual maturity. The sexually matured lobsters will migrate to a deeper environment for spawning and complete their life cycle. Siow (2021) reported a sensitive area for lobsters south of Pulau Aur. Based on his trawl net survey, an average density of 0.95 kg/km$^2$, ranging from 0.31 – 2.62 kg/km$^2$ was reported in the sensitive area. In addition, berried females were reported in the sensitive area at an average water depth of 40 m.

Nonetheless, information about the lobsters' migration route and their migration period is remained unknown and has not yet been determined. It is important to note that the signs of overfishing were observed in most the fish landing ports on the east coast of Johor. Based on the Schaefer Model, the 'Maximun Sustainable Yield' (MSY) is 129 metric tons with fMSY budget of 5,830 units a year (Siow et al., 2021; Siow & Ahmad Arshad, 2021). The declining trend of the lobsters' stocks on the east coast of Johor is likely due to overfishing as the water quality monitored along the east coast of Johor is rated as excellent (JAS, 2020)

## 2.2 LOBSTER PHYLLOSOMA SURVEYS OFF JOHOR

Zooplankton surveys for lobster phyllosoma were conducted in August 2017, October 2018, and November 2020 in the waters off Johor (Ahmad Arshad et al., 2021; Siow & Harun, 2021). These surveys were conducted only once a year and at different sampling locations. In these surveys, a 1 m diameter ring net with 500 micron conical mesh was used in subsurface tows for 10 mins from a fishing vessel. The lobster phyllosoma was collected in a rather scattered distribution and predominantly stage 1 phyllosoma (**Figure 5**). Densities were higher in the collections made in August 2017. However, no samples were taken in offshore waters where spawning was presumed to occur.

As detailed in the reproductive cycle above, it is generally known that phyllosoma larvae disperse widely into offshore waters and remain planktonic for 6 – 11 months or more. This is because their primary diet is soft-bodied gelatinous zooplankton which is larger and abounds in deeper offshore waters. A possible reason why mainly stage 1 phyllosoma was collected, and not the larger later stages, were due to biased sampling of only subsurface layers. The older and larger phyllosoma (**Figure 6**) distribution would be rarer and tend to migrate to deeper layers during the day following the vertical migration of their zooplankton prey. To catch them, one would need to sample throughout the water column using oblique or double-oblique zooplankton tows. Large

volumes of water need to be filtered due to the rare occurrence of these lobster phyllosomas. To reduce avoidance reactions to an approaching sampler, a 60cm diameter bongo-net equipped with a flowmeter would be a better choice or a large volume tucker trawl (**Figure 7**). However, a powered hydraulic winch would be needed on the vessel to operate these nets following a double-oblique tow.

Sampling along parallel transects running from inshore to offshore waters at monthly or bimonthly intervals would yield information on the spatial and temporal distribution of the phyllosoma. The survey is important to understand the phyllosoma developmental stages. Besides, the presence of stage 1 phyllosoma indicates the potential spawning ground. Although It may be costly to conduct larger zooplankton surveys over several years. However, the benefits may be worthwhile if combined into a larger Larval Fish Survey Program. It also provides opportunities to understand the occurrence, distribution, and spawning of other commercial importance fishes like marlin, tuna, mackerel, and coral reef fish.

*(Source: Ikhwanuddin, UMT)*

**Figure 5: An early stage 1 phyllosoma larva**

*(Source: Ikhwanuddin, UMT)*

**Figure 6: phyllosoma larva at the last stage**

*(Source: KC Denmark)*

**Figure 7: A 60 cm diameter Bongo net with depressor and attached flowmeter**

## 2.3 COMMUNICATION PLAN FOR THE LOBSTER MANAGEMENT IN OTHER COUNTRIES

In 1992, the United Nations Conference on Environment and Development (UNCED) identified the important role of education and public awareness in efforts to achieve sustainable development. Communication, education, and public awareness in fisheries management are one of the main strategies to implement an ecosystem or endangered animal species management plan with a higher success rate. Management plan documents, websites and social media, scientific publications, and other sources of information that can be obtained at present have been examined. This is an important step to get a comprehensive picture of the communication method of managing marine resources such as lobster in current practice. The findings of the review that has been conducted show that there are various concepts and communication strategies practiced by government bodies abroad involved in the protection of lobster resources.

### 2.3.1 California Spiny Lobster, United States (*Panulirus interruptus*)

The United States is one of the countries with a comprehensive communication program where lobster is an important economic resource in some of its coastal areas. For example, the California Lobster Fishery Management Plan published in 2016 practices the integration of an ecosystem approach based on scientific data for lobster population monitoring activities. The public can access this document from the official website of the California Department of Fish and Wildlife (CDFW) (Recreational lobster fishing information, 2022). The website also contains a summary of information extracted from the management plan and the latest lobster stock monitoring data. In addition, CDFW also produced a brochure containing detailed information on the rules and methods of lobster fishing and the life history of California lobster (*Panulirus interruptus*) (**Appendix 3A**). Lobster fishery researchers also published the results of their scientific research in educational material for teenagers (**Appendix 3B**) to increase the awareness of young people on the importance of lobster conservation.

### 2.3.2 American Lobster In Maine, United States (*Homarus americanus*)

The lobster industry is the backbone of Maine's economy. This industry's contribution to Maine's economy is worth hundreds of millions of US dollars annually. Therefore, Maine's lobster fishery has extensive management and monitoring system that meets international standards. The main communication channel is the official website of the 'State of Maine Department of Marine Resources' dedicated to Maine Lobster (Maine Lobster, 2022). Links to other pages are provided for each website detail. Among them are as follows:

- Maine lobster management: bait information, fishing license applications/renewals, review of new regulations, Maine Lobster Advisory Council and Zone councils, lobster management zones and area maps, training programs, a summary of fishing license numbers and trap markers, legal fishing hours, etc.
- Regional lobster management (Atlantic States Marine Fisheries Commission) and federal management under National Oceanic and Atmospheric Administration (NOAA)
- Lobster research, monitoring, and assessment
- Recreational lobster fishing
- Other Maine lobster industry organizations and resources: Atlantic Offshore Lobstermen's Association, Downeast Lobstermen's Association, eMOLT: Environmental Monitors On Lobster Traps, Gulf of Maine Lobster Foundation, Lobster Conservancy, Maine Lobster Dealers' Association, IAM Maine Lobstering Union, Maine Lobstermen's Association, Maine Lobster Marketing Collaborative, University of Maine, Lobster Institute, University of Maine, Wahle Lab.
- General lobster info: about Maine lobster, how to cook lobster, lobster seafood facts, and information for students and teachers
- Guide to lobstering in Maine

The NOAA website also contains general information about lobster fishery management and important commercial and recreational fishery regulations (American Lobster, 2022). The lobster information on the NOAA website is easy to access and comprehend. The NOAA website also has a signup option to receive regional news and the latest NOAA fisheries announcements. This is an effective method of communication to ensure that any latest changes in the management system can be communicated to all stakeholders.

### 2.3.3 Caribbean Spiny Lobster In Florida, United States (*Panulirus argus*)

Conservation of the Caribbean lobster fishery in this area is managed by the Florida Fish and Wildlife Conservation Commission (FWC) (Spiny Lobster, 2022). The FWC website related to lobster contains all the important information about the regulations that need to comply during the recreational lobster fishing season (sports season) and the regular season. This website also has detailed information on the legal methods of capture as well as the specifications of the capture tools that can be used. The FWC produces brochures such as Florida Keys Lobster Regulations' which provide complete guidance to local communities and visitors to the area (**Appendix 3C**). The FWC also created several YouTube video clips to reach a larger audience with the recordings of the recommended regulations (Florida Fish and Wildlife Conservation Commission, 2022).

The National Park Service also plays a role in the region's preservation and conservation of lobster populations. The Florida National Park enforces the regulations in the Biscayne Bay-Card Sound Lobster Sanctuary area (Biscayne Bay-Card Sound Lobster Sanctuary, 2017). Lobster fishing in this protected area is prohibited to ensure

sustainable lobster stocks. The agency's efforts in conserving lobster stocks are reported on its website for the general public's knowledge, which is one effective means of communication.

### 2.3.4 Caribbean Spiny Lobster In Mexico (*Panulirus argus*)

Efforts to push the lobster fishery in Mexico in a more sustainable direction are carried out by the international organization Slow Food, which has a wide network worldwide. The Slow Fish Caribe project in Mexico promotes artisanal fishing in the region and sustainable use of marine and coastal resources. A handbook on the sustainable use of Caribbean lobster (Panulirus argus) has been published for lobster fisheries. This handbook is a free handout that can be downloaded from the Slow Food website (Slow Fish Caribe, 2015). The main purpose of this guidebook is to educate the public, especially lobster consumers, about the importance of ensuring that the lobster purchased/eaten are sustainably caught and how the general public can participate in lobster conservation efforts.

### 2.3.5 Caribbean Spiny Lobster In Belize (*Panulirus argus*)

The Belize Spiny Lobster Fishery Improvement Project carries out the conservation of the lobster fishery in Belize. This environmental conservation organization uses social media, Facebook, as the main method of communication (Belize Spiny Lobster FIP + FDM, 2021). All the latest news and important announcements (especially from the Belize Department of Fisheries) regarding the lobster fishery in the region are posted on the Facebook page. This site also publishes posters (**Appendix 3D**) about activities and plans that will be carried out. The use of social media is one of the productive communication strategies that can spread widely in a short time.

### 2.3.6 Caribbean Spiny Lobster in Honduras dan Nicaragua (*Panulirus argus*)

In addition to Belize, Caribbean Island countries such as Honduras and Nicaragua have their own Spiny Lobster Fishery Improvement Projects (FIPs) programs. The non-governmental organization (NGO) World Wide Fund for Nature (WWF) is the leader of lobster conservation projects in these areas. WWF has a website that displays brief information about lobsters and the threats they face (Spiny Lobster, 2021), where the public is highly encouraged to be responsible consumers.

### 2.3.7 American Lobster Fisheries In Cape Breton, Canada (*Homarus americanus*)

Fisheries management in Cape Breton adopts a self-management approach by local fishing communities. Most of the responsibility for the conservation of the lobster fishery in this area is given to the fishing association of Cape Breton Fish Harvesters Association. The association collaborates with fisheries researchers to collect monitoring data with a strong scientific foundation. The group's website contains a map of catch zones, information on lobster fishing in Cape Breton, and various pictures and video clips about lobster fishing. An infographic was also shared on how to sample lobster data (Lobster, n.d.). The public can also learn about the Marine Stewardship Council (MSC) from the website. The MSC is an independent not-for-profit organization that sets global standards for sustainable and well-managed fisheries. Cape Breton's lobster fishery is eco-label certified under MSC standards.

### 2.3.8 Lobster Fisheries In Australia

#### 2.3.8.1 Western Rock Lobster (*Panulirus cygnus*)

The western rock lobster industry is an international class fishery based on lobster species *Panulirus cygnus* that operates along the west coast of Australia from Shark Bay to Cape Leeuwin. Like the lobster fisheries in Cape Breton and Maine, the western rock lobster industry in Australia has a progressive management system where the self-management approach is widely practiced. The lobster fishing community forms a council/association known as the Western Rock Lobster Council and actively participates in the management of this industry. The website created by the council is one of the most comprehensive sources of information about the fishing industry in this region, and it includes various links to other web pages (Western Rock Lobster, 2022). This website also displays catch and trade data and information on puerulus settlement, which is used as a key performance index and sustainability monitoring feature of the fishery. Ease of access to this data is important to ensure that all stakeholders are always aware and updated about the changes in lobster population stocks. The western rock lobster fishery is the first fishery in the world to gain MSC accreditation successfully. This significant achievement is reported on its website and can help raise public awareness of the concept of sustainability, which should be a shared responsibility. Western rock lobster fisheries also use social media channels such as Facebook and Instagram as one of their communication strategies.

#### 2.3.8.2 Southern Rock Lobster (*Jasus edwardsii*)

In Australia, the southern rock lobster (*Jasus edwardsii*) fishery is an industry equivalent to the western rock lobster (*Panulirus cygnus*) industry which contributes hundreds of millions of Australian dollars annually to the Australian economy. This industry is self-managed and represented by Southern Rock Lobster Limited (SRL), which is an organization that represents the entire industry sector to the government. The members of this organization consist of South Australian Rock Lobster Advisory Council Incorporation (SARLAC), Tasmanian Rock

Lobster Fishermen's Association (TRLFA), Victorian Rock Lobster Association (VRLA), and Australian Southern Rock Lobster Exporters Association (ARLEA). Details of research activities for the sustainable development of this industry can be found on its website (Southern Rock Lobster, 2022).

In addition to the SRL, other government bodies also have their own web pages that display lobster biology information and established fishing regulations (Southern Rock Lobster 2016; 2021; n.d.). The state government agency, the Victorian Fisheries Authority, has also developed a program to tag recreationally caught lobster using digital tags. Their website has a guide on how to run and report this catch tag with a tutorial video clip (Rock lobster tagging program, 2021). Users can report online or use the GoFishVic application. This digital tagging system encourages users to participate in collecting scientific data (citizen science) to improve the monitoring of lobster fisheries in the region.

### 2.3.9 Rock Lobster Fisheries in New Zealand (*Jasus edwardsii*)

In Australia, the lobster fishery management approach is independent; there is an organization called the NZ Rock Lobster Industry Council, which carries out lobster fishery monitoring activities in collaboration with related government bodies. The website is a communication medium to deliver information on lobster ecology, lobster fisheries, stock data, annual status reports, and important industry announcements to stakeholders (NZ RLIC, n.d.). In addition, the government body of Fisheries New Zealand also uses the website to educate the public about the regulations and methods of catching lobster that is proper and legal (Rock lobster (lobster): rules and guidelines, 2021). This agency also publishes a pamphlet that provides complete information regarding the biology and habitat of lobsters in the area (**Appendix 3E**).

### 2.3.10 Spiny Lobster Fisheries In The Pacific Islands

Lobster conservation efforts in the Pacific Islands are carried out by the scientific and technical organization, The Pacific Community, which aims to achieve sustainable development through science, knowledge, and innovation (Pacific Community, n.d.). This program covers all species of lobster and other resources such as coral reefs, high-value commercial fish (tuna), etc. For lobster, brochures on the species found in the region and information on distribution, habitat, and feeding habits have been produced to increase community and general public awareness (**Appendix 3F**). The organization actively conducts community outreach and social initiatives such as training workshops and seminars to empower the community's knowledge of better natural resource management.

### 2.3.11 Spiny Lobster Fisheries In Indonesia

The Indonesian Ministry of Marine and Fisheries has produced a documentary clip about lobster fishing on YouTube that is easily accessible to netizens (Ditjen PDSPKP, 2021). In the video clip, several lobster species found in Indonesia are introduced. This video also informs the public about sustainable fishing practices used by fishermen and their social responsibilities to produce the highest quality lobster in the world following international standards. The clip is a simple, low-cost, and widely used medium of communication

## 2.4 ARTIFICIAL REEFS FOR LOBSTER

Concerns about habitat destruction and degradation through anthropogenic and natural occurrences, as well as interest in the enhancement of local populations for exploitation purposes, have led to the study of providing additional sheltering opportunities for lobsters in shelter-limited habitats (Kanciruk & Herrnkind, 1973). According to Kanciruk (1980), lobsters did not build or modify their shelters but relied on crevices in rocks at their new or original habitats as shelter to avoid predation.

One possible solution for the lobster population decline is the construction of ARs. Various man-made structures, such as shipwrecks, not originally designed or deployed as lobsters' artificial habitat, have been known for decades as a shelter for these crustaceans. Artificial reefs constructed for sessile organisms and designed to attract other taxa have also attracted lobsters, such as the Japanese “tsukiiso,” (Sahoo and Ohno, 2000). In some areas, simple stone beds and piers have been deployed to create new spiny lobster habitats (Nonaka et al., 2000).

Artificial reefs deployed for Panulirus argus have concentrated lobsters, and enhanced fishery catches in Cuba and Mexico (Cruz et al., 1986). For more than 60 years, Cuban and Mexican fishermen have increased their catch of lobsters using simple, inexpensive, durable, and easily harvested artificial shelters called a pesquero in Cuba (Cruz and Phillips, 2000) or a casita in Mexico. In 1982 about 10,000 casitas were constructed within 160 $km^2$ (Tangley, 1987). The material used were mangrove branches or similar palm trunks, 8 to 12 cm in diameters, creating a three to four layers 4 $m^2$ raft A single pesquero module could concentrate as many as 200 lobsters, which were then captured by divers using encircling nets (Briones-Fourzán et al., 2000).

### 2.4.1 Artificial Reefs For Post Larvae, Juvenile And Sub-Adult Of Lobsters

Many spiny lobster species have an ontogenetic habitat shift from the post-larval settlement habitat of algae, kelp, or seagrass to benthic crevices as larger benthic juveniles, subadults, and adults (Butler and Herrnkind, 2000). Man-made structures for post-larval stages (passive collectors) have been useful for evaluating settlement patterns and recruiting various benthic decapod crustaceans, including lobsters. Materials that

mimic the natural nursery habitat of the target species have been critical to the successful development of post-larval collectors. Therefore, most of the research on ARs for post larvae has been conducted on commercial species, such as spiny lobsters whose natural nursing grounds are known. (Phillips and Booth, 1994).

According to Hung and Tuan (2009), a special ARs design has been used to capture post pueruli larvae as seedlings for the aquaculture industry in Vietnam (primarily *Panulirus ornatus*). The seed lobsters are collected from their settling grounds and kept in cages in the coastal waters, where they are supplied with artificial shelters (wooden poles, pieces of corals, and other materials drilled with 5 to 10 mm holes) and fed with trash fish.

Briones-Fourzán et al. (2000) emphasized that casitas/ pesqueros were most effective in shallow water habitats lacking natural crevices—habitats such as sea grass. These habitats are frequently proximate to nursery grounds where new juveniles continually emerge and from which they must find new shelters and food (Herrnkind, 1980; Kanciruk, 1980). Casitas/ pesqueros may increase the production of lobster populations by decreasing the time juveniles are exposed to predators while locating shelter and/or food, thereby increasing juvenile survivorship (Herrnkind et al., 2001). Most lobsters in the casitas/ pesqueros are below the minimum fishery size limit. Analysis of microwire tag recapture data also proved that artificial reefs were key to small juveniles' survival and that large numbers of artificial reefs were required to strongly affect the ultimate numbers of surviving juveniles. (Herrnkind and Cobb, 2008). According to Briones-Fourzán et al. (2006), the Deployment of the artificial reefs resulted in a sixfold increase in juvenile density and a sevenfold increase in biomass compared to control sites lacking natural crevice shelters.

Most juvenile and sub-adult lobsters were caught within Zone A along the east coast of Johor. This area is also identified as a major fishing ground for traditional fishers especially drift nets fishers. Installation of concrete reef lobsters for juvenile and sub-adult lobsters in this area should be managed carefully to prevent social conflict because drift nets will entangle on ARs when fishing nearby AR modules. For better management and monitoring activity by the DOFM officers, the most suitable area to install ARs for juvenile and sub-adult lobsters to hide are within Marine Park waters. Both ARs designed by the DOFM are suitable to be deployed within the Marine Park area. Construction of ARs for juveniles and sub-adult outside the Marine Park area could be done after consultation with local fishers, especially on-site selection.

### 2.4.2 Artificial Reefs For Adult Lobsters

The effort to design ARs for adult spiny lobsters has a long history. Artificial reefs were also deployed in the Mediterranean targeted for European spiny lobsters, *Palinurus elephas* (Relini et al. 2007). Researchers in Japan began experimenting with bamboo-framed structures as ARs as early as the late 1700s (Tsumura et al., 1999). Spiny lobsters prefer dens that have shaded cover with multiple entrances and avenues of escape (Eggleston et al., 1990). Hence, for social spiny lobsters, AR must be designed the ability of multiple individuals to co-den in

the same crevices. Earlier field studies showed that shelter selection by large juveniles and adults depended on lobster size, shelter dimensions, and lobster density (Eggleston and Lipcius, 1992}.

Construction of specific ARS for adult lobsters in Malaysia was started in 1992 within the Pulau Redang Marine Park area (Sukarno et al., 1994). The first artificial reef modules for lobster included six blocks with two openings facing the opposite direction. The lower part of the module consisted of four blocks, and the upper part was composed of another two blocks. This reef was deployed in 1990. The second module designed for concrete was an igloo and was deployed in 1992. The igloo structure had one opening to serve as a compartment where the lobster could hide. A sewerage pipe ceramic was also used to build ARS for lobsters. The first reefs were deployed at Redang Island in 1992. Two sizes of cylindrical ceramic with 0.4m and 0.25m diameters were used. According to Ahmad et al. (2018), larger concrete ARs for lobster were deployed in FT Labuan waters in 2008, Pulau Tinggi, Johor, and Kuala Penyu, Sabah, in 2009. In 2010, ARs for lobster were deployed near Kampung Layang-Layangan, FT Labuan.

## 2.5 FISHERIES REFUGIA IN OTHER COUNTRIES

The concept of fisheries refugia, which resembles spatial and temporary protection for certain targeted species through regulation of fishing gear and fishing seasons, were practiced in many countries to ensure the sustainability of their fisheries sector (Salas et al., 2011; Franco et al., 2018; Huang et al., 2022; Richard 2005). Fisheries management began to gain attention after the first industrial revolution in the 1800s. The revolutionized fishing vessel and the vastly improved fishing gear led to an exponential increase in fish catch. Subsequently, the fish stocks suffered from a disastrous decline. The consequence depletion stimulated a paradigm shift in fisheries management, where scientific management was introduced to manage the wild stock in the mid-1900s.

Fundamentally, sustainable fisheries management uses surplus fish stock from stock productivity (Lackey, 2005). When a fish stock is depleting, temporary interventions, such as gears and catch restriction, are used to ensure the productivity surplus of the wild stock. Below is a summary of various interventions practiced by various countries to protect their fisheries stock:

The Australian government has a comprehensive plan to protect its fisheries. Among the program is their plan to restrict catches of the blue swimming crab during the close seasons in Perth and the southwestern area. During the close season from 1 September until 30 November every year, the blue swimming crabs catch is not permitted for commercial or recreational purposes. The close season is to protect the blue swimming crabs that carry eggs (Johnson et al., 2020). Besides the blue swimming crabs, the Australian government also implemented the seasonal closure for shrimp and other fishes, including their pearl perch.

Norwegian and Russian government is working together to restore the wild skrei stock by introducing a fishing quota in 2006 (Kvamsdal et al., 2016). Both countries strictly regulate catches of the cod skrei. In Norway, only matured skrei can be caught from the wild from January to April. As a result, the skrei wild stock is at a good level (Tsiouvalas et al., 2022). Besides the skrei, the Norwegian government also implemented a close fishing season for snow crabs in their coastal water.

In Africa, the Ghana government has implemented a one-month close season for the artisanal fishermen and semi-industrial players in July (1 July 2022 – 31 July 2022) and a two-month close season for the industrial operator (1 July 2022 – 31 August 2022). The objective of the close season is to replenish their fish stocks that depleted rapidly due to unsustainable fishing practices.

The Caribbean branch of the NOAA's Sustainable Fisheries Division has worked together with the Caribbean Fishery Management Council to manage fisheries in the federal water of the US Caribbean. The US Caribbean includes the Commonwealth of Puerto Rico and the US Virgin Islands. Under the collaboration, they have implemented close seasons for fishing various species of snappers, groupers, parrotfish, and Queen conch.

In China, the Chinese government introduced various methods to restore their yellow croaker (*Johnius belengerii*), including restricting unsustainable fishery equipment, area closure, and seasonal closure in Xiamen Bay beginning in 2006. The Chinese government has incentivized and introduced a fisherman's transformation program so that the fishing community affected by the regulation becomes more competitive and able to operate in the deep sea. In addition, the Chinese government has also announced the closure of a three-month octopus fishing season (September – November starting in 2022) on the high seas for Chinese fishing vessels, one of the Chinese government's efforts to conserve squid stocks in the high seas.

Brazil, the Dominican Republic, and French Guiana implemented their close season for fishing their Penaeus shrimp. In Brazil, this closure measure has been introduced since 1984. However, in terms of implementation, it is poorly organized, and the results of the closure of the fishery season are not clearly visible. (Musiello-Fernandes et al., 2017).

The concept of fisheries refugia has been widely studied on the potential to be implemented in the ASEAN countries due to the collaborative efforts of SEAFDEC (Southeast Asian Fisheries Development Center). The concept of fisheries refugia is deemed a potential solution to integrate fisheries and their habitat management for small-scale fisheries in the region (Paterson, 2013). The fisheries refugia program in the Southeast Asian region has received support from UNDP-GEF. The information and refugia sites in the ASEAN countries are on http://fisheries-refugia.org website. Area closure, restricting the use of fishing equipment, and seasonal closure are among the common approaches in conserving fisheries stocks in ASEAN countries. The program is an ongoing effort, and its outcomes have not yet been confirmed.

## 2.6 FINANCIAL SUSTAINABILITY FOR THE PROTECTION OF BIOLOGICAL RESOURCES

Oceans are a natural resource that, along with soils and forests, contribute to the global stock of natural capital. These natural resources produce essential ecosystem goods and services, including food, climate regulation, coastal protection, and cultural value, that ensure human existence and well-being on a global scale (Sumaila et al., 2021). Damage to habitats and widespread biodiversity loss are effects of human-induced changes to marine ecosystems (Sumaila et al., 2021). This is not a new occurrence; for instance, the extensive coral reef exploitation of the Caribbean in the 17th and 18th centuries resulted in enormous losses of large vertebrates, fish, and sharks (Jackson, 2001). Therefore, it is compulsory to sustain marine resources, and the government also oversees various initiatives, one of which is the sustainable financing of marine resources. Nonetheless, sustainable financing for marine protected areas is still an important issue on the conservation agenda.

Getzner et al. (2017) identify financial sustainability through which options for funding are based on visitors' willingness to pay to conserve marine biodiversity in the Lastovo Archipelago Marine Park in Croatia. The location is appealing to sailors with private boats and general tourists arriving by ferries, which presents both a difficulty and an opportunity for creating an effective and efficient funding scheme. Based on depicting three possible scenarios, the authors examine the Willingness-To-Pay (WTP) of these two types of tourists to conserve distinctive habitats and species. When considering the perceptions and attitudes of the various tourist groups, the authors of this statistical study discover a major WTP that might help with the long-term management and financing of the site. They also co-finance the work of public institutions paying an "entrance fee" to enter the area. A portion of the protected area's income comes from access and use (e.g., fishing concession licenses, sailors' entrance fees, recreational fishing licenses, souvenirs, and merchandise) and through contributions from various organizations, charities, and ministries. Therefore, reported WTP values in this research demonstrated a strong willingness on the part of Croats to pay beyond what they already do through the tax system for the management of Croatia's priceless natural resources.

Perera-Valderrama et al. (2020) reported their finding on the "Southern Archipelagos," which was overseen by Cuba's National Center for Protected Areas and funded by the Global Environmental Facility (GEF) between 2009 and 2015. In order to ensure the financial sustainability of the MPAs, a sustainable tourism strategy and several studies on the economic value of the goods and services provided by ecosystems were carried out. The protected areas' financial planning is based on identifying the conservation objects and the risks they experience as a starting point for determining the necessary activities for their monetary quantification. The models allow the quantification of protected area revenues, costs, investments, and potential funding sources over a specific period.

In another study, Mallin et al. (2019) reported the financial analysis that sustains the Phoenix Islands Protected Area (PIPA). The analysis shows the acceptance of philanthropic foundations by the government. The government eventually gave up control over the territory and assets of PIPA. Therefore, it was argued that some

legal and financial provisions might serve as under-recognized and purposive drivers of 'ocean-control' grabbing. For the time being, the compensation plan appears to have lost importance.

Nevertheless, beyond the issue of compensation, there is still the as-yet unmet expectation of achieving the PIPA Trust's financial sustainability. Ison et al. (2018) researched a national Marine Protected Area in Fiji. The purpose of this study was to evaluate the willingness of stakeholders to pay (WTP) and volunteer their time (WtCT) to manage the iQoliqoli (area) as a potential financing mechanism for inshore MPA. The extent to which bottom-up governance systems offer a possible financing mechanism for an MPA network was investigated using the Willingness-To-Pay (WTP) and Willingness to Contribute Time (WtCT) techniques. The WTP and WtCT of stakeholders to manage an MPA were significantly influenced by factors such as proximity to a fishing market, dependence on marine resources, food security, income, and international commitments. A Provincial Trust Fund (PTF) is a financing instrument for inshore MPAs using WTP and WtCT data. A PTF is a source of sustainable financing for managing protected areas and long-term biodiversity protection. A PTF also supports the sustainable management of traditional fishing societies through its polycentric and decentralized governance model.

McClanahan et al. (2005) reported that the poor and related groups were frequently left out because they lacked strong formal organizations and the resources to stand up for them. Before 2003, financial support for initiatives was often less than US $150 000, and this, together with the institutions' poverty and the challenges of creating financial sustainability, restricted the programs' ability to address conservation issues. The general financial viability of Kenya Wildlife Service (KWS) is a source of severe worry. Most of KWS's operating budget comes from visitor fees; however, not all protected areas in Kenya receive this income, so the money must be distributed among all protected areas. However, the long-term survival of protected areas, especially the MPAs in Kenya, is in jeopardy until KWS's financial viability increases. The author then concludes that current deficiency and further alter the current resource management regimes, linkages between the MPA and integrated coastal management (ICM) activities were formed.

The lesson learned from these case studies can be summarised as follow:

- Financial sustainability shall be planned carefully prior to the implementation of a protection or conservation program.
- There must be a proper organization or proper empowerment for an entity to manage and report the financial status of a program.
- The program shall benefit all stakeholders. A biased program will eventually become neglected and abandoned by the public.
- From the financial sustainability point of view, there must be a stable source of income to sustain a protection or conservation program.

## 2.7 FUNDING MECHANISMS

This section analyses the sustainability of financial mechanisms for the marine protected area in various programs. Perera-Valderrama et al. (2020) reported the financial mechanisms to conserve Cuba's globally significant marine biodiversity. For five years (2009-2015), the Global Environmental Facility (GEF) co-financed the project with an input of US$5,710,000, while the Cuban government contributed US$14,104,907. Coordination was supervised by the National Centre of Protected Areas of Cuba (CNAP). Sustainable tourism was designed based on the economic value of the goods and services provided by the ecosystem were carried out to ensure the financial sustainability of MPAs. The financial planning of the protected areas is addressed based on the identification of the conservation objects and the dangers they face, which serves as a starting point for determining the necessary tasks to carry out their monetary quantification. In numerous places, sustainable, productive alternatives have been introduced to diversify the locals' economic pursuits.

Tirumala and Tiwari (2022) reported that projects in the blue economy are often funded by traditional public and private development financing methods. The concept of "blue economy" depends on striking a balance between the twin goals of economic development and environmental sustainability. The Republic of Seychelles issued a prominent blue bond that has garnered notice on a global scale. With the first sovereign Blue Bond ever issued, private capital companies could finance investments in sustainable fisheries management, and the 10-year US$15 million bond is intended to be used to finance initiatives. Nordic Investment Bank issued the first Nordic-Baltic Blue Bond in 2019, with SEB Bank serving as the lead manager. The 5-year US$213 million bond is intended to finance initiatives to prevent water pollution, treat wastewater, and adapt to climate change in the water sector. The bond with a 0.375 percent coupon earned more than twice as much interest. Governments, their agencies, and development finance institutions comprise most of the blue economy's funding landscape stakeholders since they have historically been the source of essential funds, policies, and institutional support. Therefore, the study identifies that the current initiatives, such as blue bonds, are only modest in scale to speed up investments, access to new financial resources, and a dramatic change in the attitudes of the involved parties are necessary. The research findings add to the continuing discussion about how to increase the financial capacity of different blue economy players so they can design more sustainable financing mechanisms.

In addition, Kong et al. (2021) detail the experiences of Xiamen in overcoming the difficulties of capacity building and creating sustainable financial mechanisms and political wills. In 1993, the Xiamen city council started an Integrated Coastal Management (ICM) program. Since then, the city has developed a successful ICM model known as the "Xiamen Model," which has been used as the operational approach for other coastal regions in China. The Xiamen Municipal Government established a sustainable financing mechanism involving government financial allocation, fees for using the sea, ecosystem services, and capital raised through social means. Since its start till the present, the financial allocation from the government has been the ICM program's main source of support in Xiamen. The other consistent funding source for the Xiamen ICM program is the sea area usage fees imposed on those who use sea regions for aquaculture, industry, and tourism, among other uses. These fees are one of the significant sources of the fiscal budget. As a city with an independent budgetary standing, Xiamen

Municipality is permitted by state laws to keep 70% of the collected sea area usage fees in the local treasury while handing over the other 30% to the central treasury. Under tight oversight and audit by the relevant central financial ministries, the sea area usage fees shall be primarily used for sea area control, protection, and management. Besides, another source of funding in Xiamen is the compensation for marine ecological damage, which entails holding those accountable for their harm to the marine ecosystem to address the problem of marine ecosystem destruction (Elliott & Cutts, 2004). Because it may more effectively absorb the consequences of human activity, marine ecological damage compensation is a useful tool for protecting the marine environment. On top of it, the public-private partnership is another long-term contractual relationship between the private sector and a government organization to provide a public good or service. In China, the private sector is responsible for managing the project and taking on a significant amount of risk, and compensation is performance-based. However, the primary source of funding for the ICM program's implementation at the moment is government financial allocation.

Nikitine et al. (2018) reported the financial model of the Pitcairn Islands Marine Reserve (PIMR), which was established in September 2016. The Pitcairn Islands have been reliant on UK budgetary assistance at rates up to £2.9 million per year since 2004 due to the failure of the Pitcairn Island Investment Fund. Philately was once the only source of income; today, it is supplemented by selling souvenir coins, landing fees, internet domain names, and honey, which generates up to NZ$ 200,000 annually. Although about 12 cruise ships and 20 to 30 private yachts visit Pitcairn a year, accessibility is still the largest barrier to the significant growth of tourism potential.

In another study, Edwards (2009) researched sustainable ocean and coastal management financing in Jamaica. This research investigates the viability of setting up a sustainable funding source for Jamaica's ocean and coastal management through tourist user fees. According to the findings, visitors would be more likely to pay an "environmental tax" than a generic "tourism development tax." The analysis shows that a US$2 environmental levy per passenger could bring in US$3.4 million a year for management, even with a 0.2 percent drop in tourist numbers. The detrimental effects of applying higher taxes on annual tourist visitation rates could be reduced by disclosing the breakdown of the tax revenues between management operations.

Furthermore, Cho (2005) researched Belize's integrated coastal management system and the marine protected areas. In order to fund a sustainable Coastal Zone Management Program, the Authority is authorized by the Coastal Zone Management Act to impose various environmental management fees for coastal zone activities and uses. Marine Protected Areas (MPAs) are to manage highly sensitive and ecologically varied marine environments. A network of MPAs has been established to ensure biodiversity protection and sustainable resource allocation and usage.

Table 2 summarises various financial mechanisms to support the protection and conservation of the marine protected area.

**Table 2: Financing Tools for Sustainable Marine Resource**

| Financial Mechanism | Measurement | Type | Reference |
|---|---|---|---|
| **Investment** | Bonds | • Blue Bonds | Tirumala and Tiwari, 2022 |
| **Grants** | Economic Valuation | • Sustainable Tourism Strategy | Perera-Valderrama et al., 2020 |
| | Integrated Coastal Management (ICM) Programme | • entails the provision of advice | Cho, 2005 |
| **Financial Allocation** | Fiscal Plan | • Royalties and eco-compensation mechanisms | Qiu et al., 2021 |
| | Program | • Sea Areas And Island Protection Programme,<br>• Marine enforcement program,<br>• Marine economy,<br>• Coastline improvement and other related programs | Kong et al., 2021 |
| **Equipment Fund**<br>**Business Fund** | Government Financial Allocation | | Kong et al., 2021 |
| **Conservation Trust Fund** | Fees for Management Services | • Conservation contract | Rotjan et al., 2014 |
| **Provincial Trust Fund** | Bottom-up approach | | Ison et al., 2018 |
| **Return On Investment** | Increased fishery profitability | | Bladon et al., 2016 |
| **Fixed Conservation Levies** | Fees from fishing vessels | | Bladon et al., 2016 |
| **National Trust Fund** | New sources of funds<br>Hilsa export taxes | | Bladon et al., 2016 |
| **Fees for sea area usage** | Market Allocation | • Bidding, auctioning, and listing | Kong et al., 2021 |

| | | | |
|---|---|---|---|
| | Environmental tax and tourism tax | • Environmental protection<br>• Tourism | Edwards, 2009 |
| | Sea areas management | • Protection, prevention, conservation,<br>• Marine Enforcement<br>• Restoration of sea areas, islands, and coastline | Edwards, 2009 |
| **Compensation** | Marine ecological damage compensation | | Kong et al., 2021 |
| **Social Raised Capital** | Public-Private-Partnership | | Kong et al., 2021,<br>Nikitine et al., 2018 |
| | Business plan | | Nikitine et al., 2018 |
| | Options for income generation | | Nikitine et al., 2018 |

# 3.0 DELINEATION OF LOBSTER REFUGIA BOUNDARY ON THE EAST COAST OF JOHOR

## 3.1 DELINEATION OF LOBSTER REFUGIA BOUNDARY

Delineation of the lobster refugium on the east coast of Johor shall be based on spatial representativeness concerning the sustainability of the lobster population. The criteria for establishing the area for lobster refugia shall include the following:

1. Existing lobster fishing ground
2. Critical habitats that harbor certain stage(s) of lobster's life cycle
3. Sea current circulation, which plays an important role in the spread/ distribution of lobster
4. Area of ecological importance

Based on studies conducted by several DOFM researchers, including Alias and Rashidah (2000), Alias et al. (2000), Siow (2021), Siow et al. (2021a), and Siow et al. (2021b) showed that Tanjung Leman waters fulfilled all criteria for the establishment of the lobster refugium. Alias and Rashidah (2000) reported that juveniles of less than 200 g/tail are mainly found on rocky bottoms in turbid water near river mouths at depths less than 10 m, while the adults are found in deeper waters, usually about 50 m deep. Mature adult, usually weight more than 400 g/tail. Berried lobsters will migrate to deeper waters to release their new hatches. Deeper waters are situated within Zone B and Zone C at more than 40 m deep.

According to Alias et al. (2000), mature lobsters are mostly caught by trawlers. Fishing operations are within Zone B and Zone C. Endau is the main landing center for mature lobsters. The distance between Endau and Tanjung Leman is about 62 km. The ranged sizes of mature lobsters sampled from Endau were between 218 – 310 mm in total length, with the body weight between 370 – 1170 g. Female lobsters carrying eggs (berried females) were also found in the catch. The composition of the newly copulated female carrying sperm in their pouch or "tar spot" was high in July. Based on the information, the breeding and migration season starts in July. The composition of berried females was high in August.

On the other hand, the juvenile lobsters were caught mainly by the traditional fishers using drift nets and traps called 'bintoh'. Sungai Musuh is a major landing site for juvenile lobsters in the southern part of east Johor. Habitat, fishing grounds, and landing jetty for juvenile lobsters are located mainly around Pulau Lima in the coastal areas of Pengerang. Juvenile lobsters sampled from Sungai Musuh were measured between 102 – 220 mm in total length, and their body weight was between 55 – 402 g. No female lobsters with eggs were found in the juvenile catch.

Siow et al. (2021a) reported that during their survey in Zone B and Zone C off east Johor waters, several berried female mud spiny lobsters were caught within the Zone C area at a depth of more than 30 m. In 2019, an observer-on-board survey was conducted by the DOFM in Zone B and Zone C waters off east Johor using fishing vessels, as reported by Siow (2021). The total number of mud spiny lobsters (Panulirus polyphagus) caught was 49 pieces, and 80% of the total catch was from the southern part of Pulau Aur within the Zone C fishing area. Among the catches were berried female lobsters ranging between 7.5-11.7 cm (Carapace Length) and weight between 470-810 g. The eggs were at the intermediate stage of development (based on the reddish color of the eggs). The lobster density in this area ranged between 0.87 - 1.17 kg/km$^2$. It was the highest reported compared to other areas during this survey. The study on the landing of mud spiny lobster on the east coast of Johor and the southern part of Pahang was conducted by Siow et al. (2021b). Based on the study recorded different sizes of spiny lobsters landed at Sedili, Tanjung Leman, and Endau. The size of the spiny lobsters was highly correlated with the fishing areas and gear.

All researchers agreed that spawning grounds on the east coast of Johor waters were in the deeper waters in Zone C. Nursery grounds were found scattered along nearshore areas in Zone A, extending from the southern region of Pahang to Pengerang, Johor. Information on the migratory routes of the adult lobsters before and after spawning was not known. The location of feeding grounds of the adult lobsters is believed to be scattered along the coastal areas in Zone B, extending from the southern part of Pahang to Pengerang.

Since the nursery area located within Zone A are also the main fishing grounds for artisanal fishers, for the beginning, we propose to monitor the size and weight oif . This strategy is to prevent social conflict between DOFM with traditional fishers and at the same time the DOFM has more time for public awareness campaign activities to them. The most potential area to be gazetted was suggested by Siow (2021) in Zone C. This area was in the southern part of Pulau Aur, in Johor waters and have a high concentration of mud spiny lobsters compared to other areas. The coordinates of 400 nm$^2$ area suggested by Siow (2021) is shows in Table 3.

**Table 3: GPS coordinates of the sensitive area for lobsters as suggested by Siow (2021)**

| Position | Latitude | Longitude |
|---|---|---|
| **Point 1** | N 2° 14.670' | E 104° 21.753' |
| **Point 2** | N 2° 23.146' | E 104° 40.334' |
| **Point 3** | N 2° 04.972' | E 104° 48.686' |
| **Point 4** | N 1° 56.441' | E 104° 30.137' |

In term of management and monitoring purposes during enforcement activity by the DOFM officers and for good memories for fishing vessel skippers, all coordinates suggested by Siow (2021) were reviewed. As an alternative, we proposed the area as shows in Figure 8, with new coordinate as listed in Table 4 covers an area

of 500 $nm^2$ (25 nm X 20 nm) of Zone C fishing area. The new area covered most of the area proposed by Siow (2021).

**Table 4: GPS coordinates of the adjusted sensitive area for lobsters**

| Position | Latitude | Longitude |
|---|---|---|
| **Point 1** | N 1° 55.000’ | E 104° 30.000’ |
| **Point 2** | N 2° 20.000’ | E 104° 30.000’ |
| **Point 3** | N 1° 55.000’ | E 104° 50.000’ |
| **Point 4** | N 2° 20.000’ | E 104° 50.000’ |

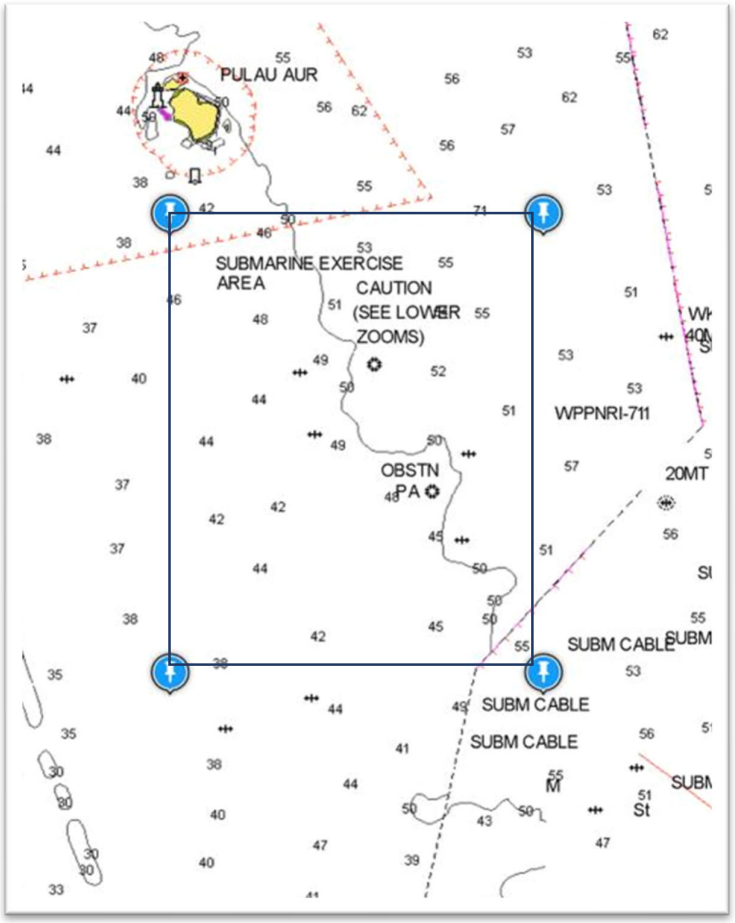



**Figure 8: The adjusted sensitive area for lobster spawning and reproduction in the lobster refugium**

### 3.1.1 Determination Of Lobsters' Habitats And Sensitive Areas

Delineation of the lobster refugium shall take into consideration critical habitats and sensitive areas of lobster, including the area of importance even for a portion of the lobster life cycle. The east coast of Johor is a biologically productive area (Liew et al., 1986; Shaw & Chao, 1984, Ku Kassim et al., 2009). Tanjung Leman is located in the middle of Johor's east coast. To the north of Tanjung Leman are Pulau Sibu and Pulau Tinggi Marine Parks, Pulau Sibu Tengah, Pulau Sibu Kukus, and Pulau Sibu Hujung. Many rocky outcrops are exposed during low tides. A similar geological configuration was also observed at Pulau Tinggi. The rocky outcrops extended south ward to Pulau Lima Kecil, Pulau Lima Besar, Pulau Tokong Raket, Karang Ambon, Tokong Gantang, Tokong Condong, Tokong Belalai, Tokong Cupak, and Pulau Tokong Ya. These rocky outcrops are critical hiding places for lobsters. The rocky substrates with cracks, crevices, and holes at less than 20m deep are the natural shelters for juvenile and sub-adult lobsters from their predators, including humans.

This rocky coastal environment made the area surrounding Tanjung Leman an ideal location for lobsters. Furthermore, most of the marine protected areas are located near Tanjung Leman; the spill-over effect populated the area with lobsters. There are no islands southwards of Tanjung Leman, though there are submerged rocky outcrops. The rocky coastal environment extended all the way to the Pengerang area. Nonetheless, the demand is mainly in the Southern region, the Pengerang. The fish landing at Sg. Musoh is the main landing area. When the lobster supply in the Pengerang area is tight, the restaurant operator and wholesaler will procure lobster from Tanjung Leman and Sedili areas. Besides the rocky coastal environment, the mangrove forest in the Mersing area and at Pulau Seri Buat, there are small patches of mangrove along the east coast of Johor, also an important habitat for lobster, particularly puerulus Abdul Haris et al. (2021). In addition, seagrass meadows at Pulau Tioman and the area nearby Tioman marine park islands are also important areas for lobster.

Based on the study by Norhanida and Nur Shahirah (2021), comprising 165 respondents from Pahang and Johor in 2018-2019, about 30% did not have a clue about the fisheries refugia, and 60% did not fully understand the concept of refugia. Only 1% fully understood, and another 9% with only partial understanding. About 80% agreed with the concept of the refugia plan proposed by the DOFM. All respondents in this survey used one or more types of fishing gear during their fishing operations. The finding reflected the need for a thorough communication plan to create public awareness of the fisheries refugium.

A technical workshop on the Development of the Management Plan of Tanjung Leman Fisheries Refugia, Johor, was conducted at UMT from 7-8 June 2022. The DOFM officers attended the workshop and are mostly involved in the initial planning to establish lobster refugia on the east coast of Johor. The participants agreed that Marine Parks Pulau Sibu, Pulau Tinggi, Pulau Aur, Pulau Pemanggil and Pulau Tioman are considered a safe zone for lobster. In contrast, deeper waters along 60m contour lines are considered a habitat for adults. The sensitive area in the C zone is a mating area and foraging habitat for mature females before and after releasing their larvae. The sensitive area identified by Siow (2021) is important for spawning and aggregation. Thus, after

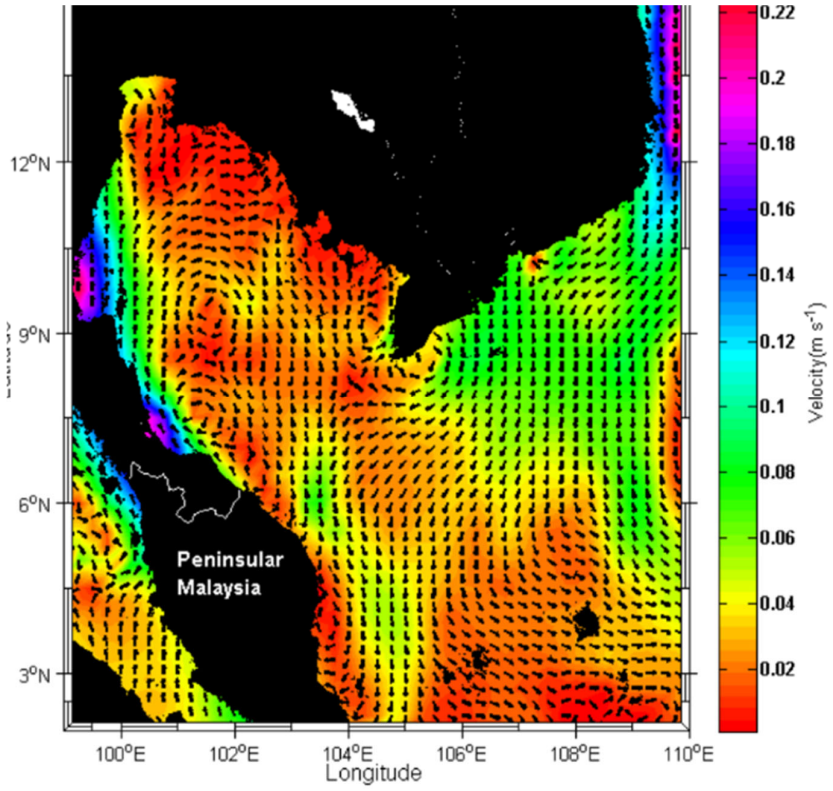
considering various factors, including the distribution of critical habitats, current ocean circulation, and the current resource management plan, the lobster refugium will not be effective if the refugium is limited to a small area in Zone C and Tanjung Leman. Instead, it should cover the whole coastal water of the east coast of Johor.

### 3.1.2 Ocean Current Circulation

Lobster is a broadcast spawner, releasing its larvae into the water column and carried by sea current. The planktonic larvae will be driven by the sea current for up to two years and eventually settle to the sea bottom at their juvenile stage. Hence, the sea current circulation played an important role in lobster distribution. Tangang et al. (2011) reported the sea current circulation pattern based on a numerical model for the east coast of Peninsular Malaysia. The monsoon affects the current circulation on the east coast of Peninsular Malaysia. The surface water is predominantly driven by the wind and tide, while the deeper water movement is affected by topography and tide. Similar findings were reported by Akhir (2014) via their field measurement. Pa'suya et al. (2014) reported the composite pattern of the geostrophic flow on the east coast of Johor during the North East and South West Monsoon (Figure 9).

Based on the hydrological studies in the region, the current circulation on the east coast of Johor circulated mainly within the maritime area of the east coast of Johor. Based on the studies, the lobster larvae, including the lobster puerulus, involved the entire east coast of Johor. Lobster spawn around the year, and spawning rate is higher from August to October (Ikhwanuddin et al., 2014)

(a) North-East Monsoon




(b) South-West Monsoon

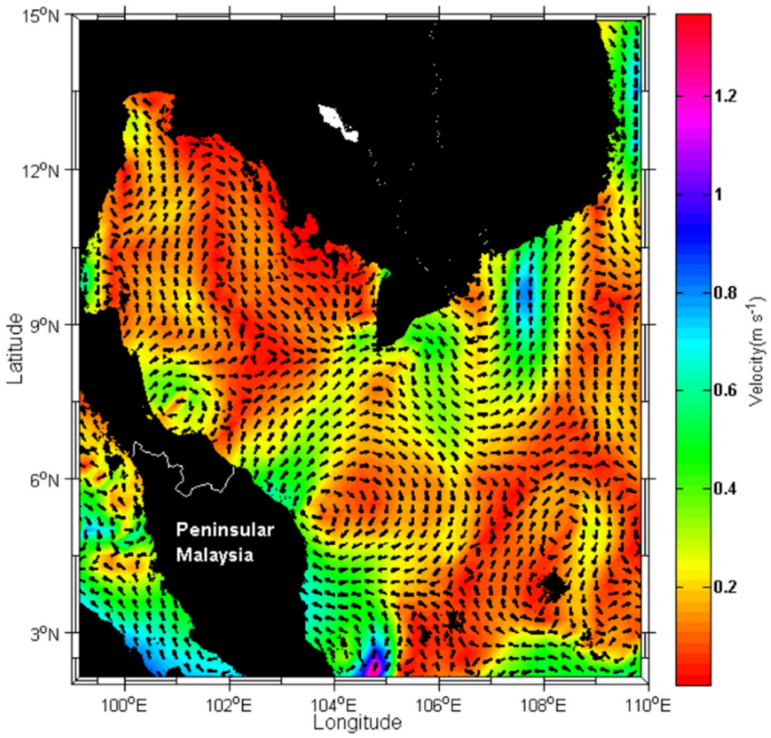



**Figure 9: Composite geostrophic flow in the region based on Pa'suya et al. (2014)**

Figure 10 shows the screenshot of the Navionics navigation chart (https://webapp.navionics.com/) that provides an overview of the water depth on the east coast of Johor. Generally, the water gradually gets deeper offshore. On average, the water depth in the refugium is around 40 m to 60 m. Based on the vessel tracking data assessed via AIS (https://www.vesselfinder.com/), Higher maritime traffic was detected in the southern area of the refugium. The sensitive area identified above is relatively less traffic, mostly used by trawlers.

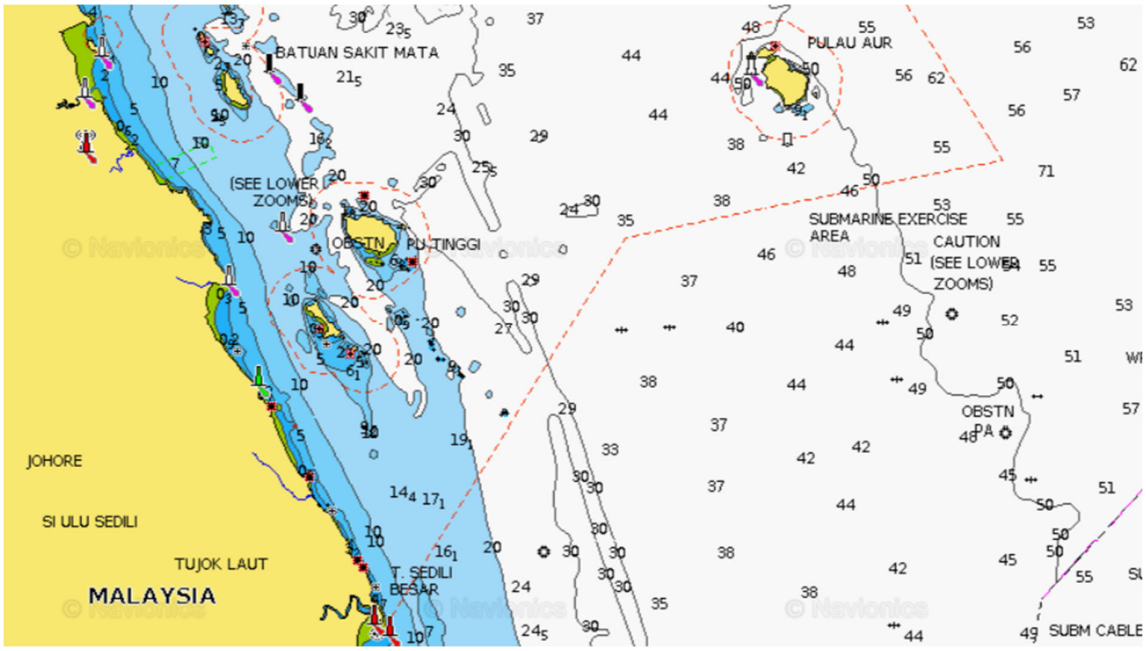
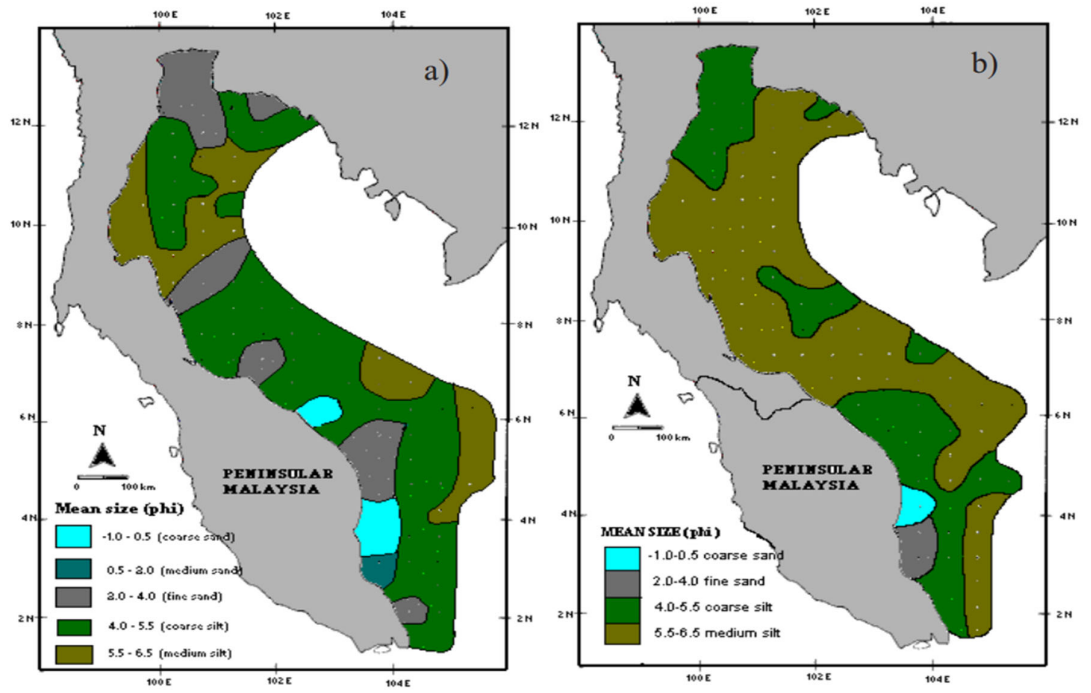


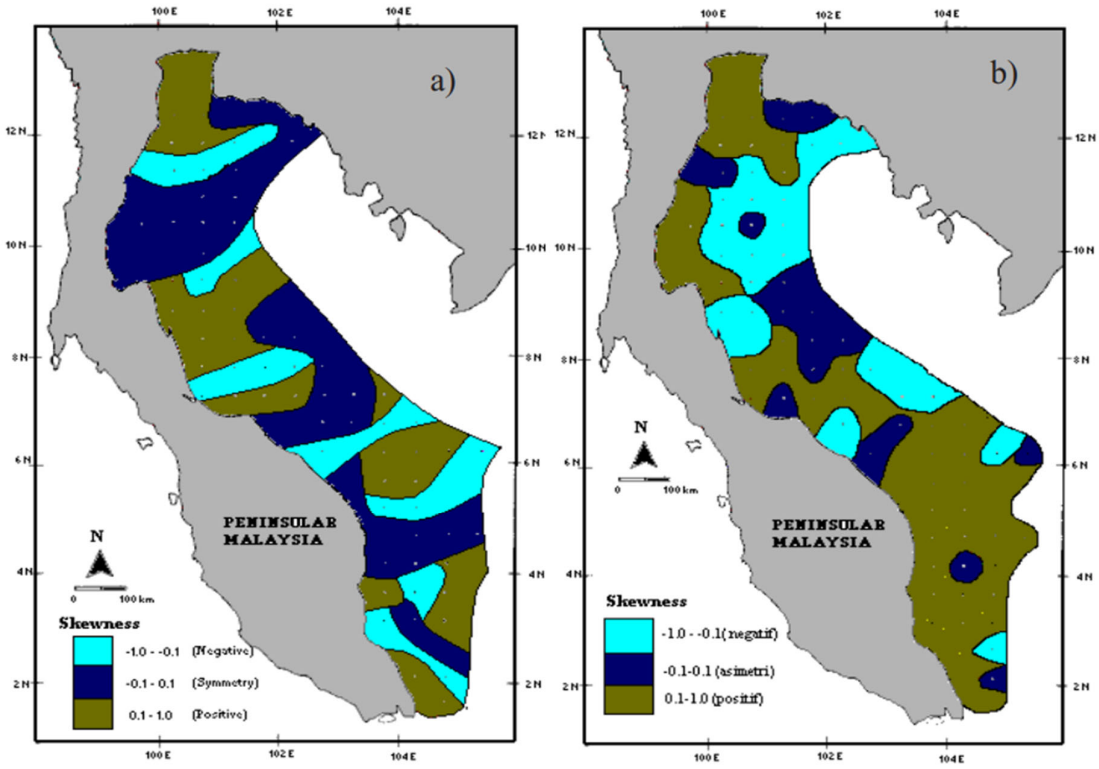

**Figure 10: Water depth of the lobster refugium (Source: Navionics Navigation Chart)**

Husain et al. (1999) reported the sediment characteristic in the area. The study is among the most comprehensive data available in the area. Based on the study, the sediment particle size in the refugium ranged between 0.5 – 5.5 phi, indicating coarse sand to coarse silt. Figure 12 shows the sediment particle size distribution in Peninsular Malaysia. The sediment particle size distribution is positively skewed. Indeed, most of the area showed an intermediate to poorly skewed particle distribution, fulfilling the criteria of artificial reef deployment.

I. Average particle size distribution on the Gulf of Thailand and the east coast of Peninsular Malaysia (a) September 1995 dan (b) April 1996.




II. Particle size skewness on the Gulf of Thailand and the east coast of Peninsular Malaysia (a) September 1995 dan (b) April 1996.



III. Sediment sorting on the Gulf of Thailand and the east coast of Peninsular Malaysia (a) September 1995 dan (b) April 1996.

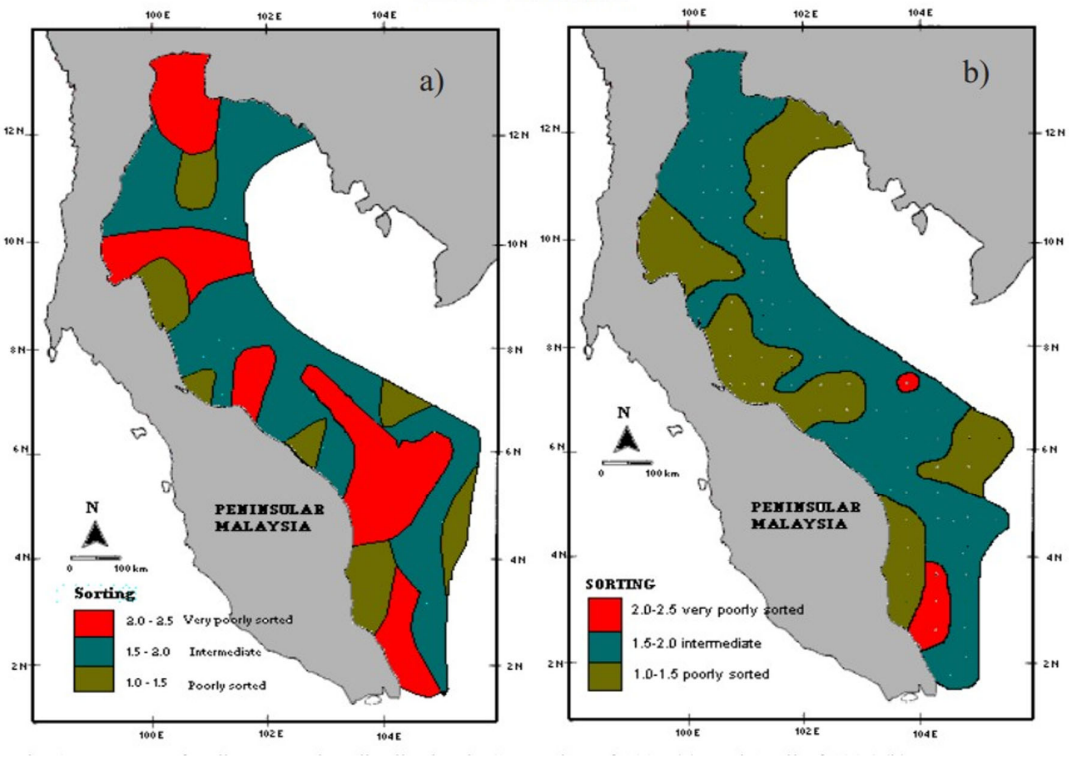



**Figure 11: Sediment characteristic of the Gulf of Thailand and the East Coast of Peninsular Malaysia (Source: Husain et al., 1999)**

### 3.1.3 Fishermen And Fishing Methods In The Lobster Refugium On The East Coast Of Johor

#### 3.1.3.1 Fishermen

According to Norhanida and Nur Shahirah (2021), the coastal area of Johor is an important fishing ground for artisanal fishermen. However, the number of fishermen who rely on lobsters as their source of income was not specified. These fishermen often use a fishing boat below 6.4 m in length and an engine power of less than 50 horsepower. There is no tow trawler at Tanjung Leman due to the shallow river mouth. The tow trawler fishermen are based in Endau on the north and in Tanjung Sedili, located south of Tanjung Leman. Lobsters are often a “by-catch,” not the main commodity for the tow trawlers.

The average catch of artisanal fishermen in Tanjung Leman is 20.4 kg/trip, of which 43.3% are lobsters. The average catch of the artisanal fishermen at Tanjung Sedili was higher, at 59.6 kg/trip, of which 24.3% were

lobsters. The catch of the fishermen from Sedili Besar is lower, at 20.4 kg/trip, of which 17% were lobsters, while Sedili Kecil fishermen only catch 9 kg/trip, 23% of the catch are lobsters. The fishermen at Sg. Musoh, in the Pengerang District, catches only 5.3 kg/trip, but 58.7% of the catch are lobsters.

#### 3.1.3.2 Fishing Methods

According to Norhanida and Nur Shahirah (2021), Zone A uses nine traditional fishing methods: pukat tangsi, drift net, lobster trap, fishing rod, crab trap, rawai, tagan, jaring tahan and pukat jerut. The average water depths in the area ranged from 12 - 45 m and catches often landed at the private jetties. The main commercial equipment is the tow trawler based in Endau and Sedili. Tow trawlers operate in Zone B and Zone C.

Sedili and Tanjung Leman fishermen use traditional fishing tools such as drift nets and Bubu. They operate adjacent to the coast. These traditional fishermen's main catch is lobster hiding in rocky areas near the coast. In contrast, mature crayfish landed in Endau are by-catches of tow trawlers operating in Zone B and Zone C.

Since this area (Zone A) has a higher lobster density than other areas, in addition to the lobster trap, drift net also contributed to a significant lobster catch in Zone A. The main season for the lobster catch is between March and November during the South West Monsoon. Apart from the Tanjung Leman fishermen, Sedili Besar, Sedili Kecil, and Sungai Musoh are important areas for lobster landing in Johor. All artisanal fishermen operate within five nautical miles of the coast.

In terms of average income, fishermen who use lobster traps earn RM3061.30 /month, while fishermen who use Jaring Tahan earn RM2,910 /month from the lobster catch. 82.4% of the fishermen who used the lobster trap reported a reduction in lobster catch compared to 2016. Nonetheless, about 9.1% of respondents reported increased lobster catch in the same survey period.

# 4.0 MANAGEMENT PLAN FOR LOBSTER REFUGIA ON THE EAST COAST OF JOHOR

## 4.1 THE PRINCIPLE FOR MANAGEMENT

The lobster refugium on the east coast of Johor is established to ensure the sustainability of the lobster industry in Johor. Although the mud spiny lobster is not listed as critical under the IUCN red list, the landing of the commodity has demonstrated a declining trend over the last decades. The declining trend required DOFM intervention to reverse it before it was too late. The lobster refugium is the best suited approach to complement the current measures on resource protection. The lobster refugium shall not be seen as the extension of the no-take zone. It is a systematic management measure to sustain the lobster fisheries in the area, which benefit all the stakeholders. Hence, the vision and mission of the lobster refugium are:

**Vision**

*Sustaining lobster fisheries on the East Coast of Johor*

**Mission**

*Improve lobster stocks via the fisheries refugium on the East Coast of Johor*

## 4.2 STRATEGIES FOR SUSTAINABLE MANAGEMENT OF LOBSTER RESOURCES ON THE EAST COAST OF JOHOR

### 4.2.1 Strategy 1: Conservation Of Lobster Habitats On The East Coast Of Johor

Critical habitats for the mud spiny lobster were identified based on the DOFM's studies and those areas of importance for lobster during a technical workshop with DOFM Officers. In the lobster refugium context, the sensitive area is defined as an area for the lobster, spawning, foraging, and areas with a high density of lobster aggregate. After identifying critical habitats and sensitive areas, they are superimposed with the existing protection implemented by various government agencies. Table 5 lists conservation efforts by various government agencies within the refugium area. Figure 12 shows the proposed refugium area on the east coast of Johor. Based on the DOFM studies, considering the spatial distribution of lobster and the critical habitats on the east coast of Johor, lobster refugium will not be effective if the refugium covers only the surrounding area

Tanjung Leman. Hence, the lobster refugium is proposed to cover the east coast of Johor with a water depth of <60m, as displayed in Figure 12.

**Table 5: Habitat conservation efforts from various government agencies on the east coast of Johor**

| Habitats and sensitive areas | Conservation effort | Agency |
|---|---|---|
| **Marine Park water** | Marine protected Area; No Take Zone | Department of Fisheries Malaysia |
| **Mangrove** | Forest Reserve | Department of Forestry Malaysia |
| **Seri Bulat Island and its adjacent area** | Marine protected Area; No Take Zone | Department of Fisheries Malaysia |
| **Coastal Area of Johor** | Fisheries A Zone and Conservation area | Department of Forestry Malaysia |
| **Underwater cable** | Prohibited Area | Marine Department Malaysia |
| **Refugium** | No take of Juvenile and berried female | Department of Fisheries Malaysia |

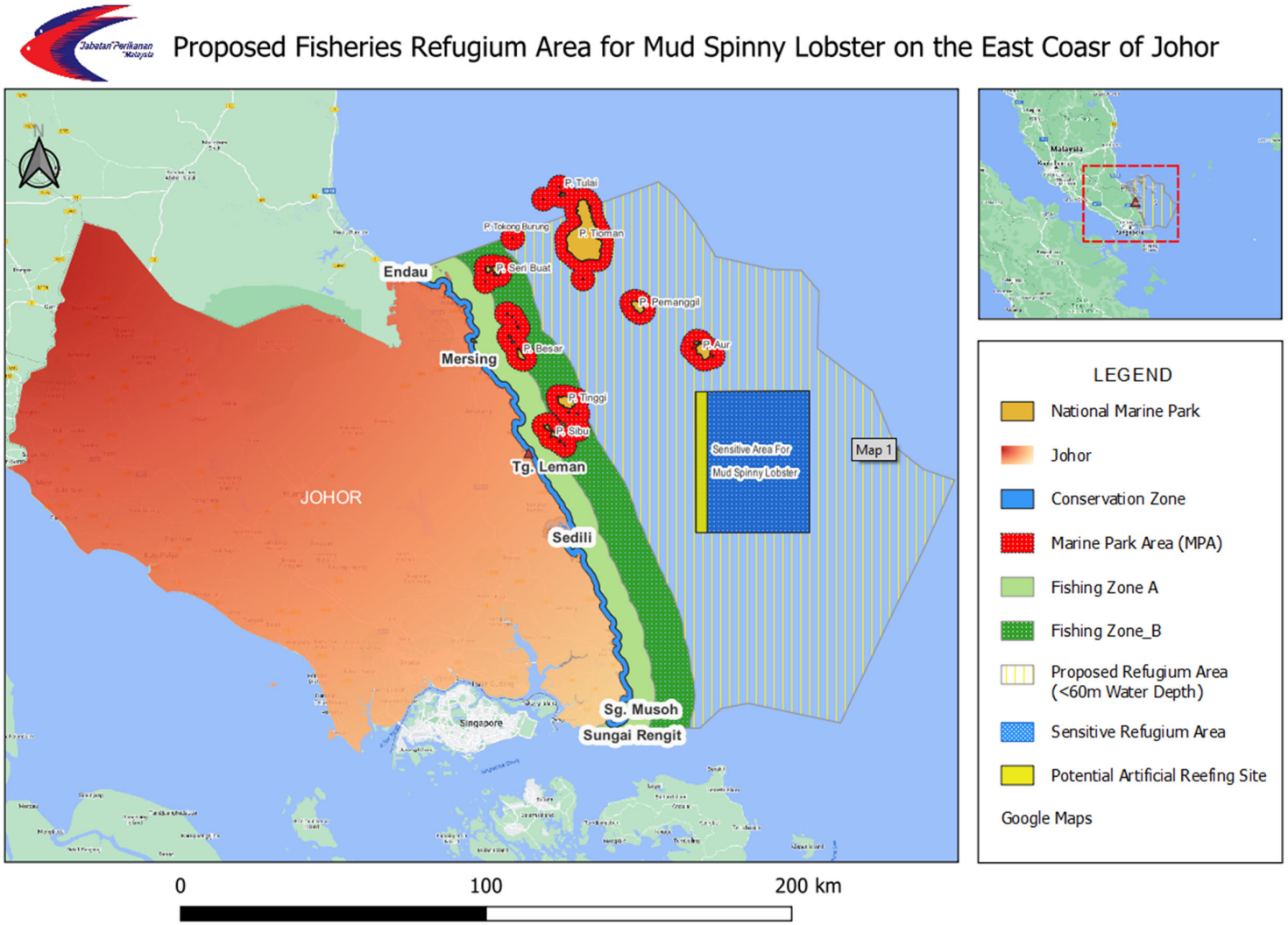



**Figure 12: Boundary of lobster refugium on the east coast of Johor**

### 4.2.2 Strategy 2: Deployment Of Artificial Reefs To Create New Habitats

The construction of artificial reefs could provide new habitats for the mud spiny lobster in the refugium. It provides an alternative habitat to shelter the lobsters, as most of the natural habitats were explored by the fishermen. The artificial reefs can be deployed in the sensitive area identified by the DOFM researchers, including Alias and Rashidah (2000), Alias et al. (2000), Siow (2021), Siow et al. (2021a) and Siow et al. (2021b). The artificial reefs will play two main roles in the refugium:

1. Create a new habitat for lobster in the refugium. This new habitat can be a no-catch area to increase the lobster population in the refugium.

2. To prevent encroachment of the trawler into the protected area. Tow trawlers have long been known to damage seabed ecosystems. This destructive method shall be slowly phased out and replaced with other sustainable methods.

Apart from building new habitats for the lobsters, the artificial reefs will also increase other fisheries resources in the refugium. As the water depth in the proposed area is about 40 m, strong and durable building materials such as concrete and iron are ideal for constructing artificial reefs. The concrete reefs designed and constructed by DOFM are the most suitable for lobster refugium. Besides, the rigs-to-reefs program provided another alternative for artificial reefs. Nonetheless, the GPS coordinate of the artificial reefs shall be made known to the Marine Department, operators, and owners of fishing vessels, particularly those parties operating in the C Zone. The Marine Department will announce and inform vessel operators regarding the reefs to ensure navigational safety.

The artificial reefs deployed in the fisheries refugium could be further color-coded to reflect their intended use. For example, red could indicate a protection zone where no fishing activities are allowed in the new habitat; At the same time, yellow indicates recreational use. It is only for recreational fishing and, in certain areas, diving or spearfishing. The yellow-coded artificial reefs are the area where fees can be collected from users. Blue could indicate artificial reefs that were constructed for commercial extraction.

The Engineering Division and Research Division of DOFM have much experience developing artificial reefs for lobster (Ahmad et al., 2018). They designed and deployed two different designs of artificial reefs for lobsters in the coastal water of Johor, Sabah, and Federal Territory Labuan. In Johor, the artificial reefs were deployed about one nautical mile from Pulau Tinggi, and the artificial reefs in FT Labuan were deployed about 0.5 nautical miles from Tg. Kabung and Kg. Layang-Layang. In Sabah, the artificial lobster reefs were deployed approximately three nautical miles from Kuala Penyu. The dimension of the first artificial reef module was 1.65 m X 1.65 m X 1.65 m

(height), and the dimension of the second module was 1.65 m x 1.65 m x 2.05 m (height); each module weighed 5 to 7 metric tonnes. Construction of the artificial reefs complied with British Standard 8110. The thickness of the columns and floor is about 15 cm, while the concrete thickness is more than 5 cm. Y12 iron rods were used to reinforce the columns and beams, while the spiral iron type R8, with a distance of 20 cm was used to reinforce the wall. The artificial reef floor was reinforced using BRC A10 iron. Ready-made concrete grade 40 is used to construct the artificial reefs.

Figure 13 shows the photo of the concrete reefs that were constructed for lobsters in 2008 at Tg Kabong, FT Labuan, Pulau Tinggi, Johor dan Kuala Penyu di Sabah. While Figure 14 shows the concrete reefs built for lobster in 2009, which were then deployed nearby Kampung Layang-Layangan FT Labuan.

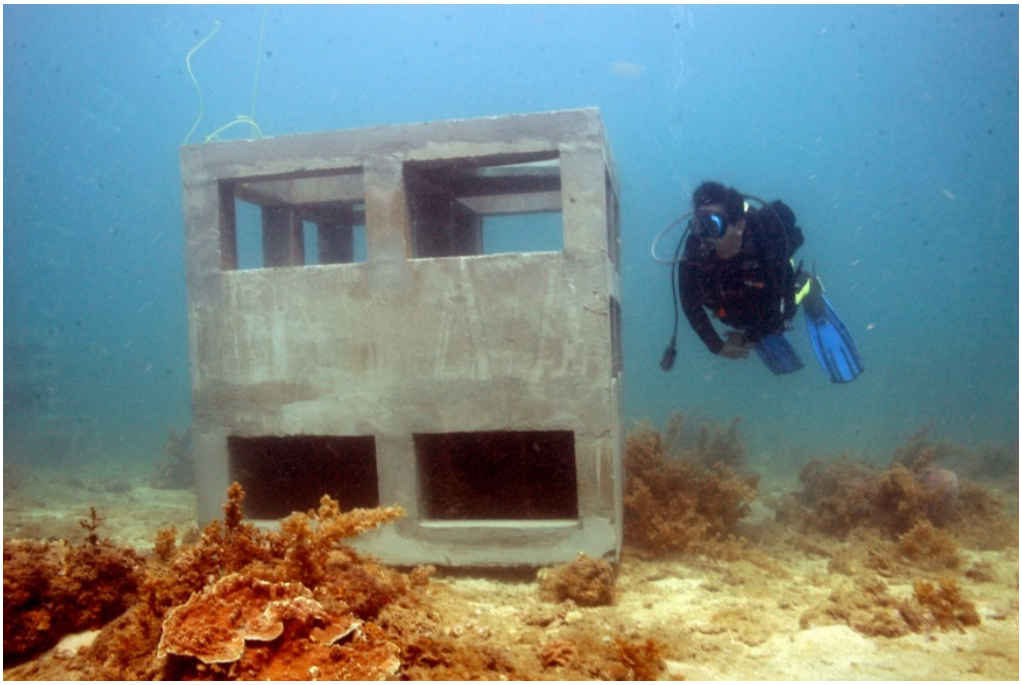


**Figure 13: Concrete reefs module for lobster built in 2008 and was deployed at Tg Kabung FT Labuan, Pulau Tinggi, Johor and Kuala Penyu in Sabah.**


**Figure 14: Concrete reefs module for lobsters built in 2009, deployed nearby Kampung Layang-Layangan FT Labuan.**

While submerging these reefs, a 50 metric-ton loaded crane and a mechanical reef relief device were used. Each module is placed approximately 2 - 3 meters apart. After the reefs are deployed on the seabed, SCUBA divers will dive to record the position of the module. The underwater environment will be recorded using an underwater video recorder as the baseline. The performance of the artificial reefs was evaluated occasionally. Based on the survey, the artificial reefs have successfully developed into new habitats for lobster, as reported by Ahmad et al. (2013) and Ahmad et al. (2018). Based on Ahmad et al. (2018), In 2016 and 2017, DOFM and PETRONAS submerged offshore structures as an artificial reef at two locations near Pulau Kapas, Terengganu, and two other locations in Miri-Sibuti and Miri, Sarawak. The rigs-to-reefs in Pulau Kapas were submerged at a depth of 20 m, while in Sarawak, the offshore structure was submerged at 46 m. Based on initial monitoring, all four reef sites have evolved into a new ecosystem for marine life. In 2019, DOFM prepared a new reef design for lobster. The concrete artificial reefs will be deployed around Pulau Lima in the Pengerang, Johor.

Since DOFM has much experience in determining suitable locations, designing, constructing, deploying, and monitoring artificial reefs for lobster, constructing artificial lobster reefs in the refugium shall be implemented successfully.

#### 4.2.2.1 Artificial Lobster Reefs As Shelters For Berried Females

The artificial reefs are important to prevent the eggs-berried females from being caught before the eggs are hatched. The artificial reefs will be the main hiding place because many natural habitats have been damaged due to unfriendly fishing activities, especially tow trawlers. Three important references published by DOFM related to the process of building artificial reefs, including artificial reefs for lobsters, are Ahmad et al. (2010), Ahmad et al. (2012), and Ahmad et al. (2018). In order to ensure the successful construction of the artificial lobster reefs, especially for the berried females, the following steps should be duly followed:

##### 4.2.2.1.1 Site Selection

This study should be carried out to obtain sediment characteristics and benthic information in the proposed site to prevent the reefs from falling into the soft mud and prevent it from falling on the coral reef. The deployment of artificial reefs should be at least two nautical miles from any sub-sea structures, including cable, pipelines etc. The Smith McIntyre Grab could be used to collect sediment samples from the sea bottom in a deeper area, while a Ponar grab may be sufficient to collect sediment samples from a shallower area. The benthic survey can be conducted in transect lines parallel to the coastline. Sediment samples can be collected about one nautical mile apart. Sediment samples were then analysed for particle size distribution. When the composition ratio of sand and clay is 50:50 to 60:40, the area is suitable for deploying artificial reefs. The mud spiny lobster *Panulirus polyphagus* lives in a muddy environment with a slightly higher sand composition than the mud.

An echo sounder can be used to determine water depth and also the sea bottom slopes. A higher-end side scan sonar, multi-beam echo sounder dan 'sub bottom profiler' could provide a clear picture of the bathymetry. Other than the sediment and bathymetry survey, interviews with the local fishermen or a biological survey will help understand the species composition of the potential site. The biological composition provides an important insight into the potential biota that will be developed in the artificial reefs.

After the results of the sediment characteristic are obtained, the selection of the site is based on the following criteria; (i) the sand composition exceeds the mud or the equal, (ii) there is no coral reef area nearby, (iii) there is evidence of lobster presence; especially the berried females, (iv) the area has no underwater structure nearby, nor the area is gazetted as a prohibited zone by the Marine Department (Ahmad et al., 2012). The potential zone for the deployment of artificial reefs in the sensitive area is highlighted yellow in Figure 12 (GPS coordinate: 2°20.000'N, 104°30.000'E; 1°55.000'N, 104°30.000'E; 2°20.000'N, 104°32.725'E; 1°55.000'N, 104°32.725'E)

##### 4.2.2.1.2 Design of artificial lobster reefs

The two most suitable materials for constructing artificial reefs in an area where the water depth is more than 40m are concrete and iron. At such depth, the type of artificial reefs deployed in Terengganu is suitable for

deployment in this area. The dimension of the first module is 1.65m X 1.65m X 1.65m (height), and the second module is 1.65 m x 1.65 m x 2.05 m (height), with a weight of each module of about five metric tons to 7 metric tons. The details and design of these two reefs can be obtained by referring to Ahmad et al. (2018).

No specific design are required if the reef is to be built using decommissioned oil/gas rigs. However, the structure can be modified to create more crevices using recycled structures for the lobsters to hide. Ideally, the structure should be large, with a weight of more than 20 tonnes per module, to have a positive impact on lobsters and other fishes in a shorter period of time. The large structure also effectively restricts trawlers' operation in the area, including the illegal fishing vessels.

#### 4.2.2.1.3 Construction Of Artificial Reefs

Building artificial reefs begins with a quotation and appointing a qualified contractor. The procurement of service should be based on the DOFM procedures. Construction of the artificial reefs complied with British Standard 8110. The thickness of the columns and floor is about 15 cm, while the concrete thickness is more than 5cm. Y12 iron rods were used to reinforce the columns and beams, while the spiral iron type R8, with a distance of 20 cm, was used to reinforce the wall. The artificial reef floor was reinforced using BRC A10 iron. Ready-made concrete grade 40 is used to construct artificial reefs. After the construction, the artificial reef must allow a curing period of not less than 28 days to maximize the structure's strength. During construction, the DOFM officers must regularly inspect and monitor the construction. Detailed processes of constructing artificial reefs are documented in the DOFM procedures by Ahmad Tarmidzi et al. (2012) dan Zaidil Abdilla et al. (2010).

Cutting oil/gas rigs usually does not involve DOFM staff, as contractors appointed by PETRONAS carried out all the hot work for the rigs-to-reefs program. PETRONAS will ensure that the contractors carrying out the works follow all the protocols set by the Malaysian government and comply with international standards throughout the cutting process so that there is no pollution to the environment.

#### 4.2.2.1.4 Deploy And Submerge Of Artificial Reefs

Deployment and submerging of the artificial reefs begin with the weather forecast. To minimize the occupational risk, especially during the lifting of the artificial reefs, the deployment and submerging of artificial reefs should be conducted in a calm sea. The Engineering Division will evaluate all the contractors involved in the deployment to ensure that only qualified contractors with the necessary equipment, training, and workforce are appointed. The contractor carries out the process of transporting artificial reefs from the construction site to load them into the pontoon and submerge it on site. DOFM has a clear SOP for the deployment work, which shall be closely adhered to by all parties.

A 50-metric-ton loaded crane and a mechanical reef relief device were used. Each module is placed approximately 2 - 3 meters apart. At each site, it should not be less than 20 modules. The reefs will provide more hiding places with closer modules.

After all the reefs are deployed on the seabed, SCUBA divers or "drop camera" or UAV (Unmanned Underwater Vehicle) can be used to survey the position of the module using the video recorder. The video footage is important because it can be used as a baseline for future reference, as explained in greater detail by Ahmad et al. (2012).

#### 4.2.2.1.5 Post Deployment Monitoring

The performance of the submerged reef should be monitored regularly to record its development in terms of species diversity and biomass. Since the proposed site for artificial lobster reefs is quite deep, using ROV is more practical than SCUBA divers. ROV can record the development of reefs, especially the presence of lobsters and other demersal organisms. The monitoring method can be referred to Ahmad et al. (2012).

### 4.2.3 Strategy 3: No Take For Juvenile And Berried Females Lobster In The Fisheries Refugium

There are two groups of artisanal fishers that fish lobster for a living. The first group fishes lobster as bycatch, extracting all types of seafood, and lobster is more important during the North East monsoon. This group of fishers is mainly in the area of Tanjung Leman, and the lobster catch landed at the Tanjung Leman jetty is sent to Endau for processing before export. Sometimes, the lobster will be sold to the Pengerang area, especially during the peak season, when the lobster supply does not match the demand. The other group of fishers focuses on the lobster catch as their main source of income. This group of fishers is mainly in the area of Sg. Rengit, Sg. Musoh and Telok Ramonia, at Pengerang. The percentage of juvenile lobster in the Pengerang area is higher than in Tanjung Leman. Waiho et al. (2021) and Ikhwanuddin et al. (2014) reported the first lobster maturation at 6.0 cm (carapace length). At 6.0 cm carapace length, the average lobster weight is about 150 g per individual. In order to ensure the lobster catches do not affect the reproductive rate, it is recommended to prohibit catches of juvenile lobster (carapace length <6 cm) and berried females within the lobster refugium throughout the year. The two protective measures will allow the lobster to at least spawn once before it is extracted. Failure to protect the juvenile and berried females, The lobster stock would eventually deplete and collapse the lobster fisheries in Johor. Lobster stock depletion will show three obvious symptoms. First, decline in the landing. Secondly, the size of the lobster will show a declining trend over the years. Lastly, increase in catch per unit effort (CPUE). More effort must be made to extract the same yield, in this case, lobster.

Monitoring and control must be in place to ensure the order of no catch of juvenile and berried females are properly executed. The monitoring and control points can be established at the fish landing along the east coast

of Johor. The control points at the fish landing jetty will reduce the monitoring cost. The other way of monitoring and enforcing is to inspect the fishing vessels from time to time. In this context, those repeat and unrepentant offenders shall be penalised according to the rules and regulations. No take of juvenile lobster and berried females shall also be reflected in the seafood export. Prohibiting the export of undersized lobster and berried females will show the government's determination to uphold sustainable fisheries.

### 4.2.4 Strategy 4: Closure Of Lobster Fishing Season In The Sensitive Area

DOFM researchers have identified a sensitive area of 1,717 $km^2$ for conserving lobster stock (Figure 8). High lobster density was reported in the sensitive area during the spawning season. Thus, this area is deemed vital, forming the basis for the close season. It is recommended to declare a close season for lobster fishing beginning 15 December until the last day of February in the following year. The sensitive area was identified based on the research finding conducted by DOFM researchers. The sensitive area shall be reviewed from time to time as more data are collected from the refugium.

### 4.2.5 Strategy 5: Aquaculture As An Alternative To Capture Fisheries

Increasing aquaculture production can help to relieve pressure on wild fisheries stocks. Lobster aquaculture is still in its developing stage. All the seedlings are mainly harvested from the wild. Nonetheless, lobster aquaculture is a lucrative business in Indonesia, Vietnam, dan Filipina. Indeed, the supply of the puerulus for aquaculture is a business itself. (Phillips & Matsuda, 2011). In general, lobster aquaculture can be divided into three phases. Phase 1: Production of lobster seedlings, phase 2: nursery, and phase 3: grow out. Production of lobster seedlings has not been commercially viable. The survival rate of the lobster puerulus in captivity is extremely low. Besides the long larvae, the planktonic stage is the major hurdle in developing the whole-cycle lobster culture (Mustapha 2013; Pramesti et al., 2021).

At this point, the collection of puerulus and juvenile is the main seedlings supply for aquaculture. Lombok, Indoesia is the main supply in ASEAN. The legalization of lobster seed collection for export purposes has resulted in an abundant seed (puerulus) supply from the fishermen leading to a reduction in lobster prices (Hilyana et al., 2021). The finding points out the importance of holistic consideration in fisheries management.

The nursery phase takes about 6 to 16 weeks, from puerulus up to a size of less than 3 g or slightly exceeding 3 g (Jones et al., 2019). The lobster seedlings released into the mariculture cage are small, approximately 12 mm in length and <5 mm in body width. Thus, the cages are small with a very fine mesh size. The lobster seedlings are stocked at 50 – 100 pieces per $m^2$. The lobster seedlings are fed with minced thrash fish, shrimps, and mollusks.

Compared to the other phases, the grow-out phase are relatively well developed. Various culture systems are used for lobster grow-out, including floating cases and fixed cages. The dimension of the culture cage is often around 3m x 3m x 4m. During the grow-out phase, lobsters can prey on their food. Fresh fish, crabs, shrimp, and mollusks are the main feed for lobster. Interestingly, studies have been reported to utilize and modify the abundant shrimp farms for lobster culture (Jones and Trang, 2013).

In Malaysia, the research and development of the lobster culture are mainly conducted by the Fisheries Research Institute and the Institute of Tropica Aquaculture and Fisheries, University Malaysia Terengganu (Ikhwanuddin et al., 2014). However, the research remains for academic purposes. More studies are needed to commercialize the lobster culture. Other than the technical aspects, it is important to conduct business viability studies for the lobster study in Malaysia before rolling out the business. More research and studies are required for lobster culture. The Fisheries Research Center at Gelang Patah could play a more vital role in coordinating lobster research in Malaysia.

### 4.2.6 Strategy 6: Co-Management And Communication

Siow et al. (2020) have given an overview of the management framework of fishing refugia sites (Figure 15). As emphasized in the desktop review, almost all successful environmental resource management systems involve all stakeholders in their management. Involvement with the local community can provide input to DOFM regarding the implementation and challenges faced. At the same time, DOFM can provide awareness and update the implementation strategy in the fishery refugia.

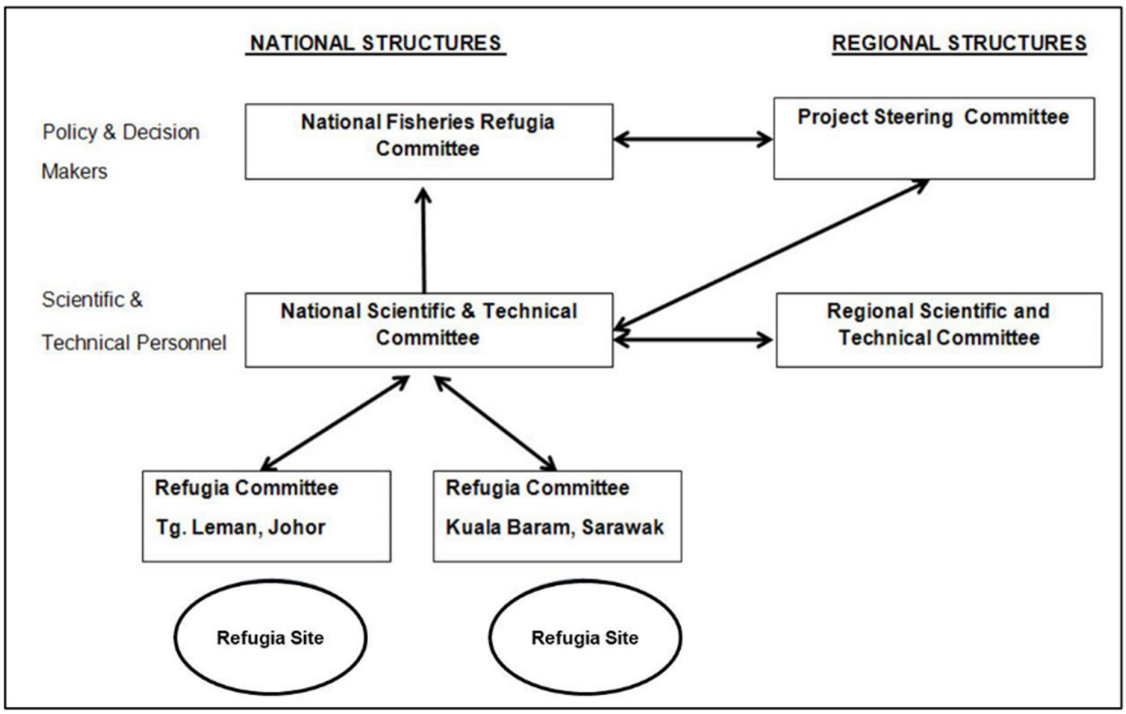



**Figure 15: National and regional coordination mechanisms for the implementation of fishery refugia in Malaysia (Siow et al., 2020)**

Two workshops with stakeholders, including fishermen, restaurant operators, wholesalers, and government agencies, were conducted in Kota Tinggi and Tanjung Leman on 28-29 September and 16 October 2022. A total of 79 participants consisting of fishermen, restaurant operators, wholesalers, and government agencies, participated in the workshops. All workshop participants generally know the importance of not catching and selling juvenile lobsters and berried females. Restaurateurs and wholesalers supported the refugia program to develop a sustainable lobster industry. However, in the current situation, they were asked to purchase the lobsters in bulk. The percentage of juveniles in the lobster catches varies seasonally. The percentage of juvenile lobsters is higher during the North-East monsoon. The percentage of juvenile lobsters is approximately 20% to 30% during the North-East Monsoon. In other seasons, it is between 15 to 20%. The berried females are rarely available. The juvenile lobsters' percentage was higher in Sungai Musoh and Sungai Rengit than Tanjung Leman.

The fishermen also expressed concern about their incomes, especially in Sungai Musoh and Sungai Rengit. However, they will comply with DOFM's prohibition order. Among the measures that can offset the impact of the ban on catching juvenile lobsters is the proposed wholesale market price. Ideally, the market price can be increased to more than RM110 per kilo for lobsters with a carapace length of around 6 cm and weight in the range of 150 g - 200 g (grade C), RM140 per kilo for size ~ 7-8 cm with a weight of 300 - 600 g each and RM180 per kilo for lobsters whose carapace size is more than 8 cm, weighing more than 700g/ head. Based on the participants' input, most fishermen are not interested in fattening lobsters or engaging in aquaculture, except

four people who showed interest in supplying juveniles to aquaculture operators. All fishermen agreed to release the juvenile lobsters and the spawning brood if the market price could be increased to balance their income. The proposed minimum pricing was discussed in **4.2.7.1**.

The participation of the public and community involvement is important to ensure success in implementing the management plan. Effective communication and mechanisms to deal with conflicts will encourage community involvement in the lobster refugia. Transparency in enforcement is an important factor in gaining the trust of fishermen and community members in the refugia enforcement process. The level of compliance with refugia regulations is expected to increase in the long term with continued enforcement. In order to obtain support from the local fishing community and the general public, specific education and training on regulations, laws, and performance monitoring of fisheries refugia should be carried out from time to time. The dissemination of knowledge and information about the efforts made to secure the future of the lobster fishery is important to foster participatory management and self-governance (Yandle, 2008).

#### 4.2.6.1 Communication Plan

Informed consumers are an important factor that can increase public awareness and promote self-monitoring of lobster fisheries in the region. Developing and disseminating educational materials is essential to gain public support for refugia management activities. Topics that focus on the target species (*P. polyphagus*), such as biology, life cycle, the importance of lobster fisheries, and the concept of fisheries refugia, are prioritized to be promoted for public awareness and understanding. All pertinent information should be supported by scientific data and highlight the effects of overfishing and illegal fishing equipment/methods on the lobster population in Tanjung Leman, as well as the benefits of developing the lobster refugia program in the area.

The following are the main goals in the communication plan identified to effectively implement *Panulirus polyphagus* lobster fisheries refugia management in Tanjung Leman, Johor. The main objectives of the communication plan are:

- To communicate the outcomes of this fisheries refugia's technical and scientific efforts clearly to all social classes.
- To integrate the concept and content of fisheries refugia in education and public awareness programs.
- To demonstrate continuous efforts in investigating the latest and most effective methods to increase public awareness of the importance of sustainable lobster resource management and its intrinsic value.

#### 4.2.6.2 Stakeholder In The Fisheries Refugia On The East Coast Of Johor

According to the Food and Agriculture Organization of the United Nations (FAO), stakeholders can be divided into two groups: 1. primary stakeholders and 2. secondary stakeholders. Primary stakeholders are those directly interested in the resource, relying on the resource for a living. Secondary stakeholders are groups with indirect interests, those involved in institutions or agencies related to resource management, or those who do not fully depend on the wealth or business resulting from the resource. Secondary stakeholders also include those with conflicting interests in using the resource.

Table 6 shows all the stakeholders directly and indirectly involved when the lobster fisheries refugia are implemented. Once the stakeholders have been identified, more effective and realistic refugia policies and regulations can be developed with the input of information and experience at the local level. In addition, with communication with stakeholders, stronger support and objections can be reduced while implementing these fisheries refugia. The communication plan will be formed based on these two target groups of stakeholders: primary and secondary.

**Table 6: List of primary and secondary stakeholders of lobster fisheries refugia**

| Primary Stakeholders | Secondary Stakeholders |
|---|---|
| 1. Lobster fisherman community (artisanal/small-scale, commercial)<br>2. Seller and dan wholeseller<br>3. Processing group (if applicable)<br>4. Boat/fishing vessel owners<br>5. Seafood companies/industry (including restaurants)<br>6. Fisheries officers (DOFM)<br>7. Fisheries researchers (academic institutions) | 1. Consumers<br>2. Environmental groups (NGO)<br>3. Recreational users (tourist, recreational fishers, sailors)<br>4. Shipping/maritim industry<br>5. Groups involved in coastal development (e.g. sand mining)<br>6. Other marine users |

#### 4.2.6.3 Communication Methods

Much of the management of protected areas such as fisheries refugia is closely related to human management procedures and spatial management in terms monitoring and reporting (technical issues do not play an important role). Therefore, efficient communication and education are crucial. In order to achieve the identified objectives, the communication strategy of the management plan of the lobster fisheries refugia in Tanjung Leman, Johor is divided according to three main target groups:

- Primary stakeholders (particularly the lobster fisherman community)
- Educational institutions (student group)
- General public (secondary stakeholders)

#### 4.2.6.4 Local Stakeholders (Primary Stakeholders)

| **Main characteristics of communication strategy:** |
|---|
| • Communication or educational messages should be delivered in the form of an continuous dialogue with local stakeholders.<br>• Communication or education messages should offer information on alternative actions if community behavior needs to be changed, especially when it affects people's livelihoods.<br>• Local committees are established to plan community activities and events that can raise awareness of the lobster fisheries refugia and encourage a stronger sense of community identity (participatory effect).<br>• The fisheries refugia initiative needs to be communicated to neighboring districts/states so that local efforts are not affected.<br>• A network should be formed between other fisheries refugia to exchange information and improve awareness raising efforts.<br>• Government agencies and researchers who conduct research in the refugia area need to work together in order to produce educational materials that can effectively convey the message of awareness.<br>• Technical training, learning workshops, and seminars from relevant parties should be held from time to time so that any regulatory updates or latest scientific findings can be shared.<br>• In addition to official conventional channels such as newsletters, communication methods need to be upgraded to the latest and reliable methods such as phone apps according to current needs and requirements.<br>• Maintain the function of the Refugia Information Center (RIC) and information officers so that they can provide long-term exposure to the community and outsiders who come to visit the refugia area. |
| **Performance monitoring criteria:** |
| • Awareness/educational materials produced. For example:<br>  ○ Manual or guidebook<br>  ○ Pamphlet/brochure or information sheet on lobster fisheries refugia (hard/softcopy)<br>  ○ Series of training and refugia information slides<br>  ○ Training video/infographics<br>  ○ Website<br>• Training and workshops on fisheries refugia regulations, sustainable fishing techniques, and others at the local level or at relevant training centers/sites<br>• Lecture or seminar/conference of expertise in fisheries and refugia or lobster research |

- Community
- University/academic
- National
- Regional
- International

- Number of visitors to the Refugia Information Center (RIC)
- Phone apps/online

**Important topics for educational material development and public awareness:**

- Lobster biology
  - Anatomy and functions
  - Detailed life cycle
  - Habitat
  - Feeding habits
- Current status of lobster fisheries
  - Landing trends
  - Catch rates
  - Intepretation of fisheries monitoring data
  - Case studies of sustainable management of lobster fisheries
- Management of fisheries refugia
  - Limitations on the usage of catching tools
  - Close season for lobster fishing
  - Lobster catch size limit
  - Catch zone(s)

#### 4.2.6.5 Educational Institutions/Students

**Main characteristics of communication strategy:**

- A comprehensive set of educational materials on lobster fisheries refugia should be prepared using stories and illustrations (infographics) to attract the interest of school students.
- Although the education system is a relatively easy approach due to the formative target group, but the support of the parents is also critical to bear part of the responsibility to foster awareness of lobster resource conservation.
- Science-based information that supports the sustainability of lobster fisheries in best management practices should be applied.
- Integration into educational programs and channels commonly used by teachers and instructors to gain wider exposure.

- Conduct study visits to refugia sites for deeper exposure to the concept of fisheries refugia.

**Performance monitoring criteria:**

a) Types of educational materials published. For example:
    - Video clips (e.g. refugia webpage, Youtube, TikTok)
    - Poster (infographics) (hard/softcopy)
    - Leaflet/brochures or information sheets (hard/softcopy)
    - Series of online learning slides

b) Special lecture/seminars by researchers of lobster fisheries, fisheries officers, and/or specialists of fisheries refugia

c) Study visits/activities to fisheries refugia

d) Publicity campaigns/exhibitions focusing on refugia, lobsters, fisheries, conservation of marine resources, etc.

e) Number of student groups visiting the Refugia Information Center (RIC)

f) Website traffic and social media (e.g. Facebook, Instagram, Twitter, TikTok, etc.)

**Important topics for educational material development and public awareness:**

a) Lobster biology
    - Interesting facts
    - General anatomy
    - Types of lobsters
    - Habitat and feeding habits

b) Lobster fisheries
    - Importance of lobster fisheries
    - Current threats
    - Lobster conservation efforts

c) Fisheries refugia
    - Concept of fisheries refugia
    - Importance of fisheries refugia
    - Enforcement of fisheries refugia
    - How increased public awareness can help sustain the lobster fisheries

#### 4.2.6.6 General Public

**Main characteristics of communication strategy:**

a) Utilizing social events and publicity campaigns to launch initiatives and raise profile in the community, attract media, and build awareness.

b) Appointing high-profile figures/individuals to be ambassadors of the fisheries refugia program so that the campaign has higher impact and exposure.

c) Education about fisheries refugia should be linked to the impact on the way of life of the community so that the content of the awareness message is easy to understand and accepted by the public.

d) Collaboration with non-governmental organizations (NGOs) to develop education and awareness program modules for the public.

**Performance monitoring criteria:**

a) Types of awareness/educational materials produced. For example:
   - Video clips (e.g. refugia webpage, Youtube, TikTok)
   - Poster (infographics) (hard/softcopy)
   - Leaflet/brochures or information sheets (hard/softcopy)
   - Newspaper articles/features (hard/softcopy)
   - Magazine articles/features (hard/softcopy)
   - Awareness slides series (online)

b) Talks/seminars by experts of fisheries refugia or lobster researchers

c) Publicity campaigns/exhibitions/expos on refugia, lobster fisheries, marine resource conservation, etc.

d) Number of visitors to the Refugia Information Center (RIC)

e) Website traffic and social media (e.g. Facebook, Instagram, Twitter, TikTok, etc.)

**Important topics for educational material development and public awareness:**

a) Lobster biology
   - Interesting facts
   - Anatomi in detail
   - Changes in habitat and ecology

b) Current status of lobster fisheries
   - General information on lobster population stock
   - Unsustainable catching methods and harmful to the environment
   - Concept of sustainable lobster fisheries

c) Fisheries refugia
   - Benefits of fisheries refugia development
   - Management strategies of fisheries refugia

- How the general public can help to conserve lobster fisheries

Community participation in awareness efforts does not involve the public in management decisions. The importance of this effort is focused on the promotion of open communication and the building of mutual support and trust between the community and the management of the fisheries refugia. This in turn leads to a better understanding of the issues on both sides. Close cooperation for common goals will create a spirit of unity, a sense of belonging, and better community management. Hence, it can be considered as a step towards full participatory management (Goldstein, 2003).

The communication method for the management of fisheries refugia needs to be dynamic, that is, it changes according to needs. A flexible and adaptive approach should be practiced because there is no fixed formula for determining the communication method used. As a first step, information dissemination and awareness raising are important. Nevertheless, building relationships with the community takes time. Temporary incentives, penalties or rewards do not guarantee continued compliance. Structural framework changes and long-term collaboration with local communities as suggested are key to the success of a good communication strategy.

### 4.2.7 Strategy 7: Sustainable Financial Resources For Refugia

The financial aspect is the most critical in the lobster refugium. It is the core to power the refugia program. The lobster refugia aim to increase the value chain to improve the social economic status of the stakeholders, especially the artisanal fishermen. The lobster fisheries must transform into premium seafood, following the fisheries transformation in Norway, Australia, and the US. After considering the present regulation and guides for funding sustainable resource management in the country, establishing a trust fund is deemed feasible for the lobster refugium on the east coast of Johor.

The selection of the trust fund approach for lobster refugia in Johor is based on four main components:

- Reducing financial costs,
- Increasing financial capital,
- Reducing actions that can damage the refugia area, and
- Increasing incentives for any positive actions or activities involving the refugium.

These four main components are essential in ensuring financial sustainability in the long term. The objectives of the trust fund for the lobster refugia are:

1. Sustainable management and conservation of lobster refugia;
2. Sharing knowledge, experience, good practices, and trust fund methods;

3. Implementation of activities that can generate financial resources for the trust fund.
4. Research and development involve innovation and commercialization to increase trust funds and financial sustainability in the long term.

The proposed trust fund will collect monetary fund from surplus units and supports the program that requires monetary fund assistance as the deficit. Hence, the surplus units contributed to funding, while the deficit units used the trust funds. The proposed trust fund could secure funding both short and long-term, including:

I. All vessel license fees involving refugia areas;
II. All payments involving breach of conditions as well as damage involving the refugia area;
III. Returns from fixed deposits of trust funds in the banking system;
IV. International and local body conservation grants;
V. Fiscal Funds from the Federal Government;
VI. Fiscal Fund from the State Government;
VII. Endowment funds of individuals, local and international companies;
VIII. Involves the issuance of unit trusts/share trusts that are equity-based and low-risk in the financial market;
IX. Issuance of blue bonds with medium and long-term maturities.

Generally, all penalties involving violation, including fees charged to vessels operating below the prescribed distance, trawling vessels, and vessels entering unauthorized areas, could be deposited into the trust fund. In addition, penalties and compensation subsequent from offenders that cause damages in the refugia areas, such as oil spills and other forms of pollution, could also be deposited into the trust fund. Other funding opportunities, including conservation grants from various organizations, could be sought to support the refugia program.

Fiscal funds from the Federal and State Governments are a potential source of support that can contribute to the trust fund via the Federal and State Budgets every year. Funds in the form of donations are also one of the sources for the trust fund through donations from corporate individuals and agencies as well as companies wholly owned by the Federal or State Government or private companies, especially oil and gas-related companies operating within the refugium.

The proposed funding source for the medium and long term involves the generation of more complex funds that can ensure long-term financial sustainability involving the financial market through the issuance of unit trusts and bonds. Issuance of unit trusts is in the form of equity instruments, while the issuance of bonds is in the form of debt instruments where repayment, which is an advance payment, must be paid to the bondholder when the bond's maturity period is sufficient.

Other than the trust fund, establishing a new institution involves public-private or NGO-private collaboration, which is another way to support the refugium. The new entity could be used to run the program that was planned under the refugium. Among the entity that successfully champions of sustainable fisheries are:

1. Western Rock Lobster Council (WRLC)
2. Canadian Lobster Council (CLC)
3. New Zealand Rock Lobster Industry Council (NZ RLIC)
4. Tasmanian Seafood Industry Council (Australia)
5. Northern Territory Seafood Council (Australia)
6. The Norwegian Seafood Council (NSC)

Table 7 summarises the organization that contributes to sustainable fisheries in various countries. Most of these organizations involved all stakeholders in the industry. Based on the various models, the Malaysia Seafood Council (MSC) could be established to lead the sustainable development of lobster fisheries on the east coast of Johor. The MSC should be participated by representatives from various stakeholders, including the institution of higher learning, private entities, government agencies, and NGOs. The MSC could serve as a platform for the various stakeholders to join forces and to have a concerted effort to leapfrog the lobster fisheries in Johor. Figure 16 shows the business segments which the MSC could pursue.


**Figure 16: Potential Business segments of the Malaysia Seafood Council**

**Table 7: Organizations that promote sustainable fisheries in various countries**

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| 1. | Western Rock Lobster Council (WRLC) https://westernrocklobster.org/ | • owner-operators<br>• processors | • Represents the industry on a range of issues, including changes to the management system of the western rock lobster fishery<br>• Preparing submissions to Government on behalf of the industry<br>• Sourcing funding for industry projects<br>• Attending meetings and lobbying Government on behalf of Managed Fishery Licence (MFL) holders<br>• Provides advice and information to committees, steering groups, and stakeholder organizations within the various sectors of the fishery<br>• Assists with safety, training and education programs for MFL holders<br>• Ensures Government processes are equitable, transparent and justifiable<br>• Strives to ensure the catching sector of this valuable industry remains a viable, effective and responsible member of the fishing community<br>• Conform to Marine Stewardship Council (MSC) standards that requires high environmental values and sustainable practices to be maintained by industry's members | • WRL Newsletter (monthly)<br>• Circulate WRL Annual Stock Assessment Report and developed by the Department of Primary Industries & Regional Development (DPIRD)<br>• Publish catch & trade statistics and puerulus settlement data from DPIRD<br>• Provide relevant industry info, events, and news<br>• Collaboration with Fisheries Research and Development Corporation (FRDC) in R&D projects (e.g., Identifying factors affecting the low western rock lobster puerulus settlement in recent years, FRDC Report – Project 2009/18)<br>• Organize Development Education Capacity Knowledge Program (DECK), WRL's annual program, designed to deliver quality professional development and learning opportunities for the industry's next generation of leaders |

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| | | | • Monitor, respond and innovate based on MSC's framework that prioritises stock assessment and harvest strategy, the impact of the fishery on the wider ecology, and management and consultation arrangements. | |
| 2. | Canadian Lobster Council<br><br>https://lobstercouncilcanada.ca/ | • harvester organizations<br>• dealers<br>• buyers<br>• processors<br>• live shippers<br>• exporters | • Address challenges in the industry and take action to make positive change<br>• Work to strengthen the international position and grow capacity to meet the demands of global markets<br>• Advise on issues of sustainability certification, food safety, and traceability<br>• Coordinate marketing initiatives regionally, nationally, and internationally<br>• Lead industry/government relations for a shared understanding of the sector's challenges and opportunities<br>• Facilitate innovation to improve returns and efficiency throughout the sector | • Advocate for local communities. Discussion and action forums at all levels of government to support the growth of industry and the well-being of the regional economy.<br>• Ensure excellent market access. Deeply connected to international markets and play an important role in exporting and growing Canadian lobster products worldwide.<br>• Build sustainability. The long history of regulation, focus on the health of the ocean ecosystem, and integrity makes Canada the world's leader in sustainable fishery management.<br>• Education. Help consumers and partners to understand the contributions, economic impact, ingenuity, and opportunities of the lobster sector. |
| 3. | New Zealand Rock Lobster Industry Council (NZ RLIC)<br><br>https://nzrocklobster.co.nz/ | • owners<br>• processors<br>• exporters<br>• fishermen | • A long-standing commitment to regional autonomy and self-determination in research and management decisions<br>• Care and responsibility for the sustainable and pragmatic management of the resource | • Participates effectively in an extensive range of consultation meetings, the NRLMG, seminars, advisory committees, research planning groups, and the stock assessment working group<br>• Takes the lead role in preparation and coordination of rock lobster industry submissions to Select Committees |

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| | | | • Maintain strategic relationships that have been developed with non-commercial stakeholder groups such as the national rock lobster management group (nrlmg)<br>• Work with stock assessment scientists and fisheries economists to develop bio-economic models to test alternative management approaches and to guide research planning in support of preferred approaches | • Supplement their practical experience with sound and credible science and policy advice contracted directly from experts<br>• Works with Government agencies to develop and implement credible standards and specifications to enable direct purchase of a range of fisheries services<br>• Accredited research provider to the Minister of Fisheries, and since then has successfully tendered for, and executed, four rock lobster stock assessment contracts<br>• Funding several regional research programmes and a major compliance initiative<br>• Develop and promote regional harvest initiatives:<br>-maximise the economic returns from a quota limited fishing opportunity<br>-minimise tensions between commercial and non-commercial fishermen, and<br>-accelerate the rebuild of stocks which prior to 1990 were assessed to be significantly less than optimum.<br>• Significant investment in post-harvest research through the auspices of the CRA8 (Southland) rock lobster industry<br>• Provide funding for DNA sequencing project using state-of-the-art DNA markers (Single Nucleotide Polymorphisms, snps) to provide information on the larval exchange (connectivity) patterns for New Zealand rock lobsters<br>• Release a Whale Safe program to assist pot and trap fishermen in avoiding and/or mitigating the risk of entanglements. Whale_Safe comprises a booklet containing detailed information about cetacean movements and behavior, a sequence of photos and illustrations to enable identification of the different |

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| | | | | cetacean species, and advice on how to set gear to avoid entanglements develop a draft product accreditation program for New Zealand rock lobsters |
| 4. | Tasmanian Seafood Industry Council (Australia)<br><br>https://www.tsic.org.au/ | • NGO | • Proactive promotion of the professional industry, delivering quality and sustainable Tasmanian seafood<br>• Work with all stakeholders to strengthen our industry<br>• Commit to exploring innovation and technology to ensure the long-term sustainability of our marine environment | • Promotion of seafood through the Australian Wooden Boat Festival display, Working on Water program, Seafood Awards, etc.<br>• Supporting the seafood workforce through the TSIC Seafood Jobs (www.seafoodjobs.org) online hub<br>• Working with Government has delivered a Seafood Election Policy and the largest Government budget commitment to Tasmanian seafood<br>• Supporting member welfare through our #stayafloat branding<br>• Communication with members through initiatives such as the Seafood Industry News magazine, TSIC Update Newsletter, the Sector Group Subcommittee, and the annual TSIC regional forum. |
| 5. | Northern Territory Seafood Council (Australia) | • NGO<br>• automatic membership for owners of a professional fishing license in | • Improve structures for an effective NT Seafood Council<br>• Build trust in our industry between our members, community, and government<br>• Demonstrate sustainability | • Helping to navigate the logistics challenges in getting products to market<br>• Takes part in a range of forums, workshops, and committees<br>• Review seafood labeling on menus, targeted education through social media platforms, and growing the *support nt caught* footprint in the hospitality sector |

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| | https://www.ntsc.com.au/ | the Northern Territory<br>• current license holders of an Aquarium Fish/Display or Fish Trader/Processor license | | • Annual membership satisfaction survey and stakeholder survey<br>• Develop a sustainability strategy for the northern territory seafood industry to put it at the forefront of an integrated approach to ecosystem-wide sustainability<br>• Partnering with researchers from the australian institute of marine sciences (aims) and research institute for the environment and livelihoods, charles darwin university (cdu) to interview professional fishers to understand the distribution and status of sawfish and river sharks<br>• Adopting a new data capture tool to improve knowledge and stewardship of the northern territory mud crab fishery. A deckhand app is being trialed to identify whether, through the support of an app, fishers can improve their data collection and, thereby, sustainable harvest methods and start to restore trust in their operations |
| 6. | The Norwegian Seafood Council (NSC) | • public company owned by the Ministry of Trade, Industry, and Fisheries and is financed through fees levied on all exports of | • NSC is a marketing communications organization working together with the Norwegian seafood industry to increase the value of Norwegian seafood in new and established markets all over the world<br>• The “Seafood from Norway” brand promotes Norwegian seafood in international markets | • Main services provided:<br>1. Market insight<br>2. NSC services in markets<br>3. What is the Seafood from Norway-trademark<br>4. Joint marketing opportunities<br>5. NSC Brand Portal<br>6. Exporter registry |

| No. | Organization | Members | Responsibilities | Key activities |
|---|---|---|---|---|
| | https://norwegianseafoodcouncil.com/ | Norwegian seafood<br>• headquartered in Tromsø, Norway<br>• 13 international offices<br>• invest in over 20 countries worldwide | • Contribute to the industry's and individual exporter's efforts, helping them to reach their goals by increasing the knowledge and preferences of seafood from Norway<br>• The most important segments of the seafood industry are represented in the advisory groups, which ensures that our investments are aligned with the industry's needs | • Working with advisory groups to give NSC input and opinions regarding the work being performed ensures the flow of information between NSC and the Norwegian seafood industry. The advisory groups consist of individual members from different parts of the seafood industry and meet two to four times annually (e.g., prawns & shellfish, cured products, salmon & trout, whitefish, pelagic)<br>• Utilizes the "Seafood from Norway" trademark in its marketing and on promotional materials outside of Norway<br>• Developed strict guidelines for the use of the trademark (license required), which for instance, prohibits any use of the trademark in Norway and by building and maintaining a global brand<br>• Licensing of the quality-approved skrei (cod) trademark; companies processing quality-approved skrei outside Norway have to apply for a license in order to obtain the right to use the trademark<br>• Market insight webpage – the main source for market information at the NSC that offers statistics about trade, consumption, and consumer studies<br>Joint Marketing Program - NSC's co-financing program for marketing activities where the Norwegian origin and/or the industry's trademark, "Seafood from Norway," is an important part of the communication |

In the early stage, the government could consider tax exemption for those companies that are registered and willing to collaborate under the Malaysian Seafood Council. The tax exemption will encourage the current market champion to collaborate and work together under the umbrella of the Malaysian Seafood Council to increase its presence in the global premium seafood market. At the same time, the Malaysian Seafood Council (MSC) shall study market branding and certification for sustainable fisheries. The study should consider existing certifications and establish new approaches for certification, including capitalization on the halal certification. The MSC should play a role in assisting and facilitating the export of sustainable seafood to the world market. A portion of the MSC profit shall be channeled into the refugia trust fund to continue to support the financial needs of the fisheries refugia.

The other critical success factor for the MSC is to invite and select reputable companies with a strong presence in the market. These companies could be leapfrogged and lead the MSC to achieve its goal and objective. The MSC shall be empowered via a special committee under the minister of agriculture and food industries or the Menteri Besar of Johor.

#### 4.2.7.1 Establishing Lobster Floor Price

The key success factors in sustaining the lobster stock on the east coast of Johor are not to catch juvenile lobsters and not catch berried females. The catch prohibition will affect the incomes of fishermen, especially artisanal fishermen who rely on the lobster catch to sustain their living. On that note, the lobster floor price will play an important role in offsetting the fishermen and eventually protecting the stock. The lobster floor price shall take into the current market price and percentage of juvenile lobsters in the catches. A simple formula is recommended for the lobster floor price as follows:

**Recommended minimum pricing = (Percentage of juveniles * market price) + market price**

Establishing the lobster floor price formula should be easy to understand and transparent. This formula can serve as the basis for the consideration of the site management committee. The formulation shall be discussed and debated within the committee, eventually realizing it. The percentage of juvenile lobster in the catches will be based on the data collected from the fish landing port, restaurant, and wholesale market. More importantly, the formula is an interim measure. Upon establishing the no catch of juvenile and berried female policy, a new formula that shall reflect the market could replace the existing formula. Although there are representatives of the government agencies in the site management committee, the floor price discussion should be driven by the industrial players, i.e. restaurant operators, wholesalers, and fishermen. The fundamental driver for a higher market price lies in the global seafood market, particularly premium seafood.

### 4.2.8 Strategy 8: Research And Development In The Lobster Refugium

Continued research is vital for improving the performance and efficacy of the lobster refugium on the east coast of Johor. Research shall be properly planned with clear targets and objectives that fill the knowledge gaps of sustainable lobster fisheries. Three fundamental aspects of the lobster refugium needed knowledge inputs from the research activities.

1. **Biology of the mud spiny lobster in the coastal water of Johor.** Presently, there is limited knowledge of the population dynamic, migrating route, and sensitive area for spawning. The output of this research could provide a clear improvement in the protection measures, especially the closure of the lobster fishing season.
2. **Socio-economic research.** The ultimate end of the fisheries refugia is to ensure the sustainability of the fisheries industries, which improves the social economic status of the stakeholders, particularly the artisanal fishermen. In line with the objectives, socio-economic research is critical. The socio-economic research should focus on exploring new approaches to improve the stakeholders' well-being and, at the same time, identify gaps to be filled in the management plan.
3. **Business strategies and marketing research.** One of the key areas in the lobster refugium management plan is to increase and strengthen the presence of Malaysian seafood in the global market. Hence, research on business strategies and marketing research plays an important role in realizing this objective. In fact, a better-up value of the lobster fisheries will simultaneously overcome most obstacles in achieving sustainable fisheries in the country.

# 5.0 ASSESSMENT AND BENCHMARKS FOR THE LOBSTER REFUGIUM ON THE EAST COAST OF JOHOR

Continuous data collection on the lobster refugium, especially size, weight, and puerulus, is essential to provide feedback to improve the lobster refugium. These data are useful to understand further the biology, ecology, and population dynamics of the spiny mud lobster on the east coast of Johor. In fact, continuous data collection is the backbone of the data-driven management for the lobster refugium.

## 5.1 SIZE AND WEIGHT PROFILE OF *PANULIRUS POLYPHAGUS* ON THE EAST COAST OF JOHOR

Based on the literature, the male lobster matured at an average carapace length of 6.02 cm, while the female lobster matured at an average carapace length of 6.59 cm (Ikhwanuddin et al., 2014). On average, there is no obvious difference in the male and female lobster size. Normally, the catch ratio of male lobsters is higher in the trawler. The female lobsters are hiding in crevices, especially the berried female. The berried females were not feeding when they were eggs berried. The number of lobsters landing and their size and weight are important information that provides insight into the status of the lobster stock. More importantly, continuous sampling enables a better understanding of the refugium's seasonal variation of the lobster stock. Based on the lobster landing data, the phenomenon of catching down the size was clearly observed on the east coast of Johor, a clear sign of overfishing. In general, there are two types of overfishing; recruitment overfishing and Fisheries overfishing. Recruitment overfishing is due to catches of juveniles smaller than the size that can generate maximum stock in each recruitment. While the fisheries' overfishing is over-catching, which caused the depletion in the catch, it will be reflected in the declining landing, despite higher inputs of efforts. Both overfishing types may occur simultaneously, and one may be more critical than the other. In the case of lobster fisheries on the east coast of Johor, recruitment overfishing is a clear cause of concern in the lobster fisheries on the east coast of Johor. The clear way forward to resolve the issue is to prohibit juvenile lobster catches and not catching the berried females. In this management plan, it is recommended not to consume the juveniles and the berried females, thus providing a window for the juvenile lobsters to at least complete their biological tasks for one life cycle.

## 5.2 LOBSTER PUERULUS WATCH

The lobster larvae remained at the planktonic stage for up to two years. The sea current drifted the lobster larvae until they grew into the puerulus stage. At this stage, the puerulus is transparent and lives as a nekton. It

swims actively against the sea current towards the coastal area to look for suitable habitat, The puerulus eventually settles down and grows into its juvenile stage. The settlement of puerulus is an important stage in the lobster life cycle. Many countries, including Australia, New Zealand, A.S., Mexico, Japan, and India, have their monitoring program for the lobster puerulus. The puerulus data could contribute to identifying the sensitive habitats and provide insight for forecasting lobster landing four to five years ahead. On that note, a puerulus settlement index was developed based on the correlation between the puerulus data and the lobsters' landing pattern. The index was reported as useful in Australia and New Zealand (de Lestang & Rossbach, 2018; Foreman et al., 2019; Kolbusz et al., 2021).

Until now, there has been no study on the lobster puerulus reported on the east coast of Johor. In November 2020, there was a research attempt to monitor lobster phyllosoma in the coastal water of Johor. However, there are no phyllosoma samples collected from the survey. One factor that could likely improve the sampling of phyllosoma is employing a Bongo net for the survey. The Bongo net collects nekton samples that could swim actively to avoid other plankton nets. Figure 17 shows the photo of lobster puerulus at different stages.

*(Source: https://www.flickr.com/photos/myfwc/ Michelle Kerr/FWC)*

**Figure 17: Lobster puerulus at different stages**

The selection of useful indicators and benchmarks is critical to ensure the successful implementation of the lobster refugium. It provides feedback on the efficacy of the management plan, as well as its implementation. Indeed, the indicators and benchmarks are the key components of the refugium report. Inappropriate indicators and benchmarks may lead to the wastage of resources and time. Hence, the selection of indicators and benchmarks for the lobster refugia on the east coast of Johor must take into account the following criteria:

- Strong scientific basis
- Schedule monitoring in a systematic manner. The monitoring program has sufficient funding
- Relatively easy to conduct, a clear procedure to follow, including data analysis.
- Proper QAQC procedure and data verification to ensure reliability and integrity. Sufficient training for the person in charge.
- Maintain historical data for continuity, and assessment of temporal variation

Based on the above criteria, two programs are recommended as indicators and benchmarks for the lobster refugia on the east coast of Johor.

1. **Data collection at the fish landing jetties/ restaurant/wholesale market.** Lobsters landed at fish landing jetties/ restaurant/ wholesale markets will be sub-sampled to measure the carapace length and weight. The weight and carapace length of the lobster measured over time provides insight into the status of the stock. It is an important benchmark to be reported and published for public consumption. Besides, the data can be used to improve the refugium management plan. The procedures for measuring a lobster's carapace size and weight are attached in **Appendix 4**.

2. **Puerulus Watch.** The puerulus watch program complements carapace length and weight monitoring by forecasting lobster landing 4 to 5 years ahead. It is recommended that a monthly puerulus sampling program be initiated using a Puerulus trap. These traps can then be deployed at varied coastal locations (islands, mainland, estuaries, mangroves, coral reefs, and sea-grass beds) to find preferred settlement habitats. Others have found puerulus collection most efficient during the new moon and poor during the full moon, where lights attract them. Together with the puerulus, other commercially important post-larval and early juvenile fishes will also be collected, enabling new fields of study on their recruitment. The procedure for the puerulus watch program is attached as **Appendix 5**.

# 6.0 SUMMARY AND ACTION PLAN

Based on the literature and outputs from the technical workshop with fisheries officers for the lobster refugium on the east coast of Johor, the management plan for the lobster refugium is proposed as below:

**Vision:** *Sustaining lobster fisheries on the east coast of Johor*

**Mission:** Increase lobster stock on the east coast of Johor via fisheries refugium

**Delineation of refugium boundary.** The lobster refugium covers the maritime area off the east coast of Johor, including all critical habitats for the mud spiny lobster. Based on the studies conducted by DOFM, an area of 1,717 $km^2$, located southward of Pulau Aur, is identified as the sensitive area for the mud spiny lobster.

Eight key strategies were highlighted in the lobster refugium management plan to sustain the lobster fisheries in Johor:

- **Strategy 1**: conserving mud spiny lobster habitats through collaborative efforts of various government agencies.
- **Strategy 2**: Establishing artificial reefs for lobsters. One of the programs that could be capitalized on is the rigs-to-reefs program.
- **Strategy 3**: Prohibiting catches and export of juvenile lobster (carapace size < 6 cm) and berried female.
- **Strategy 4**: Closure of the lobster fishing season in the sensitive area from 15 December until the last day of February of the following years.
- **Strategy 5**: Lobster aquaculture research and development. Lobster aquaculture could reduce the harvesting pressure of the wild stock while creating job opportunities for the community.
- **Strategy 6:** Involving stakeholders in co-managing the refugium. The managing committee includes establishing a lobster floor price and monitoring the current status of the lobster stock. The lobster floor price is intended to compensate the fishermen for not catching juvenile lobster and berried females.
- **Strategy 7**: Modulating the lobster demand chain and sustaining the financial viability of the lobster refugium. A refugia trust fund will be established to aid in managing the fisheries refugia. Meanwhile, the Malaysian Seafood Council will be formed to aid in the transformation of Johor's lobster fisheries.
- **Strategy 8**: Research to improve management of the fisheries refugia. The research should focus on three key areas, the biology of the mud spiny lobster, the socio-economics of the fishing community, and market research for high-end seafood.

## 6.1 ACTION PLAN OF LOBSTER REFUGIUM ON THE EAST COAST OF JOHOR

Implementation of the lobster refugium uses a 'soft landing' approach. The soft-landing approach emphasizes public awareness of the importance of sustaining the lobster stock. The importance of sustainable fisheries should be made known to all stakeholders. The other important aspect is to increase the value chain of the lobster fisheries. The increased value chain will lead to higher and more stable incomes for the stakeholders. A social-economic well-being community is more ready to cooperate for sustainable fisheries. Enforcement and punishment will be the last resort to regulate repeat and unrepentant offenders. All stakeholders shall gain benefits in the fisheries refugia. In other words, no one loses in the implementation of fisheries refugia. Hence, all stakeholders in the fisheries refugia should embrace these fundamental principles, particularly the management team.

Unlike the *hard* approach, which emphasizes punishment and regulation, the soft-landing approach is always more time-consuming. The lobster refugium is anticipated to take more than five years to implement. The action plans can be planned short-term (within a year), mid-term (within three years), and long terms (within five years). Table 8 shows the Gantt chart for the lobster refugium action plan on the east coast of Johor.

**Table 8: Gantt chart for implementing the action plan of the lobster refugium on the east coast of Johor**

| No. | ACTION PLAN | EXPECTED OUTCOMES | SHORT-TERM 1 YEAR (2023 - 2024) | MID-TERM 3 YEAR (2023 – 2026) | LONG-TERM 5 YEAR (2023 – 2028) |
|---|---|---|---|---|---|
| **1.** | **Monitoring of size and weight of lobster in the refugium** | • Database of monthly lobster size and weight based on landing/ measured in restaurant and wholesale | Q1 2023 | | |
| 2. | **Puerulus watch program**<br><br>1. Training for DOFM officers<br>2. Establishing monitoring stations and instruments<br>3. Analysis and reporting | • Number of competent officers in conducting the puerulus watch<br>• Database of puerulus collected from various locations<br>• Analysis and reporting of lobster puerulus, which can be used to predict the future landing | Q1 2023<br><br>Q2 2023 | Q1 2025 | |
| **3.** | **Publicity and campaign on lobster refugia nationwide**<br><br>1. Collaboration with NGOs<br>2. Public awareness among stakeholders, including consumers, restaurant, wholesalers *<br>3. Awareness campaign via social media and website) *<br>4. Distribution of promotional materials to schools and institute of higher learning*.<br>***For each campaign, there must be a mechanism for the public to pledge their support** | • Cooperate with NGOs to promote sustainable fisheries<br>• Awareness campaigns focus on restaurant and wholesalers<br>• Posting and campaigns on social media i.e. Facebook, Instagram and Tik Tok<br>• Poster and brochure on the fisheries refugia for stakeholders | Q3 2023<br><br>Q3 2023<br><br>Start Q3 2023 | Q2 2025 | |

| | | | | | |
|---|---|---|---|---|---|
| **4.** | **Establish Site Management Committee to set lobster floor prices to compensate fishermen for not catching juveniles and berried females** | • Establish a pro tem committee to finalize terms of reference for the site management committee<br>• The wholesalers, LKIM, DOFM, fishermen, and restaurant operators determine lobster floor prices. Upon confirmation of the floor price, fishermen should stop supplying undersized lobsters and berried females.<br>• Site management committee plays an important role in the 'self-regulate' mechanism for sustainable lobster fisheries | Q2 2023<br>Q1 2024<br>Q1 2024 | Q1 2025 | |
| **5.** | **Closure of lobster fishing season in the sensitive area identified by researchers** | • Announcement of seasonal closure for lobster fishing in the sensitive area<br>• Monitoring and enforcement in the sensitive area to ensure proper implementation<br>• Gazette seasonal closure of lobster fishing in the sensitive area | Q3 2023<br>Q4 2023 | Q1 2024 | |
| **6.** | **Announce export prohibition for undersized lobsters and berried females.** | • Order to prohibit export of undersized and berried females; both live organisms and processed produce<br>• Monitoring and enforcement to ensure proper implementation of the prohibition order | Q3 2023<br>Q4 2023 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | • Gazette the order of export prohibition | | Q1 2024 | |
| **7.** | **Order of no catch of juvenile lobsters and berried females in the refugium** | • Announce no catch of juvenile lobsters and berried females<br>• Monitoring at fish landing jetty and spot check on fishing vessels<br>• Gazette order to prohibit catch of juvenile lobsters and berried females | | | Q1 2028<br>Q2 2028<br>Q4 2028 |
| **8.** | **Research to improve the fisheries refugia**<br>1. Biological: population dynamic, migration pattern, and sensitive area<br>2. Socio-economic research aims to improve the socio-economical status of the stakeholders<br>3. Marketing research to promote Malaysian seafood to penetrate the global market | • Scientific publications | Q1 2024 | | |
| **9.** | **Research and development on lobster aquaculture (Not limited to the mud spiny lobster)**<br><br>**Viability studies of lobster aquaculture in Malaysia** | • Publish guides and technical papers of lobster aquaculture<br><br>• Publish technical papers | Q1 2024 | | Q4 2027 |
| **10.** | **Develop artificial reefs to create habitats for lobster** | • Deployment of aritificial reefs for lobsters<br>• New design of artificial reefs | | Q1 2026<br>Q1 2026 | |

| | | | | | |
|---|---|---|---|---|---|
| **11.** | **Establish endowment and trust fund for fisheries refugia**<br><br>**Establish Malaysian Seafood Council** | • Establish a trust fund and secure allocation for the fisheries refugia<br><br>• Establish the Malaysian Seafood Council and finalize the business model for the MSC. | | Q1 2025<br><br>Q4 2028 | |
| **12.** | **Assessing the performance of the lobster refugium**<br>• **Size and weight of lobster at landing port/ restaurant/ wholesale**<br>• **Puerulus watch** | • Annual report of the lobster refugium | Q4 2024 | Q4 2026 | Q4 2028 |

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# 8.0 GLOSSARY

**NSC (Norwegian Seafood Council):** The Norwegian Seafood Council is a public company owned by the Ministry of Trade, Industry and Fisheries, and is financed through fees levied on all exports of Norwegian seafood. The Norwegian Seafood Council is a marketing communications organisation working together with the Norwegian seafood industry to increase the value of Norwegian seafood in new and established markets all over the world.

***Stakeholder*:** Kumpulan ataupun individu yang mana hak dan kepentingan mereka/ individu akan terjejas hasil daripada implementasi peraturan ataupun sesebuah polisi.

**Operational Taxonomy Unit (OTU): K**luster organisma yang berkait rapat. Lazimnya OTU boleh dirujuk sebagai spesies, genus mahupun kelas organisma yang sama.

**SWOT analysis:** SWOT analysis is a technique developed at Stanford in the 1970s, frequently used in strategic planning. SWOT is an acronym for Strengths, Weaknesses, Opportunities, and Threats and is a structured planning method that evaluates those four elements of an organization, project or business venture.

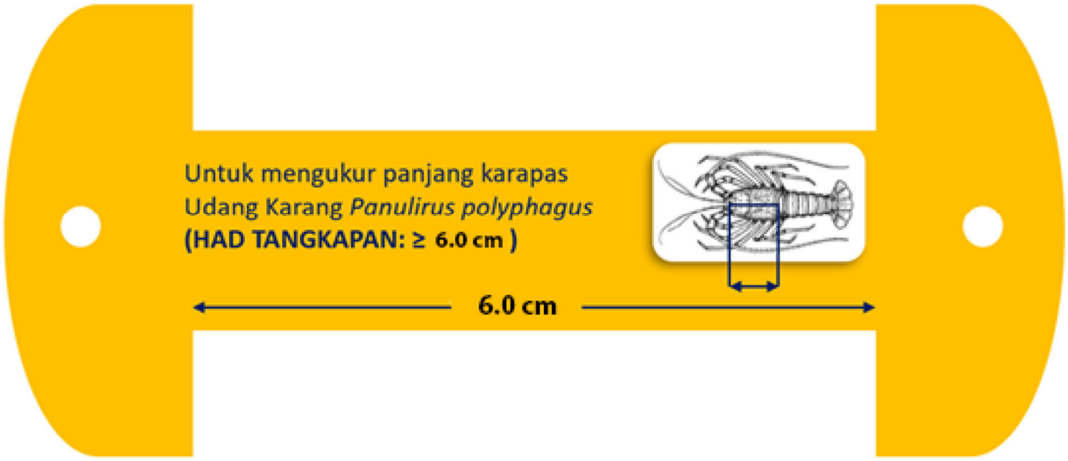
**ASEAN:** The Association of Southeast Asian Nations, or ASEAN, was established on 8 August 1967 in Bangkok, Thailand, with the signing of the ASEAN Declaration (Bangkok Declaration) by the Founding Fathers of ASEAN: Indonesia, Malaysia, Philippines, Singapore and Thailand. Brunei Darussalam joined ASEAN on 7 January 1984, followed by Viet Nam on 28 July 1995, Lao PDR and Myanmar on 23 July 1997, and Cambodia on 30 April 1999, making up what is today the ten Member States of ASEAN.

**RTR (Rigs-to-reefs)**: A program to reuse end of life span offshore from the oil and gas industry as artificial reefs

**Marine Stewardship Council (MSC):** The Marine Stewardship Council is an international non-profit organisation. We recognise and reward efforts to protect oceans and safeguard seafood supplies for the future.

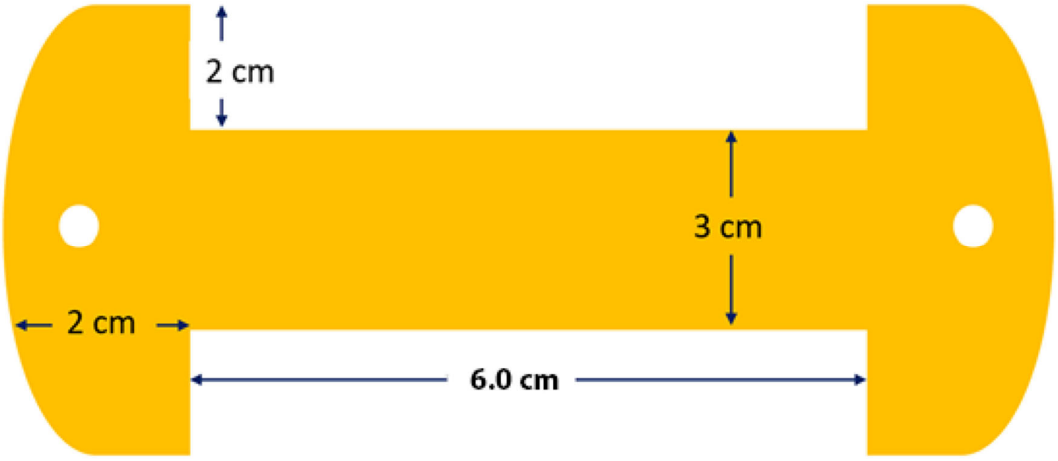
## Appendix 1: Caliper Design for Spiny Lobster Carapace Size Measurement

**Front view:**



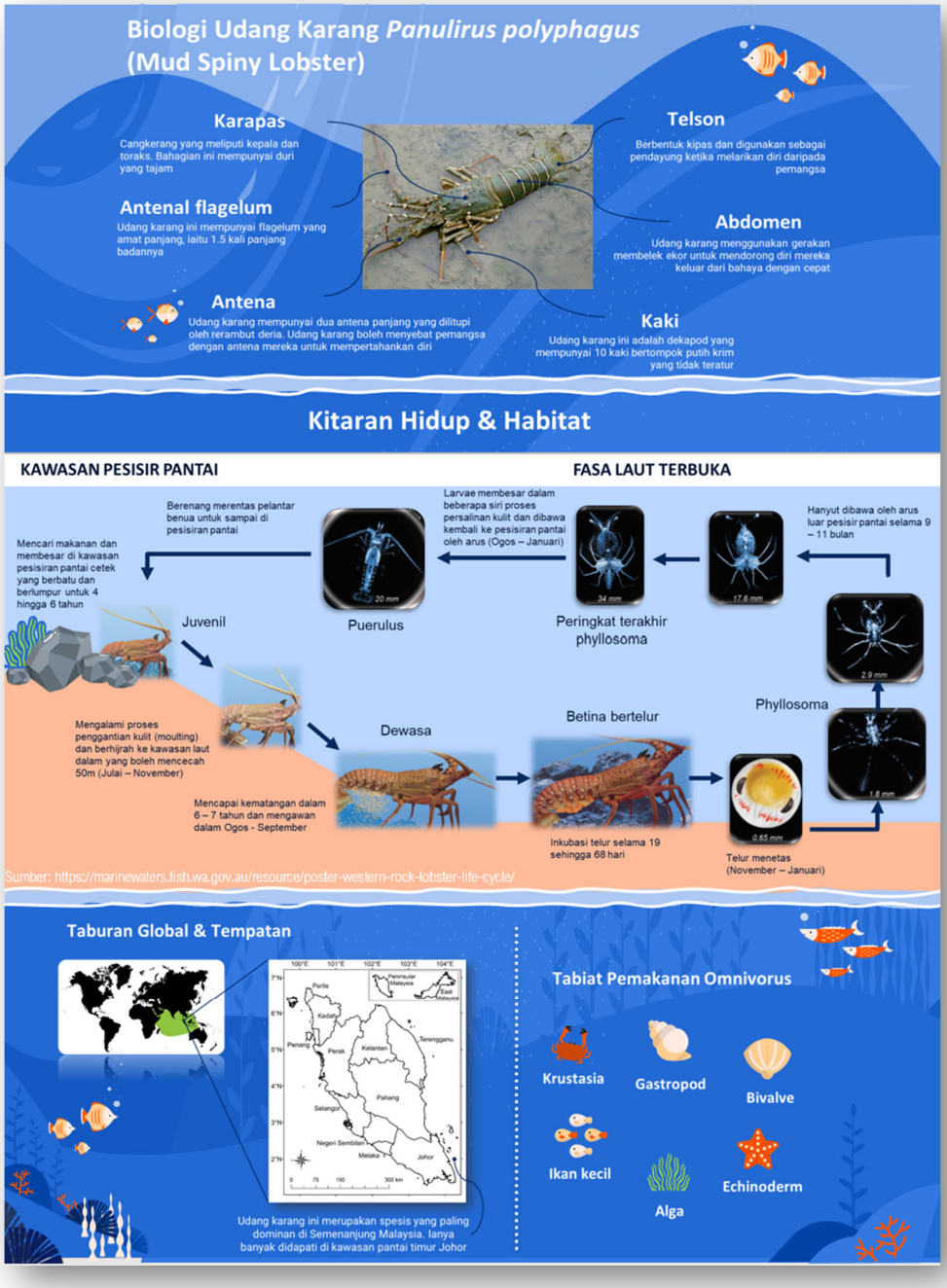

**Back view:**

**Actual size:**



## Appendix 2: Samples of Infographics

### *Lobster Biology*



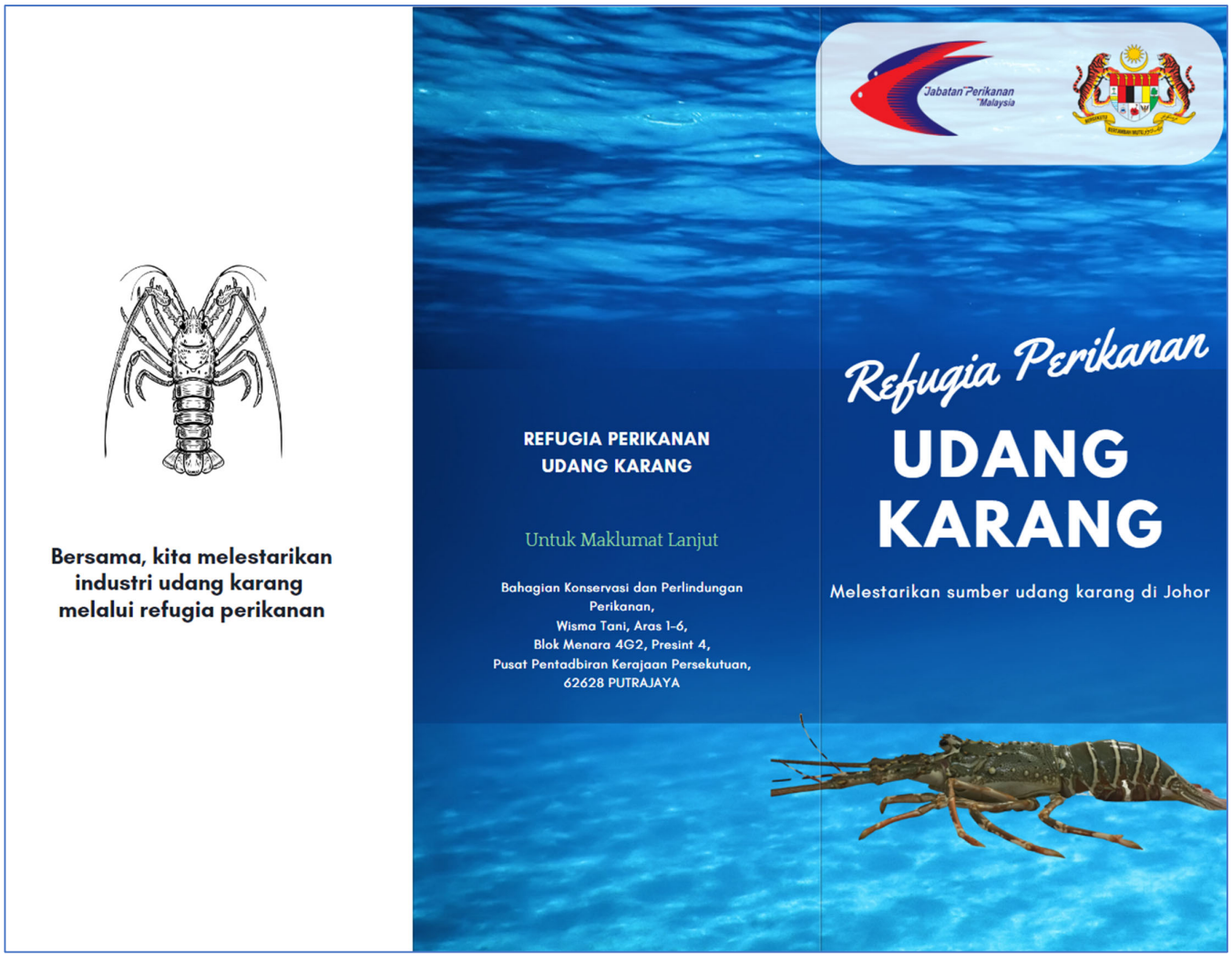
*Lobster Fishery*


Nota: Imej dan grafik yang digunakan adalah diperoleh daripada internet

*Concept of Lobster Fishery Refugia*


Nota: Imej dan grafik yang digunakan adalah diperoleh daripada internet

*Brochure for Lobster Refugium (Front)*



*Brochure for Lobster Refugium (Back)*

## Refugia Perikanan

Penubuhan Refugia Perikanan merupakan salah satu pendekatan baharu yang dibuat oleh Jabatan Perikanan Malaysia untuk mengurus sumber udang karang negara kita secara lestari. Tanpa pengurusan yang lestari, industri udang karang yang ada sekarang akan mengalami kemerosotan dan akan berakhir dengan keruntuhan pada masa akan datang, seperti mana yang pernah berlaku di negara-negara lain.

Penubuhan Refugia Perikanan tidak akan menyekat sebarang aktiviti menangkap sumber perikanan lain, seperti ikan, ketam, udang laut dan lain-lain hidupan marin yang sedang dijalankan sekarang. Sehubungan itu tidak ada peralatan perikanan yang akan diharamkan dan tidak ada zon larangan tangkapan baharu akan diwujudkan.

*"Ayuh rakan-rakan! lepaskan balik anak udang karang dan induk yang membawa telur. Kalau bukan anda yang melakukannya, harapkan siapa lagi?"*

**Nelayan yang menjalankan aktiviti perikanan di dalam kawasan Refugia Perikanan cuma dipohon agar:**

**MELEPAS BALIK UDANG KARANG PERINGKAT JUVENIL**

- Melepaskan balik udang karang yang m asih di peringkat juvenil (panjang karapas < 6cm) untuk memberi peluang mereka membiak kerana pada saiz ini mereka belum pernah bertelur,

**MELEPAS BALIK UDANG KARANG BETINA YANG MEMBAWA TELUR**

- Melepaskan balik jika tertangkap induk betina yang membawa telur di tempat mereka tertangkap,

**TIDAK MENANGKAP UDANG KARANG DI KAWASAN SENSITIF SEMASA MUSIM PENUTUPAN**

- Tidak menjalankan aktiviti menangkap udang karang di dalam kawasan sensitif Refugia Perikanan semasa musim penutupan.

## Appendix 3: Examples of communication/educational materials produced by other countries

*Appendix A*

### What You Need to Know to "Stay Legal"

**Basic Sport Fishing Regulations for Spiny Lobster**

A **California sport fishing license** with ocean enhancement stamp is required to take lobster south of Point Arguello. Divers must keep their fishing license either aboard the vessel or, if beach diving, with their gear within 500 yards from shore.

A **Spiny Lobster Report Card** is required for every person fishing for or taking spiny lobster. This includes persons who are not required to have a sport fishing license, such as children under the age of 16, persons fishing from a public pier, and persons fishing on free fishing days. Report cards must be carried by hoop netters, and divers must keep it with their fishing license. Prior to fishing, record the month, day, location, and gear code on the first available line of the card. When you are done fishing at that location, when you switch gear, or when you are done fishing for the day, record the number of lobster kept, then move to the next available line on the card. Report cards are valid for the entire season. If a lobster fisherman fills up a card before the season ends, the card can be returned and a new one purchased. The Spiny Lobster Report Card must be returned to the California Department of Fish and Wildlife (CDFW) no later than April 30 following the end of the season.

The **spiny lobster open season** runs from 6 a.m. on the Saturday preceding the first Wednesday in October through the first Wednesday after March 15 (the first Wednesday in October is when commercial season opens).

No **implements** other than hoop nets may be used to take lobster. Divers may only use their bare or gloved hands to take lobster. **Spear fishing equipment** may be possessed by divers taking lobster, but spearfishing equipment may not be used to aid in taking lobster.

Both lobster divers and hoop netters must carry a **lobster gauge** when attempting to take lobster. The gauge is a metal or plastic measuring device that has a fixed gap of 3¼ inches for determining the legal size of the lobster. Lobster gauges can be purchased at most dive and tackle shops. Divers may bring lobster to the surface of the water for the purpose of measuring. Hoop netters may bring lobster aboard a vessel but are required to measure them immediately upon retrieving the net, and any undersized lobster must be released immediately. No undersized lobster may be retained or placed in any type of receiver.



*A legal-sized lobster carapace is as large or larger than the fixed gap of the measuring gauge.*

The **lobster daily bag and possession limit is seven (7) lobsters.** This includes any lobster stored at home or elsewhere; at no time may more than seven lobsters be in anyone's possession.

A maximum of **five (5) hoop nets** may be fished by an individual, except on piers, jetties, and other shore-based structures where each angler is limited to **two (2) hoop nets**. No more than **10 hoop nets** may be fished on a vessel, regardless of how many licensed anglers are aboard. **Hoop net buoys** south of Point Arguello (Santa Barbara County) must be marked with the operator(s) GO ID number(s). Hoop nets deployed from shore/pier do not need to be marked with a surface buoy.

It is illegal to **disturb or rob** commercial lobster traps.

#### Why all the regulations?

The CDFW's mission is to manage all of California's wildlife and the habitats they depend on, so that everyone can enjoy and use these resources for years to come. The minimum size limit allows each lobster to reproduce at least once before it is captured. The closed season protects lobster that are carrying eggs or molting. Gear restrictions help to prevent injury or death before the animal can be legally harvested. Bag limits prevent too many lobster from being taken. With report card and other information, biologists can determine whether the lobster resource is healthy and if current fishing regulations are working correctly.

### How to Measure Lobster




To determine whether the lobster you've just caught is large enough to keep, you must measure the length of the body shell, or *carapace*, along the mid-line from the rear edge of the eye socket (between the horns) to the rear edge of the carapace with a lobster gauge (*see diagram above*). This straight-line measurement should be a minimum of 3¼ inches. The carapace of a legal-sized lobster is larger than or equal to the gauge's cutout. If the lobster is too small, it should immediately be released back into the water. Undersized lobster should never be retained by divers or hoop netters or placed in any type of receiver.

Current spiny lobster sport fishing regulations can be found in the Saltwater Sport Fishing regulation booklet, available at most sporting goods stores and wherever fishing licenses are sold, or on the CDFW website at:

**www.wildlife.ca.gov/regulations**

Do you have questions about California spiny lobster or lobster fishing? Contact your local CDFW office or visit the following online resource:

**www.wildlife.ca.gov/Conservation/Marine/Invertebrates/Lobster**

**Help Fish and Game Wardens Put an End to Poaching**

If you witness poaching or polluting, call

**1-888-DFG-CALTIP**

**(1-888-334-2258)**

*Alternate communication formats of this document are available upon request. If reasonable accommodation is needed, call CDFW at (916) 322-8911. The California Relay Service for the deaf or hearing-impaired can be utilized from TDD phones at (800) 735-2929.*

*CDFW_Marine Region_lobster-Ver2_09.18*

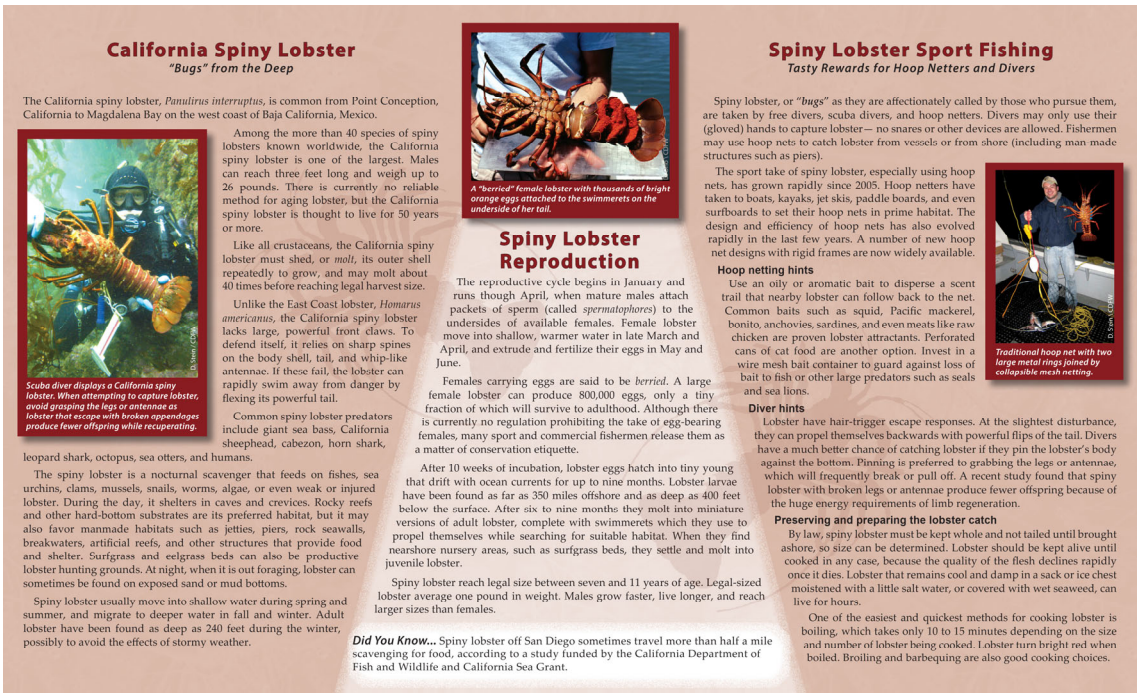
### CALIFORNIA SPINY LOBSTER

*fishing and life history information*



CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Sea Grant California



### California Spiny Lobster

*"Bugs" from the Deep*

The California spiny lobster, *Panulirus interruptus*, is common from Point Conception, California to Magdalena Bay on the west coast of Baja California, Mexico.



*Scuba diver displays a California spiny lobster. When attempting to capture lobster, avoid grasping the legs or antennae as lobster that escape with broken appendages produce fewer offspring while recuperating.*

Among the more than 40 species of spiny lobsters known worldwide, the California spiny lobster is one of the largest. Males can reach three feet long and weigh up to 26 pounds. There is currently no reliable method for aging lobster, but the California spiny lobster is thought to live for 50 years or more.

Like all crustaceans, the California spiny lobster must shed, or *molt*, its outer shell repeatedly to grow, and may molt about 40 times before reaching legal harvest size.

Unlike the East Coast lobster, *Homarus americanus*, the California spiny lobster lacks large, powerful front claws. To defend itself, it relies on sharp spines on the body shell, tail, and whip-like antennae. If these fail, the lobster can rapidly swim away from danger by flexing its powerful tail.

Common spiny lobster predators include giant sea bass, California sheephead, cabezon, horn shark, leopard shark, octopus, sea otters, and humans.

The spiny lobster is a nocturnal scavenger that feeds on fishes, sea urchins, clams, mussels, snails, worms, algae, or even weak or injured lobster. During the day, it shelters in caves and crevices. Rocky reefs and other hard-bottom substrates are its preferred habitat, but it may also favor manmade habitats such as jetties, piers, rock seawalls, breakwaters, artificial reefs, and other structures that provide food and shelter. Surfgrass and eelgrass beds can also be productive lobster hunting grounds. At night, when it is out foraging, lobster can sometimes be found on exposed sand or mud bottoms.

Spiny lobster usually move into shallow water during spring and summer, and migrate to deeper water in fall and winter. Adult lobster have been found as deep as 240 feet during the winter, possibly to avoid the effects of stormy weather.



*A "berried" female lobster with thousands of bright orange eggs attached to the swimmerets on the underside of her tail.*

### Spiny Lobster Reproduction

The reproductive cycle begins in January and runs though April, when mature males attach packets of sperm (called *spermatophores*) to the undersides of available females. Female lobster move into shallow, warmer water in late March and April, and extrude and fertilize their eggs in May and June.

Females carrying eggs are said to be *berried*. A large female lobster can produce 800,000 eggs, only a tiny fraction of which will survive to adulthood. Although there is currently no regulation prohibiting the take of egg-bearing females, many sport and commercial fishermen release them as a matter of conservation etiquette.

After 10 weeks of incubation, lobster eggs hatch into tiny young that drift with ocean currents for up to nine months. Lobster larvae have been found as far as 350 miles offshore and as deep as 400 feet below the surface. After six to nine months they molt into miniature versions of adult lobster, complete with swimmerets which they use to propel themselves while searching for suitable habitat. When they find nearshore nursery areas, such as surfgrass beds, they settle and molt into juvenile lobster.

Spiny lobster reach legal size between seven and 11 years of age. Legal-sized lobster average one pound in weight. Males grow faster, live longer, and reach larger sizes than females.

***Did You Know...*** Spiny lobster off San Diego sometimes travel more than half a mile scavenging for food, according to a study funded by the California Department of Fish and Wildlife and California Sea Grant.

### Spiny Lobster Sport Fishing

*Tasty Rewards for Hoop Netters and Divers*

Spiny lobster, or "*bugs*" as they are affectionately called by those who pursue them, are taken by free divers, scuba divers, and hoop netters. Divers may only use their (gloved) hands to capture lobster— no snares or other devices are allowed. Fishermen may use hoop nets to catch lobster from vessels or from shore (including man made structures such as piers).

The sport take of spiny lobster, especially using hoop nets, has grown rapidly since 2005. Hoop netters have taken to boats, kayaks, jet skis, paddle boards, and even surfboards to set their hoop nets in prime habitat. The design and efficiency of hoop nets has also evolved rapidly in the last few years. A number of new hoop net designs with rigid frames are now widely available.



*Traditional hoop net with two large metal rings joined by collapsible mesh netting.*

#### Hoop netting hints

Use an oily or aromatic bait to disperse a scent trail that nearby lobster can follow back to the net. Common baits such as squid, Pacific mackerel, bonito, anchovies, sardines, and even meats like raw chicken are proven lobster attractants. Perforated cans of cat food are another option. Invest in a wire mesh bait container to guard against loss of bait to fish or other large predators such as seals and sea lions.

#### Diver hints

Lobster have hair-trigger escape responses. At the slightest disturbance, they can propel themselves backwards with powerful flips of the tail. Divers have a much better chance of catching lobster if they pin the lobster's body against the bottom. Pinning is preferred to grabbing the legs or antennae, which will frequently break or pull off. A recent study found that spiny lobster with broken legs or antennae produce fewer offspring because of the huge energy requirements of limb regeneration.

#### Preserving and preparing the lobster catch

By law, spiny lobster must be kept whole and not tailed until brought ashore, so size can be determined. Lobster should be kept alive until cooked in any case, because the quality of the flesh declines rapidly once it dies. Lobster that remains cool and damp in a sack or ice chest moistened with a little salt water, or covered with wet seaweed, can live for hours.

One of the easiest and quickest methods for cooking lobster is boiling, which takes only 10 to 15 minutes depending on the size and number of lobster being cooked. Lobster turn bright red when boiled. Broiling and barbequing are also good cooking choices.

## *Appendix B*

ENVIRONMENTAL SCIENCE JOURNAL FOR TEENS
MAY 2021

# How can protecting lobsters be good for fishermen?

**Authors:**
Hunter S. Lenihan and others
**Associate Editors:**
Liesa Ziegler and Lindsay Martin

## Abstract

Millions of animals, plants, and other organisms live in the ocean. Humans rely on marine *ecosystems* for seafood and other resources. Fishing is important, but if fishermen are not careful, they can overfish and damage the ocean habitats with their fishing gear. So, many people are working to protect the ocean.

However, sometimes people living closest to the ocean worry that protecting it might harm their jobs. Fishermen depend on the ocean's resources. If they are not allowed to continue fishing, they will lose their jobs and cannot provide fish for people to eat.

Our study shows this worry is not necessarily true. Protecting the marine environment can actually benefit fishermen, and therefore all of us.

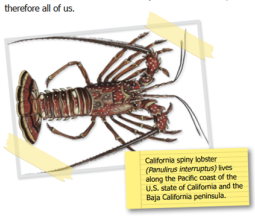
## Introduction

One way to protect the ocean is to establish *Marine Protected Areas (MPAs)*. In these areas fishing may be forbidden, allowing the animals there to flourish without human interference. MPAs are specifically created to enhance *biodiversity*.

But of course, establishing MPAs is easier said than done. Many people earn their income by fishing, and we all rely on fish to eat. Many worry that reducing the area where fishing is allowed could cost *fishers* (fishermen and women) their only income. *Fishery* managers must take that into account when deciding which areas should be protected.

But is this fear justified? Following the results of other studies, we thought that establishing MPAs could benefit fishermen in the area.

After all, if animals could reproduce without simultaneously being targeted for fishing, their population would increase. At some point, too many individuals will be living in the same area and would compete for food and places to hide from their predators. So some fish would leave the MPA and wander into adjacent fisheries to look for food and hiding places. We call this *spillover*. This means that fishermen would find more catch around the MPA than in other areas.



California spiny lobster (*Panulirus interruptus*) lives along the Pacific coast of the U.S. state of California and the Baja California peninsula.

We designed an experiment to test this theory in the California spiny lobster fishery. We wanted to see if protecting lobsters in certain zones would let them reproduce enough to positively affect the fishermen's catch in the surrounding areas. Then, we compared the *biomass* of lobsters, lobster *landings*, and other measurements.





## Methods

The fishery managers split the fishery into four blocks and established two MPAs in one of them. Therefore, in one of the blocks, the fishing area was reduced by 35%. The three adjacent blocks were open for fishing as usual.

We gathered two types of data:

1. Fishermen's landing reports to the fishery. These include the number of lobsters they caught, how much they weighed, the number of traps they have pulled, and which block they were fishing in (Figure 1). These data were collected 6 years before and 6 years after the MPAs were established.
2. Scuba diver's reports. Once a year from 2012 (the beginning of the MPA) to 2018, we sent scuba divers into the four blocks right before the start of the fishing season. They used handheld lights to search the reef habitat for lobsters, count them, and estimate their size.

Then we compared data from the blocks with and without the MPAs. We wanted to see where the greatest catches occurred and if this changed over the years.

**Figure 1:** Fishermen use small boats to deploy lobster traps (wired boxes with bait inside). They are set on the bottom of shallow reef habitats where lobsters live.

## Results

We found that the catch of lobster in the fishermen's reports increased in all fishing blocks during the period after the MPAs were established compared to beforehand (Figure 2). The increase in the catch in the block with MPAs was three times higher than in the other blocks.

Exactly the same was true for lobster density counted by the scuba divers: it generally increased in all the blocks. The increase was three times higher in the block with the MPAs.

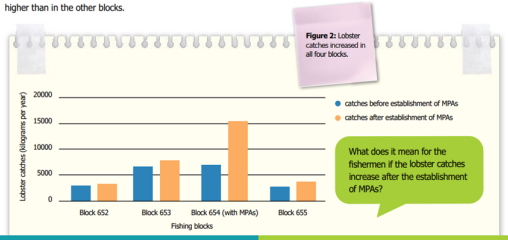



**Figure 2:** Lobster catches increased in all four blocks.





## Discussion

Our data showed that reducing the fishable area actually resulted in more lobsters being available for fishing. How? The answer is spillover! The best explanation for these results is that lobster abundance increased in the reserves where they were not fished for 6 years. Then lobsters spilled out of the MPAs to find food and hiding places. This allowed fishermen to make a greater catch.

MPAs in fisheries allow us to hit two birds with one stone. They can protect marine ecosystems and increase fishermen's landings.

This shows that MPAs do not necessarily harm fishermen, even though they lose fishable areas. Instead, they can make up the lost catch by harvesting the spillover.

Of course, we tested our theory only in one specific area, and we cannot say for sure that exactly the same will happen in other places. However, other scientific studies have also revealed that spillover enhances fisheries. Most likely, the size of the effect depends on how heavily the area was fished before the establishment of MPAs. How much of the area is closed for fishing is also important.

It is also possible that other reasons, not just the lack of fishing, led to the lobster spillover. It could be that right outside the MPAs there are reefs with better habitats, causing more lobsters to leave the protected area. Therefore, exactly how MPAs are designed is very important for fishing and conservation purposes.

Still, it is clear that the introduction of no-fishing zones into this fishery was a win-win situation for both lobsters and fishermen.

## Conclusion

People sometimes worry that protecting our environment will mean an economic loss for humans. But this does not always have to be true. In some cases, it is exactly the opposite.

You could say that to protect marine life you should stop eating fish (even if you like the taste). This may be a good idea until you start thinking about the fishermen who may lose their jobs. So let's take the smarter route and find solutions that work for everyone: humans, plants, animals, and especially lobsters!

### Glossary of Key Terms

**Biodiversity** – how many different species (bacteria, animals, plants, etc.) live in one specific area. High biodiversity means that lots of different species share this habitat.

**Biomass** – the summed mass of all lobsters that were observed in a specific area.

**Ecosystem** – a complex biological network of all life forms living in it (ranging from things as little as viruses or bacteria up to plants and animals) that somehow interact with each other.

**Fishers** - a collective noun in place of "fishermen" reflecting that both men and women fish.

**Fishery** – a place where fish are raised and harvested for commercial purposes.

**Lobster landings** – the number and/or weight of all caught lobsters.

**Marine protected area (MPA)** - parts of the ocean established to protect marine natural environments, natural resources, and plant and animal life. There are different kinds of marine protected areas. In some MPAs, fishing is forbidden. In others, there may be a research facility that helps us to understand certain natural events or processes.

**Spillover** – If a lot of individuals of one species live in the same area (for example, because they were protected in that location) it might get too crowded for them. To find enough shelter and food, some individuals move from inside the MPA to the surrounding area.

**Acknowledgment:**
This article's adaptation was supported by the Goggio Family Foundation.





## Check your understanding

1. In the block with the two MPAs, how much was the reduction in the size of the fishable area?
2. What is a spillover and what are the possible causes?
3. How are lobsters caught?
4. Why is it sometimes hard to establish an MPA?
5. Can you find out where MPAs along the Californian coast already exist?

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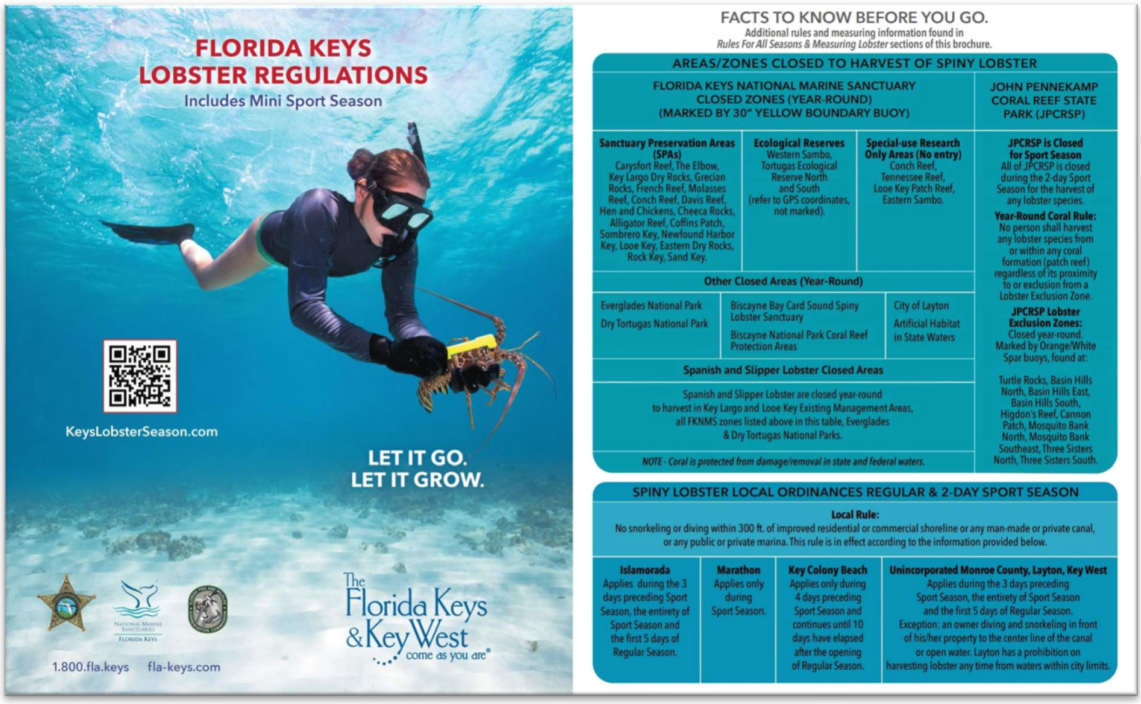
https://doi.org/10.1038/s41598-021-82371-5

Natural World Facts: The Deep-Sea Hub
https://www.naturalworldfacts.com/deep-sea-hub

California Marine Protected Areas
https://californiampas.org/explore/fun-activities

National Geographic: Marine Protected Area
https://www.nationalgeographic.org/encyclopedia/marine-protected-area/

## *Appendix C*



# FLORIDA KEYS LOBSTER REGULATIONS

Includes Mini Sport Season

KeysLobsterSeason.com

LET IT GO.
LET IT GROW.

1.800.fla.keys fla-keys.com

The Florida Keys & Key West come as you are

## FACTS TO KNOW BEFORE YOU GO.

Additional rules and measuring information found in *Rules For All Seasons & Measuring Lobster* sections of this brochure.

### AREAS/ZONES CLOSED TO HARVEST OF SPINY LOBSTER

**FLORIDA KEYS NATIONAL MARINE SANCTUARY CLOSED ZONES (YEAR-ROUND) (MARKED BY 30" YELLOW BOUNDARY BUOY)**

**Sanctuary Preservation Areas (SPAs)**
Carysfort Reef, The Elbow, Key Largo Dry Rocks, Grecian Rocks, French Reef, Molasses Reef, Conch Reef, Davis Reef, Hen and Chickens, Cheeca Rocks, Alligator Reef, Coffins Patch, Sombrero Key, Newfound Harbor Key, Looe Key, Eastern Dry Rocks, Rock Key, Sand Key.

**Ecological Reserves**
Western Sambo, Tortugas Ecological Reserve North and South (refer to GPS coordinates, not marked).

**Special-use Research Only Areas (No entry)**
Conch Reef, Tennessee Reef, Looe Key Patch Reef, Eastern Sambo.

**Other Closed Areas (Year-Round)**

Everglades National Park
Dry Tortugas National Park

Biscayne Bay Card Sound Spiny Lobster Sanctuary
Biscayne National Park Coral Reef Protection Areas

City of Layton
Artificial Habitat in State Waters

**Spanish and Slipper Lobster Closed Areas**

Spanish and Slipper Lobster are closed year-round to harvest in Key Largo and Looe Key Existing Management Areas, all FKNMS zones listed above in this table, Everglades & Dry Tortugas National Parks.

*NOTE - Coral is protected from damage/removal in state and federal waters.*

**JOHN PENNEKAMP CORAL REEF STATE PARK (JPCRSP)**

**JPCRSP is Closed for Sport Season**
All of JPCRSP is closed during the 2-day Sport Season for the harvest of any lobster species.

**Year-Round Coral Rule:**
No person shall harvest any lobster species from or within any coral formation (patch reef) regardless of its proximity to or exclusion from a Lobster Exclusion Zone.

**JPCRSP Lobster Exclusion Zones:**
Closed year-round. Marked by Orange/White Spar buoys, found at:

Turtle Rocks, Basin Hills North, Basin Hills East, Basin Hills South, Higdon's Reef, Cannon Patch, Mosquito Bank North, Mosquito Bank Southeast, Three Sisters North, Three Sisters South.

### SPINY LOBSTER LOCAL ORDINANCES REGULAR & 2-DAY SPORT SEASON

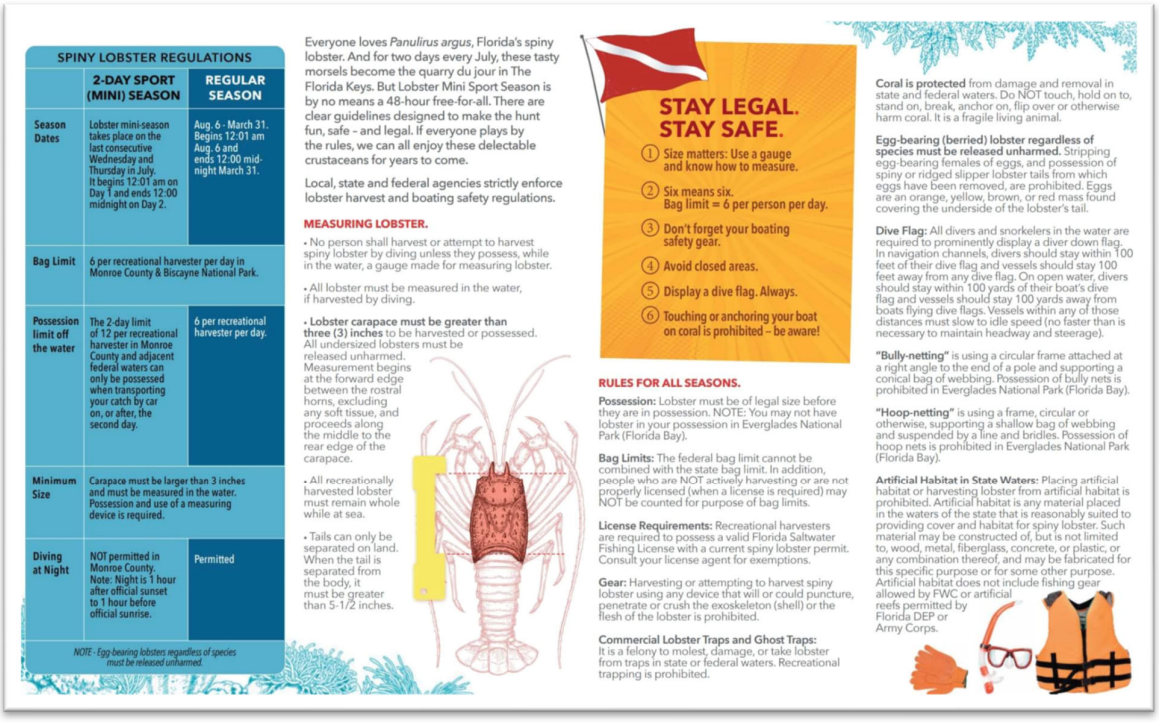
**Local Rule:**
No snorkeling or diving within 300 ft. of improved residential or commercial shoreline or any man-made or private canal, or any public or private marina. This rule is in effect according to the information provided below.

**Islamorada**
Applies during the 3 days preceding Sport Season, the entirety of Sport Season and the first 5 days of Regular Season.

**Marathon**
Applies only during Sport Season.

**Key Colony Beach**
Applies only during 4 days preceding Sport Season and continues until 10 days have elapsed after the opening of Regular Season.

**Unincorporated Monroe County, Layton, Key West**
Applies during the 3 days preceding Sport Season, the entirety of Sport Season and the first 5 days of Regular Season.
Exception: an owner diving and snorkeling in front of his/her property to the center line of the canal or open water. Layton has a prohibition on harvesting lobster any time from waters within city limits.



## SPINY LOBSTER REGULATIONS

| | 2-DAY SPORT (MINI) SEASON | REGULAR SEASON |
|---|---|---|
| Season Dates | Lobster mini-season takes place on the last consecutive Wednesday and Thursday in July. It begins 12:01 am on Day 1 and ends 12:00 midnight on Day 2. | Aug. 6 - March 31. Begins 12:01 am Aug. 6 and ends 12:00 mid-night March 31. |
| Bag Limit | 6 per recreational harvester per day in Monroe County & Biscayne National Park. | |
| Possession limit off the water | The 2-day limit of 12 per recreational harvester in Monroe County and adjacent federal waters can only be possessed when transporting your catch by car on, or after, the second day. | 6 per recreational harvester per day. |
| Minimum Size | Carapace must be larger than 3 inches and must be measured in the water. Possession and use of a measuring device is required. | |
| Diving at Night | NOT permitted in Monroe County. Note: Night is 1 hour after official sunset to 1 hour before official sunrise. | Permitted |

*NOTE - Egg-bearing lobsters regardless of species must be released unharmed.*

Everyone loves *Panulirus argus*, Florida's spiny lobster. And for two days every July, these tasty morsels become the quarry du jour in The Florida Keys. But Lobster Mini Sport Season is by no means a 48-hour free-for-all. There are clear guidelines designed to make the hunt fun, safe – and legal. If everyone plays by the rules, we can all enjoy these delectable crustaceans for years to come.

Local, state and federal agencies strictly enforce lobster harvest and boating safety regulations.

### MEASURING LOBSTER.

- No person shall harvest or attempt to harvest spiny lobster by diving unless they possess, while in the water, a gauge made for measuring lobster.
- All lobster must be measured in the water, if harvested by diving.
- **Lobster carapace must be greater than three (3) inches** to be harvested or possessed. All undersized lobsters must be released unharmed. Measurement begins at the forward edge between the rostral horns, excluding any soft tissue, and proceeds along the middle to the rear edge of the carapace.
- All recreationally harvested lobster must remain whole while at sea.
- Tails can only be separated on land. When the tail is separated from the body, it must be greater than 5-1/2 inches.



## STAY LEGAL. STAY SAFE.

1. Size matters: Use a gauge and know how to measure.
2. Six means six. Bag limit = 6 per person per day.
3. Don't forget your boating safety gear.
4. Avoid closed areas.
5. Display a dive flag. Always.
6. Touching or anchoring your boat on coral is prohibited – be aware!

### RULES FOR ALL SEASONS.

**Possession:** Lobster must be of legal size before they are in possession. NOTE: You may not have lobster in your possession in Everglades National Park (Florida Bay).

**Bag Limits:** The federal bag limit cannot be combined with the state bag limit. In addition, people who are NOT actively harvesting or are not properly licensed (when a license is required) may NOT be counted for purpose of bag limits.

**License Requirements:** Recreational harvesters are required to possess a valid Florida Saltwater Fishing License with a current spiny lobster permit. Consult your license agent for exemptions.

**Gear:** Harvesting or attempting to harvest spiny lobster using any device that will or could puncture, penetrate or crush the exoskeleton (shell) or the flesh of the lobster is prohibited.

**Commercial Lobster Traps and Ghost Traps:** It is a felony to molest, damage, or take lobster from traps in state or federal waters. Recreational trapping is prohibited.

**Coral is protected** from damage and removal in state and federal waters. Do NOT touch, hold on to, stand on, break, anchor on, flip over or otherwise harm coral. It is a fragile living animal.

**Egg-bearing (berried) lobster regardless of species must be released unharmed.** Stripping egg-bearing females of eggs, and possession of spiny or ridged slipper lobster tails from which eggs have been removed, are prohibited. Eggs are an orange, yellow, brown, or red mass found covering the underside of the lobster's tail.

**Dive Flag:** All divers and snorkelers in the water are required to prominently display a diver down flag. In navigation channels, divers should stay within 100 feet of their dive flag and vessels should stay 100 feet away from any dive flag. On open water, divers should stay within 100 yards of their boat's dive flag and vessels should stay 100 yards away from boats flying dive flags. Vessels within any of those distances must slow to idle speed (no faster than is necessary to maintain headway and steerage).

**"Bully-netting"** is using a circular frame attached at a right angle to the end of a pole and supporting a conical bag of webbing. Possession of bully nets is prohibited in Everglades National Park (Florida Bay).

**"Hoop-netting"** is using a frame, circular or otherwise, supporting a shallow bag of webbing and suspended by a line and bridles. Possession of hoop nets is prohibited in Everglades National Park (Florida Bay).

**Artificial Habitat in State Waters:** Placing artificial habitat or harvesting lobster from artificial habitat is prohibited. Artificial habitat is any material placed in the waters of the state that is reasonably suited to providing cover and habitat for spiny lobster. Such material may be constructed of, but is not limited to, wood, metal, fiberglass, concrete, or plastic, or any combination thereof, and may be fabricated for this specific purpose or for some other purpose. Artificial habitat does not include fishing gear allowed by FWC or artificial reefs permitted by Florida DEP or Army Corps.

*Appendix D*


DID YOU KNOW?
The closed season for the Caribbean Spiny Lobster is March 1st to June 30th.
During the close season no person or establishement should have in possesion any lobster.
No person or establishement should have in posession any diced or fillet lobster.
It is illegal to have in posession any soft shell (molting) lobster or females with eggs (berried).
It is illegal to remove from any female lobster, any eggs or spawn or the setae or fibre to which any eggs or spawn are or have been attached.
The minimum carapace length is 3 inches.
The minimum tail weight is 4 ounces.
Carapace
Tail

*Appendix E*

## New Zealand Rock Lobster

Fisheries New Zealand
Tini a Tangaroa

New Zealand has two common species of rock lobster: the red or spiny rock lobster (*Jasus edwardsii)* and the green or packhorse rock lobster (*Sagmariasus verreauxi*).

- Packhorse rock lobster, the world's largest rock lobster, can be as large as 70 cm and 20 kg.
- Red rock lobster are generally smaller, but can reach about 60 cm overall length and weighing up to 8 kg.

Spiny red rock lobster
*Jasus edwardsii*
Dark red colour with spiny body and tail

Packhorse rock lobster
*Sagmariasus verreauxi*
Green colour with smooth tail segments

### Red rock lobster life cycle

Red rock lobsters have a long and complex life history:

- Mating occurs within a few weeks of the female moult.
- The adults mate and the females carry eggs (berried) under the tail for 3-6 months.
- Females bear up to 1 million eggs depending on area and their size.
- Larvae hatch and swim in the open ocean for 12-24 months, during which they undergo numerous moults and changes (11 phyllosoma stages) and fall prey to a variety of plankton feeders.
- Larvae may move considerable distances with ocean currents, returning to inshore areas to settle on the bottom as transparent puerulus, which resemble miniature adults.
- The puerulus stage settles and moults into the juvenile stage.
- At this stage they may suffer heavy predation from bottom feeding fish, until they find adequate shelter.
- Juveniles mature and become adults after 5-10 years.

Photo: A. Blacklock

### Growth and age

To increase in size, a rock lobster must shed or moult its shell and grow a new larger one which is initially soft, leaving it very vulnerable to predators. It absorbs water rapidly and expands to its new size. The shell hardens within a few days, taking longer to thicken to full strength.

Moulting frequency and times depend on age and sex. Red rock lobsters reach legal size in 5–10 years, depending on the sex of the lobster, area, and growth rates. Rock lobster may live for over 30 years.

New Zealand Government

Fisheries New Zealand
Tini a Tangaroa

## Distribution, habitat and movement

Both red rock lobsters and packhorse rock lobsters are found in coastal areas where there is plenty of cover. Red rock lobsters are widespread, while packhorse rock lobsters are found more to the north of New Zealand.

During the day, rock lobsters are normally found in rock crevices (dens), which provide shelter from predators, storms, and the sun. They generally leave the dens around dusk to forage for prey, returning just before dawn and staying in the safety of crevices during the day. They eat a wide variety of bottom-dwelling life, with a preference for shellfish, crabs, seaweeds, small fish and sea urchins.

They move into shallow water seasonally for moulting and mating, and females move to the edges of reefs to spawn their eggs. Rock lobster migrate in large numbers. Movements of up to 460 km by red rock lobsters, and up to 1,070 km by packhorse lobsters have been recorded.

## Recruitment

Recruitment to rock lobster stocks is highly variable. The long oceanic larval phase of red rock lobsters means that larvae hatched in one area may be retained in that area by local eddy systems, carried to other areas by currents, or lost to New Zealand entirely. For most areas, larvae may originate a considerable distance from the settlement site.

The number of 'puerulus' larvae that settle to the sea floor varies among areas and from year to year, and may be affected by environmental factors such as the amount of suitable habitat available, the persistence of storms, prevailing ocean currents, sea temperature, food availability, and predation.

Large numbers of puerulus larvae also die before reaching suitable habitat, which is due in part to predation, but may also be a result of unfavourable environmental conditions.

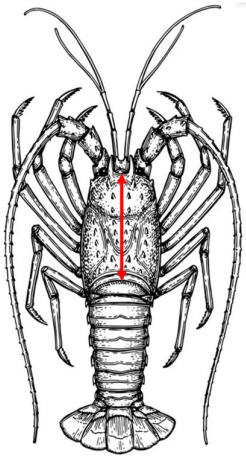
For more information about rock lobster biology and stock status, see the Fisheries Stock Assessment Plenary: https://www.mpi.govt.nz/dmsdocument/43321 or https://www.fisheries.govt.nz/news-and-resources/science-and-research/fisheries-research

New Zealand Government

## Appendix 4: Spiny Lobster Carapace Length Measurement Guide

**Guide to measure lobster carapace size**

| | | |
|---|---|---|
| 1. |  | Place the lobster on the floor or hold it firmly with one hand by its antennae. |
| 2. |  | If the lobster is put on the floor, slide both pairs of antennae to the side so that the base is open and the measuring gauge may be easily placed. |

| | | |
|---|---|---|
| 3. |    | Place the tip of the vernier caliper on the end of the notch between the eye sockets and measure the distance from the notch to the end of the carapace. Record the vernier caliper reading to two decimal places. If the carapace length is more than 6 cm, the lobster is mature and can be captured. |

**Guide to Weighing Spiny Lobster**

| | | |
|---|---|---|
| 1. |  | Clean the weighing scale with a soft cloth before placing the lobster on it. |
| 2. |  | Make sure the display shows “0” when the weighing scale is turned on. |

| | | |
|---|---|---|
| 3. |  | Place the lobster neatly on the weighing scale. Record the weight reading (in grams) displayed. |

## Appendix 5: Guide to Puerulus Monitoring Program

**Collector/Trap design**

A collector that resembles an artificial seaweed frame will be used to trap lobster puerulus (Figure 1). This collector device is modified from the 'Witham collector' (Witham, Ingle & Joyce, 1968) by using sheets of PVC (thickness 2 mm) which are grey as its top surface. It consists of a slotted, triangular, lightweight aluminum frame supporting three gray PVC sheets, each measuring 0.61 m high and 0.30 m wide. The collector will be supported by buoys on the surface of the water (two 8" buoys in the middle and two 8" buoys at the top of the central pole) and anchored with large concrete blocks (Figure 2). A total of 25 tassels of synthetic rope fibers (polyethylene) will be attached to each PVC sheet, with a brown 'Netlon' mesh as a base. Each tassel is about 0.23 m long, bound with monel wire, and then tied by a plastic cord to the PVC sheet on which the 'Netlon' mesh has been installed. The plastic curtain ring on the back of the PVC sheet will ensure that each tassel is firmly attached to the PVC sheet. The PVC panels are held within the aluminum frame with a lightweight chain and shackle, with the pin passed through the top of the PVC sheet.

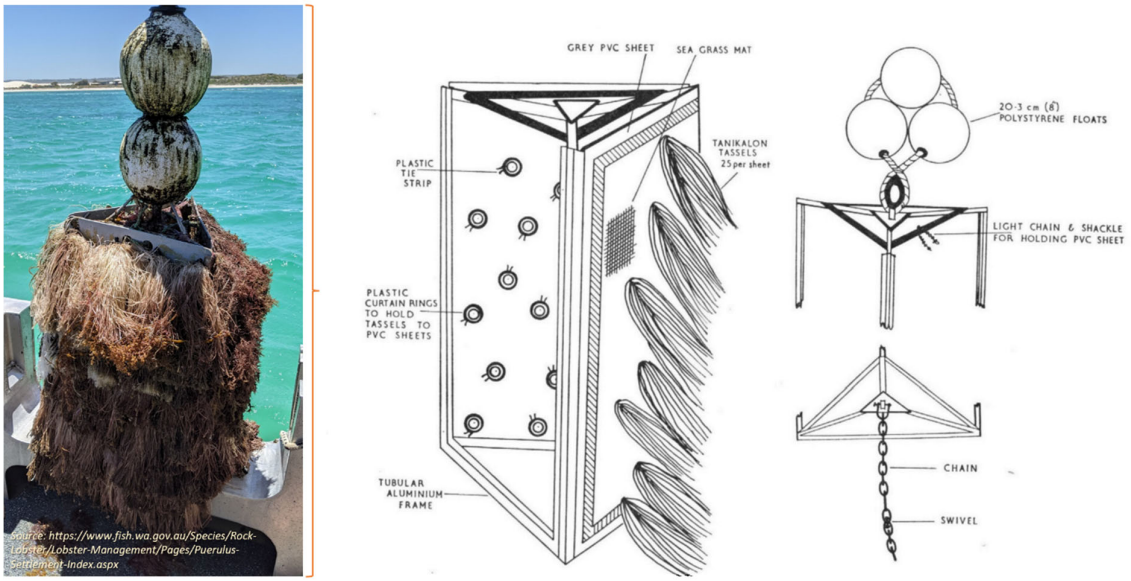



**Figure 1: Puerulus trap design (Phillips, 1972)**


**Figure 2: Frame design without PVC panel to show the inner construction of the puerulus trap (de Lestang et al., 2011)**

**Sampling method**

The collecting device is placed in shallow waters near the shore (< 10 m), and sampling is carried out every full moon (three days before or after the full moon) during the settlement season, which lasts from May until the following April. During sampling, the collector can be lifted from the water onto the boat without losing the pueruli because they tend to hide further into the tassels when disturbed. The collector is lifted onto the boat, and each PVC sheet will be removed and placed face down in a rack to be shaken over the collection tray. Then, the aluminum shaker frame is mounted on a PVC backing board. Two operators will hold the shaker by the handle and give 20 "shakes" before being placed on the deck of the boat, where the fibrous tassels side of the panel is facing down (Figure 3a). The contents of the collection tray are poured through a sieve (Figure 3b) before the sheet is shaken another ten times. If more pueruli appear in the tray after the second set of shakes, then the panel is given another ten shakes until no more pueruli appear. The PVC panel is then removed from the frame and repeated for the remaining two sheets.

After all three PVC panels were shaken, the number of puerulus (transparent) and post-puerulus (similar in size but pigmented) were counted and recorded. Any specimens significantly larger than post-puerulus, which may not have shaken out during the previous sampling, should be counted and identified as settled specimens in the previous month. Puerulus should be returned to the water and released at a certain distance from the collection device to avoid data contamination. Once all three panels are shaken, the collector is reassembled, cleaned of marine growth/fouling, and inspected for any degradation and damage. All maintenance on the collector, such as the replacement of PVC panels, is also recorded (**Record Form**).

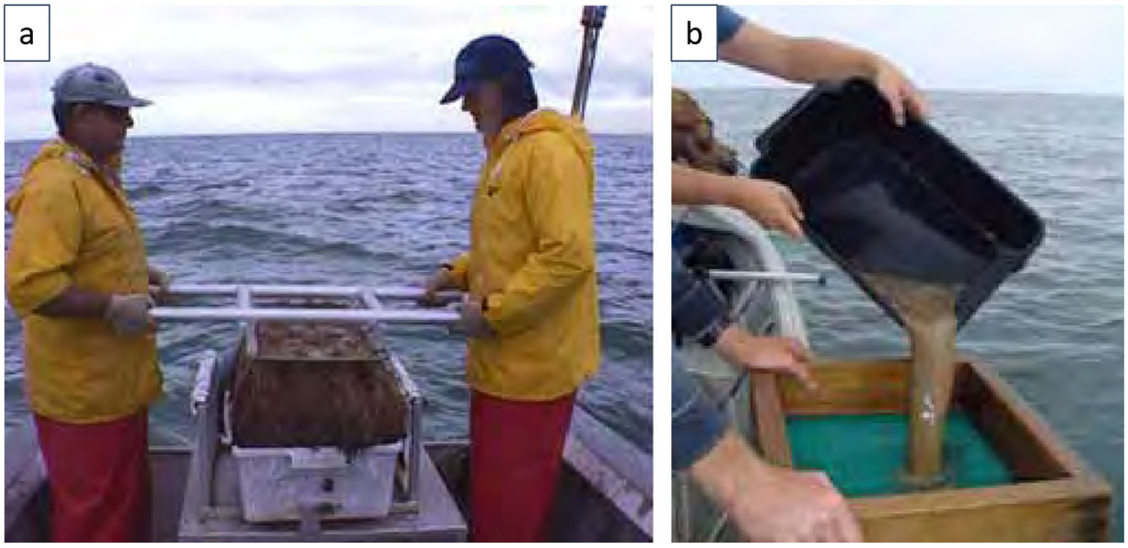



**Figure3: Puerulus collection procedures: a) shaking the collection panel, and b) sieving the accumulated contents of the collection tray (de Lestang et al., 2011)**

## Spiny Lobster (*Panulirus polyphagus*) Puerulus Monitoring Record Form

Date: _____

Name of sampling personnel:

1) _____
2) _____
3) _____

| No. | Collector ID | Location | Time | Number of puerulus | Note |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
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| | | | | | |

Puerulus settlement index of lobster at each sampling location, $P = \sum (\alpha_1 + \alpha_2 + \alpha_3 + \ldots + \alpha_n)$

whereby,

$$\alpha = \frac{total\ number\ of\ puerulus\ count\ in\ a\ month}{Number\ of\ collector}$$

n = settlement season