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

MANAGEMENT PLAN FOR TIGER SHRIMP, *Penaeus monodon* FISHERIES REFUGIA AT KUALA BARAM, MIRI, SARAWAK

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MANAGEMENT PLAN FOR TIGER SHRIMP, *Penaeus monodon* FISHERIES REFUGIA AT KUALA BARAM, MIRI, SARAWAK

FINAL REPORT

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Executive Summary

The Tiger shrimp, *Penaeus monodon* fisheries refugia was proposed by the Department of Fisheries Malaysia (DoF) to preserve the *P. monodon* population at the Kuala Baram, Miri area for sustainable harvest through the implementation of specific fishery management strategies. This concept differs from the Marine Protected Area (MPA) zone concept where a refugium only focuses on more effective fishing management instead of complete fishing prohibition on selected areas such as in MPAs. Two areas identified for the fisheries refugia management around the Kuala Baram, Miri include the nursery ground (Area A) Batang Baram, Sungai Pasu, Sungai Lutong and Sungai Miri and the spawning grounds (Area B) involving deep waters (depths up to 50m) off Kuala Baram up to 12 nautical miles from the beach with the total area of 852km^2 (85, 200 hectares). As the fisheries refugia aims for sustainable fisheries, the protection of *P. monodon* at different life stages is proposed. Some of the elements taken into account for the success of *P. monodon* Fisheries Refugia are the revision of harvest methods and fishing gears during close season, environmental parameter analyses for 10 years seasonal forecast modelling, determination of allowable size for capture of *P. monodon* to >30cm Total Length (TL) and >90g Body Weight (BW) as well as financial sustainability plan. The close season is proposed to be implemented between August and October to protect female spawners during their high reproductive period and allowing the offspring to grow without the risk of environmental disturbance caused by fishing activities. The involvement of the communities is important including the fishermen community, government agencies (e.g. DoF and authority agencies) and shrimp sellers. The participations of these stakeholders especially in complying to the terms and regulations of the *P.* monodon fisheries refugia is important to ensure the success of the program. As financial stability is an important element for a long-term and sustainable management of the fisheries refugia of *P. monodon*, a trust fund is needed through incorporation of the existing trust funds from both federal and regional government agencies.

CONTENT

Abbreviations

ASPIC	A stock Production Model Incorporating Covariates
B1	Total biomass in the first year of stock assessment
BMC	Broodstock Multiplying Centre
BRD	Bycatch Reduction Devices
BW	Body weight
CBOs	Community Based Organizations
CPUE	Catch per Unit of Effort
DoF	Department of Fisheries
ES	Ecosystem Services
CSR	Corporate Social Responsibility
CZMA/I	Coastal Zone Management Authority and Institute
CZM	Coastal Zone Management
ICM	Integrated Coastal Management
CNAP	National Centre of Protected Areas of Cuba
GEF	Global Environment Facility
FCLP	Fisheries Comprehensive Licensing Policy
IUCN-WCPA	International Union for the Conservation of Nature's World Commission on Protected Areas
MINTUR	Cuban Ministry of Tourism (MINTUR)
MLS	Minimum Landing Size
MSY	Maximum Sustainable Yield
MSC	Marine Stewardship Council

NBC	Nucleus Breeding Centre
NCTF	National Conservation Trust Fund
NPF	Northern Prawn Fishery
NTF	National Trust Fund
NOAA	National Oceanic and Atmospheric Administration
K	Carrying Capacity
OY	Optimum Yield
PES	Payments for Ecosystem Services
PIPA	Phoenix Islands Protected Area
PNK	Persatuan Nelayan Kawasan
PTF	Provincial Trust Fund
RWG-F	Regional Working Group of Fisheries
SPF	Specific Pathogen Free
TLA	Traffic Light Approach
TL	Total length
UMT	Universiti Malaysia Terengganu
UNCED	United Nations Conference on Environment and Development
WtC	Willingness to Contribute Time
WTP	Willingness To Pay

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1.0 Introduction

1.1 Background

1.1.1 Fisheries Refugia – The Concept

The term “refugia” has numerous definitions depending on the concept and purposes. According to Ashcroft (2012), this term was initially used to describe locations in which certain species survived during the glacial period. The modern term of refugia is defined as areas that required conservation to limit the impacts of climate change (Rull, 2009). Keppel et al. (2012) conferred that in terms of habitat-based refugia, it refers to sites where a biota retreats, stays and potentially expand from under changing environmental conditions. Dobrowski (2011) defined it as places where local climate is separated from regional climate. In general, the term refuge means temporal and/or spatial protection from disturbances, predation or competition as well as anthropogenic disturbances (Keppel et al., 2012). In terms of fisheries approach, the concept of fisheries refugia refers as “spatially and geographically defined, marine or coastal areas in with specific management measures for sustainability of important species during critical stages of their life cycles, for their sustainable use” (UNEP, 2005). The main priority of refugia often emphasised on conservation purposes under projected anthropogenic related climate change (Loarie et al., 2008). Refugia offers a better chance for the selected ecosystems of survival and adaptation to climate change (Groves et al., 2012). While there is growing interests on the conservation concept through refugia, more studies on the protocols for their identification and conservation is still required (Keppel et al., 2012).

1.1.2 Fisheries Refugia for Fisheries Management

The establishment of fisheries management was a way to resolve the issue of overfishing, to reduce the impact caused by the coastal habitat degradation and potential climate change-induced impacts. However, the matter of habitat conservation and fisheries management incorporation is that, it does not necessarily improve the habitat and fish stock. Therefore, the concept of fisheries refugia emerged as an innovative approach in which priority areas were identified and designated based on various factors, including the biology and ecology of the targeted species, for fisheries and habitat management integration (Paterson et al., 2013). Unlike other forms of marine reserves management such as “no-take zones”, “fisheries reserves”, “fully protected marine reserves”, “highly protected marine reserves” and “fish stock recovery areas” which strictly ban fishing activity of a selected area, fisheries refugia focused on the nature of the particular habitat and prioritise the life-history of the fished species. In other words, fisheries refugia focuses on the habitat of the fishing area management instead of restricted access, either temporarily or spatially (Paterson et al., 2013). According to Pauly (1997), the concept of fisheries refugia focused on areas of critical importance to the life cycle of the targeted species and that the conservation efforts were aimed to protect the particular individuals such as the juveniles and spawners from incidental capture and predators.

1.1.3 Fisheries Refugia Management Area Description

The fisheries refugia for *P. monodon* at Kuala Baram, Miri involves two areas, namely the nursery ground and spawning ground. Nursery grounds, where juveniles are commonly found, were identified along the rivers of Batang Baram, Sungai Pasu, Sungai Lutong and Sungai Miri. Spawning grounds, where the adults and spawners were found in abundance, are located at areas of deeper waters (10-60m) off Kuala Baram shore (Nurridan, 2021a; Hadil & Albert, 2001; Hadil, 1994). The proposed *P. monodon* Fisheries Refugia area in Kuala Baram involved the demarcation of the mangrove area at least 20m of the lower water edge of four rivers including Batang Baram, Sungai Pasu, Sungai Lutong dan Sungai Miri. The geographical location of the *P. monodon* fisheries refugia area is further described in Chapter 3.

1.2 Problem Statement and Significance

1.2.1 Current scenario of *P. monodon* in Malaysia

1.2.1.1 Distribution of *Penaeus monodon*

P. monodon is a large brackish-marine prawn widely distributed in the Indo-West Pacific area from Africa, to South East Asia and the Sea of Japan as well as Australia and Mediterranean Sea (Cawthorne, 1983; Nahavandi et al., 2011), generally at 30°E to 155°E longitude and from 35°N to 35°S latitude (Motoh, 1985). *P. monodon* are found in waters of 18-34.5^{o}C and 5-45 ppt (Chen, 1990; Branford, 1981). Commercial fishery of this shrimp species is being carried out intensively in most tropical countries particularly Indonesia, Malaysia and Philippines (Motoh, 1985).

Ecologically, penaeid shrimps have to go through two major ecosystems: the offshore and the coastal inshore environments in order to complete their life cycle. Mature penaeids breed in deep water while post-larval and juvenile shrimps inhabit inland marshes; estuaries, brackish water and mangrove areas, and then they migrate back to the sea for maturation and breeding (Mosha & Gallardo, 2013).

P. monodon resource in Malaysia is scattered and very much associated with deep marine water next to a healthy mangrove ecosystem such as in the waters of Kedah, Perak, Selangor, Kelantan, Sabah, Labuan and Miri in Sarawak. According to Rosle and Ibrahim (2017), *P. monodon* was found to be one of the most abundant shrimp species in the Kelantan delta, contributing approximately 38.67% to the total shrimp population. They were found abundant in the marine and brackish area with higher abundance of adult shrimp in brackish waters where the population was influenced by mangrove vegetation. Resource survey on *P. monodon* of Sarawak, Labuan and Sabah was carried out in 2012 and the estimated maximum sustainable yields, MSYs derived were 23 tonnes for Miri, Sarawak; 160 tonnes for Labuan; 28 tonnes for Kudat; 68 tonnes for Sandakan; 46 tonnes for Lahad Datu and 156 tonnes for Tawau (Hadil & Mushidi 2014). In Miri, Sarawak, *P. monodon* was found to be the largest and one of the most important commercial shrimp species (Hadil et al., 2017), with 62.5% of its resources found in the area between 11m to 50m deep while the remaining percentage were reportedly caught in shallow waters (Hadil & Albert, 2001). *P. monodon* are mostly found in the waters off Kuala Baram and are not caught in large quantities (Hadil et al., 2017; Hadil, 2007). While *P. monodon* was not common along the Johor Straits, previous study reported that they were still found along the area (Upanoi, 2015).

1.2.1.2 Current Harvest and Fisheries Production

The statistics from the Department of Fisheries Malaysia (DoF) has shown that the landing pattern (Fig. 1.1) for *P. monodon* has fluctuated from around 1,900 MT in 2000 (Manap, 2016) to 1,418 MT in 2021 (Siow et al., 2020). It was noted that intensive exploitation of *P. monodon* broodstock from wild habitat for mass production in shrimp fry hatcheries (Wong et al., 2021) and the destruction of mangrove ecosystem for development (Siow et al., 2020) have contributed to this trend in landings of this species. A positive correlation between mangrove area and near-shore yields of fish or shrimp has been documented in Australia, the Philippines, Indonesia and Malaysia (Valiela & York, 2001; Lacerda, 2002; Primavera, 1995). During the last 3 years from 2019 to 2021, *P. monodon* landings in Malaysia were 1237, 1302 and 1418 metric tonnes. The annual *P. monodon* landing percentage contributions by each region of Malaysia: West Coast Peninsular, East Coast Peninsular, Sarawak, Labuan and Sabah are roughly about 20%, 15%, 1%, 10% and >50% respectively.

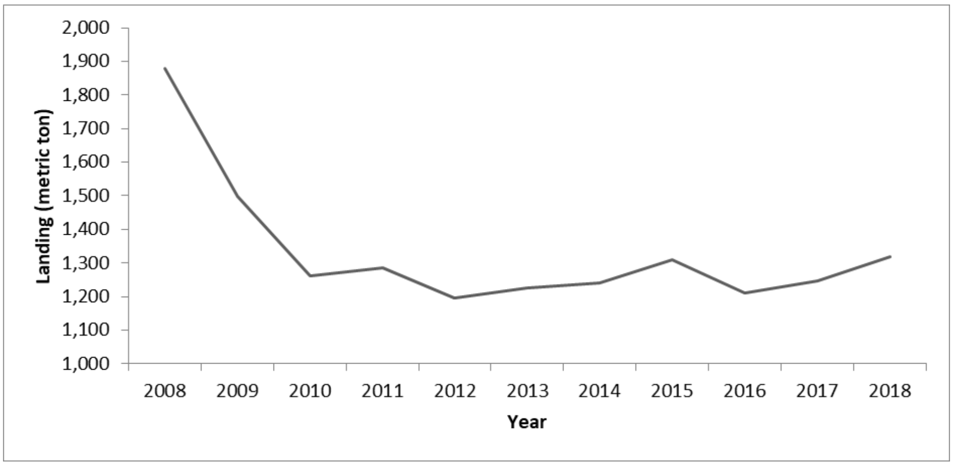

Fig. 1.1: Annual landing of *P. monodon* recorded between year 2008 to 2018 (Siow et al., 2020).

The exploitation of *P. monodon* in Sarawak has been going on since early 70s after the introduction of trawl gear. Since then, the fishing activity increased with annual catches of 19 MT until 1990s. Landings fluctuated after 1990 with the lowest catch at 11 MT in 1998 (Hadil & Helmi 2001). For the last 3 years: 2019, 2020 and 2021, *P. monodon* landings in Sarawak were 11, 13 and 11 metric tonnes respectively. The wild *P. monodon* population in Miri, Sarawak is the few remaining healthy *P. monodon* populations in Malaysia.

Marine aquaculture contributes more than 20% of Malaysian seafood production. Marine shrimp (both capture & aquaculture) is one of the most important items for Malaysian seafood industry, contributing 57,743 metric tonnes in 2021. In the last twenty years, marine shrimp aquaculture production has increased by 208% from 27,014 metric tonnes in 2001 to 56,325 metric tonnes in 2021. Two main marine shrimp species are farmed in Malaysia: the native *P. monodon* and the non-native Pacific white shrimp, *Litopenaeus vannamei*. *L. vannamei* production in Malaysia peaked in 2010 at 69,049 MT, but has since declined to 38,205 MT in 2021. By comparison *P. monodon* production has decreased from its peak of 26,352 MT in 2001 to 18,120 MT in 2021. Over the years, to some extent shrimp farming has acquired the reputation of being destructive (being linked to mangrove clearing) and unsustainable. With greater public awareness of the ecological importance of the mangrove, high-lighted by an increasingly vocal environmental movement in the country, many state governments are being much more cautious in the allocation of large parcels of coastal land for such venture.

1.2.1.3 Current Threats to *P. monodon* Population

While this *P. monodon* species has been extensively farmed to meet increasing demand, they were also caught in the wild for seed production purposes. The high dependency of wild-caught spawners for seed production thus resulted in over-exploitation of the natural population, affecting the sustainability and biodiversity of fishery resources (Wong et al., 2021). The study conducted by Hadil et al. (2017) revealed a negative allometric growth in shrimps in which the body length growth was not proportional to the body weight growth indicating an inconsistent growth among the shrimp within the population. Another possibility for such occurrence may be due to frequent catching activities at the same area, deforestation and uses of inappropriate gear type.

1.2.2 SWOT (Strengths-Weaknesses-Opportunities-Threats) Analysis

A SWOT analysis is a strategic planning method to evaluate the Strengths, Weaknesses, Opportunities and Threats involved in any project. A SWOT analysis in fisheries helps to identify these components that is and may occur to the fisheries sector thus, allowing the policy makers and the scientific community to continuously adjusting their strategies of management to make it a success.

Strengths: *P. monodon* is known to be highly valuable commodity. According to the statement by the director of Department of Marine Fisheries, Sarawak during the engagement session in October 2021, the total landings of *P. monodon* in Miri, Sarawak between 2015 – 2020 was reported to reach up to 78.79 metric tonnes with sales value worth RM5.6 million (Daily Dayak, 2021). *P. monodon* are fast growing species, known as the largest shrimp species and are tolerant to wide range of water conditions particularly salinity (Nahavandi et al., 2010). Therefore, they offer much contribution to the fisheries and aquaculture in terms of production and profitability. Shrimp plays important role in maintaining a balance ecosystem. At different stages of their lives from larvae to adult, *P. monodon* transition from pelagic feeding on zooplanktons to omnivorous benthic individuals feeding on algae and plant materials, other invertebrates and other organic matter. They too are food for larger organisms such as fish which makes a balanced population of *P. monodon* vital to ensure the sustainability of local food web community and ecosystem (Oceana, 2022). A balanced population of *P. monodon* also ensure a continuous production of *P. monodon* in fisheries which in terms maintaining the livelihood of the local fishermen.

Weaknesses: *P. monodon* fisheries management is quite challenging to carry out because the biological and physiological data of wild caught *P. monodon* are limited and inconsistent. In terms of governance, there is still no policy specifically for *P. monodon* fisheries management to date. When it comes to wild stock, it is difficult to determine the age of an aquatic animal. Therefore, size-based capture is important where the shrimp are caught according to allowable size. However, the knowledge of this approach is still limited and insufficient for fisheries refugia set up.

Opportunities: Since this is the first establishment of *P. monodon* Fisheries Refugia, the community that involved in the early development may gain maximum profit when this approach become increasingly commercialised in the near future. Furthermore, the success of *P. monodon* Fisheries Refugia will also ensure the sustainability of *P. monodon* Fisheries which resulted in continuous supply of *P. monodon*. As fisheries refugia is a conservation effort, it involved in creating awareness as well as knowledge transfer of the latest trend and technology in sustainable fisheries among related individuals such as the fishermen, local communities, students, Non-Government Organisation (NGO) and many more.

Threats: The ecosystem in the wild are always subjected to weather and water quality fluctuations. Climate change is often the cause of declining population of marine fishes and shrimp. Climate change was reported to be the reason for organisms of fisheries refugia unable to survive or move fast enough to their suitable habitat. However, despite the implication, refugia still offer the best survival chance for species negatively impacted by climate change (Keppel et al., 2012). Pollution cause by anthropogenic activities such as town development, dredging, industrial waste, deforestation and many more also affect the shrimp populations. This problem is difficult to tackle due to limited enforcement capability. The SWOT analysis for *P. monodon* Fisheries Refugia at Kuala Baram, Miri, Sarawak is summarised in Fig. 1.2.

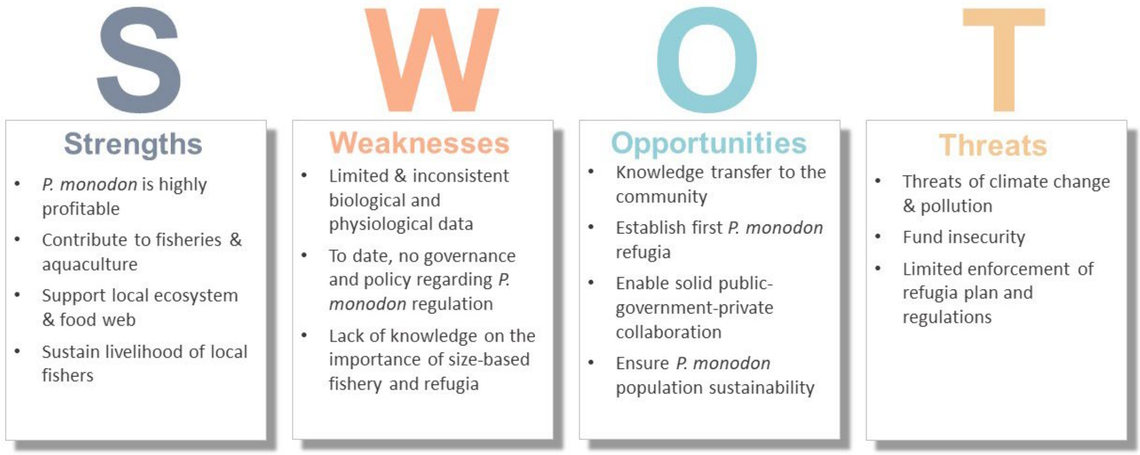

Fig. 1.2: SWOT analysis for *P. monodon* fisheries refugia at Kuala Baram, Miri, Sarawak.

1.3 Objectives of *P. monodon* Fisheries Refugia Management

The management of *P. monodon* Fisheries Refugia Plan aims to achieve the following objectives:

1. To develop a sustainable plan for a long-term protection of *P. monodon* population at Kuala Baram, Miri, Sarawak.
2. To identify ways for optimal utilisation of *P. monodon* resources.
3. To ensure the ecological integrity of fisheries refugia is maintained.
4. To generate a plan and strategy to reduce conflict and create awareness among stakeholders.

2.0 Literature Review

2.1 General Biology and Life Cycle of *P. monodon*

In general, the morphology of *P. monodon* is similar to other penaeid shrimp species, such containing a cephalothorax, tail, five pairs of swimming legs (pleopods) and walking legs (pereopods). This species is then distinguished by their distinct black and white stripes on the backs and tail. *P. monodon* are large in which they can grow up to 330mm or greater in length with females are generally larger than male shrimp (Kiel, 2013).

2.1.1 Reproductive biology

The sexes of *P. monodon* are distinguished by the external morphology of their reproductive organs namely petasma and a pair of appendix masculine in male and thelycum in female. The petasma is situated between the 1st pleopods (Fig. 2.1) and the appendix masculine on the exopods at the 2nd pleopods (Fig. 2.2). The petasma functions as interlocking structure for spermatophore transfer, while the appendix masculine branched out of the second pair of pleopods and serve to separate the petasma into two component halves (Motoh, 1985).

Thelycum is presence between the 4th and 5th pereopods of female shrimp (Fig. 2.3) (Motoh, 1985). There are two types of thelycum which are “open” or “closed” thelycum depending on the species. *P. monodon* has closed thelycum type. For a “closed” thelycum, the thelycum is enclosed by exoskeleton plate. In the case of mating, spermatophore is placed in the groove below these plates by a male when the female exoskeleton is soft right after moulting took place. The spermatophore will be stored for some time before spawning. Therefore, female shrimp with spermatophore presence within the thelycum is evidence of successful mating.

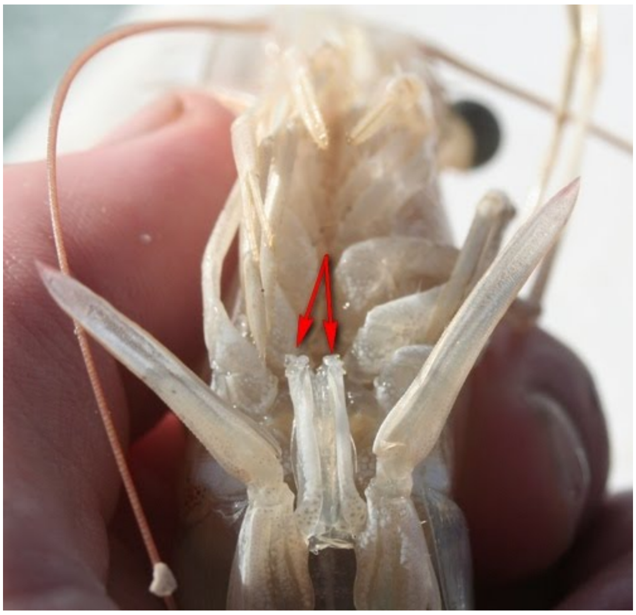

Fig. 2.1: Arrow showing petasma presence in male shrimp (Lewis, 2010).

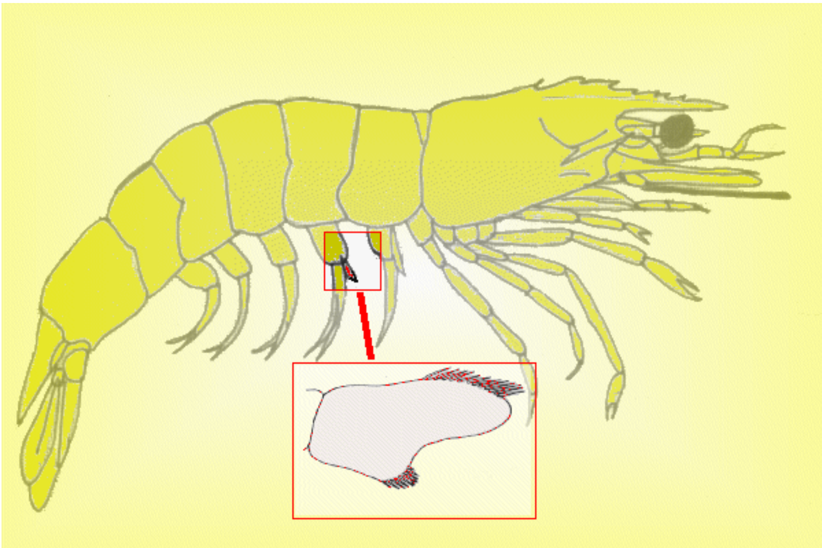

Fig. 2.2: Appendix masculine is located at the 2nd pleopods in male shrimp.

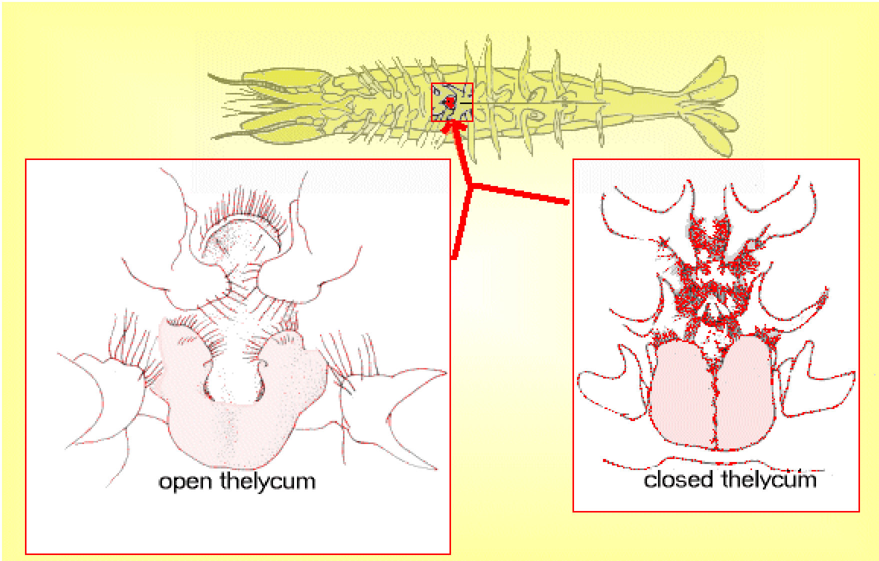

Fig. 2.3: Thelycum is situated between the 4th and 5th pereopods of female shrimps. There are two types of thelycum (open & closed) depending of the shrimp species.

2.1.2 Ovarian maturation

Females of *P. monodon* are categorised as non-spawning or spawning based on their ovaries. There are four stages of ovarian maturation as followed (Kannan et al., 2014):

Stage 1 Immature: The ovaries are thin, translucent, unpigmented and confined to the abdomen. They contain oocytes and small spherical ova with clear cytoplasm and conspicuous nuclei.

Stage 2 Early mature: Ovary increases in size with light yellow and yellowish green in colour. Opaque yolk granules are formed in the cytoplasm and partly obscure the nuclei.

Stage 3 Late mature: The ovary is light green and is visible through exoskeleton. The anterior and middle lobes are fully developed. The accumulation of yolk resulted the maturating ova to appear opaque.

Stage 4 Mature: The ovary is dark green and clearly visible through exoskeleton. The ova are larger than in the previous stage and the peripheral region becomes transparent.

Stage 5 Spent recovering: After spawning has ended. The gonad reverts almost immediately to the immature condition. This stage is therefore, distinguishable from that found in the immature virgin females only from the size of the shrimp.

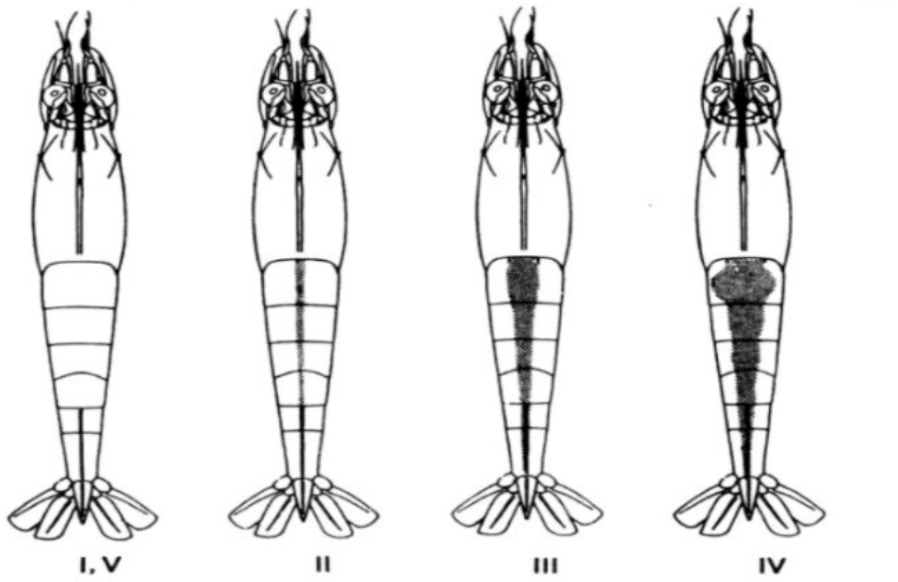

Fig. 2.4: Ovarian maturation stages of penaeid shrimp.

2.1.3 Spawning behaviour

Spawning generally takes place at night. Female shrimp usually swims actively in the water column and slowed down when spawning take place. Eggs are extruded from the genital pores at the base of the 3rd pereopods and as the eggs are released, they passed through the spermatozoa being stored in the thelycum and the eggs are fertilised in the water column. Depends on the size and weights of the shrimp, a spawner usually produces between 250,000 to 1,000,000 eggs per spawning (Motoh, 1985).

2.1.4 Life cycle of *P. monodon*

The larval development of *P. monodon* consists of 6 nauplius, 3 protozoea and 3 mysis stages before they entered the juvenile and postlarvae stages (Fig. 2.5). The larval developmental stages of *P. monodon* take place in the offshore waters and they are planktonic. At the end of the postlarvae stage, *P. monodon* move to the nursery ground at the estuaries which include wide brackish water rivers (mostly upstream and middle portion), mangrove swamps and interior portions of enclosed bays where they become mostly benthic. In this area, shrimps are exposed to wide physico-chemical fluctuations (especially temperature and salinity) (Motoh, 1985).

P. monodon at early juvenile stage has transparent body with dark brown streak on the ventral side (Fig. 2.6a) in which the body will then gradually turns blackish (Fig. 2.6b). The length of the carapace at this stage varies between 2.2 to 11.0mm. The sexes of the shrimp can be distinguished when they become adolescent through the presence of petasma in the male and thelycum in the female. The onset of sexual maturity happens during the sub-adult stage. At this stage female grows faster than male shrimp with spermatozoa present in the thelycum. Adult phase is when the shrimp has achieved sexual maturity. At this stage the ovary of the shrimp is at Stage 4 and is ready to spawn (mostly at the offshore, some spawn in shallow water). Male shrimp on the other hand is not quite different from the sub-adult stage except from size increment and different habitat (offshore area of about 160m). The maximum adult shrimp size is about 270mm in body length and 260g in weight with the carapace length varies between 37 and 71mm in males and 47 and 81 mm in females (Motoh, 1985). The complete life cycle of *P. monodon* is shown in Fig. 2.5. The summary of *P. monodon* life cycle is as described in Table 2.1.

Table 2.1: Life cycle summary of *P. monodon* (Motoh, 1985).

Life Stages	Description	Mode	Carapace length
Larvae	Begins at hatching: Consist of 6 nauplii stages, 3 protozoea, 3 mysis and 3-4 megalopa.	Planktonic	-
Juvenile	Completion of gill system.	Benthic	2.2-11.0mm
Adolescent	Resembles adult shrimp. Sexes are distinguishable.	Benthic	11.0-30.0mm (male) 11.0-37.0mm (female)
Sub-adult	Onset of sexual maturity. First copulation. Presence of spermatozoa in female thelycum.	Benthic	30.0-37.0mm (male) 37.0-47.0mm (female)
Adult	Completion of sexual maturity.	Benthic	37.0-71.0 (male) 47.0-81.0 (female)

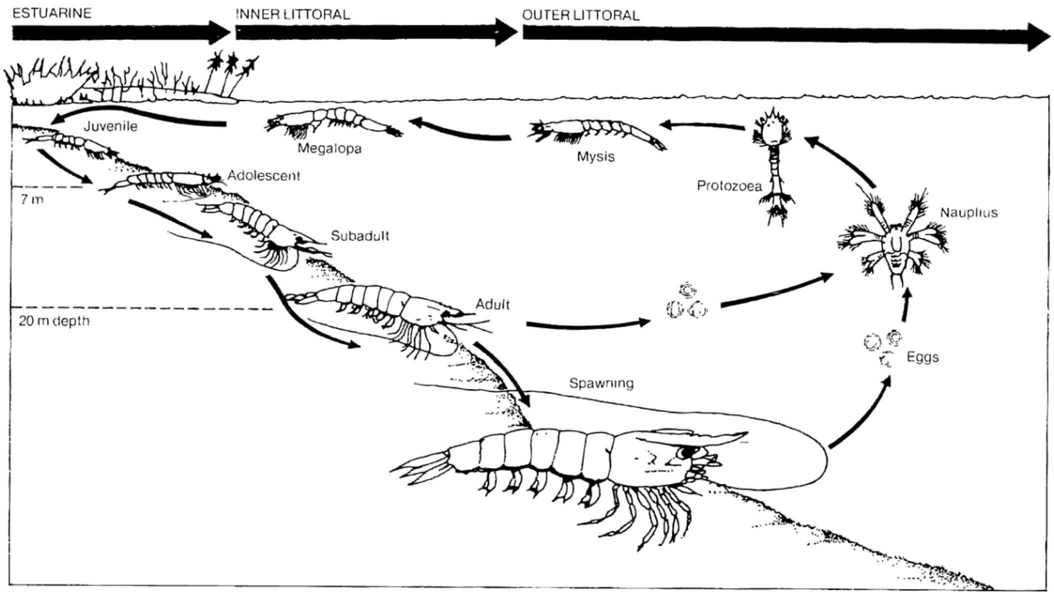

Fig. 2.5: Life cycle of *P. monodon* (Source: Motoh, 1985).

(a) (b)

Fig 2.6: (a) Lateral view of *P. monodon* juvenile (b) Juvenile gradually turn blackish as they grow.

2.2 General Criteria for *P. monodon* Fisheries Refugia Management Plan

The concept the fisheries refugia emphasised on the effort to protect the population of selected fishery species in a particular fishing area for sustainable fishery. This program was initiated by SEAFDEC-UNEP-GEF in the South East Asia Region involving six member countries including Malaysia, Cambodia, Thailand, Vietnam, Indonesia and the Philippines (Siow et al., 2020). Fisheries refugia was established under the project funded by Global Environment Facility (GEF) entitled "*Reversing Environmental Degradation Trends in the South China Sea* *and Gulf of Thailand*" where it falls under the fisheries component of the project entitled "*Over Exploitation of Fisheries in the Gulf of Thailand*" (Paterson et al., 2013).

Identification of refugia is important in managing climate change impacts caused by anthropogenic activities (Loarie et al., 2008). The development of precise methodologies for the identification and description is crucial for the success of refugia (Steffen et al., 2009). Generally, there are two major approaches to identify and describing refugia. First is through the study of biogeographic patterns which involved data collection on paleobiology, ecology and/or genetics of target biota. This approach often suggests that refugia was once existed naturally for a period of time in the past. The second approach is through investigation of refugial habitats which involved data collection on environmental and physical geographical processes which may provide valuable information on refugia formation and maintenance such as climate conditions, resource availability and disturbance (Keppel et al., 2012). A simplified criteria of refugia identification and description is as shown in Fig. 2.7.

The main criteria of fisheries refugia is the identification of critical spawning and nursery areas. The Regional Working Group of Fisheries (RWG – F) also identify the areas where the fish population are impacted by over-fishing especially spawning ground, juveniles and migration grounds of pre-recruits. Therefore, the RWG – F decided to focus on management of nursery and spawning grounds to safeguard juvenile fish (Paterson et al., 2013). As fisheries refugia has not been well established, one of a limiting factor of the development is the limited information related to the early-life history of aquatic species of any targeted species (Paterson et al., 2013).

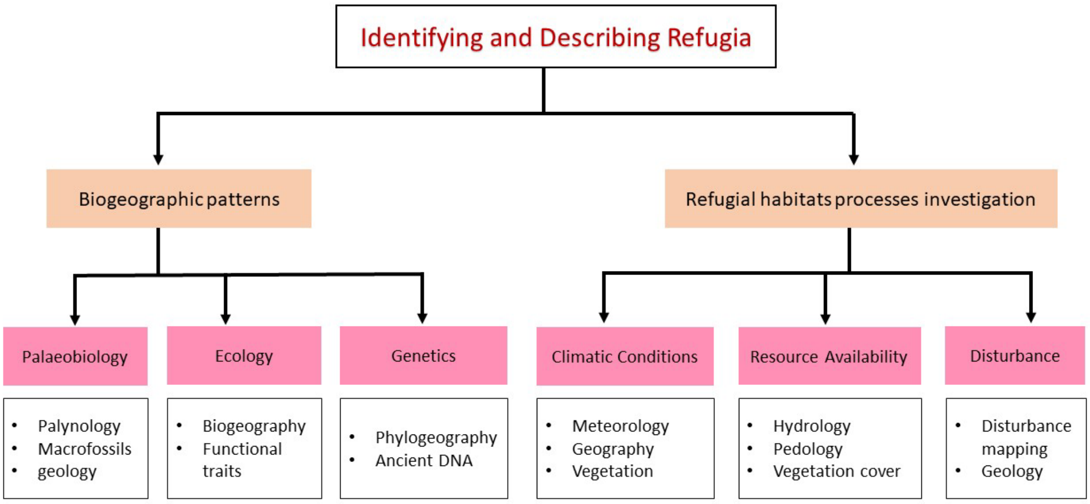

Fig. 2.7: Outline of the refugia identification and description approaches (Keppel et al., 2012).

2.3 International Fisheries Communication on *P. monodon*

Fisheries management theory on the whole is traditionally based on a rather biocentric philosophical viewpoint and focusing on physical output and aim to sustain fish stocks and harvest. Modern perspectives of fishery management focus on whole systems and aim to produce healthy ecosystems and human systems. To date, there has not been any scientific reports found on the establishment of *P. monodon* Fisheries Refugia. In Malaysia, fisheries refugia program had started for lobster (*Panulirus* spp. and *Thenus orientalis*) in Tanjung Leman, Johor and *P. monodon* in Kuala Baram, Miri, Sarawak. Some of the important information for a successful *P. monodon* Fisheries Refugia Program includes the landing data of the animal, maturation stage and life cycle of the shrimp (Siow et al., 2020).

2.3.1 Catch Limit of *P. monodon* Using Bycatch Reduction Devices (BRDs) in Australia

According to Australian Fisheries Management Authority, the commencing of Northern Prawn Fishery (NPF) *P. monodon* season began in 1st August 2020. The full implementation of BRDs such as Kon's Covered Fisheye, FishEX 70, Popeye Fishbox and Tom's Fishey BRDs was one of the efforts for sustainability fisheries in protecting other marine species from accidental capture. With the new implementation, it is compulsory for vessels to use one of these devices in each fishing net throughout the *P. monodon* season. The test data showed that the use of BRDs improved bycatch reduction by 37 – 44% (Australian Fisheries Management Authority, 2020).

2.3.2 Sustainable Fishery in United States

United States' commercial fisheries are generally being managed with sustainability goals. Hence the term "Commercial Fishery" denoted the process of managing, catching, processing and selling of any natural resources of the sea. According to Marine Stewardship Council (MSC) of Oregon, reduction of bycatch is the main factor of their success in economic fisheries sector as well as their achievement in obtaining MSC certification in 2006. The bycatch devices used, "Otter trawl" and "round gate" directs fish into the trawl nets reducing the bycatch of shrimp by 2% or less (Trickey, 2020).

2.3.3 Shrimp Fisheries Management in Gulf of Mexico

The amendment of shrimp fisheries under National Oceanic and Atmospheric Administration (NOAA) on the yield, threshold number of permits and transit provisions addresses the aggregate Maximum Sustainable Yield (MSY) and aggregate Optimum Yield (OY) and determined a minimum number of commercial vessel moratorium permits in the fishery. The purpose of the amendment was to maintain catch efficiency, economic efficiency and stability in shrimp fishery. According to the amendment, the moratorium permits are valid for 1 year in which individuals are required to renew their permit annually or it is no longer renewable and is terminated. The amendment 17B established the aggregate MSY for Federal Gulf shrimp fishery at 112, 531, 374 lb (51,043,373 kg) tail weight and aggregate OY at 85,761,596 lb (38,900,806 kg) tail weight (The Daily Journal of the United States Government, 2018).

2.4 Review on International Fisheries Refugia

Fisheries refugia was adopted at Ham Ninh, Vietnam as part of integrated fisheries and habitat management. This approach was aimed to improve the management of fish stock and habitat at Ham Ninh as was agreed among associated parties including Kien Giang Department of Science and Technology (DoST) and Department of Fisheries (DoF) as well as the community of Ham Ninh. According to the report, the implementation was well accepted for its concept that highlights on the "sustainable use" of the refugia rather than "no take" approach as enforced in marine protected area. The issue on limited data on distribution and abundance of fish eggs and larvae as well as management issue for refugia site identification was resolved through active involvement and cooperation of local fishermen, environment department, border army officials and scientists from Viet Nam's Institute of Oceanography (UNEP/GEP Project, 2008).

In other countries such as Myanmar, the concept of fisheries refugia was used as *de facto* protected areas such as "shark protected areas", "crab protected zones", "lobster protected zone" and many more in which fishermen are prohibited from illegal fishing collection and sell of these organisms. The regulation also includes temporal closed seasons to protect specific fish species. In Thailand, fisheries refugia was implemented since 2008 at Andaman Chub mackerel closed area with annual closed season from 1st April to 30th June during fish spawning and breeding. The fisheries refugia site at coastal fisheries conservation area was also implemented in 1992 with prohibition of any kind of fishing gear used with boat engine such as trawlers and push nets within any area 3 km from the shore. In Maldives, fisheries refugia was established on spawning and aggregating sites for pelagic species especially tuna (BOBLME, 2011).

In South Africa, the establishment of both natural and artificial fisheries refugia of Eastern Cape redfin benefited the population when in involved in conservation of both species and ecosystem (Magellan et al., 2021). Strauch et al. (2014) also reported success of fisheries refugia with increased fish biomass and richness with increasing refugia size. However, the study on the effect of land-use and water-use on habitat quality is necessary to ensure the improvement of rural livelihood of the fisheries refugia area. According to Ssanyu et al. (2011)

fisheries refugia was expected to improve plankton diversity and biomass which in turn improved the growth and the size of fish fingerlings during harvest.

2.5 Socio-economic aspect

2.5.1 Policy framework and legislation on *P. monodon* Fisheries Management

The policy on shrimp management in Malaysia was established to overcome one of the critical issues which is overfishing by both licensed and illegal fishermen. The fishing equipment used by Malaysian fishermen for both fish and shrimp are mostly trawl and drift net on the west coast of Peninsular Malaysia and trawl and purse seine fisheries on the east. The policy and legislation framework for fisheries management was implemented under the Fisheries Act 1985 which provides law for conservation, management and development of marine fishing. Fisheries Act 1985 however only provides policy and regulation for the conservation and management of Marine Parks. The main issue with Malaysian coastal fisheries is that the sector lacks strict regulations in fishing operations which resulted in extensive illegal fishing (Yassin, 1997)

The management of marine fisheries aimed for sustainable coastal fisheries for both fish and shrimp species. Some of the general considerations under the policy of marine fisheries management include:

- Assessing the effectiveness of Fisheries comprehensive Licensing Policy (FCLP).
- Protected areas (nursery area) identification to ensure the survival of juveniles.
- Identify the impact of development on fisheries and fishing communities for better management plan for conservation.
- Facilitating cooperation effort between government bodies and academe in terms of data/knowledge transfer for better construction of management plan.
- Establish stringent regulation and enforcement regarding illegal fishing issue.

2.5.2 Implementation and Financing of Management Plan

When it comes to financial support regarding fisheries activities in Malaysia for the past decades, most was in the forms of governmental subsidies to aid in improving the incomes of fishers. These included beneficial subsidies such as budgets for research and development and fisheries management purposes as well as harmful subsidies which support boat constructions, fleet modernisation and fuel support which resulted in overfishing issue. The harmful subsidies thus considered as an impact of unsustainable fisheries resources (Lee & Viswanathan, 2019). Subsidies are generally being provided in numerous forms such as grants, loans, equity, tax preferences or exemptions, and price or income support programs (Ali et al., 2017). According to Islam et al. (2016), fisheries subsidies do not support sustainable fisheries or even improving the income of small-scale fishers. However, subsidy elimination also does not reduce overfishing which means effective planning is necessary in achieving sustainable fisheries both on the resources and the well-being for fishers in Malaysia.

3.0 *P. monodon* Fisheries Refugia Establishment at Kuala Baram, Miri, Sarawak

3.1 Proposed Site and Focused Area

3.1.1 Description of the Habitat, Fisheries and Ecosystem

This initiative by the DoF, Malaysia to adopt fisheries refugia concept in preserving the only known area for *P. monodon* resource in Sarawak is praiseworthy and timely. The delineation of the *P. monodon* Fisheries Refugia at Kuala Baram, Miri shall be based on the critical habitats in the *P. monodon* life cycle (Fig. 3.1). The life history of *P. monodon* has an offshore planktonic larval phase of about 14 (Silas et al., 1978) to 20 days (Kenway & Hall, 2002); an estuarine, benthic postlarval and juvenile phase of over 6 months (33 g); a coastal subadult phase of 5 to 6 months (60 g); and an inshore and offshore ocean adult and spawning phase (60 to 261 g) (Dall et al., 1990, Kenway & Hall, 2002). In its natural range, *P. monodon* frequently found in water temperature of 18-34.5°C and salinities of 5-45 ppt (Branford, 1981; Chen, 1990).

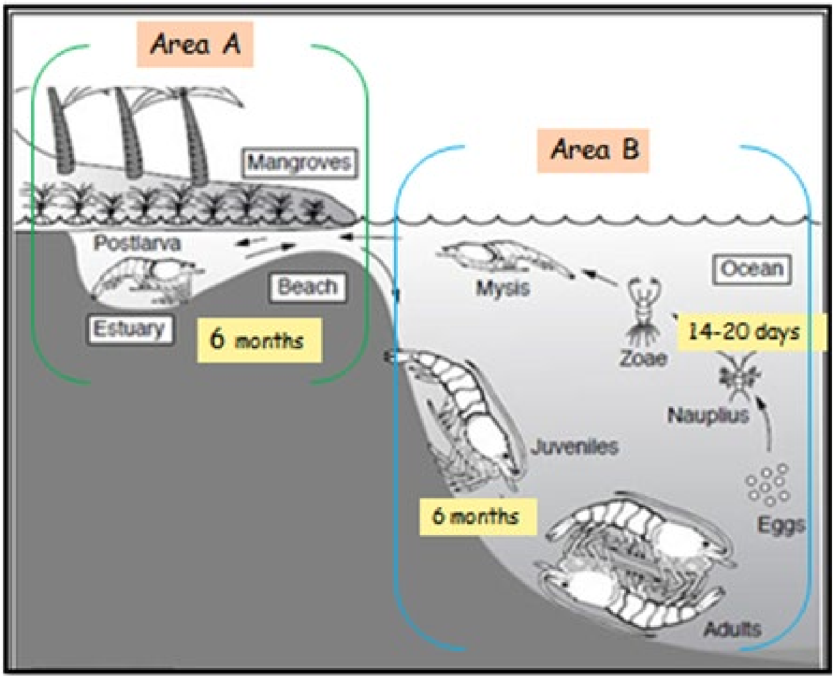

Fig. 3.1: *P. monodon* life cycle (Rosenberry, 2009; Motoh, 1981)

Area A involves the inclusion of the mangrove areas (at least 20m from the mean high-water level) of the 4 rivers: Batang Baram, Sungai Pasu, Sungai Lutong and Sungai Miri. While, Area B covers the waters off Kuala Baram to Marina Bay extending outwards to about 12 nautical miles from the beach with water depths up to 50m (Fig. 3.1).

3.1.2 *P. monodon* Fisheries Refugia Border Establishment

The fisheries refugia site was designated based on past and current research findings (Hadil & Albert, 2001; Hadil, 2007; Nurridan, 2021a) with the integration of knowledge on *P. monodon* life-cycle and its critical marine habitats. The proposed site encompasses the brackish riverine mangrove areas (Area A in Fig. 3.1) of the adjoining rivers: Batang Baram, Sungai Pasu (Fig. 3.2), Sungai Lutong and Sungai Miri and the marine waters off Kuala Baram (Area B).

In 2020, a total of 79 juveniles (38 male & 41 female) *P. monodon* (324.8 g) were sampled from Sungai Pasu, Sungai Lutong and Sungai Bakam and the average density was 6.8 g/m^2, 1.66g/m^2 and 1.20 g/m^2 respectively. Biomass estimate are directly proportional to the catch rate and the length of the river with the highest biomass at 31.94 kg contributed by Sungai Pasu, followed by Sungai Bakam (25.33 kg) and Sungai Lutong (4.80 kg) respectively (Nurridan, 2021a).

Fig. 3.2: Sungai Pasu mangrove fringes

Recent studies show that post-larvae and juvenile *P. monodon* were found in the rivers, like Sungai Pasu, Sungai Lutong, Sungai Bakam and Sungai Sibuti (Nurridan, 2021a) indicating that that these rivers (Area A) are important nursery ground for the post-larvae and juvenile *P. monodon* (Rosle & Ibrahim, 2017).

P. monodon was found up to a depth of 110m and their preferred habitat is muddy and sandy bottoms. The life cycle of *P. monodon* encompasses both brackish (post-larvae & juveniles) and marine (adults and spawners) environments (FAO, 1980). In Area B, more than 60% of the *P. monodon* adults and spawners were found in this deeper water area (10-60m) at 4-6NM offshore of Kuala Baram (Hadil, 1994; Hadil & Albert, 2001; Nurridan 2021a). These individuals were caught using small Zone B trawler (Fig. 3.3a) and bigger 70-tonnage twin outrigger trawler (Fig. 3.3b).

(a) (b)

Fig. 3.3: (a) Small (40-tonnage) Zone B stern-trawler and (b) Big (70-tonnage) twin-outrigger trawler from Kuala Baram, Miri Sarawak.

Catch data on *P. monodon* from surveys carried out at sea (Area B) were readjusted to the catch rate of the net with head-rope length of 24.8 m used by the trawler in 2012 survey (Hadil, 2014). The adjusted catch rates were then used to determine the high *P. monodon* density areas of the proposed fisheries refugia site so that the final size of the fisheries refugia can be ascertain. The proposed Area B was based on the trawl stations having *P. monodon* adjusted catch rates >1.0kg per hour or trawl stations having >5 tails male & >3 tails female *P. monodon* caught (Hadil & Albert 2001; Hadil 2007; Nurridan 2021a).

Fig. 3.4 is the map showing the location of the proposed *P. monodon* Fisheries Refugia site off Kuala Baram (red-dash lines), covering an area of approximately 852 km^2 (85,200 hectares).

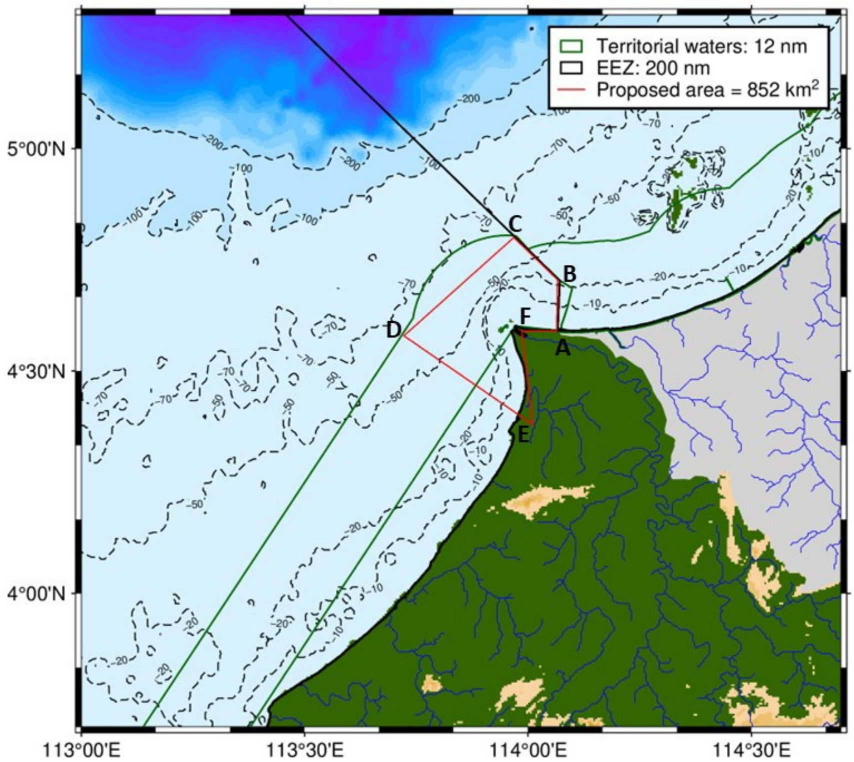

Fig. 3.4: Proposed *P. monodon* Fisheries Refugia site off Kuala Baram, Miri, Sarawak.

3.1.3 Coordinates of *P. monodon* Fisheries Refugia Site

The coordinates for the *P. monodon* Fisheries Refugia site are as followed:

Point	Latitude	Longitude	Bearing
A	4° 35.40’	114° 3.84’	N 4° 35.40’; E 114° 3.84’
B	4° 42.30’	114° 3.96’	N 4° 42.30’; E 114° 3.96’
C	4°48.00’	113° 58.08’	N 4°48.00’; E 113° 58.08’
D	4° 34.74’	113° 43.32’	N 4° 34.74’; E 113° 43.32’
E	4° 22.80’	114° 0.60’	N 4° 22.80’; E 114° 0.60’
F	4° 35.40’	113° 59.16’	N 4° 35.40’; E 113° 59.16’

The boundary of the fisheries refugia starts from latitude N4° 35.40’ longitude E114° 3.84’ at the point A (at Sungai Tujuh) where the EEZ boundary for Malaysia and Brunei starts. It then heads to the sea with points B and C along the EEZ boundary with points C and D are under 12NM territorial water line. Point E is at Marina Bay, Miri. The land area encompassed from point E to point F includes the 4 rivers: Sungai Miri, Sungai Lutong, Sungai Pasu and Batang Baram. The ending position latitude N4° 35.40’ longitude E113° 59.16’ (point F) is at Kuala Baram river mouth. Once this fisheries refugia is established, points A, B, C, D, and F (with the exception of position E) will be marked with lighted buoy.

Under the Department of Irrigation and Drainage (DID) guidelines on the development related to river and reserve, since the 3 rivers (Sungai Miri, Sungai Lutong & Sungai Pasu) excluding Batam Baram fall under the category of 10-20m river width, mangrove buffer zone of 20m from mean high water level along these riverbanks will be preserved. In doing so, the nursery area of the *P. monodon* post larvae and juvenile is protected.

Stock enhancement program whereby Specific Pathogen Free (SPF) fries from local hatcheries using spawners from Kuala Baram are release in the refugia-designated river should be carried out at least twice a year. This is to increase shrimp stock in the fisheries refugia area as well as the surrounding sea. Stock assessment and biological survey for post larvae and juveniles in the area before and after the release program should also be carried out. Additionally, the stock enhancement of *P. monodon* is suggested to be carried out every time after dredging and clearing of mangrove fringes (approximately 2 weeks after). Dredging to deepen the river channel up to 10m is carried out once a year by the Department of Irrigation and Drainage (DID), Sarawak to mitigate floods and the latest was on the 12 of May, 2022 at Sungai Lutong (Fig. 3.5).

Fig. 3.5: Dredging carried out by Department of Irrigation and Drainage (DID), Sarawak at Sungai Lutong to deepen the channel.

This proposed fisheries refugia site for *P. monodon* at Kuala Baram, Miri can be established under the existing Fisheries Act 1985.

3.2 Seasonal Closure

Numerous studies have shown that environmental factors can directly and indirectly affect shrimp's life cycles (Salini et al., 1990; Hill, 2000; Vance et al., 2003; Manson et al., 2005). In the worst-case scenario, a change in the environment can cause the recruitment of shrimp to collapse (Dambacher et al., 2015). Hence, managing an exploited natural resource such as the *P. monodon* requires an integrated approach that encompasses not only its population dynamics, but also the ecosystem's effects on all life cycle stages of the *P. monodon* stock.

Environmental factors and habitats have direct impact on the living conditions and food sources of shrimps. For example, early wet season rainfall has shown to increase food supply for larvae, juveniles and adults (Vance et al., 2003). In addition, changes in the environment conditions can also influence the emigration pattern of shrimp. The emigration of juvenile shrimps can be triggered and even accelerated by rainfall through the effects on river flow and a reduction in salinity, which triggered the emigration of smaller shrimps (Vance et al., 1998; Loneragan & Bunn, 1999). Meanwhile, late wet season can reduce inshore salinities, causing adult shrimps to move offshore and increased they chances to be harvested (Vance et al., 2003). Furthermore, an increase in turbidity due to rainfall can make it difficult for predator to prey on juvenile shrimp in estuary (Vance et al., 2003). In terms of habitat, mangroves provide ecosystem services such as retaining nutrients that enrich juveniles' food supply and providing refuge from predators, and cover for juveniles in estuary (Manson et al., 2005). Study carried out in Peninsular Malaysia shows that mangrove detritus and benthic microalgae constitute major dietary component for shrimps living in the estuaries, whereas shrimps living offshore were mainly consuming phytoplankton (Newell et al., 1995). Therefore, to ensure a sustainable *P. monodon* fishery in Kuala Baram, an in-depth understanding on the environmental conditions in each habitat hosting different stages of *P. monodon* is required. Specifically, it is essential to identify key environmental parameters influencing *P. monodon* stocks in Kuala Baram.

In Miri, mangrove forest can be found around the coastal area, which around 678 ha of the mangrove forests are 45 km west away from Miri town and had been declared as wildlife sanctuary in year 2000, commonly known as Sibuti mangrove forest (Shah et al., 2016). From all the documents collected in the desktop review, there is no study that combine the economically importance fishery resources such as shrimp, and environmental parameters to study the effect of ecological stress on their temporal and seasonal abundance. It is rather crucial as there are increasing ecological stress such as sedimentation or effluent discharge in the Miri estuary, which can potentially alter the ecological landscape as well as the regional community structure, affecting the fisheries production in this region.

The presence of several industries such as timber processing plants, palm oil estates and petroleum industries which are located on the banks of Baram and Miri rivers have raised the concern of pollutants or effluents especially trace metals. Such unwanted discharges might potentially be introduced into the coastal environment as the estuaries of both rivers are the final destination of the runoff water from the upstream areas, harming the coastal ecosystem (Anandkumar et al., 2017; Billah et al., 2017) which include *P. monodon* habitats. Among the rivers, Sungai Baram was reported to contribute the higher sediment input into the Miri coast as compared to Sungai Miri and Sungai Sibuti due to the deforested agricultural lands (Anandkumar et al., 2019; Nagarajan et al., 2015).

3.2.1 Seasonal Patterns Comparison of *P. monodon* with Seasonal Variabilities

Variability in recruitment to the nursery ground relies on factors that affect the survival during the early life-history stages, the offshore subadult and the population of the adult (van der Velde, 2021). This section focused on the relationship between seasonal variabilities of *P. monodon* and several key environmental parameters. Due to the limitation in in-situ observations, the current analysis of the environmental variables such as Sea Surface Temperature (SST), Sea Surface Salinity (SSS), ocean current direction and speed, chlorophyll-a (Chl-a, proxy of phytoplankton biomass and indication of food source), and suspended particulate matter (SPM, indication of river runoffs and nutrients) were derived from satellite data. The satellite data were then analysed to investigate the seasonal fluctuation of the environmental variables and their relationships with *P. monodon* stock in Kuala Baram.

SST were obtained from National Oceanic and Atmospheric Administration (NOAA), whereas ocean current, SSS, Chl-a and SPM data were obtained from Copernicus Marine Service. Monthly average of the hydrological parameters was calculated based on a spatial area of 4.25˚N to 5˚N and 113.5˚E to 114.25˚E (Fig. 3.6), a region that covers *P. monodon* landings for the Miri district.

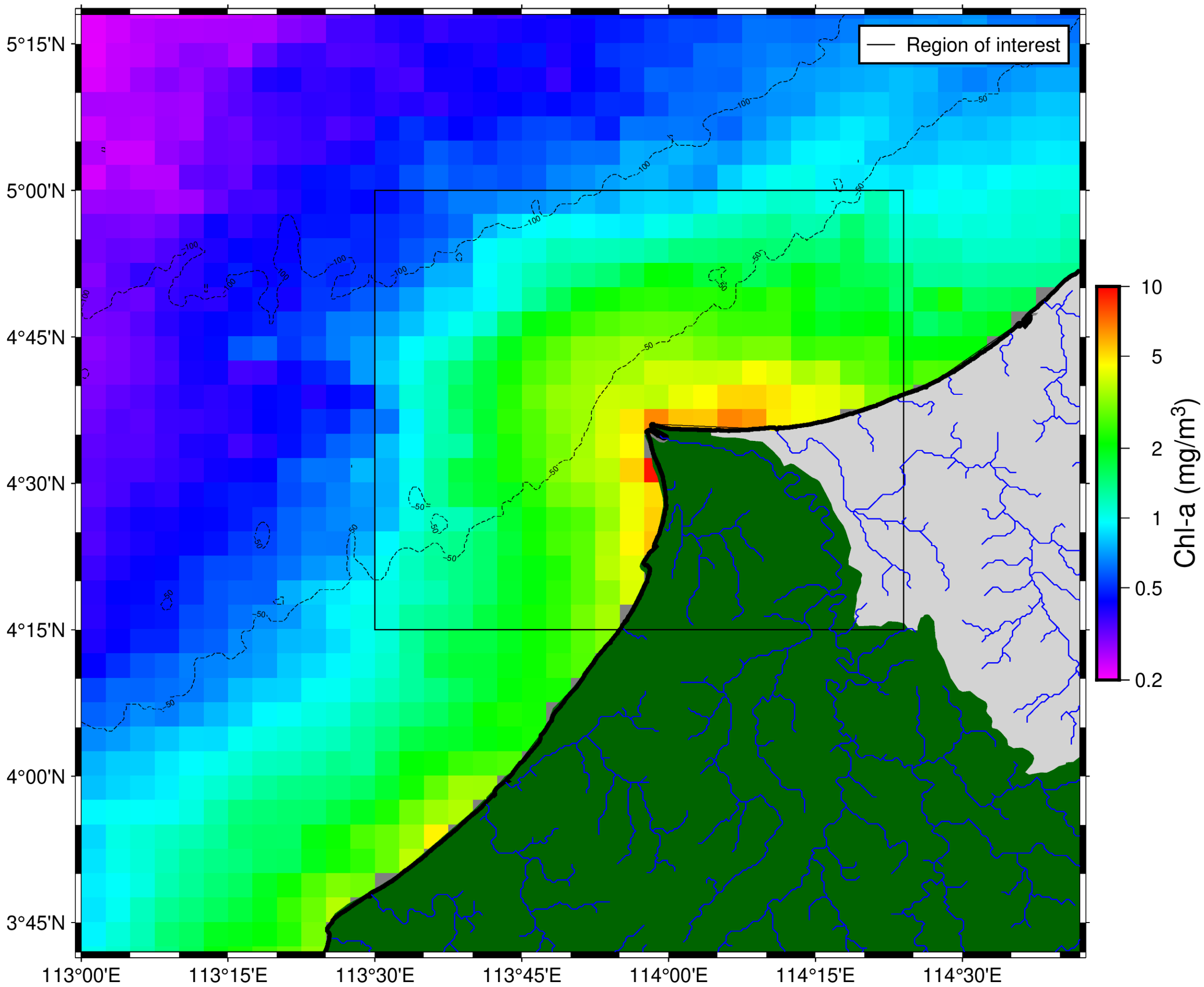

Fig. 3.6: Satellite derived Chl-a concentrations in the month of January with high concentrations of Chl-a as indicated in yellow and red colours can be observed in the coastal waters near Kuala Baram. The rectangle box in black indicates the region of interest indicating *P. monodon* active area at Kuala Baram, where monthly data of hydrological parameters were averaged.

Spatial and temporal distribution of the hydrological parameters were analysed and the correlation between *P. monodon* landings and hydrological parameters was calculated. Fig. 3.6 shows a snapshot of the typical spatial distribution of satellite derived Chl-a concentrations in the month of January in the study area. High concentrations of Chl-a were observed in the coastal waters near Kuala Baram indicating that there was high concentrations of phytoplankton i.e., primary food source at Kuala Baram. Temporal distribution of Chl-a and SPM showed similar seasonal trends with higher concentrations usually observed at the end of the year and low values in the middle of the year (Fig. 3.7).

Seasonal pattern of *P. monodon* landings for Miri was less clear than in Chl-a and SPM. In general, *P. monodon* landings were usually higher in months between February and October and lower from November to January.

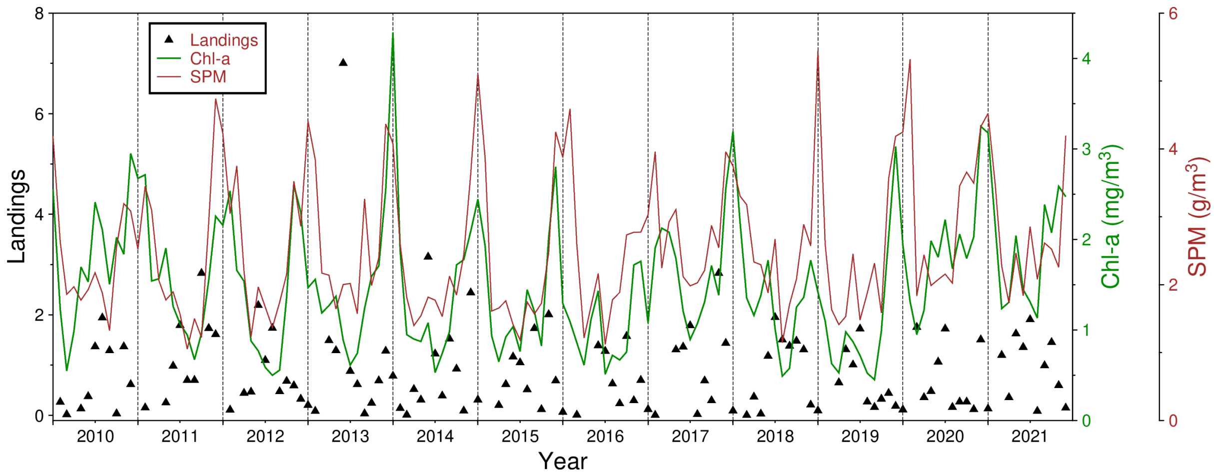

Fig. 3.7: Monthly values of *P. monodon* landings for Miri, and monthly average of Chl-a and SPM concentrations for the region of interest as indicates in Fig. 3.6 from 2010 to 2021.

Similar to Chl-a and SPM, monthly satellite data of SST and SSS also demonstrated a clear seasonal trend (Fig. 3.8). SST values were usually high (~30.5 ˚C) in May and June and the lowest (~27.5 ˚C) was recorded between February-March (Fig. 3.8). The seasonal pattern of SST showed that the salinity at Kuala Baram usually peaked (~33.5 ppt) before SST and reached the lowest values (~32.3 ppt) between December and January. The seasonal patterns of Chl-a and SPM were of the opposite seasonal trend of SST. This indicates that wind-driven water mixing or upwelling was probably the main contributing factor bringing additional nutrients from deeper depths of the ocean to the surface waters where phytoplankton carried out photosynthesis, converting CO_2 to biomass.

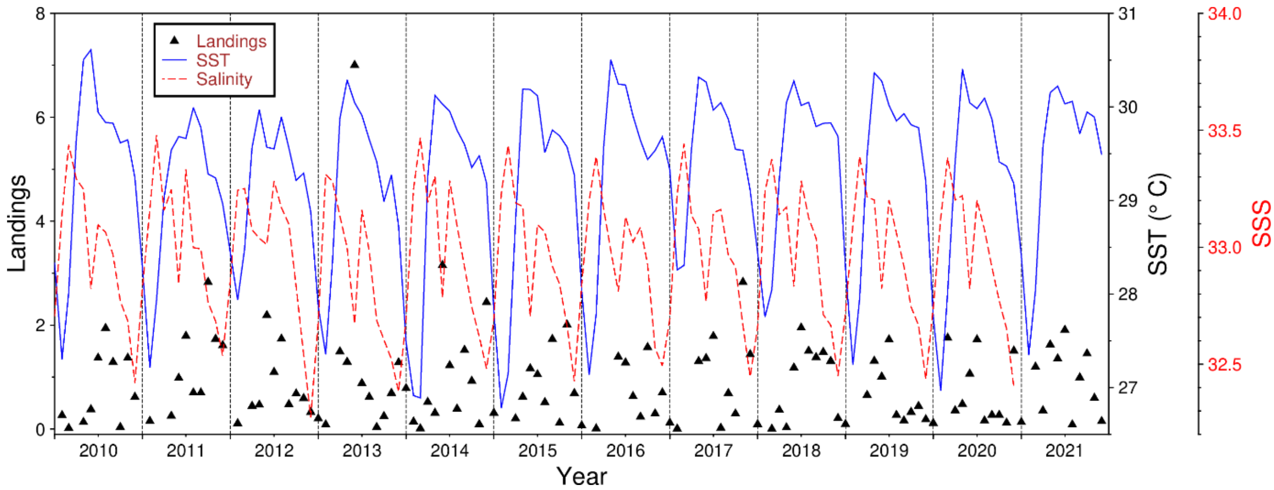

Fig. 3.8: Monthly values of *P. monodon* landings for Miri from 2010 to 2021 and monthly average of sea surface temperature (SST) and sea surface salinity (SSS) for Kuala Baram as indicates in Fig. 3.6.

The opposite trend was observed between tiger prawn landings and Chl-a showing negative correlation although the correlation was not significant (Fig. 3.9a). Significant negative correlation was observed between landings and SPM (Fig. 3.9b). The negative correlations between landings and the proxies of food source (Chl-a and SPM) suggested that there could be a lag period between food source availability and landings, in which phytoplankton are the main food source for *P. monodon* larvae than they are for adult shrimps. The significant positive correlation between landings and SST (Fig. 3.9c) indicated that either more landings or fishing activities of *P. monodon* usually took place during the months where seawaters are warmer i.e., stronger stratification and less mixing. This could lead to less migration and accumulation of *P. monodon* in certain areas, thus contributed to higher catch effort. The insignificant correlation between landings and SST suggested the lack of influence of rainfall or river runoffs dilution on landings. It is worth noting that landings are not a direct indication of *P. monodon* stock availability in their natural habitat, which might skew the interpretation of the influence of hydrological variables on *P. monodon* stocks in Kuala Baram.

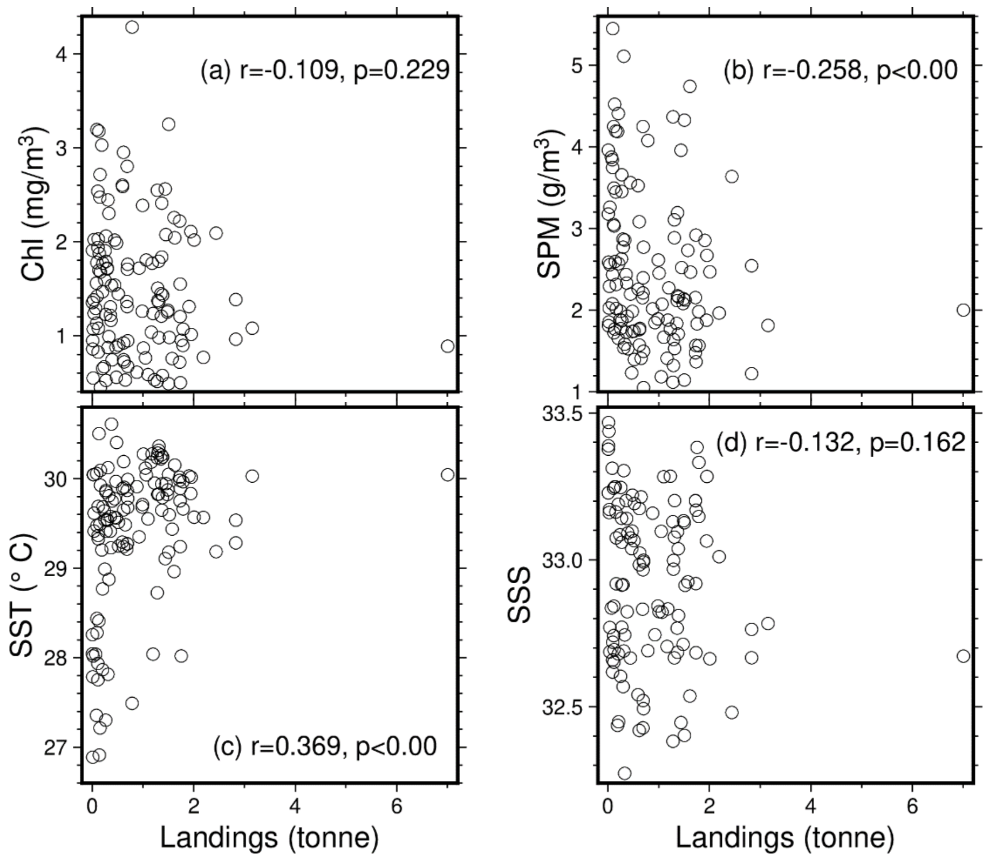

Fig. 3.9: Spearman rank correlation between *P. monodon* landings and hydrological variables. Data are monthly observations from 2010 to 2021 as shown in Fig. 3.7 and Fig. 3.8. n = 124.

3.2.2 Seasonal Forecast Modelling

Carbon emissions released from burning of fossil fuels and other anthropogenic activities caused significant changes to the ocean. Ocean warming, ocean acidification and oxygen loss are among the known consequences of ocean soaking up more heat and dissolved carbon dioxide. The upper oceans have warmed at 5.31 and 4.02 ZJ/year from 2005 to 2017 according to the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (Bindoff et al., 2019). The surface ocean warming is very likely to increase stratification, which will perturb nutrient cycles of the open ocean, thus disrupting the marine food chains. Ocean warming has contributed to changes in biogeography of organisms ranging from phytoplankton to marine mammals, changing in community composition and altering interactions between organisms (Pörtner, 2021). It is estimated that marine epipelagic and benthic organisms had been shifted at 51 km per decade and 29 km per decade, respectively, since 1950. The rise of sea level and enhanced nutrient loads as well as sediments in deltas on the other hands, also contributed to salinisation and deoxygenation in the estuaries causing upstream redistribution of benthic and pelagic species according to their tolerance limits. Furthermore, ocean warming coupled with other anthropogenic stressors such as coastal development, pollution, and overfishing, can threaten the marine ecosystems, habitat of marine organisms and individual species. Thus, it is important to understand the risks of climate change on marine ecosystems in Kuala Baram for a better-informed mitigation and management planning.

An enhanced suite of marine ecosystem model from the Fisheries and Marine Ecosystem Model Intercomparison Project (Fish-MIP) (Tittensor et al., 2021) was used to predict how climate change will affect the marine ecosystem and subsequently *P. monodon* population in Kuala Baram in the future. Among the models available on Fish-MIP, the latest EcoOcean fisheries model forced by the new-generation Earth System Model Version (ESM4) outputs were selected. Key variables such as biomass density of small demersal (< 30cm) obtained from the model was used as an indication to predict the projected density of *P. monodon* stock in the future at Kuala Baram.

The impact of global warming in the future depends on the how much greenhouse gases (GHG) is continuously being emitted into the atmosphere. As some industries and countries have embarked on the initiatives to reduce GHG emission, the amount of available GHG in the future will be determined by which pathways are taken by the society. Climate scientists have termed this pathway as the shared socioeconomic pathway (SSP) and five pathways have been developed to project the impact of global warming different socioeconomic scenarios. In this study, we examined the impact of global warming on small demersal organisms (< 30 cm) under two scenarios or pathways: SSP126 and SSP585. The former represents the impact of global warming in a low GHG emissions scenario with an expected warming of 1.8˚C by 2100 (SSP126), whereas the latter indicates an extreme scenario with very high GHG emissions resulting in an estimated warming of 4.4˚C by 2100 (SSP585).

The projection from the EcoOcean model shows that the biomass density of small demersal < 30cm at Kuala Baram without any fishing activity will fluctuate and slightly decline by 2100 under the optimistic SSP126 scenario. In contrast, a significantly decline were observed from the current biomass density of approximately between 0.04 g/m^2 to less than 0.01 g/m^2 by the year 2100 under the extreme SSP585 scenario. The modelling results show that there will be a 300% reduction in small demersal biomass at Kuala Baram if future warming of 4.4˚C will occur by 2100 (Fig. 3.10). This will have a severe implication to tiger prawn stock at Kuala Baram and the livelihoods of fishing communities that rely on it.

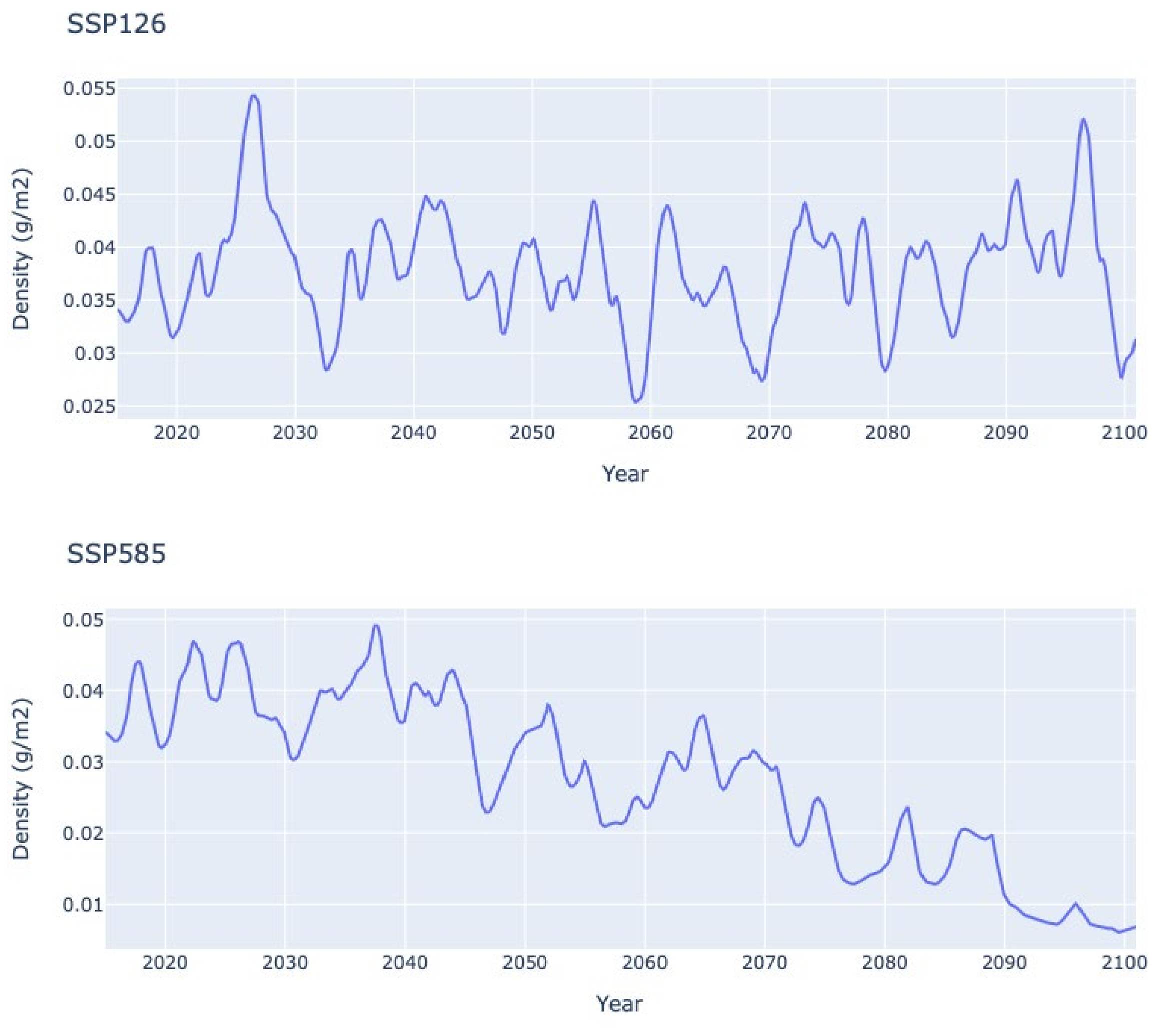

Fig. 3.10: Future projection of biomass density of small demersal < 30cm at Kuala Baram under the shared socioeconomic pathways (SSP). (Top) Under low GHG emissions scenario (SSSP126) and (bottom) under very high GHG emissions scenario (SSP585) by the year 2100.

3.3 Minimum Landing Size (MLS)

3.3.1 Concept of size-based fishery

A consistent and standardised fisheries management is needed to tackle the problem of increasing exploitation of wild fish stocks. Age-based fishery was developed by Beverton and Holt (1957), but faced several challenges, including (i) unable to assess stocks with limited data and the required parameters for age-based assessments are unknown; (ii) do not address the evolutionary side-effects of fishing; (iii) do not incorporate the impact of density-dependent growth and/or cannibalism. The body size determination is commonly used in aquatic species, including fish stock and other economically important species, and is regarded as a more important physiological parameter than age (Andersen, 2020). The reason behind the usage of body size instead of age is because body size is directly related to food consumption, mortality, maturation, fecundity, fish gear selectivity, and population variation. In addition, the measurement of body size is feasible and relatively easy to be conducted, making body size data largely availably (Andersen, 2020). Size-based fishery (minimum catch size) is often used in marine species, including shrimps (Larsen et al., 2018). For example, the overall shrimp, *Pandalus borealis* catch can only contain less than 10% by weight of undersized shrimps in Norway.

Length-weight relationship has been widely used in various fisheries ecological researches, including stock assessment modelling, population health and condition estimation, and comparison of life history and characteristics among populations (Fazhan et al., 2021). Understanding the relationship between length and biomass (weight) is important to understand the overall population health and dynamics, and the general structure and growth of a population. In times, mass is easier to be estimated from length, if the length-weight relationship is available beforehand, compared to direct measurement in most aquatic species. Therefore, length-weight relationship is an important parameter to estimate and gauge the health condition of a given population, whereby a general assumption that higher body weight at a given length indicates better health quality. Minimum Landing Size (MLS) is often based on the smallest size measurement of mature individuals, and usually estimated from size at maturity (Atherley et al., 2021).

In order to establish the size at sexual maturity and subsequently estimate the MLS of *P. monodon* at Kuala Baram, several data and biological parameters are required, including sufficient data on the total length, body weight, maturation status. Similarly, to establish the length-weight relationship of *P. monodon*, at least length and weight data are required. In addition, the availability of gonadal maturation stage will also allow the prediction and proposition of close season due to spawning of *P. monodon* at Kuala Baram.

To ensure that all harvesting size and technology of *P. monodon* are being integrated into this report, a full literature review related to the size at sexual maturity of *P. monodon* was conducted.

- Public reliable databases were used, including Web of Science (https://www.webofknowledge.com) and Scopus (https://www.scopus.com). However, due to the scarcity of this information, the search with key word "penaeus monodon" AND "size at maturity" returned with 0 results from both WoS and Scopus databases.
- The search using key word “Penaeus monodon” AND “length-weight” resulted in 14 articles in WoS, and 12 articles in Scopus.
- After removing duplicates, 19 unique articles were retrieved. However, after removing articles unrelated to length-weight relationship of Penaeus monodon, only 8 papers were found.
- Data from these 8 papers were retrieved and those related to tropical zones were used as baseline for this report.

An interview with the local fishermen community at Kuala Baram was conducted to review the knowledge and experience regarding the capture of *P. monodon* in the specific location, specifically landing and maturation status at different seasons. A workshop was also conducted with the relevant governmental agencies, including the DoF, Malaysia to obtain relevant information and data on the length weight and gonadal development of *P. monodon* from Kuala Baram. The workshop serves as important platform for all stakeholders to discuss and close the gap of knowledge regarding the available data and willingness to follow through the proposed size-based *P. monodon* fisheries.

3.3.2 Size at Sexual Maturity and Minimum Landing Size (MLS)

Size at sexual maturity is a point of time where an organism transition from immature individuals to mature adults that can reproduce offspring. It is an important parameter to determine the reproductive output of a species and the growth rate of its population. Size at sexual maturity can be determined based on three common main criteria, namely, morphometric variations that occur during the transition of maturity (also known as morphometric size at sexual maturity), gonadal maturation (also known as physiological size at sexual maturity), and sexual functionality based on the presence of mating scars (also known as functional maturity). The estimated value at which 50% of the population reached size at sexual maturity is termed as CL_{50} (CL, carapace length). It is often based on the size at sexual maturity that stakeholders determine the minimum landing size (MLS) for specific species.

In tiger prawns, the two easiest methods to determine size at sexual maturity is via morphometric analysis and gonadal maturation analysis. Morphometric analysis depends on the measurement of specific morphometric characters that show abrupt growth during the transition from immature juveniles to mature adults. Such measurements are often being measured using vernier caliper. To determine physiological size at sexual maturity, tiger prawns need to be dissected to allow for the determination of ovarian maturation stages (under 2.1.2, Figure 2.4).

3.3.3 Minimum Landing Size (MLS) for *P. monodon*

Length-weight relationship of *P. monodon* is known to be negatively allometric, meaning that weight tends to increase at a faster rate than length as length increases. Length at first capture was 12.44 cm in Nigeria (Wilson & Amiye, 2017). However, the related data on *P. monodon* in South East Asia (SEA) is limited. The availability of the length of maturity is crucial to setting and imposing MLS and other regulatory measures to protect the harvested species and prevent overfishing. For example, Turkey has successfully introduced MLS to eleven taxa based on the length of maturity of these species (Yildiz & Ulman, 2020). In addition, Australia also incorporated size-structured population model to assess its northern *P. monodon* fishery consist of three main species, i.e., *Penaeus semisulcatus*, *P. esculentus*, and *Metapenaeus endeavouri*. By integrating data on catches, catch rates, length frequency data, and tag release-recapture data, the study suggest that a reduction in fishing effort is warranted to achieve economic goals (Punt et al., 2010). The introduction of such a policy to prevent the capture of immature individuals is important as overfishing is known to be a plausible factor in the reduction of mean maturity sizes for many taxa, including economically important crustaceans (Waiho et al., 2016). However, it is also important to note that MLS measures can only be successful if they are accompanied by controls and implementation at the specific landing sites (Yildiz & Ulman, 2020). The implementation of MLS will ensure a more balanced and sustainable harvest of *P. monodon* (Fig. 3.11).

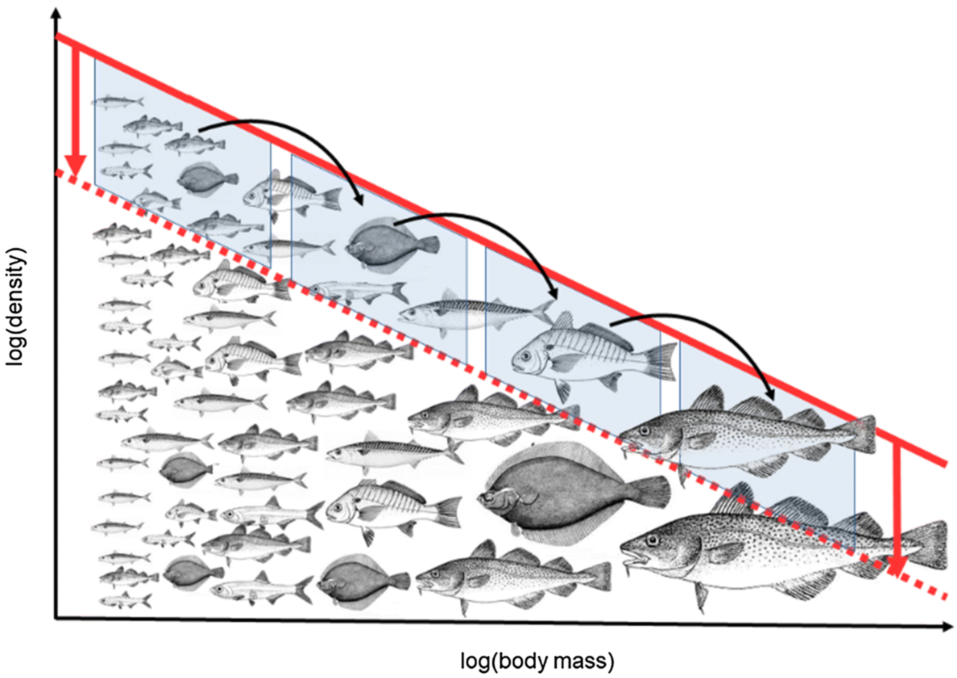

Fig. 3.11: The ideal equilibrium community size spectrum, with increasing body mass and decreasing density in an unexploited fish community (solid red line). Balanced harvest removes (harvests) a cross-section of this size-structured community, eventually reduces the overall density, but has little impact on the slope (dashed red).

In regards to the *P. monodon* population in Kuala Baram, there is currently no knowledge on the size at maturity and thus, no limit of catch based on their body sizes has been proposed. All sizes of *P. monodon* and all maturation stages, from immature juveniles to mature adults and berried females, are harvested. This scenario is especially dangerous because it will cause the collapse of a population in near future. Additionally, there is a strong correlation between female fecundity with body size (carapace length) of *P. monodon* (Yousuf et al., 2009). Therefore, an unregulated capture of females, especially those above size at maturity and larger sized females might jeopardize the *P. monodon* population by directly decreasing the potential regeneration.

The current data available on *P. monodon* was provided by the research of Nurridan (2020b; 2020c) as an effort to establish a regional system of fisheries refugia in the South China Sea and Gulf of Thailand. Based on the 95 individuals caught and measured, the length-weight relationship of *P. monodon* from Kuala Baram is as in Fig. 3.12.

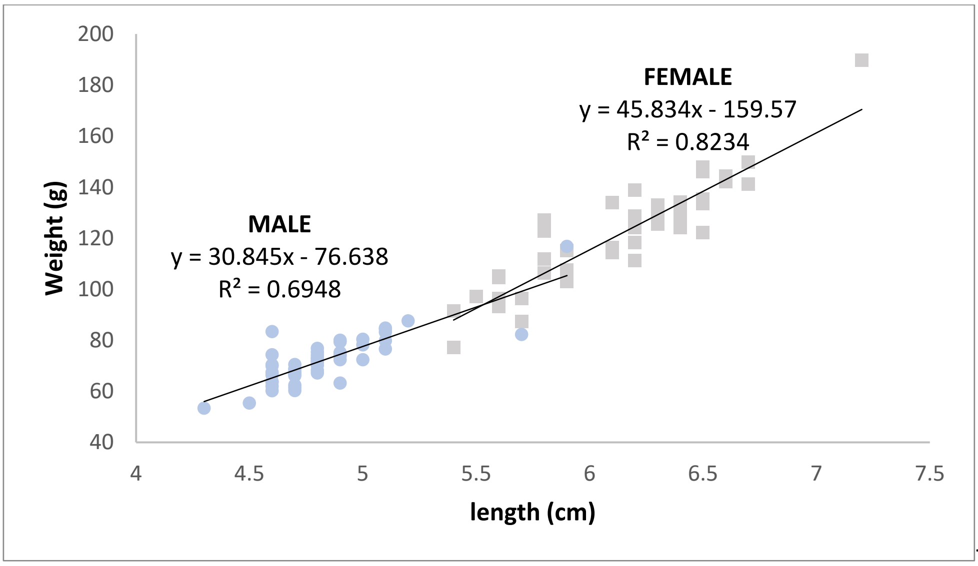

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Fig. 3.12: The length-weight relationship of *P. monodon* in Kuala Baram (n = 95) sampled in August 2019 by Nurridan (2020b).

In general, at the same length, females exhibited higher body length compared to males after the cut-off value of approximately more than 5.5 cm. The higher body weight of females is attributed to the development of gonads for reproduction purposes. However, due to the limited number of specimens and the lack of knowledge on the maturation status of both sexes in the specific area, the exact size at maturity of *P. monodon* from Kuala Baram is still undetermined. To account for the lack of data, we also based on the results of Motoh (1985) where females were sexually mature at the size of 82g BW, 18.0cm TL whereas males mature at 35g BW, 13.4cm TL. The average size between the two sexes, i.e., 60g BW and 15cm TL is then used in this study as the standard for the size at sexual maturity. Therefore, it is proposed the MLS of *P. monodon* at Kuala Baram Refugia is > 30cm TL and > 90g BW. Shrimps caught above this standard should be released to protect the shrimp spawner. However, it is important to note that, in near future, the continuous collection of total length and body weight data, and additional collection of maturation data is important in the consistent monitoring of population health and the estimation of size at sexual maturity of the *P. monodon* population at Kuala Baram.

In addition, based on the results of Nurridan (2020c), the maturation stages of female *P. monodon* at Kuala Baram are similar to other crustaceans and can be divided into five stages. Out of the six survey trips conducted from June to November, females with Stage 4 ovarian maturation stage dominated in the month of August, and the highest concentration of Stage 4 and 5 ovarian maturation stages can be found between August to October (Fig. 3.13).

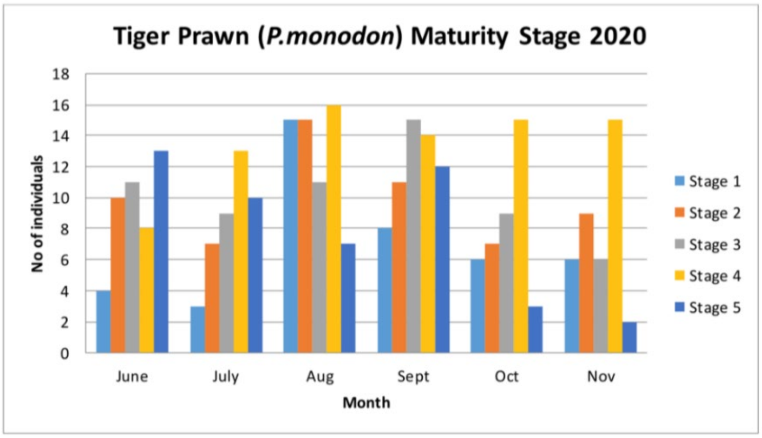

Fig. 3.13: The distribution of maturation stages of female *P. monodon* from June to November 2019 in Kuala Baram, Miri, Sarawak (Nurridan, 2020c).

Therefore, we agree with the suggestion of Nurridan (2020c) to implement closure or other protective measures from August to October to ensure that females are protected during such a high reproductive output period. It is, however, important to note that, future studies that incorporate at least a one-year period with a higher number of individuals and more concrete data should be conducted to provide a solid foundation and support for the identification of the high fecundity period of *P. monodon* in Kuala Baram.

The following is the general conclusion on the findings related size-based capture of *P. monodon* at Kuala Baram, Miri, Sarawak:

- Females exhibited higher body length compared to males after the cut-off value of approximately more than 5.5 cm TL.
- MLS of *P. monodon* from Kuala Baram is **> 30cm TL and > 90g BW.**
- Minimal closure or at least prevent harvest during August to October.

3.4 Revision of Harvest Methods and Gears

3.4.1 Fishing Gears and Trawling Areas

A total of 112 fishers operate drift net, hook and line and trawl net (twin out-rigger) at the coastal waters up to 15NM in Miri. These fishers are from Kampung Kuala Baram, Kampung Pengkalan Lutong, Kampung Pulau Melayu, Kampung Piasau Utara, Kampung Kuala Bakam and Miri town. The number of licenses by zones: C12-30 units; C10-1 units; C7-24 units and the rest (57 units) are traditional operators from Zone's B and A. Local fishermen claimed that the sea off Kuala Baram contributed 70-80% to their income. As shown in Fig. 3.14 below, the survey carried out in 2016 on local fishermen showed that 44% of them has landed *P. monodon* within 3NM; 32% (3-5NM); 13% (5-7NM) and 11% (7-12NM). The survey resulted in 92% of the respondents supporting the establishment of *P. monodon* Fisheries Refugia proposed by the DoF (Norhanida et al., 2020).

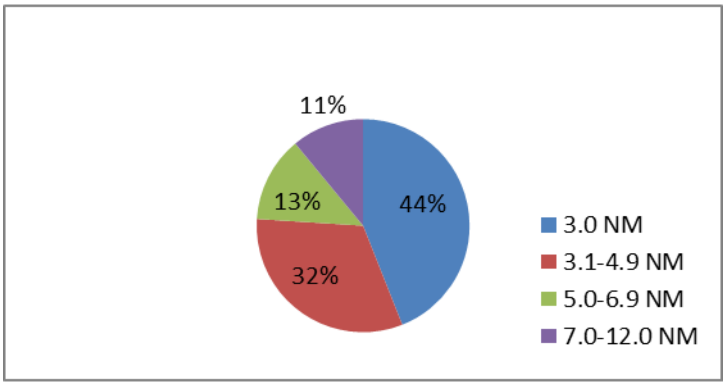

Fig. 3.14: Distant in Nautical Miles (NM) from the coast where local fishermen landed *P. monodon* in their catch from Kuala Baram, Miri, Sarawak.

In Malaysia, the *P. monodon* farming efforts are growing rapidly with increasing involvement from the private sector, government agencies and even individuals. Among the factors that encourage *P. monodon* farming is due to the availability of aquaculture potential areas, high demand, guaranteed good market prices in the country and abroad. Cultured *P. monodon* in the size range of 25-35 pieces per kg fetch a price between RM30 to RM50 per kg.

Shrimp spawners will usually be obtained from identified natural areas. These spawners will be sold to shrimp hatchery and rearing centre operators. And the price of *P. monodon* broodstock (Fig. 3.15) obtained naturally in Sarawak can reach between RM165 to RM180 per piece.

Fig. 3.15: *P. monodon* broodstocks kept in aerated tank ready for hatchery production.

With the new regulation of shifting further up the trawling area to 8NM and above, those areas of less than 6 NM are considered protected from trawling activities where the stations of high concentration of *P. monodon* spawners are in the range of 4.47 – 5.76 NM (Nurridan, 2021a). But, the lucrative nature of the business (Hadil, 2004) encourages encroachment of trawlers to the coastal zone to catch spawners (Fig. 3.16).

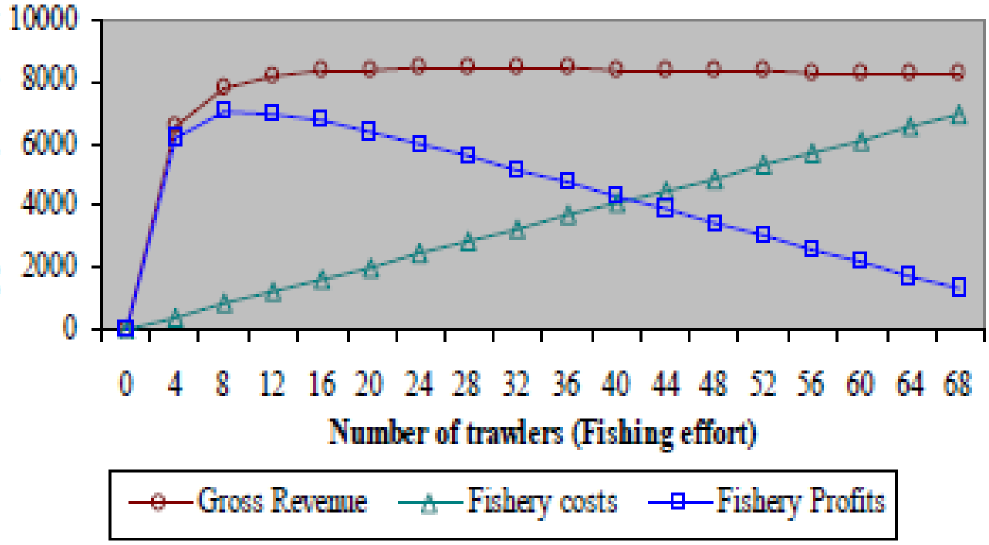

Fig. 3.16: Fishery profit (RM x 1000) and revenue (RM x 1000) versus fishing effort (Hadil, 2004).

The length-based Thomson and Bell yield analysis is used to assess the bio-economics of the *P. monodon* trawl fishery of Kuala Baram (Hadil, 2004). About 18 tonnes of spawners are harvested annually in Miri. The projected optimum annual returns (profits) to 67 local trawlers would be about RM1.4 million or a monthly profit per vessel of about RM2,000 (Fig. 3.16). With 22 trawlers actively targeting for *P. monodon* since the year 1997, the profit will be about RM6,195,500 or a profit of about RM28,161 per month per vessel. The maximum profit of about RM7 million could be attained if the effort level is at 8 vessels.

The maximum sustainable yield, MSY for the tiger shrimp resource of the proposed refugia area was estimated at 23 tonnes (Hadil & Mushidi 2014). The number of spawners estimated at MSY was 46,819 and 88,460 tails for male and female shrimp respectively. In term of aquaculture potential, a Nucleus Breeding Centre (NBC) can be set up in Miri to produce Specific Pathogen Free (SPF) fry. With the available natural spawners, it was projected that about 22 million of SPF fry can be produced annually valued at RM1.32 million. These SPF fries can then be cultured for grow-outs in ponds throughout the country. Further to this development, Broodstock Multiplying Centre (BMC) can also be set up in Miri to rears shrimp SPF post larvae up to adult broodstock for supply to hatcheries. It was envisaged that about 30,000 SPF spawners can also be produced annually with an estimated value of RM9 million at a price of RM300 per tail.

The problem of over-exploitation of the *P. monodon* resource is aggravated by the deployment of destructive fishing gears such as beam-trawl and mechanized push net in the coastal shrimp nursery areas. Shrimp nursery area in the riverine ecosystem is also affected by deforestation of mangrove area for development and housing.

3.4.2 Harvest Strategy

The harvest strategy is required to be responsive to the state of the stock and should be designed to achieve the stock management objectives reflected in the Limit Reference Points (LRPs). The LRP are maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it might endanger the capacity of self-renewal of the stock (Cadima, 2003). The primary strategy would be to introduce measures that would reduce fishing capacity by 50% through limited access and the use of rights-based approaches in small-scale fisheries. Among the measures suggested are:

i. Spatial & temporal closure of the refugia Area B (marine)
ii. Reduce of the number vessels and gears licensed
iii. Prohibiting the use of destructive fishing gears
iv. Spatial closure for Area A (riverine)
v. Prohibit the distribution and selling of all live stages and gravid females without license
vi. Vessel monitoring system, VMS mandatory for every vessel
vii. Establish a Fisheries Management Plan, FMP Division in the Fisheries Department
viii. Establish Monitoring, Control & Surveillance, MCS enforcement groups.

Gonad study was undertaken to determine the breeding season of *P. monodon* at Kuala Baram, Miri, Sarawak. Gonad maturation Stage 4 started to increase from July to Nov 2020, with the peak in August (Nurridan, 2021c). The results indicated peak breeding season during the July-August period when the percentage of Stage 4 gonad was the highest (Fig. 3.13). This maturation trend is similar to the findings in India that suggest fully mature ovaries occur throughout the year with August and March as peak spawning months (Kannan et al., 2014). In Kuala Baram, spawning season for *P. monodon* starts from July to November each year with August being the highest month (Nurridan, 2021c). To protect the gravid shrimp from being caught and overexploited, it is suggested that August to October as a closed season for trawling but other licenced gears are allowed to operate in the area.

The spatial and temporal closure of the fisheries refugia from August to October is to safeguard *P. monodon* spawning aggregations which eventually will lead to increase recruitment levels of their juveniles. This spatial management of fishing effort can be used to avoid catching undesirable size classes for target species, and improve yield-per-recruit for the exploited stock. Many highly targeted seasonal closures during the critical periods have proven to be effective management options (Kripke & Fujita, 1999). However, increased in fishing activities after the closure period must be managed accordingly to avoid sudden fishing pressure to the protected fish stock (Beets & Manuel, 2007; Colwell et al., 2018; Sys et al., 2017). Adaptive management of closures has often been proposed to more effectively utilize spatial management. Seasonal closure as a form of fisheries management must be accompanied with other forms of management measures such as gear, effort, capacity restrictions and catch quotas (Erisman et al., 2017; Halliday, 1988; Watson et al., 1993) So, to further maintain the exploitation *P. monodon* resource at sustainable level, other measures that should be implemented are:

Restriction of prohibited fishing gears. These include trawl net, beam trawl and mechanized push net. This effort is to prevent the capture of individuals below size at maturity (post-larve & juvenile shrimps). Shrimps grow rapidly in the estuarine nursery and then migrate to the sea during the late juvenile stage, where they persist briefly within inshore waters, before gradually moving offshore to spawning grounds where they grow and mature. In nature *P. monodon* attains full maturation and spawns for the first time at 10 months (Motoh, 1981).

Consequently, there is a general spatial gradient in shrimp size, with size increasing from estuaries to offshore. It is during this migratory phase that most fishing mortality occurs. Modelling suggested that yield from shrimp stock could be increased by reducing fishing effort and increasing the size at first harvest (Die & Watson, 1992).

Spatial closure for fisheries refugia Area A (or a permanent legislated fishery closure as nursery grounds) and prohibit land-based activities 200m from the river to protect post-larvae and juveniles. Similarly, continual closure of the shrimp nursery area in the 1NM conservation zone from the beach to fishing activities. *P. monodon* should be protected during their inshore phase by extensive spatial management arrangements. For example, in the case of Eastern king prawn of New South Wales, Australia (Roelofs & Taylor, 2021). These closures were legislated in the late 1990s and early 2000s, and are positioned adjacent to the mouths of estuaries to protect juvenile Eastern king prawn during their rapid growth phase within inshore waters. The goal is to reduce growth overfishing and increasing overall yield and value by partially restricting harvest of concentrations of smaller-sized animals.

Prohibit the distribution and selling of all live stages and gravid females without license in order to prevent smuggling of these spawners. Licenses or permits for buying wild spawners with accreditation from local fishermen's associations are necessary in monitoring wild spawner catches and movements. Spawners (FAO, 2005) in the size range: female 22-30cm Total Length (200-320g) and male 20-25cm Total Length (100-170g) can be collected for the purpose of aquaculture and research development and that permits can be issued by the DoF, Malaysia.

It is mandatory for every vessel to be equipped with a Vessel Monitoring System (VMS), so that there is an improvement in VMS control as well as its reporting. A Fisheries Management Plan (FMP) Division should be established in the DoF, Malaysia as well as an advisory group from stakeholders. Last but not least, Monitoring, Control and Surveillance, (MCS) enforcement groups in all stakeholder agencies should also be established to further oversee the implementation of the *P. monodon* Fisheries Refugia in Kuala Baram, Miri.

4.0 Communication Plan for Refugia Fisheries

4.1 Objectives of Communication Plan

Kuala Baram, Miri is known for the abundance of wild *P. monodon* populations, providing important food resources and employment opportunities, especially to the coastal communities and the fishery sector of Malaysia in general. Most of the fishermen that are involved in the harvest of *P. monodon* are small-scale fishers that operate along the coastal zones and utilize traditional gears, although there are also some fishermen that operate trawlers and purse seine in deeper off coastal zones of more than 5 Nautical Miles. Therefore, a careful communication plan is essential to ensure success of the fisheries refugia which lead to sustainable fishing at the area. Stakeholders play a critical role in ensuring the success of the establishment and sustainability of fisheries refugia. It is essential that these groups are involved at every stage of the fisheries refugia development process to ensure that the perspectives, ideas, knowledge, and support from all parties are being considered. Furthermore, research has proven that appropriate and meaningful discussion and engagement with relevant stakeholders lead to better decision-making, higher compliance with the suggested rules and regulations, and more self-sustainable management activities.

4.2 Stakeholder Engagement

Stakeholder engagement is an ongoing process of involving all related and interested stakeholders/parties in all processes of fisheries refugia development, establishment, implementation, assessment, and maintenance. In these recent years, fisheries refugia and protected areas have shifted from a state- or government-dominated protected towards a more holistic community-based and multi-stakeholder co-management process to ensure inclusivity of all parties (Katikiro et al., 2021).

The establishment of fisheries refugia requires the combined effort from various stakeholders such as the Persatuan Nelayan Kawasan (Area Fishermen Association), Sarawak Trawlers Association, shrimp farm owners (with hatcheries facilities), NGOs, industrial players, the state government and Jabatan Alam Sekitar (JAS), Angkatan Penguatkuasaan Maritim Malaysia (APMM), Jabatan Perhutanan Sarawak, and DoF itself. On the other hand, public participation and the active involvement of community players are critical to ensure the successful implementation and sustainability of any fisheries refugia management plan.

To ensure a holistic review of the available literature, we searched through public databases such as Web of Science and Scopus for papers detailing the establishment and assessment of fisheries refugia and Marine Protected Areas (MPA). MPA were included to serve as baseline knowledge as MPAs also involve multi-stakeholders in all stages of their development, from planning to implementing. From the available literature, we determined the important criteria that would lead to the success of marine zone management activities. Specifically, important criteria that should be included in the establishment of Kuala Baram fisheries refugia regarding stakeholder engagement were highlighted.

According to the findings, the main stakeholders will be the fishermen's community, a critical player that will play a vital role in ensuring the success of this refugia project.

- In Malaysia, fishermen are being registered and monitored under the Area Fishermen Association (Persatuan Nelayan Kawasan).
- It is a multi-purpose cooperative that provides a much-needed platform for fishermen to voice their opinions, in addition to handling various administrative and commercial-related activities such as marketing, input supply, insurance, educational activities etc.

In addition to the fishing communities, another important player in the establishment of the Kuala Baram *P. monodon* Fisheries Refugia would be the government sector, specifically the DoF, Malaysia and its subsidiary Fisheries Research Institute (FRI). The DoF, Malaysia is a core stakeholder of this project as it holds vital monitoring, regulatory and advisory role in the *P. monodon* fishery and harvest activities. Studies have shown that although many MPA and fisheries refugia in developing countries are still being governed under a monocentric organizational structure, which provides a clear authority and jurisdictional clarity (Cinner et al., 2012), the lack of involvement of multi parties/stakeholders limits the collaborative synergies and the incorporation of resources, capacities and knowledge from other actors (Katikiro et al., 2021).

A stakeholders' engagement with other relevant stakeholders, including Miri Port Authority, Sarawak Fishing Vessel Association, Department of Marine Fisheries, Sarawak, Sarawak Forestry Corporation, Miri Area Fishermen Association, Department of Irrigation and Drainage, Miri, and Sarawak Rivers Board was held on 23rd September 2021 and 21st October 2021, chaired by the Director of Department of Marine Fisheries, Sarawak. The full report of the engagement session can be found in the report of the DoF, Malaysia (2021). Based on the report, all stakeholders understand the importance of the establishment of *P. monodon* fisheries refugia to safeguard the wild *P. monodon* populations at Kuala Baram, Miri, Sarawak.

To facilitate and revalidate the proposed management plan, a direct consultation/engagement with all stakeholders, including the DoF and Area Fishermen Association, Miri was conducted on 11-13 May 2022. A direct consultation/engagement method was selected as this will ensure an accurate representation of information from all relevant authorities and parties, and also owing to the scarce data available in the public domain. In addition, stakeholders, particularly fishermen, will feel more comfortable and more ready to collaborate in a relaxed setting and face-to-face nature. Moreover, this allowed all parties, especially the consultancy group members, a chance to visualize the site location and the local communities in person. Such engagement opportunity will be critical for the upcoming workshop and future engagement activities. The engagement sessions conducted during this consultancy are outlined in Chapter 7.

As a general conclusion, stakeholder engagement is essential in all stages of the planning, establishment, and implementation of the Kuala Baram fisheries refugia. Among the identified stakeholders include the local community – *P. monodon* fishermen, DoF (both state and federal), Southeast Asian Fisheries Development Centre (SEAFDEC), Miri local based oil operators, and local *P. monodon* farmers.

4.3 Proposed Monitoring and Management Plan for Fisheries Refugia

To gain trust and support from the community for the management of *P. monodon* fisheries refugia, transparency in the regulation and enforcement, and awareness on the importance of fisheries refugia should be conducted. These aspects include management regulations, the importance of enforcement, the general biology and life cycle of *P. monodon*, the long-term benefit of fisheries refugia, and the responsibility of all stakeholders to safeguard its population. Such strategies would ensure voluntary participation from all stakeholders and self-governance of the fisheries refugia program in the long run.

The management and monitoring plan reflected the impact of the fisheries refugia on the target species, the *P. monodon*. The following described the proposed management and monitoring plan of *P. monodon* fisheries refugia at Kuala Baram.

- This fisheries refugia aligned with law enforcement (main habitat protection/restriction of the fishing area) and public awareness program (promoting conservation programs and sustainable fisheries at certain season or size) to protect the selected area and the population of the target species.

- Monitoring of the *P. monodon* population were proposed to be done in every six months after the development of the fisheries refugia. During the monitoring process, the biological parameters such as Body Weight (BW), Total Length (TL), maturation stages, sexual ratios and water quality parameters were proposed to be collected to assess the population of the *P. monodon*. BW will be determined individually by the method described by Motoh (1985) while TL of individual shrimp will be measured from tip of the rostrum to the telson using vernier caliper (Motoh 1985). Females of *P. monodon* are categorised as non-spawning or spawning based on their ovaries. Study by Kannan et al. (2014), shows that there are four stages of ovarian maturation and for more details please refer to the previous Sub-chapter 2.1.2. The sexes of *P. monodon* are distinguished by the external morphology of their reproductive organs namely petasma and a pair of appendix masculine in male and thelycum in female. The petasma is situated between the 1st pleopods and the appendix masculine on the exopods at the 2nd pleopods. Thelycum is presence between the 4th and 5th pereopods of female shrimp (Motoh, 1985). *P. monodon* has closed thelycum type and for a "closed" thelycum, the thelycum is enclosed by exoskeleton plate.

- Frequent monitoring of the protected area was proposed to avoid law violation or fisheries refugia invasion by the fishermen.

- We have also included and considered the previously decided decisions by the DoF in the current proposal of the monitoring and management plan for the Kuala Baram *P. monodon* Fisheries Refugia.

To ensure that the establishment of refugia was comprehensive, the four components for refugia establishment identified by Mohd Ghazali (2016) were used, which include:

- The identification and management of fisheries and critical habitats.

- Improvement of the management of critical habitats for fish stocks of transboundary significance via national actions based on knowledge-based management.

- Information management and dissemination in support of the national level implementation of the concept of fisheries refugia.

- National coordination for integrated fish stocks and critical habitat management.

Public awareness and education of the coastal community, fishermen and other stakeholders about the biology, ecology, life cycle and hatchery production of *P. monodon* is important for them to understand deeply on this species. Promoting the local shrimp farm to use the local broodstocks (provided or approved by the DoF only) is also important to ensure the sustainability of the marine environment and promote increment of the *P. monodon* population in the wild from the conservation program or the accidental release of the post larvae to the wild. Besides that, public awareness programs such as conservation and sustainable fisheries programs involving the release of the post-larvae by the stakeholders and the implementation of the size-based fishery should also be considered to ensure that the stakeholders understood the importance such approaches in sustainable fisheries. However, these two approaches are limited to the stakeholders with hatchery facilities (conservation program) and small-scale or coastal fishermen only (using the net). The big-scale fishermen with trawling equipment are unable to select the shrimp based on the sex or size due to the abundant captured shrimps at one time. Based on this situation, protection of certain fishing areas is the best way to avoid the continuous decrease in the *P. monodon* population over time.

The specific protected areas should be implied in the law to ensure there are no invasion and fishing of *P. monodon* in the protected area or fisheries refugia. Law enforcement on the invasion of fisheries refugia is important to preserve the area for *P. monodon* to reproduce and grow up. This fisheries refugia will be the specific breeding sites of the *P. monodon*, which will benefit the surrounding areas outside of the fisheries refugia. Fishermen can still catch the *P. monodon* outside the fisheries refugia area as the larvae of the shrimps will disperse all over the place.

Monitoring of the protected area can be done by the stakeholders involves in this fisheries refugia project such as the DoF and the coastal communities. Frequent monitoring can be made by DoF to ensure the safety of the fisheries refugia. In short, it can be divided into two main sections;

1. A baseline scientific and technical personnel level for data verification and suggestion

2. And the subsequent policy/law and decision makers level, where suggestions from the various scientific and technical communities will be incorporated into policy/law (Fig. 4.1).

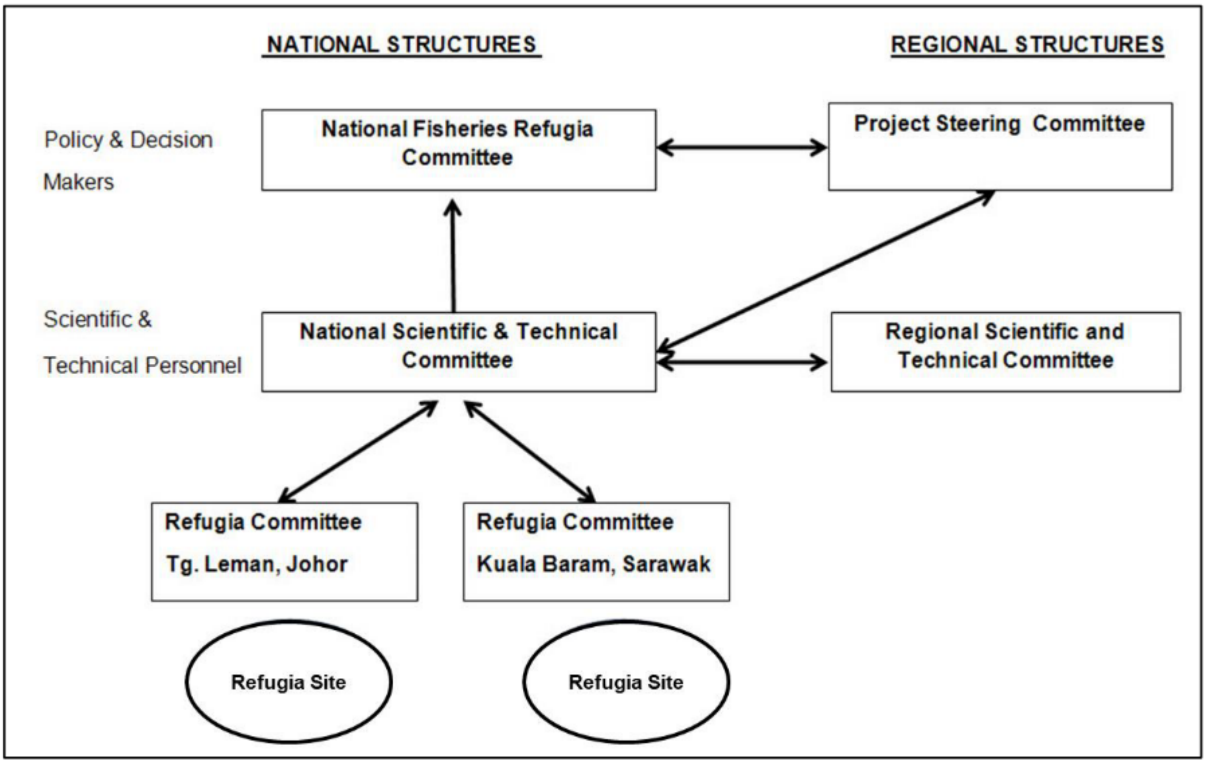

Fig. 4.1: The coordination mechanism for the establishment of fisheries refugia in Malaysia (Siow et al., 2020).

A similar coordination mechanism is used in the establishment of fisheries refugia of *P. monodon* in Kuala Baram, Miri, Sarawak, and Mud spiny lobster in Tanjung Leman, Johor. Since fisheries refugia are defined as "marine or coastal areas in which specific management measures are applied to sustain important species during critical stages of their life cycle, for their sustainable use", the identification and securing of habitats rely heavily on local knowledge and co-management. Therefore, the DoF brought together all stakeholders, and based on the previous engagement session (DoF, 2021), where all stakeholders agreed with the proposal of the *P. monodon* fisheries refugia establishment.

Below are some of the agreed highlights during the engagement session:

1. August to October will be regulated as the closed season for *P. monodon*.

2. This regulation is applicable to all trawlers in Zone C7. All fishing activities by the trawlers must operate at a distance of 12 Nautical Miles from the shoreline.

3. 2021 was the first year of the implementation of this regulation.

4. The department also encourages the fishermen to comply with this regulation voluntarily for this year. In the year 2023, the department will fully enforce these regulations.

5. For *P. monodon*, specifically for Kuala Baram, the close season from August to October will be included as an additional clause in the Vessel License and Fishing Equipment for fishermen's Zone C7.

To ensure the success of this plan, proper monitoring and management are essential in each stage of project including planning, establishment, and implementation. Monitoring and management plan involving all the stakeholders in public awareness program (conservation and sustainable fishery) and protected area, and law enforcement and frequent monitoring of the *P. monodon* population is essential to ensure the effectiveness and success of the fisheries refugia project.

5.0 Financial Implication

The coastal area is the meeting point of land and sea (Rosly et al., 2020; Longhorn, 2004). Except for Laos, all of Southeast Asia's countries are sea-bound. Coastal areas all around the world are dynamic ecosystems that exist at the intersection of terrestrial, marine, and freshwater systems. Oceans enable life and provide a living for billions of people. Nearly 2.4 billion people, or 40% of the world's population, now reside in these places (United Nations, 2017; Milon & Alvarez, 2019). Maintaining a balance between ecological and economic needs is essential to the idea of a sustainable ocean economy (Tirumala & Tiwari, 2022). However, the effects of human activity on the planet's natural ecosystems are accelerating alarmingly. The condition of the oceans, the greatest natural system on the planet, is quickly declining. Marine pollution is mostly caused by the discharge of chemicals and debris from land-based sources into the oceans. Climate change, environmental degradation, unsustainable fishing, and unchecked coastal expansion are other factors that have an impact on the oceans and pose a serious threat to marine life and ocean productivity (Tirumala & Tiwari, 2022). Coral reef loss has increased by almost 50% in the last three decades, and if it continues at this rate, this unique ecosystem is expected to disappear by around 90% by 2050 (Becatoro, 2017). Marine life is negatively impacted when plastic bags, fishing nets, and other trash are dumped into the ocean. Each year, these are the unnatural causes of death for a significant number of seabirds and sea turtles. These substances enter the food chain through the seafood chain and present significant health risks when consumed by human beings. The daily use of chemicals, including household cleaners, poses a threat to about two thirds of marine life (Tirumala & Tiwari, 2022). Therefore, the sustainable use and conservation of marine and coastal biodiversity is important in this current era. In order to achieve sustained ocean health and governance and a sustainable ocean economy, there must be sufficient financing mechanisms that generate, invest, align, and account for financial capital.

Globally, the health of marine and coastal ecosystems is in decline. Ecosystem collapse is occurring in all of the world's main coastal and ocean regions as a result of overfishing, runoff of fertilizers and other land-based pollution, habitat loss, and the escalating effects of climate change (Green et al., 2011; Hughes et al., 2005). Therefore, sustainable development of coastal and marine environments has grown to be a top priority due to growing economic development demands, as evidenced by the 1992 Rio de Janeiro United Nations Conference on Environment and Development (UNCED) (Cicin-Sain et al., 1995; Kong et al., 2021; United Nation, 1992) and to sustain the marine resources, the government also implemented variety of initiatives, one of which is the sustainable financing of marine resources. As a crucial element of all facets of sustainable development initiatives, sustainable financing mechanisms place more emphasis on institutionalizing measures and funds to protect environmental conservation and environmental infrastructure improvements and also considering policies and programs lay in place to improve the climate for public and private sector financing of coastal management activities (Kong et al., 2021). Moreover, Wiederkehr et al. (2019) stated that any conservation gains are likely to be lost without maintaining competent conservation management if sustainable financing is not guaranteed. Volatility in funding has a significant impact on conservation outcomes.

5.1 Economic Analysis

P. monodon is a species of marine shrimp that gives a good return and has high economic potential. In 2021, 1,418 metric tons of *P. monodon* was landed along Malaysian waters and marketed at an average price of RM45.48 per kilogram. The price of *P. monodon* is the second highest after lobster, which is RM72 per kilogram. Most of this species landed in the waters of Sabah, Labuan, and Sarawak, at 871 metric tons, followed by the West Coast and East Coast of Peninsular Malaysia at 343 and 204 metric tons, respectively.

Various efforts have been planned and implemented to preserve the resources of this species, such as the establishment of a *P. monodon* Fisheries Refugia in Kuala Baram, Miri, Sarawak. The *P. monodon* landings in Miri from the year 2010 to 2021 were recorded as 109.6 metric tons at a value of RM4.8 million. Year 2020 recorded the highest catch value of RM572,960, with a total catch of 12.1 metric tons. While the year 2015 recorded the highest amount of catch which was 22.2 metric tons at a value of RM471,985. Landing data and sales value like this is beneficial as a guide to designing and implementing conservation programs to strengthen the resources of fishery species such as *P. monodon*.

Therefore, time series data analysis that includes modelling and forecasting is very important in an organisation. Managers, researchers and planners need to have forecast values or at least the future trend in order to make decision on future plans or policy actions. This report will present the findings of the forecast value of landings and sales of *P. monodon* for 60 months from January 2022 to December 2026. This forecast is made based on time series data from 2010 to 2021.

The ARIMA model developed by Box and Jenkins is the widely used tool for modelling and forecasting univariate time series. Generally, it can analyse both non-seasonal and seasonal series. The ARIMA models are simple yet it can produce good short-term forecast. Theoretically, this procedure works well for sample size larger than 50 observations. Hence, if we are using monthly data, the minimum data set should span for a period of at least 5 years.

However, when there are irregularities and a lot of fluctuations in the data set, ARIMA models might give poor forecast values. Hence, more accurate tools are required to meet these challenges.

In this analysis, the most recent time series data analysis and forecasting tool is used. It is developed in July 2022 by Dr. Ranjit Kumar Paul, Mr. Sandipan Samanta and Dr. Md Yeasin. The title of the package is "Wavelet-ARIMA Model for Time Series Forecasting". It is an algorithm developed using a hybrid of Wavelet and ARIMA model for forecasting.

To illustrate the path of future landings and sales trends, the original time series together with the forecasted values are plotted and are shown in Fig. 6.1 and Fig. 6.2. Note that the vertical red line indicates the end of the sample periods and the beginning of forecasting periods.

Next, we estimate the long-term trend for the 60 month's forecasted values using the Wavelets ARIMA procedure for landings and sales. The explanations of the results for landing and sales are given below.

5.1.1 *P. monodon* Landings

The 12-, 24- and 60 month's forecasted values for landings are 0.91, 0.89 and 0.92 tonnes, respectively. As can be seen from these values, there is no significant increase in landings tonnage over the 5 years span.

Next, we perform linear regression analysis on the 60 month's forecasted values to estimate the average increment. The results are given below.

Landing = 0.86 + 0.001*t

t = 1,2...60

R-squared = 0.10

Hence, we expect on average there is an increase of 0.001 (1 kg) per month in the future (5 years) landings.

In conclusion, the long-term trend for landings is estimated to be constant at 0.86 tonnes, since there is no significant increase per month in the future landings over the 5 years period ahead.

5.1.2 *P. monodon* Sales

The expected future monthly sales for the 12-, 24- and 60 month's forecasted values are RM46.99, RM48.51 and RM48.78 per kg respectively. There is no significant increase in sales over the 5 years span. The results for linear regression analysis on the 60 month's forecasted values are given below.

Sales = 46.32 + 0.039*t

t = 1,2...60

R-squared = 0.14

The long-term trend for sales is estimated to be constant at RM46.32, since there is only RM0.039 increase per month in the future sales over the 5 years period ahead.

Fig. 5.1 and Fig. 5.2 show that the long-term trends of the 5 years forecasts for both landings and sales in Miri are constant.

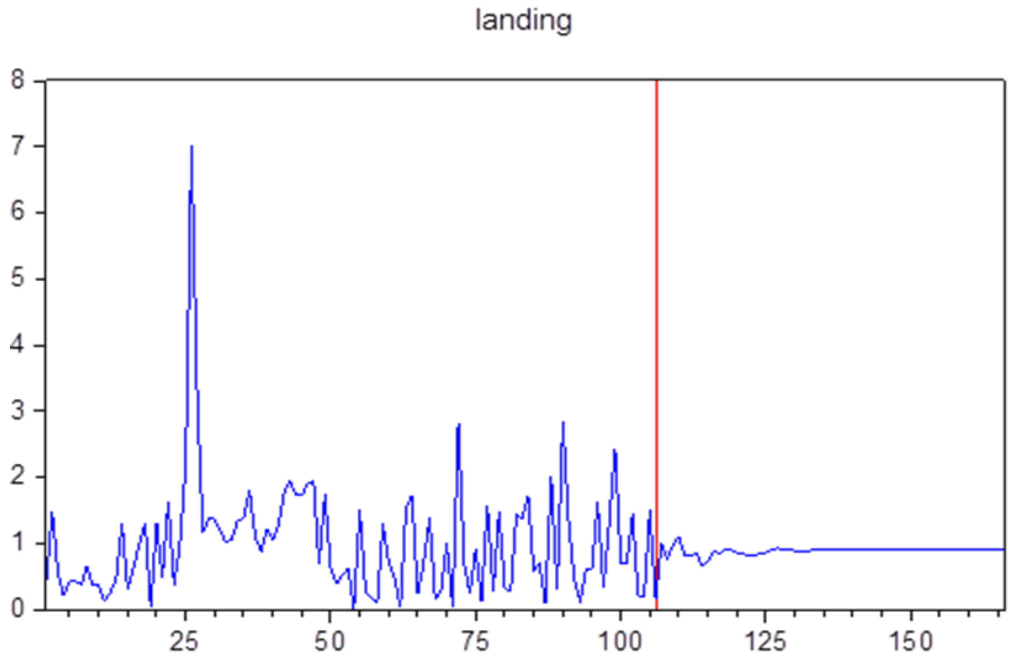

Fig. 5.1: Time series plot of *P. monodon* landings with forecasted values for Miri.

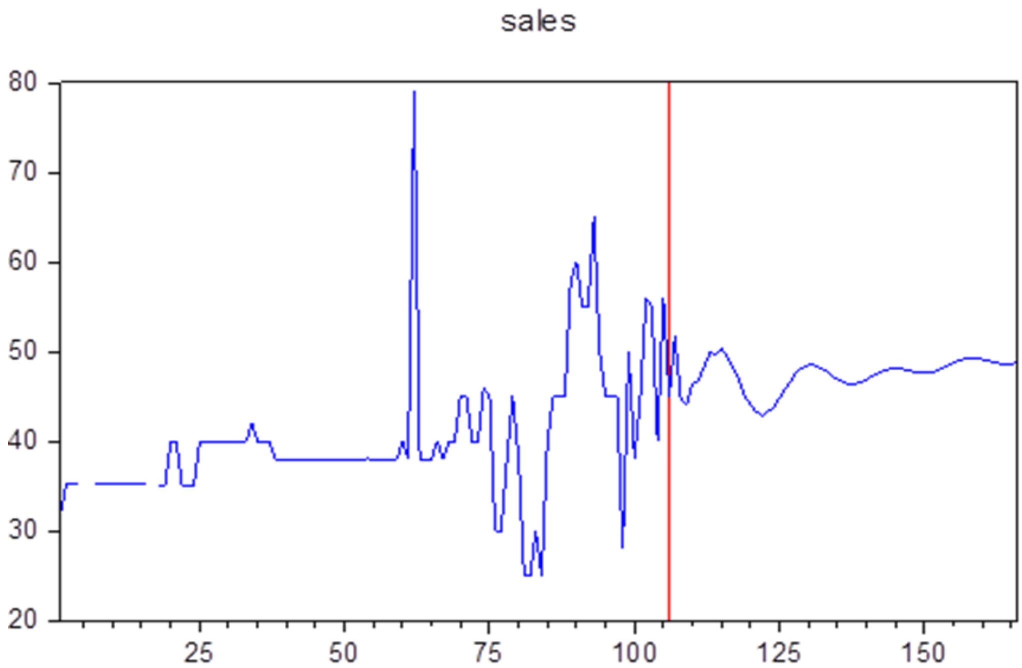

Fig. 5.2: Time series plot of *P. monodon* sales with forecasted values for Miri.

Table 5.1: 60 months forecast for *P. monodon* landings

No.	Month-Year	Forecast Value
1	Jan-22	1.0068
2	Feb-22	0.7701
3	Mar-22	0.9832
4	Apr-22	1.1008
5	May-22	0.8050
6	Jun-22	0.8093
7	Jul-22	0.8639
8	Aug-22	0.6510
9	Sep-22	0.7330
10	Oct-22	0.8774
11	Nov-22	0.8484
12	Dec-22	0.9080
13	Jan-23	0.9128
14	Feb-23	0.8570
15	Mar-23	0.8456
16	Apr-23	0.8045
17	May-23	0.8191
18	Jun-23	0.8609
19	Jul-23	0.8648
20	Aug-23	0.9097
21	Sep-23	0.9280
22	Oct-23	0.9028
23	Nov-23	0.9048
24	Dec-23	0.8891
25	Jan-24	0.8733
26	Feb-24	0.8881
27	Mar-24	0.8942
28	Apr-24	0.9069
29	May-24	0.9211
30	Jun-24	0.9163
31	Jul-24	0.9140
32	Aug-24	0.9070
33	Sep-24	0.8957
34	Oct-24	0.8975
35	Nov-24	0.8994
36	Dec-24	0.9033
37	Jan-25	0.9123
38	Feb-25	0.9140

39	Mar-25	0.9139
40	Apr-25	0.9131
41	May-25	0.9083
42	Jun-25	0.9072
43	Jul-25	0.9080
44	Aug-25	0.9093
45	Sep-25	0.9136
46	Oct-25	0.9162
47	Nov-25	0.9171
48	Dec-25	0.9177
49	Jan-26	0.9160
50	Feb-26	0.9146
51	Mar-26	0.9143
52	Apr-26	0.9142
53	May-26	0.9155
54	Jun-26	0.9170
55	Jul-26	0.9177
56	Aug-26	0.9182
57	Sep-26	0.9178
58	Oct-26	0.9170
59	Nov-26	0.9165
60	Dec-26	0.9162

Table 5.2: 60 months forecast for *P. monodon* sales

No.	Month-Year	Forecast Value
1	Jan-22	51.7231
2	Feb-22	44.8654
3	Mar-22	43.9971
4	Apr-22	46.4257
5	May-22	46.6795
6	Jun-22	48.2979
7	Jul-22	49.8845
8	Aug-22	49.7495
9	Sep-22	50.4102
10	Oct-22	49.3808
11	Nov-22	48.1056
12	Dec-22	46.9968
13	Jan-23	45.0950
14	Feb-23	44.1736
15	Mar-23	43.2912

16	Apr-23	42.8794
17	May-23	43.3210
18	Jun-23	43.7532
19	Jul-23	44.7854
20	Aug-23	45.8469
21	Sep-23	46.7537
22	Oct-23	47.7176
23	Nov-23	48.2034
24	Dec-23	48.5066
25	Jan-24	48.5251
26	Feb-24	48.2058
27	Mar-24	47.8562
28	Apr-24	47.3495
29	May-24	46.9066
30	Jun-24	46.6056
31	Jul-24	46.4006
32	Aug-24	46.4396
33	Sep-24	46.6068
34	Oct-24	46.8954
35	Nov-24	47.2725
36	Dec-24	47.6067
37	Jan-25	47.9049
38	Feb-25	48.0873
39	Mar-25	48.1401
40	Apr-25	48.1012
41	May-25	47.9670
42	Jun-25	47.8170
43	Jul-25	47.6933
44	Aug-25	47.6352
45	Sep-25	47.6913
46	Oct-25	47.8497
47	Nov-25	48.1058
48	Dec-25	48.4222
49	Jan-26	48.7427
50	Feb-26	49.0278
51	Mar-26	49.2259
52	Apr-26	49.3152
53	May-26	49.2939
54	Jun-26	49.1750
55	Jul-26	49.0011
56	Aug-26	48.8162

57	Sep-26	48.6696
58	Oct-26	48.6037
59	Nov-26	48.6399
60	Dec-26	48.7847

5.2 Socio-economic and Environmental Returns

This section focuses on the returns to the social, economic and environment from the marine protected area, refugia as well as marine reserve area. The returns can be measured by using the economic valuation method that takes into account all the returns from socio-economic activities as well as the impacts to the environment. Economic valuation is significant because it provides methods and techniques for determining how changes in coastal and marine ecosystem services translate into societal benefits and costs. Economic values are significant in daily life because they give useful information regarding human satisfaction and welfare. Valuation provides a consistent framework for understanding human–nature interactions across a wide range of coastal and marine resources as well as assessing the sustainability of these relationships (Milon & Alvarez, 2019). It is becoming increasingly clear that including an economic approach to ecosystem management is critical for preserving the flow of essential commodities from marine ecosystems (Farber et al., 2006; Teh et al., 2018). Quantifying the economic value of ecosystems to social and economic wellbeing allows for informed trade-offs in conservation planning, possibly improving stakeholder buy-in and leading to more effective marine management.

Marine biodiversity, one of the most established research disciplines in environmental science in general and ocean science in particular, embraces a wide variety of regional and temporal dimensions for examining patterns of change in marine biodiversity globally (Tolochko & Vadrot, 2021). Marine biodiversity is important for the structure and functioning of ocean ecosystems, as well as for delivering the complete spectrum of ecosystem services that benefit people on local, regional, and global scales (Lotze, 2021). Thus, to analyse the economic value of marine biodiversity resources, we separated marine biodiversity into two categories: marine resources and mainland socio-economic resources.

Protecting marine megafauna from human impact is a global conservation priority. Marine turtles in Sabah still face substantial threats from illegal hunting and human activities, including incidences of mass killings for unknown reasons and smuggling. Therefore, Teh et al. (2018) paper did about an economic approach to marine megafauna conservation in the coral triangle. Acceptance, involvement, and buy-in from resource stakeholders are required for successful conservation, which is frequently difficult to obtain. Therefore, their research determines the total economic value that sea turtles have on Semporna, Sabah's fishing villages.

Another marine resource focused on in this study is coral reefs. Malaysia has around 4,006 km2 of coral reefs, with over 550 species contributing to the nation's economy, while coral reefs in Malaysia are under threat. The poor to fair state of Peninsular Malaysia's coral reefs is owing to increased sedimentation and tourism impacts. Overfishing and fish blasting were the two most serious threats to coral reefs in Sabah. Coral reefs in Sarawak are endangered by heavy sedimentation and sand mining. Therefore, Praveena et al. (2012) reviews studies on coral reefs, dangers, and the aquatic environment in Malaysia.

Furthermore, Akhter (2014) study also chose coral reefs as the focus of their marine resources study. They conducted their research on the Pulau Perhentian Marine Park (PPMP), which is one of the most stunning coral reef islands in Malaysia. However, because of the quick growth of tourism, pollution and resource exploitation have escalated. Marine Park was established to protect coral reefs and the flora and wildlife that go along with them, but because of lax enforcement, resources are being damaged. As a result, the primary objectives of this research are to evaluate the activities that negatively impacted the environment and resources at PPMP and to propose corrective measures to stop further degradation.

An estimated 500,000 people worldwide participate in the rapidly expanding tourism sector of shark diving each year, and the research study of Vianna et al. (2018) chose shark populations as their focus of marine resources. Therefore, poll of consumers' willingness to pay was conducted to determine the industry's viability as a source of funding for the administration and enforcement of a fictitious Marine Protected Area (MPA) intended to protect shark populations. Faizan (2014) study also focuses on the impact of anthropogenic pressure on coral reefs around Cape Rachado, Malacca. Coral reef management practices are essentially nonexistent in these regions, leaving the reefs vulnerable to several stresses brought on by the fast growth of the nearby coastal areas. This means the biggest barrier to managing and conserving this vulnerable yet significant resource is the lack of adequate funding due to a lack of knowledge about the true economic value of coral reef ecosystems. Therefore, focusing on coral reefs, they performed their research and study to determine the economic benefits of better coral reef management in Fisheries Prohibited Areas (FPAs).

While for the mainland socio-economic resource, Arabamiry et al. (2013) analysed the Marine Park Visitors' Trade-off among Marine Ecological Attributes in Terengganu, Malaysia. Perhentian Island Marine Park was the study site for this research. Human activities on the islands, such as sewage and mechanical damage (e.g. submarine freshwater pipelines), have also affected the coral life and water quality. Moreover, the felling of trees causes a reduction in coral growth due to rain water that carries fine soil into the coastal zone, whereby sediment prevents light from reaching the benthos, resulting in a high concentration of sedimentation that can kill corals. Therefore, their study's major focus is the economic valuation of ecological function values using ecological features and biophysical indicators.

Zaiton et al. (2019) focused on mangroves as another mainland socioeconomic resource. A mangrove ecosystem provides a variety of services to people, society, and the economy as a whole. Local communities rely heavily on mangrove ecosystems for food, firewood, charcoal, timber, and other resources. However, mangrove deterioration is becoming a major problem due to land conversion for aquaculture and coastal development. As a result, their study employed the contingent valuation method (CVM) to estimate the economic value of an ecosystem by polling people on their willingness to pay for the conservation of mangrove. In addition to serving as fishing grounds, the protected coral reefs off the coast of Malaysia are also a reason for being visited by many tourists. The necessity for more costly conservation measures becomes more pressing as a result of these combined environmental constraints. It seems only reasonable to think about the possibility of expanding the "user pays" idea, which is already in place in the form of different user fees. Therefore, in the Emang et al. (2016) study investigated the possibility of price discrimination among scuba divers at Sipadan in Malaysia.

The public's enjoyment and appreciation of natural resources tends to benefit naturally from the establishment of marine parks. Marine parks support the growth of both ecotourism and tourism. Nevertheless, overuse and environmental degradation have happened as a result of unfettered access to marine park resources and the market system's failure to impose restrictions on their use. The viability of ecotourism may be impacted in the future by the degradation of marine parks. Additionally, consumers don't really cover the full costs of using the natural resources in the marine parks, which contributes to the market failure. Therefore, Yacob et al. (2009) study's objective is to determine the value of ecotourism resources using environmental economic tools, with a particular emphasis on the WTP contingent valuation method.

More specifically, based on the selected articles by using the systematic literature review process, we identify the attribute levels, trade-offs, values, and supporting evidence for conservation and biodiversity maintenance. Teh et al. (2018) developed an economic approach to marine megafauna conservation in the coral triangle. Their study revealed that the total economic value (TEV) of sea turtles was projected to be USD 23 million per year, with a range of USD 21–25 million. In their study, tourists were willing to give USD 1.5 million to sea turtle preservation and conservation each year, which may help support conservation. A scenario study found that if comprehensive turtle protection were implemented today, the discounted TEV of sea turtles could reach USD 716 million over the next 30 years. Meanwhile, Arabamiry et al. (2013) analysed the marine park visitors' trade-off on the marine ecological attributes in Malaysia. They argued that, as per Multinomial Logit Models, the highest degree of visitors' choice for various attribute levels is the coral and water quality. With RM59.5, visitors preferred coral cover improvement from high level (5% to highest level) to highest level (10%) the most. The next marginal value, at RM51.5, was for the increase in water quality from the highest level to the highest level (from 5% to 10%), as well. This economic value contributes significantly to conservation efforts and the preservation of biodiversity.

Instead, Zaiton et al. (2019) scrutinised the conservation of mangroves in Kuala Perlis, Malaysia. It's a case study of socio-economic attributes of fishermen driving valuation in sustaining livelihoods through forest management. Their study was conducted face-to-face interviews among the fishermen. To examine the elements that impacted the fishermen's willingness to pay (WTP) for conservation, a binary logit model, namely the Contingent Valuation Method (CVM), was utilised in their study. Their findings revealed that bid level, education level, and marital status all had a substantial impact on fishermen's WTP. It also demonstrates that socio-demographic characteristics impacted respondents' willingness to pay for environmental conservation. Additionally, as foreseen in the Department of Marine Park Malaysia's strategy plan 2011-2015, the primary focus of the study by Arabamiry et al. (2013) is the economic valuation of ecological function values through ecological features and biophysical indicators (DMPM). This study applying non- market valuation technique which is choice modelling in their study. The Status Quo for cost or entrance fee for Marine Park is RM 5 and the Improvement status is to RM 10, RM 15 and RM 30.

Teh et al. (2011) quantify the overlooked socio-economic contribution of small-scale fisheries in Sabah, Malaysia. Their study concentrates on the small-scale fishing industry in Sabah, Malaysia, and estimates the economic value of these fisheries using a previously rebuilt time series of Sabah's small-scale catches. A fisheries economic multiplier is used to calculate the entire economic impact of small-scale fishing, and it shows that in 2009, unreported small-scale fisheries value could have contributed RM 1.36 billion, or 4% of Sabah's GDP, to the Sabah economy (GDP). Overall, their findings indicate that the socioeconomic contributions of small-scale fishing to Sabah society have been significantly devalued or even ignored historically and in current fisheries statistics. This undervaluation also indicates that fishing pressure on Sabah's coastal marine resources is likely much greater than currently perceived. It raises concerns about the long-term sustainability of fishing resources and Sabah's coastal fisheries' ability to support coastal livelihoods in the future.

The economic evaluation of Pulau Perhentian Marine Park's (PPMP) ecotourism resources is the focus of Akhter (2014) study. Using the contingency valuation technique, this study calculated the conservation value of the marine environment and resources at PPMP. The willing-to-pay (WTP) was calculated using both the single-bounded and double-bounded contingent valuation approaches in this study. To preserve the maritime environment and resources in PPMP, about 61.2% of the visitors were prepared to pay a higher entry charge. In 2011, the median WTP per person per visit was between RM17.98 and RM21.72, which might have contributed to an overall benefit between 1.62 million and 1.96 million. Additionally, the median WTP of foreign visitors was significantly greater than that of locals, ranging from RM23.89 to RM27.86 and RM8.64 to RM13.40, respectively.

Pascoe et al. (2014) research about estimating the potential impact of entry fees for marine parks on dive tourism in South East Asia. According to the model the entire non-market use value linked with diving in the area is anticipated to be in the range of USD 4.5 billion per year.

Because the price elasticity of demand in the region is highly inelastic, raising the cost of diving through a management tax would have minimal effect on total diver numbers. While the stimated expenditure and non-market value of dive tourism in Malaysia: Total expenditure- USD 521.5 million and total consumer surplus USD 2014.4 million. The purpose of the Ismail et al. (2020) research is to account for environmental degradations such as resource overrun and overcapacity, as well as exploitation of natural assets. This paper briefly explored the assessment of tourism revenue based on 923 visitors spending time on Perhentian Island, which was done using a two-step Chi-Square Automatic Interaction Detection method (CHAID). Environmental costs were estimated using a combination of ecological footprint and tourism carrying capacity principles, as well as economic valuation approaches. According to the findings, the cost of the environment consists of an RM 5, 446, 563 overshoots, an RM 506, 576 overcapacities, and an overuse of environmental assets ranging from RM 1, 343, 041 to RM 3, 357, 602. Overall, the environmental cost of tourism on Perhentian Island ranged from RM 7, 296, 180 to RM 9, 310, 741.

Besides, the Mokhtar et al. (2020) study tries to determine the advantages and expenses created by Terengganu's marine parks using cost-benefit analysis (CBA). The total benefits were found to outweigh the total costs by RM 399, 980, 502. This is calculated by aggregating all of the benefits, which include the RM 528, 101 entry fees, the RM 220, 000 trust funds received from the government, the RM 47, 877, 431 enterprise sales in marine parks, and the RM 354, 000, 000 total economic value of Pulau Redang, for a total benefit of RM 402, 625, 532. The overall expenses of RM 2, 645, 030 were calculated by adding all of the charges we gathered from various sources, which included RM 481, 232 for equipment maintenance and development of marine parks, RM 991, 128 for employee salary, and RM 1, 172, 670 for environmental loss. Therefore, they come to the conclusion that the main issue with marine parks is their small budgets for management, operation, maintenance, research, and conservation.

Besides, Emang et al. (2016) study examined the possibility of price discrimination among scuba divers at Sipadan in Malaysia. The study uses a choice experiment to determine how likely scuba divers are willing to pay higher user fees to avoid or improve environmental and recreational components of the diving experience. They identify potential for a third-degree price discrimination strategy that takes advantage of higher willingness to pay among international divers (45% with 0.00159 parameter mean), male divers (16% with 0.00069 parameter mean), and people who have visited Sipadan multiple times (25 % with 0.00101 parameter mean). Thus, they believed that new pricing systems may greatly enhance funds for Sipadan's preservation.

Gaps of study can be found in the literature by listing all the arguments. The Fig. 5.3 below explains the gap in the literature specifically. As a result, these gaps have been found and divided into three categories: mankind, the economy, and the environment. Besides, the figure shows that each and every subtopic that is categorized according to the main topic of the literature here and under mankind has three specific categories: lifestyle, skill and knowledge, and health or disease. Then there are subtopics such as socioeconomics, tourism, fisheries, and telecommunications under economics. In the area of the environment, there are 4 main subtopics, which are: ecosystem, climate change, coastal hazard, and waste, water and sewage.

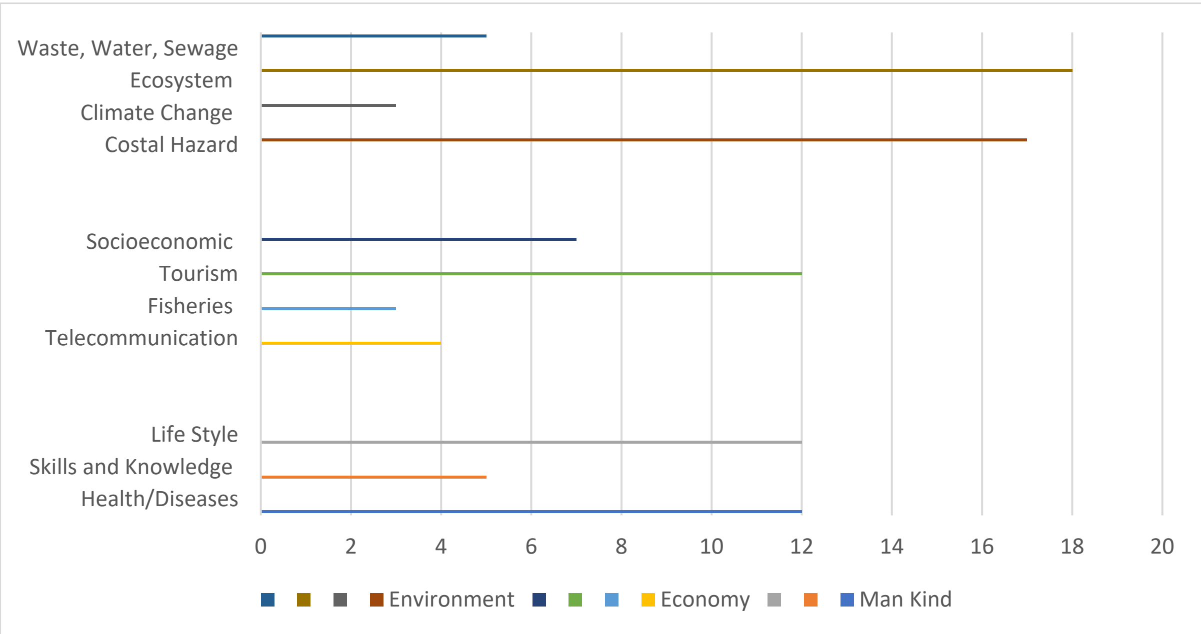

Fig. 5.3: The Most Common Gaps Discovered

5.3 Financial Sustainability

Oceans, which make up more than 70% of the Earth's surface and according to estimates, more than a billion people would reside in coastal areas by the year 2060 (Sumaila et al., 2021; Tilman et al., 2017). 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). Diverse renewable and non-renewable resources (such as fisheries, oil, and gas reserves) can be found in the oceans, and these resources supply intermediate inputs like waves and fish stocks to enable ocean-based industries like seafood production and renewable energy (Sumaila et al., 2021). However, a lot of things about how we now use ocean resources make it unsustainable. 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 the marine resources, and the government also oversees a variety of initiatives, one of which is the sustainable financing of marine resources. Even though the sustainable financing of marine protected areas is still an important issue on the conservation agenda, we will discuss about the financial sustainability of marine resources using the six articles we previously chose.

More specifically, 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 both 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 the depiction of three possible scenarios, the authors examine the Willingness-To-Pay (WTP) of these two types of tourists for the conservation of 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 licences, souvenirs and merchandise), as well as 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 to the management of Croatia's priceless natural resources.

Besides, the project of Perera-Valderrama et al. (2020) is "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, is covered in their paper, along with trends of the success indicators. In this research, the authors provide their experiences on how the process of marine planning and growing the MPA network in Cuba successfully improved marine biodiversity conservation while also boosting the MPAs' financial sustainability. In order to ensure the financial sustainability of MPAs, a sustainable tourism strategy and a number of studies on the economic value of the goods and services provided by ecosystems were carried out. The financial planning of the protected areas is based on the identification of the conservation objects and the risks they experience as a starting point for determining the necessary activities to carry out their monetary quantification. The models allow the quantification of protected area revenues, costs, investments, and potential funding sources over a specific time period.

Further, Mallin et al. (2019) researched about the Phoenix Islands Protected Area's (PIPA) political economy, charity, and environmental protection. The political, legal, and financial growth of PIPA was experimentally tracked through content analysis of major documents. The analysis shows how, in accepting finance from philanthropic foundations, government gradually gave up control over the territory and assets of PIPA. Therefore, it was argued that some legal and financial provisions may serve as under-recognized and purposive drivers of 'ocean-control' grabbing. It follows that for the time being, the compensation plan appears to have lost importance. But beyond the issue of compensation, there is still the as-yet unmet expectation of achieving the PIPA Trust's financial sustainability.

Moreover, 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/or volunteer their time 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 proximity to a fishing market, dependence on marine resources, food security, income, and international commitments. A Provincial Trust Fund (PTF) is considered as a financing instrument for inshore MPAs using WTP and WtCT data. A PTF is a source of sustainable financing for the management of protected areas and long-term biodiversity protection. A PTF also supports sustainable management of traditional fishing societies through its polycentric and decentralized governance model.

In addition, McClanahan et al. (2005) says that the government and larger economic interests were involved in policy and planning, which was another issue in Kenya, but the poor and related groups were frequently left out because they lacked strong formal organizations and the resources to stand up for them. Prior to 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 issues. The general financial viability of Kenya Wildlife Service (KWS) is a source of severe worry. The majority of KWS' operating budget comes from visitor fees; however, not all Protected Areas, PAs in Kenya receive this income, so the money must be distributed among all PAs. However, the long-term survival of PAs, especially MPAs, in Kenya is in jeopardy until KWS's financial viability increases. Hereby, the author concludes that current deficiency and further alter the current resource management regimes, linkages between the MPA and integrated coastal management (ICM) activities were formed.

5.3.1 Financial Mechanism

This section analyses the sustainability of marine financial resources based on the empirical works around the world. The research by Perera-Valderrama et al. (2020), taking into consideration the ecological importance of the region and its recognized threats the "Application of a Regional Approach to the Management of MPAs in Cuba's Southern Archipelagos" project, also known as the Southern Archipelagos, was carried out. The main scope of this project was to protect Cuba's globally significant marine biodiversity by expanding, fortifying, and integrating the network of coastal and marine protected areas in the Southern Archipelagos. This will help to conserve Cuba's globally significant marine biodiversity and ensure its conservation and sustainable use. For a 5- years period (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). The purpose of this study is to present their observations on how the process of marine planning and growing the MPA network in Cuba successfully boosted marine biodiversity protection while also bolstering the MPAs' financial sustainability. They carry out research on marine resource sustainability financing through a grant which is Sustainable Tourism Strategy by the economic valuation of the goods and services offered by ecosystems**.** All the project region's tourism stakeholders were represented in the development of the sustainable tourism strategy, together with officials from the Cuban Ministry of Tourism (MINTUR) and the country's top travel agencies. The theoretical foundation for the planning, management, and oversight of tourism operations in protected areas was developed as part of a sustainable tourism strategy. Therefore, a sustainable tourism strategy was designed and a study on the economic value of the goods and services given by ecosystem were carried out in order to ensure the financial sustainability of MPAs. Further, the financial planning of 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 diversifying the locals' economic pursuits.

Moreover, the research by Tirumala and Tiwari (2022) reported that projects in the blue economy are often funded by traditional public and private development financing methods. This article's purpose is to determine whether the current blue economy initiatives are sufficient to meet sectoral investment needs and to build the general framework that can hasten blue economy investments. This paper states that they investigated the financing of marine resource sustainability through blue economy investment projects, in particular, blue bonds. The concept of establishing a "blue economy" depends on striking a balance between the twin goals of economic development and environmental sustainability. Recent times have seen the issuance of bonds expressly for ocean-related activity. 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 were able to finance investments in sustainable fisheries management, and the 10-year US$15 million bond is intended to be used to finance initiatives. The first Nordic-Baltic Blue Bond was issued by Nordic Investment Bank in 2019 with SEB Bank serving as the lead manager. The 5-year US$213 million bond is intended to be used to finance initiatives aimed at preventing water pollution, treating wastewater, and adapting 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 make up most of the stakeholders in the blue economy's funding landscape since they have historically been the source of the essential funds, policies, and institutional support. Therefore, the study identifies that the current initiatives, such as blue bonds, are only modest in scale, and that in order 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) paper details the experiences of Xiamen in overcoming the difficulties of capacity building, creating sustainable financial mechanisms, and political will are demonstrated. Thus, the author studied the financing of marine resource sustainability using government financial allocation which is the essential source of support for the implementation of the Integrated Coastal Management (ICM) program. In 1993, Xiamen 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. Although there are many elements that contribute to the Xiamen ICM program's success, in this paper they concentrate on exchanging expertise in capacity-building, sustainable finance, and political will. Thus, the Xiamen Municipal Government established and managed a model sustainable financing mechanism that involves government financial allocation, fees for using the sea, fees for ecosystem services, and capital raised through social means. Since its start until-the present, the financial allocation has been the ICM program's main source of support in Xiamen. The financial allocation for Xiamen maritime management, which includes funds for business fund, equipment funds, sea areas and island protection programme and personnel expenditure. Further, most important and consistent sources of funding for the Xiamen ICM programs continue to be sea area usage fees, which are assessed to 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 in order 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. Additionally, public-private-partnerships, PPPs under sustainability financing is a long-term contractual relationship between the private sector and a government organization for the provision of a public good or service. In PPPs, 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.

Apart from this, the study of Qiu et al. (2021) presents the primary drivers and favourable circumstances that will allow the implementation of Integrated Coastal Management (ICM) projects in Xiamen, China. A review of the literature and interviews with professionals in related fields form a significant part of how this study comes to its conclusion. Information was gathered through conversations with specialists and concerned government officials as well as reports from government and intergovernmental organizations. The city of Xiamen was chosen for the case study because it is well known for hosting one of the most successful

ICM programs in all of East Asia, including China (Chua, 2006; Hong & Xue, 2006). Coordination mechanisms, law, financial sustainability, information management and dissemination, and capacity development all played a part in creating an environment that allowed ICM initiatives in Xiamen to continue to thrive. The many of ICM initiatives were externally funded and therefore had short durations. However, the majority of ICM programmes and projects were supported by local governments in China, which is a more reliable and sustainable source of funds than external funding. In order to allocate adequate financial resources for ICM activities, the Xiamen Municipal Government is thus permitted to create its own fiscal plans. For instance, the Xiamen Municipal Government allocates 70% of the royalties from sea use to the municipal budget, with a portion of the money going toward funding the rehabilitation of the marine and coastal ecosystems (Mao & Kong, 2018). The Municipal Government is also discovering cutting-edge eco-compensation techniques to generate additional revenue for environmental preservation (Mao & Kong, 2018).

Additionally, based on the study by Nikitine et al. (2018), the Pitcairn Islands Marine Reserve (PIMR), which was established in September 2016, was assessed using a framework built around ten criteria that were taken from the International Union for the Conservation of Nature's World Commission on Protected Areas (IUCN-WCPA) Guidelines for Design and Management of Large-Scale MPAs. The PIMR was assessed using a traffic light approach (TLA) employing 10 criteria that were modified from these guidelines, as well as grey literature, interviews, and other sources. Each criterion was evaluated based on performance and given a red (does not satisfy the criterion), amber (inadequately fulfils the criterion), or green rating (meets the criterion). A few of the stakeholders who were actively involved in the PIMR design and implementation process were interviewed informally. These individuals included present and past Pew employees, members of the Pitcairn Environment Group, academics and professionals with expertise in the effectiveness of MPA management, members of the Big Ocean Network, and IUCN-WCPA members. Grey literature, Pew papers and reports, as well as pertinent journals and articles, made up the majority of the information gathered and used to assess the PIMR's compliance with the Big Ocean and WCPA-Marine Guidelines. Moreover, this study indicates that they looked into business plans, methods for generating money, and collaborations (public-private) as ways to finance the sustainability of marine resources. Pitcairn is constrained by its remoteness, aridity, and unsuitability for any substantial industrial or agricultural development. Even though it has been predicted that climate change will enhance stocks, a speculative assertion, nutrient-poor waterways provide a low-value fishery that is not suited for commercial usage. The Pitcairn Islands have been reliant on UK budgetary assistance at rates up to £2.9 million per year since 2004 as a result of failure of the Pitcairn Island Investment Fund. Philately was once the only source of income; today, it is supplemented by the selling of souvenir coins, landing fees, internet domain names, and honey, which generates up to NZ$ 200,000 annually. Although there are about 12 cruise ships and 20 to 30 private yachts that visit Pitcairn year, accessibility is still the largest barrier to the significant growth of tourism potential. Pew requested an economic assessment in 2005 to establish the MR's financial justification and to pinpoint potential areas for achieving financial sustainability. However, preliminary research indicates that the PIMR's isolation contributed to financial sustainability issues.

Furthermore, Edwards (2009) has conducted research on sustainable financing for ocean and coastal management in Jamaica. This research investigates the viability of setting up a sustainable funding source for ocean and coastal management in Jamaica. However, the purpose of this study is to determine whether it is feasible to secure sustainable financing (through tourist user fees) for the maintenance of the ecosystem and the recreational benefits offered by coral reefs and beaches. To acquire data that is pertinent to policy, recreational users (tourists) were the main source of information. The data was specifically gathered from tourists who stopped over on the island. All travellers who stayed on the island for one or more nights were included in the sampling frame for this study. The appropriate policy makers would need to do the following in order to assess the viability of establishing an environmental user fee. The first step would be to identify the costs of ocean and coastal zone management programs. Then based on these costs policy makers can determine the necessary ranges for the per person tax that would cover the annual costs of resource management. The second stage would be to utilize statistical models of contingent behaviour (based on survey data) to evaluate the influence that different pricing ranges would have on the number of tourists who would visit. It would give decision-makers the information they need to weigh the trade-off between possible visitor declines and the preservation and management of crucial coastal ecosystems like coral reefs and beaches. Finally, a choice can be made regarding the price that would satisfy the objectives of environmental protection and the sustainable development of the coastal tourism industry after taking into account all of the aforementioned factors and consulting with the pertinent stakeholders (hotels, environmental agencies, NGO's, municipalities, etc.). According to the findings, visitors would be more likely to pay an "environmental tax" as opposed to a generic "tourism development tax." As the analysis shows, 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. By disclosing the breakdown of the tax revenues between management operations, the detrimental effects of the application of higher taxes on annual tourist visitation rates could be reduced.

Furthermore, Cho (2005) has conducted research on Belize's integrated coastal management system and the marine protected areas. The article makes use of grants and projects from international entities to finance the sustainability of marine resources. With the help of Integrated Coastal Management (ICM) attention was turned to an integrated strategy. In order to safeguard biodiversity and manage fragile habitats, marine protected areas were added to the ICM program. The establishment of a network of marine protected areas was a crucial element and a tool in accomplishing ICM under a UNDP/GEF funded project for the "Conservation and Sustainable Use of the Belize Barrier Reef Complex" executed by the Coastal Zone Management Authority and Institute (CZMA/I). The CZMA/I, Fishing industry, Forestry, Ministry of Natural Resources, Ministry of Tourism, fishing cooperatives, conservation NGOs, Community Based Organizations (CBOs), and international donors like World Wildlife Fund, The Nature Conservancy, and Wildlife Conservation Society are important partners in ICM and MPA initiatives. For the gain of all Belizeans and the global community, the principal aim of integrated coastal management in Belize is to assist the allocation, sustainable use, the development programmes of Belize's coastal resources through enhanced knowledge and the formation of alliances. Integrated Coastal Management is ruled through a key piece of law, the Coastal Zone Management (CZM) Act of 1998. According to the Act, the CZM Institute must give the Authority technical guidance as it develops the CZM Plan and other ICM-related policies. Its primary responsibilities include conducting research and monitoring in Belize's coastal region and offering instruction and training on issues related to managing coastal resources. In order to fund a sustainable CZM Program, the Authority is authorized by the CZM Act to impose a variety of environmental management fees for coastal zone activities and uses. Marine Protected Areas (MPAs) are used to manage highly sensitive and ecologically varied marine environments, and a network of MPAs has been established to ensure biodiversity protection and sustainable resource allocation and usage. This has led to a more comprehensive coordination of activities within MPAs as part of a larger ICM process, which has increased their integration.

Table 5.3: Financing Marine Resource Sustainability Tools

Financial Sustainability Mechanism	**Measurement**	**Type**
Investment *(Tirumala & Tiwari, 2022)*	○ Bonds *(Tirumala & Tiwari, 2022)*	• Blue Bonds *(Tirumala & Tiwari, 2022)*
Grants *(Perera-Valderrama et al., 2020), (Cho, 2005)*	○ Economic Valuation *(Perera-Valderrama et al., 2020)*	• Sustainable Tourism Strategy *(Perera-Valderrama et al., 2020)*
	○ Integrated Coastal Management (ICM) Programme *(Cho, 2005)*	• entails the provision of advice *(Cho, 2005)*
Financial Allocation *(Kong et al., 2021), (Qiu et al., 2021)*	○ Fiscal Plan *(Qiu et al., 2021)*	• Royalties and eco-compensation mechanisms *(Qiu et al., 2021)*
	○ Programme *(Kong et al., 2021)*	• Sea Areas And Island Protection Programme, Marine enforcement programme, Marine economy, coastline improvement and other related programmes *(Kong et al., 2021)*
	○ Expenditure *(Kong et al., 2021)*	• Personnel Expenditure *(Kong et al., 2021)*
Equipment Fund *(Kong et al., 2021)*	○ Stated under Government Financial Allocation *(Kong et al., 2021)*	
Business Fund		

(Kong et al., 2021)		
Conservation Trust Fund *(Rotjan et al., 2014)*	○ provision of financial support and paying any fee *(Rotjan et al., 2014)*	• conservation contract *(Rotjan et al., 2014)*
Provincial Trust Fund (PTF) *(Ison et al., 2018)*	○ bottom-up approach (*Ison et al., 2018)*	
Return On Investment *(Bladon et al., 2016)*	○ Via increased fishery profitability *(Bladon et al., 2016)*	
Fixed Conservation Levies *(Bladon et al., 2016)*	○ From fishing vessels *(Bladon et al., 2016)*	
National Trust Fund *(Bladon et al., 2016)*	○ capitalized with new sources of funds such as earmarked hilsa export taxes *(Bladon et al., 2016)*	
Fees for sea area usage *(Edwards, 2009), (Kong et al., 2021)*	○ Market Allocation *(Kong et al., 2021)*	• Bidding, auctioning and listing *(Kong et al., 2021)*
	○ Environmental tax and tourism tax *(Edwards, 2009)*	• environmental protection and tourism are important to their decision framework *(Edwards, 2009)*
	○ Sea areas management *(Kong et al., 2021)*	• Protection, prevention, conservation, marine enforcement and restoration of sea areas, island and coastline *(Kong et al., 2021)*

Compensation For Ecosystem Service *(Kong et al., 2021)*	○ Marine ecological damage compensation *(Kong et al., 2021)*	
Social Raised Capital *(Kong et al., 2021), (Nikitine et al., 2018)*	○ Public-Private-Partnership *(Kong et al., 2021), (Nikitine et al., 2018)*	
	○ Business plan *(Nikitine et al., 2018)*	
	○ options for income generation *(Nikitine et al., 2018)*	

5.4 Financial Model

This section focuses on the Trust Funds model based on the previous studies by Rotjan et al. (2014), Bladon et al. (2016) and Ison et al. (2018).

5.4.1 Trust Funds

The Phoenix Islands Protected Area (PIPA), a part of the Republic of Kiribati, is the world's largest and deepest UNESCO World Heritage site. It is situated in the equatorial central Pacific. It was the first Marine Protected Area (MPA) of its sort and, at the time of its creation, the largest in the world. Eight low-lying islands, shallow coral reefs, buried shallow and deep seamounts, and a substantial open-ocean and ocean floor ecosystem are all included. According to Rotjan et al. (2014), PIPA was developed as a result of a collaboration between the Kiribatian government and two international NGOs, Conservation International and the New England Aquarium (Fig. 5.4). Their article makes use of PIPA Conservation Trust to finance the sustainability of marine resources. The Kiribati Government agreed to support the notion of establishing a large MPA in the Phoenix Islands but emphasized that the MPA should not have any adverse effects on the country's economy, which was heavily dependent on fishing revenues. The key to the strong political support from Kiribati and its people was the development of a sustainable financing mechanism to replace any lost income Kiribati might incur from closing the Phoenix Islands to commercial fishing while also compensating Kiribati for any increased costs for PIPA management activities. Due to this concept, Parliament passed the PIPA Trust Act in 2009, thus establishing the PIPA Conservation Trust as the MPA's non-profit charitable organization's "financing mechanism." The PIPA Conservation Trust engages in a variety of activities, such as providing financial support for PIPA management and paying any fine that may be necessary to make up for any proven decreases in national fishing earnings brought on by PIPA closures. A conservation contract was signed by the Kiribatian government and the PIPA Conservation Trust in 2014, and it serves as the framework for managing and carrying out these operations. This is the first instance of a marine conservation contract.

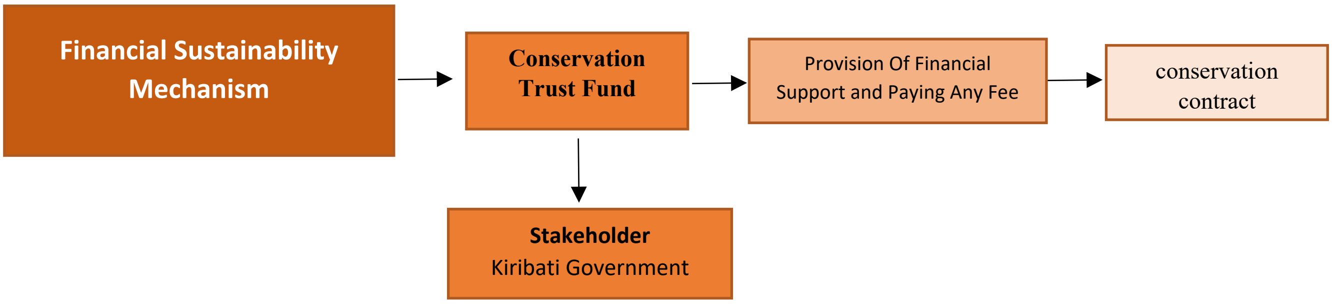

Fig. 5.4: Framework of Conservation Trust Fund by Rotjan et al. (2014).

Besides, Bladon et al. (2016) analysed four distinct fisheries: the Namibian hake, the Mozambican shallow-water shrimp, the Western, and the Central Pacific skipjack. Payments for Ecosystem Services (PES), a potent economic mechanism that provides positive conditional opportunity for the supply of extra ecosystem services over the status quo and has been extensively employed in land conservation, is a way to pay for ecosystem services (Fig. 5.5). Here, they take into account how PES might help fill in the management of fisheries' current gaps. A tool for financial sustainability must be in place to assure the continuity of a PES scheme, if either this is achieved through a tool that generates a steady flow of funds, such as user fees or levies on fishing license fees, or via a tool that produces revenue from investments in Ecosystem Services (ES) provision. This study examines how to finance the sustainability of marine resources through return on investment, fixed conservation levies and national trust fund. Fishers may have a tremendous intention to improve their behaviour as a group, but as individuals, they individually have an incentive to behave otherwise in a scheme where they are the providers. This is because fisheries stakeholders are frequently many, dispersed, and mobile. Any agent who receives a benefit from the supply of a service may function as the buyer in a PES scheme, including consumers, NGOs, government agencies, private businesses, and fishermen.

Table 5.4 shows potential structure of financial sustainability mechanisms in four contrasting fisheries.

Table 5.4: Financial Sustainability Mechanisms and Measurement in Four Contrasting Fisheries.

Four Contrasting Fisheries	Financing Sustainability Mechanism	Measurement
Namibian hake	Return on investment	Via fishery profitability
Mozambican shallow-water shrimp	Return on investment	Via fishery profitability
Western and Central Pacific skipjack tuna	Fixed conservation levies	From fishing vessels
Bangladesh hilsa	National trust fund	Capitalized with new sources of funds such as earmarked hilsa export taxes

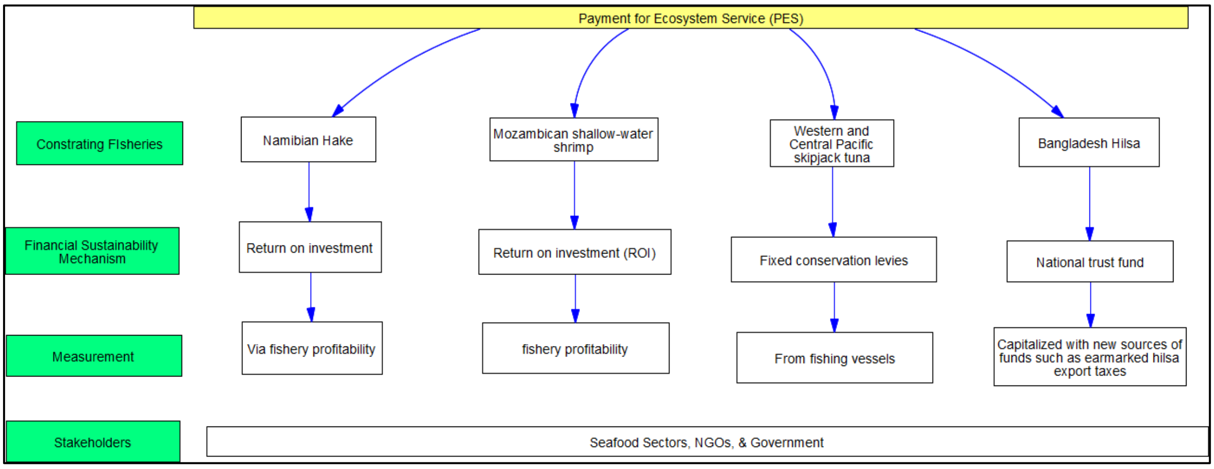

Fig. 5.5: Framework of Payment of Ecosystem Service (Bladon et al., 2016).

Focusing on the national trust fund, the development of a trust fund can enhance long term PES benefits (Goldman-Benner et al., 2012). The prospect of creating a national trust fund for hilsa conservation is being investigated, even though compensation presently comes straight from national government budget allocation. This fund might be financed with additional sources of money such targeted hilsa export taxes.

Additionally, Ison et al. (2018) made use of empirical data to examine potential advantages for recipient local stakeholders from particular community based MPAs, among whom are youth, heads of village, household (women), subsistence fishermen, and commercial fishermen (Fig. 5.6). Moreover, this study looks into alternative funding sources for MPAs to the usual direct government budget support. The extent to which bottom-up governance systems offer a possible funding option for an MPA network was investigated using the Willingness to Pay (WTP) and Willingness to Contribute Time (WtCT) techniques. When using the concepts of WTP and WtCT, there are several financing solutions accessible. A Provincial Trust Fund (PTF) is taken into account as a financing method for inshore MPAs using WTP and WtCT findings. Therefore, this paper states that they investigated the financing of marine resource sustainability using PTF. PTFs are an international conservation instrument that, by diversifying the sources of funding, may help achieve financial sustainability. They can also support fostering collaboration and enhancing institutional capacity on a local and national level. The PTF will act as a tool for managing finances and as a middleman between people who use resources and those who protect them. For instance, the Phoenix Islands Protected Area in Kiribati uses PTFs as a system of financial inducement. It serves as a middleman to gather donations and direct them to organizations that provide ecosystem services (Govan, 2015). The management of inshore MPAs in Fiji has shown to be increasingly successful when using a bottom-up approach. In the instance of PTF, it is questioned whether inshore rewards will encourage beneficiaries to carry out MPA management tasks related to WtCT results. According to evidence from their interviews, conserving beneficiaries' inshore marine environment is a more financially appealing option for beneficiaries than taking part in payment schemes, given the low WTP in comparison to the opportunity costs of marine resources. Therefore, a Provincial Trust Fund (PTF) might encourage an equitable and benefits-based contributions by using WTP and WtCT to support financing of an MPA network. A PTF's polycentric and decentralized governance approach, which supports the sustainable management of traditional fishing societies, is also significant.

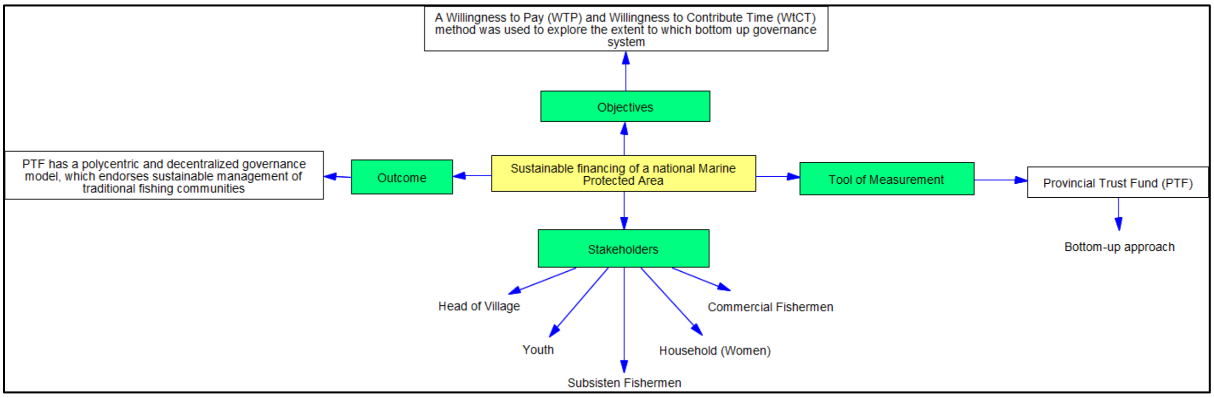

Fig. 5.6: Framework of Provincial Trust Fund (Source: Ison et al., 2018).

Provincial Trust Fund (PTF) is a source of sustainable financing for the long-term conservation of biodiversity, particularly for the management of protected areas and it considered as a financing mechanism for inshore MPAs. Through the diversification of finance mechanisms, PTFs, an international conservation instrument, may help achieve financial sustainability. The PTF will act as a tool for managing finances and a middleman between people who use resources and those who protect them. First component of financial sustainability is budgetary allocation for 2016–2017 does not consider funding for MPAs. This financing models have the potential to enhance government spending through the national budget based on the percentage of funds that each stakeholder is willing to contribute. Second component of financial sustainability is economic limits such as through tourist user fees.

5.4.2 Proposed Refugia Trust Fund

This section is a recommendation that has been put forward to ensure the financial sustainability of the *P. monodon* Fisheries Refugia area in Kuala Baram, which is located in Miri. For the *P. monodon* Fisheries Refugia area to be managed and operated in a way that is financially sustainable, there must be a sustainable source of funds as well as a sustainable utilization of that money over the long term. This new funding source proposal therefore takes into account a variety of financial sources, design cues from trust funds already in place within federal government agencies and case studies conducted in countries that already make use of them.

The selection of trust fund for *P. monodon* Fisheries Refugia in Kuala Baram, Miri 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 refugia area. These four main components are essential in ensuring financial sustainability in the long term.

Thus, the objectives of the trust fund for the Kuala Baram *P. monodon* Fisheries Refugia are:

1. Sustainable management and conservation of *P. monodon* Fisheries 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.

As the basis of the theory of financial intermediaries, the proposed trust fund will act as a financial fund that collects monetary funds from surplus units that have a financial surplus as well as deficit units that require monetary fund assistance. Hence, surplus units contribute to funding sources, and deficit units use trust funds. In detail, the proposed funding source involves a variety of financial sources in the short and long term, including:

i. All vessel license fees involving refugia areas;
ii. All special permit fees involving refugia areas;
iii. All payments involving breach of conditions as well as damage involving the refugia area;
iv. Returns from fixed deposits of trust funds in the banking system;
v. International and local body conservation grants;
vi. Fiscal Funds from the Federal Government;
vii. Fiscal Fund from the State Government;
viii. Contribution funds of individuals, local and international companies, especially those involving oil and gas companies;
ix. Taxes or surcharges to be paid by domestic and international tourists through the payment of flight tickets to Miri;

x. A surcharge of RM1 is included in the hotel accommodation fee in Miri;
xi. Involves the issuance of unit trusts/share trusts that are equity-based and low-risk in the financial market;
xii. Issuance of blue bonds with medium and long-term maturities.

The special permit fee includes the fee for obtaining a special permit to catch *P. monodon* broodstock for seeding and research purposes. Fees involving a violation of license conditions are fees charged to vessels operating below the prescribed distance, trawling vessels, and vessels entering unauthorized areas. Generally, all payments involving violations are stipulate in the Fisheries Act 1985. In contrast, payments that cause damage to refugia areas include compensation payments that are the cost of environmental damage such as oil spills and so on, including payment of the cost of damage that involves a court case, whether it is a settlement in court or out of court. The fixed deposit return of the trust fund is also the generation of trust fund resources without involving the use of the principal fund.

Next, international bodies' conservation grants can be obtained directly from the bodies involved. Among the funds that offer resource and environmental conservation funds are the Global Environment Facility (GEF); Gordon & Betty Moore Foundation; French Fund for the global environment; United States Agency for International Development (USAID); World Wide Fund (WWF); United Nations Development Program (UNDP); World Resources Institute (WRI); The United Nations Environment Programme; The World Bank's COREMAP project; MacArthur Foundation; Coca Cola Malaysia and other bodies and institutions. The Coca-Cola Malaysia Fund focuses corporate initiatives on a world without waste, water, women, and community are among the opportunities that can be explored.

Fiscal funds from the Federal and State Governments are an annual channeling of funds to trust funds through 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 in the waters of Sabah and Sarawak. Next is the proposal to generate funds through tax payments or surcharges involving tourism activities to Miri in the form of airline ticket and hotel accommodation payments.

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.

As for the use of funds, recommendations include:

i. Financial costs of management and conservation of refugia areas;
ii. Education and training activities for the community, in particular, involving resource sustainability awareness campaigns, innovation, and commercialization;
iii. Activities that can generate financial resources for the refugia trust fund;
iv. Research and development activities in innovation and effective commercialization increase trust fund resources and long-term financial sustainability.

The proposed trust fund requires the cooperation of various stakeholders. Among the stakeholders proposed to help obtain funds for the Kuala Baram refugia trust fund are the Federal Government, State Government, Government agencies and institutions, the private sector, business entities, non-governmental organizations (NGOs), local public universities, and the community.

6.0 Addressing Key Issues and Options

6.1 Key Issue 1: Insufficient Data for The Estimation of Size at Maturity and Minimum Landing Size (MLS)

6.1.1 Issues

- Size at maturity is an essential criterion to estimate MLS of marine organisms, including various types of crustaceans (Atherley et al., 2021). This is because MLS is often chosen or proposed based on the smallest size of mature individuals to ensure that all mature individuals, especially females, are able to reproduce before being captured. For example, the MLS of edible crab *Cancer pagurus*, set at 130 mm and 110 mm CW for north and south populations were found to sufficiently restrict the catch of immature females, as the MLS are around and below the estimated size at sexual maturity of 112.3 mm CW (Bakke et al., 2018).

- However, one of the major drawbacks that leads to the inability to estimate size at maturity is the lack of information on the maturation status of *P. monodon* and the lack of consistent data (data of individual length, weight, and maturation status of at least one year) from Kuala Baram, Miri, Sarawak.

- It is also important to note that size at maturity might widely vary between populations, even for the same species (McIntyre et al., 2015).
- Therefore, it is not possible to use the size at maturity of *P. monodon* from other geographical locations.

- In addition, there is no report of the size at maturity of *P. monodon* within the same region.

6.1.2 Options

- Albeit insufficient data to account for the estimation of size at sexual maturity, the use of females at Stage 1 (6.7 cm) will be temporary sufficient as a substitute for MLS.

- It is highly recommended that local fishermen community with the aid of Department of Fisheries, Malaysia could act as citizen scientists and participate in the data collection of *P. monodon* for the calculation of length-weight relationship and size at sexual maturity from Kuala Baram, Miri, Sarawak.

- The importance and relevance of size at sexual maturity and MLS, and the impact of MLS on the sustainability of wild *P. monodon* populations, as well as the minimum data required (including how to obtain and record the needed data) will be demonstrated to the local communities, and monitor closely by the relevant authority throughout the establishment and implementation of Kuala Baram *P. monodon* fisheries refugia.

6.2 Key Issue 2: Incidental Catch of Juveniles and Sub-adults During Open Season

6.2.1 Issues

- According to a survey conducted at the waters of Bintulu and Miri in 2016, 44% of the fishermen catch was *P. monodon* within 3NM between February to April. The shrimp caught in this shallow and estuarine waters are mostly juveniles and sub-adults.

- This is because recruitment process increases after monsoon.

- During the latest stakeholder engagement workshop in 2021, local fishermen agreed that if the proposed 3 months (August-October) close season for fisheries refugia is to be implemented, fishing will be shift to 12NM. This is to avoid fishing been concentrated within the 7NM high *P. monodon* density area.

- However, the possibility of incidental catch of immature shrimp (male: <35g BW, 13.4cm TL; female, <82g BW, 15.7cm TL) during off closed season (May, June, July, November, December and January) is also high.

- These individuals are in need of protection to allow them to reach the desired size and spawn at least once before they are caught.

6.2.2 Options

- The concept of *catch and release* should be instilled among the fishermen in which they advised to release the immature shrimps.

- Mandatory *catch and release* regulation should be imposed in shallow area or area of concern to all license holders.

- A reward can be awarded to those who support the *catch and release* concept (evidence through social media, e.g. Facebook, Twitter, emails, etc.) to encourage related individuals in conserving the *P. monodon* population of the fisheries refugia area.

6.3 Key Issue 3: Environment-related Habitat Changes

6.3.1 Issues

- Based on the engagement session with local fishermen and observations during site visit to Kuala Baram and the nearby locations around Miri, the potential sites within the proposed *P. monodon* Fisheries Refugia is threatened by several environment-related issues, including:

- Oil spills
- Sand mining activities
- Destruction of coastal habitats within the refugia zone

- The main issue that the local fishermen are currently facing has been the sawmill along the river at Kuala Baram run by the nearby companies (Fig. 6.1). The on-going accumulation of saw dust could potentially sabotage the Fisheries Refugia Plan for *P. monodon* as it caused not only pollution at the area, but also the shallowing of the water depth along the river as well as the estuarine (Fig. 6.2).

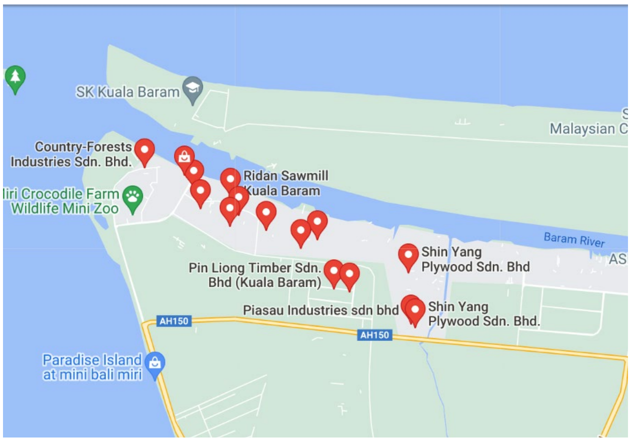

Fig. 6.1: Sawmill and plywood companies along the Kuala Baram river.

(a) (b)

Fig. 6.2: Saw dust accumulation along the river at Kuala Baram potentially destruct the habitat of wild *P. monodon* at Kuala Baram due to pollution and shallowing of the water.

- The local fishermen were concerned that their efforts in following through the recommendations and regulations set forth in the *P. monodon* Fisheries Refugia Management Plan might be wasted, if the habitat of *P. monodon* within the refugia zone is being disrupted by other environmental factors as mentioned above.

6.3.2 Options

- The local fishermen are encouraged to report each incident directly to the relevant authorities immediately to facilitate fast response.

- Local authorities could increase monitoring frequency within the proposed *P. monodon* Fisheries Refugia site to ensure minimal habitat destruction.

- Local authorities should propose a plan to the sawmill companies in which agreements could be achieved for the success of the environmental preservation as well as the profitability of the companies.

6.4 Key Issue 4: Warmer Water Due to Hydropower Electrical Turbine

6.4.1 Issue

- The hydropower electrical turbine is used as a cooling system around the industrial area. The system is designed to take up water from the river and estuary and heated waste water is released into the environment.

- The released of the waste water into the environment caused a rise in water temperature of the area. This will potentially disrupt the natural ecosystem such as plant survival, nutrient content and food web. Such disruption then affects the population of *P. monodon*.

6.4.2 Options

- Appointed authorities could conduct frequent monitoring of the cooling system such as the flow rate in which the water should move at the speed that they are cool enough when they are ready to be released back into the environment.

- Frequent monitoring of the water temperature at the refugia area is necessary to ensure that the water is maintain at the normal temperature.

- Frequent monitoring on *P. monodon* population, nutrient content and water quality is also vital to make sure that the waste water do not affect the natural ecosystem of the refugia area.

7.0 Summary from Main Stakeholder Engagement

7.1 Meeting with Department of Fisheries Malaysia on 28th – 29th July 2022

The first engagement was conducted with the main stakeholders of the *P. monodon* Fisheries Refugia Plan at Meritz Hotel, Miri, Sarawak on 28th – 29th July 2022 with the members include representatives from DoF, Malaysia, Fisheries Research Institute (FRI), Lembaga Kemajian Ikan Malaysia (LKIM) and Persatuan Nelayan Kawasan (PNK) Miri division (Fig. 7.1 & Fig. 7.2).

Fig. 7.1: First engagement with main stakeholders of the *P. monodon* Fisheries Refugia Plan at Meritz Hotel, Miri, Sarawak on 28th – 29th July 2022.

Fig. 7.2: First engagement with main stakeholders of the *P. monodon* Fisheries Refugia Plan at Meritz Hotel, Miri, Sarawak on 28th – 29th July 2022.

Some of the agreements had been achieved regarding the aspect of fisheries refugia site, harvest method, satellite analysis and hydrological parameters, size-based fisheries and financial sustainability. These criteria are divided into strategies as detailed in the following:

7.1.1 Strategy 1: Fisheries Refugia Site

1. The proposed fisheries refugia site comprises of two areas:
    - **Area A:** Nursery ground for postlarvae and juveniles which include Sungai Lutong, Sungai Pasu, Sungai Miri and Batang Baram.
    - **Area B:** For adults and spawners

2. Total area of the proposed fisheries refugia site is 852km^2 (85, 200 ha). This area involves 6 coordinates that was agreed by the National Technical Committee of Fisheries Refugia, DoF as described in chapter 3.1.3.

3. The mangrove buffer zone is maintained at 20m from the Mean High-Water Level by the local government authority.

4. Stock enhancement program will be carried out by releasing the Specific Pathogen Free, SPF *P. monodon* postlarvae within the fisheries refugia Area A.

5. The establishment of fisheries refugia site can be done under Fisheries Act 1985.

7.1.2 Strategy 2: Harvest Methods and Gears

1. Close season:
   - The proposed close season will begin in August up to October of the 2022 as part of an awareness program.
   - The official closure however will be implemented after the establishment of the refugia site.
   - This closure will be included in the license regulation.
   - The closure is only meant for trawl net and trammel net.

2. *Catch and release* season:
   - *Catch and release* season will be implemented on February until April.
   - This approach will be applied to all fishing gears.
   - This activity will be carried out for both Miri and Bintulu waters.

7.1.3 Strategy 3: Satellite Analysis and Hydrological Parameters

1. The purpose of satellite analysis is as followed:
    - To investigate the seasonal variability of satellite-derived chlorophyll a concentration and its relationship with the landings of *P. monodon* in Kuala Baram, Miri, Sarawak.
    - To investigate the seasonal variability of satellite-derived ocean currents in Kuala Baram, Miri, Sarawak for the determination of larvae distribution.
    - To produce a 10-year forecast on the state of hydrological parameters including chlorophyll and the influence on *P. monodon* stock in Kuala Baram, Miri, Sarawak.

7.1.4 Strategy 4: Size-based Fisheries

1. Based on the available data provided by the DoF, there is insufficient information on the population of *P. monodon* in Kuala Baram, Miri, Sarawak for size at maturity determination.

2. Therefore, the proposed size at maturity will be established according to the size described by Motoh (1985) as followed:
    - **Female:** 82g BW, 18.0cm TL
    - **Male:** 35g BW, 13.4cm TL
    - The average size at maturity for both male and female will be at 15cm TL and 60g BW
    - Therefore, the minimum allowable size for capture should be > 30cm TL and 90g BW for shrimp spawners.
    - Captured shrimp spawners that is more than the allowable size should be released back into the habitat.
    - The catch and release effort should be done on voluntary basis during the first year of the establishment.
    - After the 2nd year of the establishment, the regulation on minimum allowable size will be included in the license.

3. Special permit for sample *P. monodon* spawners must be >30cm TL and >90g BW for any research and aquaculture activities can be issued by the DoF Malaysia.

7.1.5 Strategy 5: Financial Sustainability

1. Bioeconomic Model is the proposed financial sustainability model. The economic evaluation on this approach will be conducted according to the catch and effort data provided by the fishermen.

2. The mechanism of the financial sustainability will be done according to National Trust Fund (NTF). Some of the proposed reference agency for this mechanism is as below:
   - Proposed to refer to the present National Conservation Trust Fund (NCTF) from the Ministry of Energy and Natural Resources.
   - Proposed to refer to the National Park Trust Fund from the Ministry of Agriculture and Food Industry.
   - Proposed to secure Corporate Social Responsibility (CSR) grant from local oil and gas companies and operators.

7.2 Meeting with Department of Fisheries in Putrajaya on 15th August 2022

Another meeting with the DoF Malaysia was held in Putrajaya on 15th August 2022 at Palm Garden hotel (Fig. 7.3 & Fig. 7.4).

Fig. 7.3: Meeting with the DoF Malaysia was held in Putrajaya on 15th August 2022 at Palm Garden hotel.

Fig. 7.4: Meeting with the DoF Malaysia was held in Putrajaya on 15th August 2022 at Palm Garden hotel.

7.3 Meeting with Department of Fisheries in Port Dickson on 8th November 2022

A pre-council of the final report was presented at Port Dickson on the 8th November 2022. The meeting was attended by representatives from the DoF and FRI (Fig. 7.5 & Fig. 7.6). The meeting highlighted the important element of the Fisheries Refugia for *P. monodon* regarding the establishment of the allowable size for capture of *P. monodon* at Kuala Baram.

Fig. 7.5: Pre-council meeting for the final report presentation at Port Dickson on the 8th November 2022.

Fig. 7.6: Pre-council meeting for the final report presentation at Port Dickson on the 8th November 2022.

7.4 Engagement with Local Fishermen

7.4.1 Online Engagement with Local Fishermen on Refugia for Keys to Sustainable Fisheries Management and Conservation

FORAS was held on 22nd September 2022 with the theme "Refugia: Keys to Sustainable Fisheries Management and Conservation via online through Cisco Webex (Fig. 7.7). The forum was on the proposal of *P. monodon* fisheries refugia management in Kuala Baram, Miri Sarawak and its potential for sustainable fisheries. The discussion was attended by representatives from Department of Fisheries (DoF), Fisheries Research Institute (FRI), Persatuan Nelayan Kawasan (PNK) of Miri and Lembaga Kemajuan Ikan Malaysia (LKIM), Malaysia.

Fig. 7.7: Poster for the FORAS which was held on 22nd September 2022 with the theme "Refugia: Keys to Sustainable Fisheries Management and Conservation via online through Cisco Webex.

The forum was a success with significant remarks from the manager of PNK Miri in which the association agreed strongly for Kuala Baram as the chosen area for the refugia management of *P. monodon* based on the following justifications:

1. The area is in need of conservation to maintain the potential of the *P. monodon* resources in the long term.
2. Refugia management of *P. monodon* at Kuala Baram may provide a long-term benefit to the local fishermen in complementing their income.

The representative of the PNK praised the DoF for the efforts in introducing the *P. monodon* fisheries refugia management plan and the subsequent engagements with the stakeholders to ensure understandings among them.

7.4.2 Workshop with Members of Persatuan Nelayan Kawasan Miri

An exclusive meeting with the Fishermen Association of Miri was held at Kompleks Lembaga Kemajuan Ikan Malaysia (LKIM) on 26th September 2022 (Fig. 7.8 & Fig. 7.9).

Fig. 7.8: Meeting with the Fishermen Association of Miri was held at Kompleks Lembaga Kemajuan Ikan Malaysia (LKIM), Miri Sarawak on 26th September 2022.

Fig. 7.9: Meeting with the Fishermen Association of Miri was held at Kompleks Lembaga Kemajuan Ikan Malaysia (LKIM), Miri Sarawak on 26th September 2022.

Some of the issues and suggestions being discussed regarding the *P. monodon* Fisheries Refugia Management Plan were listed as in Table 7.1.

Table 7.1: Issues and suggestions raised by the local fishermen regarding the proposed *P. monodon* Refugia Management Plan.

Issues	Suggestions
Trawling cause substantial damage to refugia habitat of *P. monodon*.	Fishermen can be assigned to monitor the trawling activities and report to DoF.
Unclear border establishment caused the trespassing of fishing activities	Border indicator (e.g.: buoy) should be placed to mark the limit point of the entry allowances of vessels during close season.
Close season fishing activities	Include *fishing prohibition policy during close season* as a supplementary regulation in the fishing license and permit.

8.0 Final Recommendations of Fisheries Refugia Management Plan for *P. monodon* at Kuala Baram, Miri

8.1 Location and Area

The Fisheries Refugia Management for *P. monodon* will be conducted on two major areas which include the nursery ground (Area A) covering Sungai Lutong, Sungai Pasu, Sungai Miri and Batang Baram as well as spawning ground of marine water off Kuala Baram (Area B) for adult shrimps and spawners. The total area of the proposed fisheries refugia site is 852km^2 (85, 200 ha). The 6 coordinates of the site are as described in chapter 3.1.3.

8.2 Restocking program

Restocking of *P. monodon* post-larvae is proposed to be implementation to increase shrimp stock in the wild habitat using the Specific Pathogen Free (SPF) post-larvae from local hatcheries. This strategy is to be carried out at least twice a year. Stock assessment of *P. monodon* at the refugia area will also be conducted before and after the release of the stock.

8.3 Minimum Landing Size

The minimum landing size for *P. monodon* at Kuala Baram under the Fisheries Refugia Management Plan for *P. monodon* will be established as the minimum allowable size for capture for both male and female shrimps. The allowable *P. monodon* size for capture was agreed at >30cm TL and >90g BW in which captured shrimps above this standard must be released back into the habitat.

8.4 Seasonal Closure and License Regulation

The seasonal closure for shrimp fishing will be implemented explicitly for trawlers. The closure will first be carried out as an initial awareness program which began in August up to October 2022. The legislation of the official closure will be implemented as soon as the official establishment of the refugia site. The closure is in accord with the prediction on how climate change affects the marine ecosystem and *P. monodon* population in Kuala Baram in the next 10 years or so using the Fisheries and Marine Ecosystem Model Intercomparison Project (FISH-MIP). The inclusion of license during close season of *P. monodon* has been agreed and approved on 21st October 2022 by DoF with the regulation as followed:

Management Subjects	Location	Duration	Group Involved	Meeting Recommendation
Prohibition from capturing *P. monodon* spawners that is more than 30cm in length in Miri and Bintulu area	Miri and Bintulu waters	All year	All Fishermen	Implemented in an administrative and voluntary approach
Close season for trawlers and trammel net at the refugia site	Refugia site	1st August – 31st October	All trawlers and trammel net fishermen	Incorporate in the license regulation during the official implementation of close season in January 2023

8.5 Community Engagement Program

The key to successful Fisheries Refugia Management involved the integration of both life cycle and habitat preservation as well as the social participation throughout the whole program. The participations of these stakeholders are to comply to the terms as coordinated by both local and federal government managements. Some of the roles of the stakeholders to ensure the success of the *P. monodon* Fisheries Refugia Management include:

1. Role of the fishermen community

- Complying to the refugia guideline established by the DoF Malaysia.
- Identifying refugia area, close season and minimum allowable size for catch.
- Supporting the effort of DoF and to keep updated with the latest instructions by the DoF.
- Report of any trespassing and law violation to the authority.

2. Role of DoF

- Frequent monitoring of fishermen activity both at and off shore.
- Frequent monitoring of *P. monodon* sales at seafood market.
- Organising scientific program related to refugia among schools, government department and the community at the shore.
- Collaboration with other government agency to strengthen the management strategy
- Frequent monitoring and assessment of the *P. monodon* population at Kuala Baram to determine the effectiveness of the refugia strategy.
- Organising technical workshop with Universiti Malaysia Terengganu on the determination of size at sexual maturity for the field officers from DoF.

3. Role of other government agency

- Active collaboration with the DoF, Jabatan Alam Sekitar (JAS), Agensi Penguatkuasaan Maritim Malaysia (APMM), Jabatan Perhutanan Sarawak, fishermen community and local community of the area.
- Involve in monitoring the activities of the fishermen and trawlers.

- Aid in monitoring the selling activities of *P. monodon* at the seafood market.
- Take legal action against the violation of refugia law.
- Continuous participations of related government agencies such as Department of Forestry, Sarawak and Department of Environment to ensure no further destruction of the mangrove ecosystem within the proposed Area A of the nursery ground for fisheries refugia.

4. Role of shrimp sellers

- Cooperate with the effort of DoF, government agencies, fishermen community as well as the local communities by monitoring the selling of *P. monodon* at the seafood market.
- Do not sell undersized *P. monodon* according to the criteria set for the refugia management.

8.6 Proposed Refugia Trust Fund

The sustainability of *P. monodon* Fisheries Refugia Management required a long-term financial funding. Therefore, the sustainability of financial aspect is important to support the management and the operation of the *P. monodon* Fisheries Refugia area. And that a trust fund is needed by taking into account:

i. The existing trust funds from both federal and regional government agencies.
ii. The proposal for new funding by combining various financial sources for a long-term and more secured financial sustainability.

9.0 Action Plan for Fisheries Refugia Management Plan for *P. monodon* at Kuala Baram, Miri

Action plan for *P. monodon* Fisheries Refugia Management at Kuala Baram, Miri will the guideline for a steady execution of the plan. In this section, management party responsible to each plan are identified and proposed to participate as the management team to ensure the success of the plan. The action plan for *P. monodon* Fisheries Refugia Management is as followed:

No.	Action Plan	DoF Management	Expected Outcome
1.	Location and Area	1. Department of Survey and Mapping Malaysia (JUPEM) 2. Office of Legal Counsel, Ministry of Agriculture and Food Industries (MAFI) 3. Fisheries Conservation & Protection Division, DoF, Malaysia.	Refugia area will be covering Sungai Lutong, Sungai Pasu, Sungai Miri and Batang Baram
2.	Restocking program	1. Fisheries Research Institute (FRI), DoF, Malaysia. 2. Fisheries Conservation & Protection Division, DoF, Malaysia.	Will cover 3 main mangrove area of the Refugia nusery arean of Area A; Sungai Lutong, Sungai Pasu and Sungai Miri
3.	Seasonal Closure	1. Fisheries Conservation & Protection Division, DoF, Malaysia. 2. Capture Fishery Resources Division, DoF, Malaysia. 3. Office of Legal Counsel, MAFI.	(i) Seasonal closure for trawlers from August to October every year. (ii) *Catch and release* to be carried out from February to April and August to October (iii) Regulation during seasonal closure to be included into the license.
4.	Minimum Landing Size	1. Fisheries Conservation & Protection Division, DoF, Malaysia. 2. Fisheries Research Institute (FRI), DoF, Malaysia.	Allowable size for the capture of male and female shrimp should be **>30cm TL and >90g BW**
5.	Community Engagement Program	1. Fisheries Conservation & Protection Division, DoF, Malaysia. 2. Fisheries Research Institute (FRI), DoF, Malaysia. 3. Office of Legal Counsel, MAFI.	Establishment of refugia guideline. Monitoring of fishermen activities and sales activities. Outreach program (6 months)

6.	Proposed Refugia Trust Fund	1. Ministry of Energy and Natural Resources 2. Oil and Gas Companies	Obtaining National Conservation Trust Fund (NCTF) Securing Corporate Social Responsibility (CSR) grant
7.	Stock assessment study	1. Fisheries Research Institute (FRI), DoF, Malaysia. 2. Local public university (e.g. UMT).	Determination of actual total biomass of before and after the implementation of the proposed *P. monodon* Fisheries Refugia management plan. The stock assessment study will be conducted using ASPIC model. Essential data for stock assessment with ASPIC model include: i. Catch per Unit of Effort (CPUE) ii. Maximum Sustainable yield (MSY) iii. Total biomass in year of stock assessment (B1) iv. Carrying capacity (K) One course titled 'Size at Maturity will be conducted to the DOF Officer.

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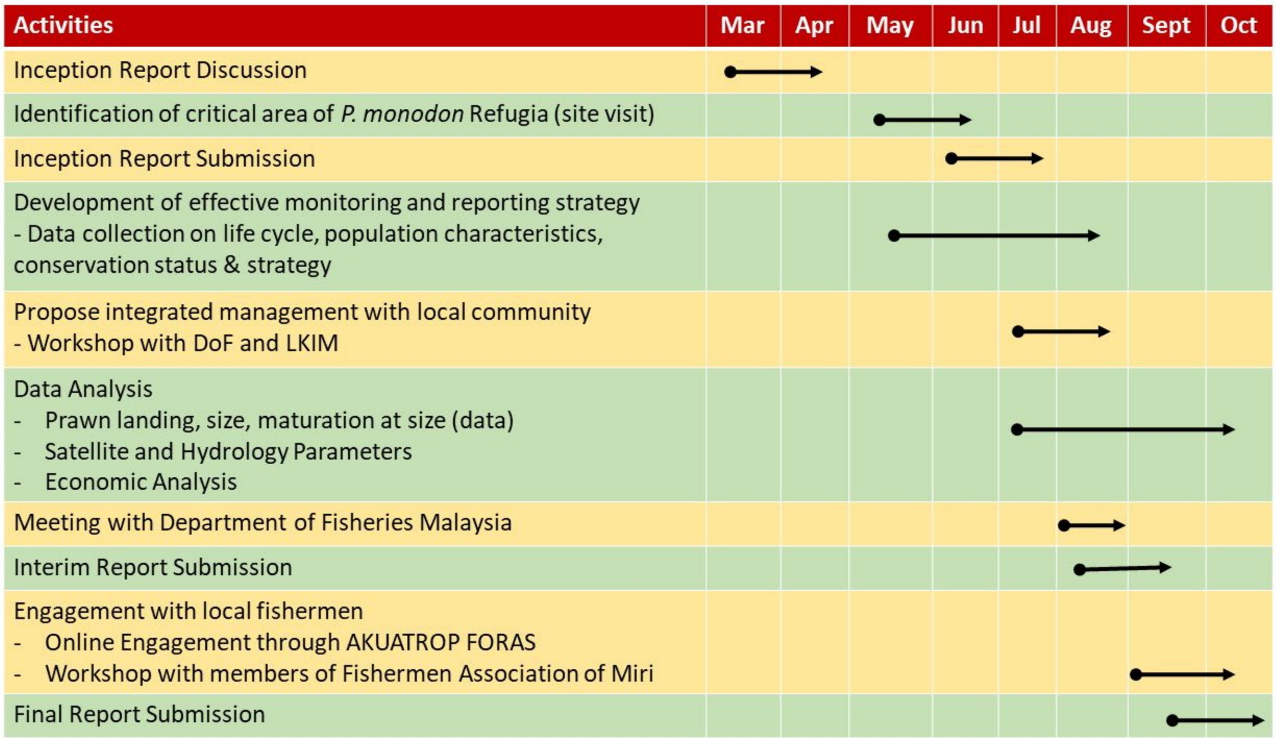
Appendices

Appendix A: Gantt Chart

The procedures of the *P. monodon* Fisheries Refugia management plan was detailed in the form of Gantt Chart.



Appendix B: Project Milestone

According to table below, the *P. monodon* Fisheries Refugia Management Plan started in May 2022 and is scheduled to end in October 2022.

Activities	Start Date	End Date	Status	% Completion
Inception report discussion and planning	1.03.2022	30.03.2022	Completed	10%
Identification of critical area of *P. monodon* Fisheries Refugia and site visit	1.05.2022	30.06.2022	Completed	20%
Data collection for effective monitoring and reporting strategy	1.05.2022	30.08.2022	Completed	40%
Integration management and engagement with local community	1.07.2022	30.08.2022	Completed	50%
Interim report preparation	1.08.2022	15.09.2022	Completed	60%
Data Analysis on shrimp landing, satellite & hydrology parameters and economic aspect	1.07.2022	1.10.2022	Completed	80%
Engagement with local fishermen ▪ Online Engagement through AKUATROP FORAS ▪ Workshop with members of Fishermen Association of Miri	1.09.2022	7.08.2022	Completed	90%
Final report	1.09.2022	31.10.2022	Completed	100%

Appendix C: Published Reports

Inception Report:

SEAFDEC-UNEP-GEF-MALAYSIA: REP-MY33

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

MANAGEMENT PLAN FOR TIGER PRAWN REFUGIA AT KUALA BARAM, MIRI, SARAWAK

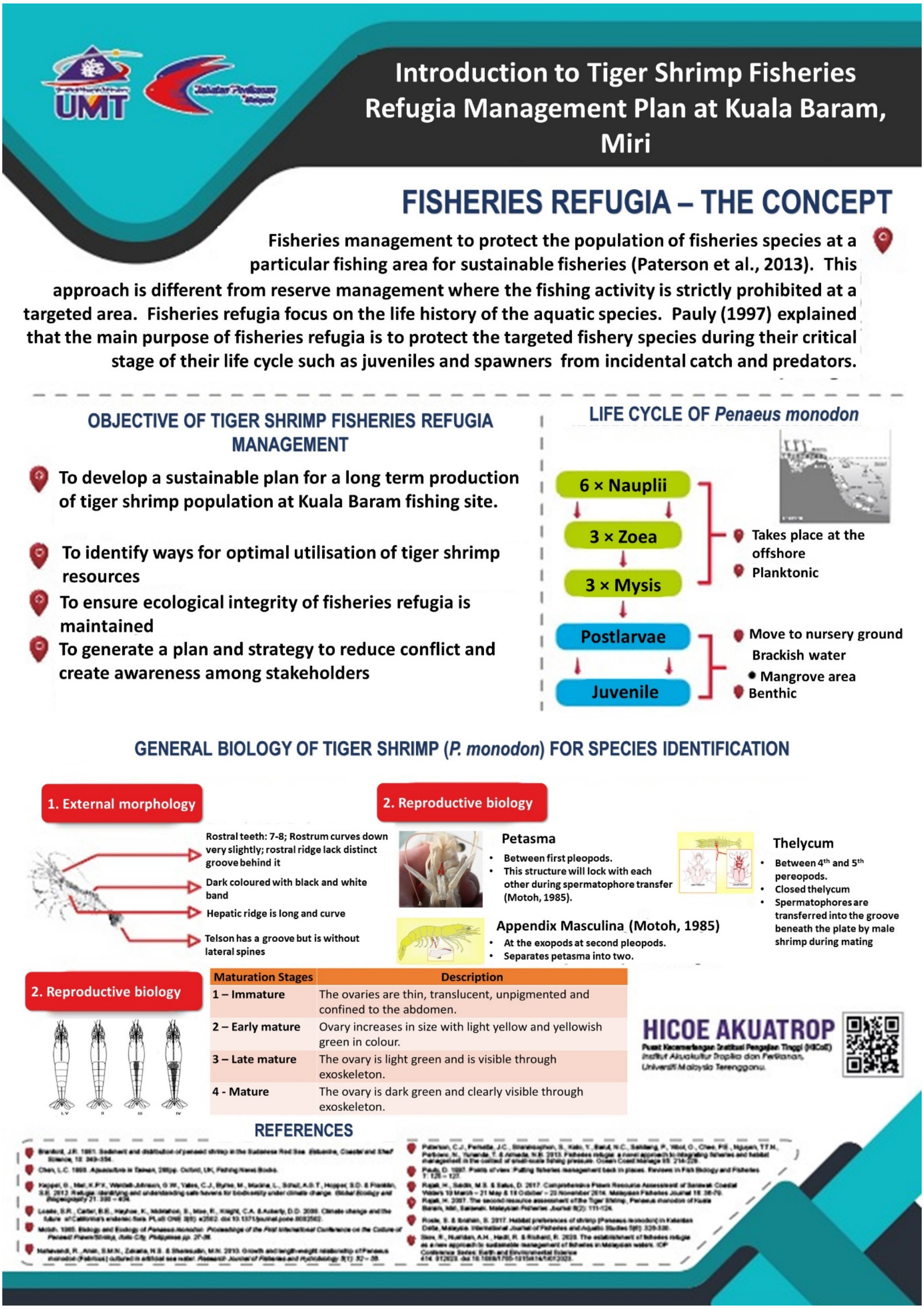
Mhd Ikhwanuddin Abdullah
Haji Hadil bin Rajali
Cheah Wee
Fazhan Hanafiah
Khor Wai Ho
Nur Azura binti Sanusi
Julia Moh Hwei Zhong

Department of Fisheries, MALAYSIA

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
TRAINING DEPARTMENT

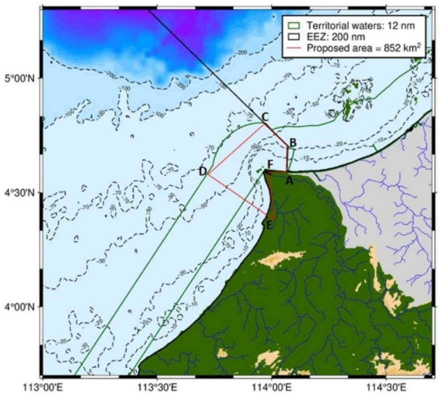
http://hdl.handle.net/20.500.12067/1821

Appendix D: Posters



Proposed Fisheries Refugia Area for Tiger Shrimp at Kuala Baram, Miri

TIGER SHRIMP FISHERIES REFUGIA AREA AT KUALA BARAM



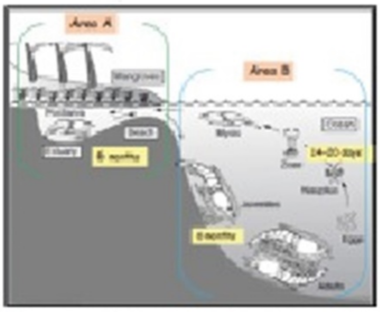
Total Area:
852km² (85, 200 hectare)

Coordinate

Point	Latitude	Longitude	Description
A	4° 35.40'	114° 3.84'	Start of Malaysia & Brunei border
B	4° 42.30'	114° 3.96'	Exclusive Economy Zone (EEZ) border
C	4°48.00'	113° 58.08'	
D	4° 34.74'	113° 43.32'	12NM from coastline
E	4° 22.80'	114° 0.60'	Marina Bay, Miri
F	4° 35.40'	113° 59.16'	Land area

TIGER SHRIMP FISHERIES REFUGIA BORDER ESTABLISHMENT

- **Border establishment based on the habitat of tiger shrimp during their life cycle.**
- **Area A:**
  - **Nursery Ground**
  - **Sungai Pasu, Sungai Lutong, Sungai Miri, Sungai Bakam and Sungai Sibuti**
- **Area B:**
  - **Spawning ground**



- **Kuala Baram waters up to 12 nautical miles from the shore (depth up to 50m)**
- **Shrimp stays at the bottom**
- **Postlarvae, juveniles and spawners**

TIGER SHRIMP SAMPLING DATA

In 2020, 79 juveniles were sampled (Nurridan, 2021):-

- **Male shrimp: 38**
- **Female shrimp: 41**
- **Area: Sungai Pasu, Sungai Lutong and Sungai Bakam**
- **Biomass: Directly proportional with the fishing rate and the river length (Highest biomass: 31.94kg)**

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Institut Akuakultur Tropika dan Perikanan,
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Proposed Close Season for Tiger Shrimp Capture at the Fisheries Refugia Management Plan Area at Kuala Baram, Miri

TIGER SHRIMP AND SEASONAL VARIATION PATTERN COMPARISON

01 Hydrological Parameter

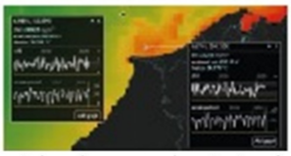
- Water temperature
- Rainfall
- Salinity
- Current
- Chlorophyll-a (Indicator for food source)
- Dissolved Oxygen
- Suspended material/particles (Indicator for turbidity)

02 Environmental Parameter

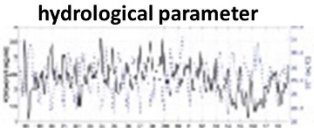
- Due to limited time series data, e.g.: continuous monthly hydrological parameters data at Kuala Baram.
- Recommendation – alternative data can be obtained from the satellite data

Close Season for Capture

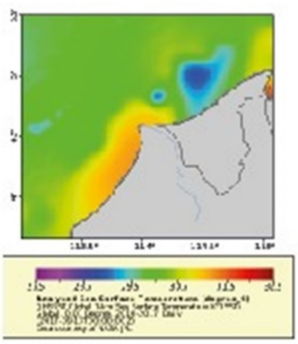
- To protect spawners
- Spawning season:-
  - July – November
  - Peak season - August
- Protection of postlarvae and juvenile population
- Close season will be included in the license regulation
- Close for trawls and trammer net



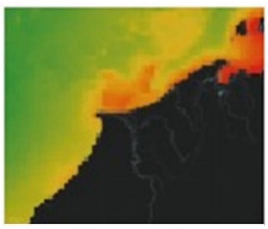
Spatial and temporal variation for hydrological parameter



Example of time series data for environmental parameters via satellite



Water temperature



Chlorophyll-a (food source)

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Proposed Landing Size for Tiger Shrimp at Kuala Baram, Miri

IMPORTANCE OF SIZE-BASED FISHERIES

- A common structuring variable
- Directly related to food consumption, mortality, maturation, fecundity, fish gear selectivity and population variation
- Feasible and relatively easy to be conducted

METHOD FOR SIZE-BASED HARVESTING

01 Size at sexual maturation

- Data required
  - Total length
  - Body Weight
  - Individual maturation status

02 Gonad maturation stage

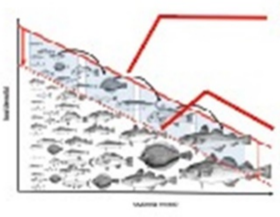
- Data required
  - Individual maturation status
  - Time of maturation

03 Length-weight relationship

- Data required
  - Total length
  - Body Weight

DISCUSSION

01 Ideal equilibrium community



- When body mass increases and density decreases
  - Can be seen in an unexploited fish community (solid red line)
- Balance harvest removes this cross section
  - Reduces the overall density, but contribute very little effect on the gradient (red dotted line)

02 Proposed implementation of size-based fishery

- Proposed size at maturation (Motoh, 1985)

Sex	Weight	Length
Female	82 g	18.0 cm
Male	35 g	13.4 cm

- Allowable size
  - Average size between male and female shrimp at maturation
  - Weight: > 60g
  - Length: > 15cm

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Appendix E: Pamphlets

Information on the Fisheries Refugia Management on Tiger Shrimp Area at Kuala Baram, Miri

- Divided into two areas

1. Nursery Ground

- Sungai Pasu
- Sungai Lutong
- Sungai Bakam
- Sungai Sibuti

2. Mating and Spawning Ground

- Area where broodstocks are found
- Offshore of Kuala Baram at deeper waters (10-60m)

For Inquiry

Jabatan Perikanan Malaysia

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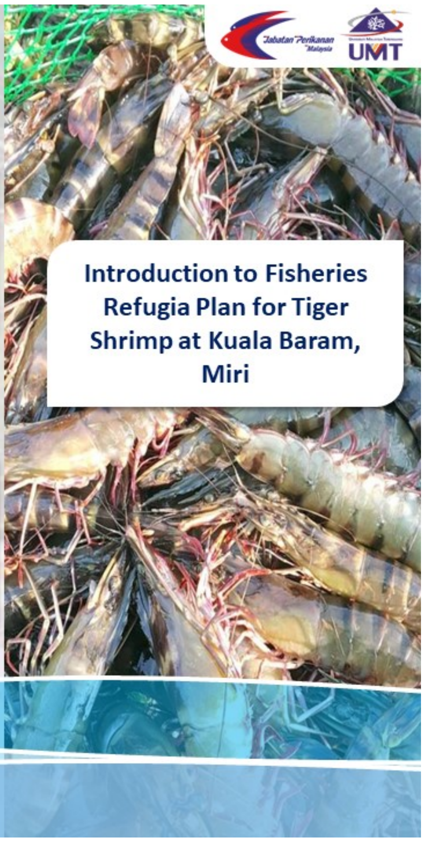


Jabatan Perikanan Malaysia · UMT

Introduction to Fisheries Refugia Plan for Tiger Shrimp at Kuala Baram, Miri

Concept of Fisheries Refugia

- Fisheries refugia is an innovative approach which involved in the identification and determination of areas for the integration of both fisheries and habitat management.
- Refugia management is different from reserve management:

Refugia	Reserve
Focus on the management of the habitat of fisheries interest	Full restriction on fishing activities of aquatic species

- The main focus of refugia is to preserve the area/population of targeted species from climate change related to anthropogenic activities.

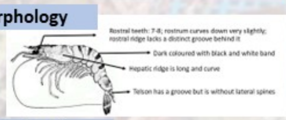
Tiger Shrimp Fisheries Refugia Objectives

- ❑ To develop a sustainable plan for a long term production of tiger shrimp population at Kuala Baram fishing site.
- ❑ To identify ways for optimal utilisation of tiger shrimp resources.
- ❑ To ensure ecological integrity of fisheries refugia is maintained
- ❑ To generate a plan and strategy to reduce conflict and create awareness among stakeholders.

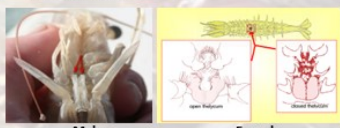
Important Aspect on the Fisheries Refugia Management for Tiger Shrimp

1. General Biology

Morphology



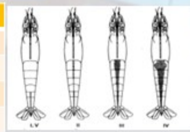
Reproduction



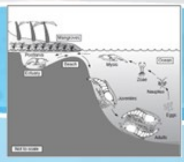
Male Female

Sexual Maturity

Maturity Stages
i - Immature
ii – Early Mature
iii – Late Mature
iv - Mature



2. Life Cycle



6 × Nauplii → 3 × Zoea → 3 × Mysis → Post Larval → Juvenile → Adult

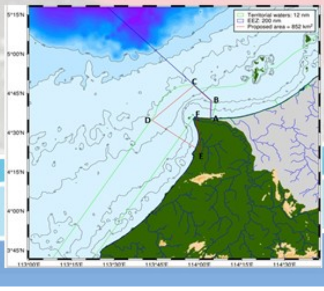
Proposed Area for Refugia Area Plan Coordinates

Coordinates:

Point	Latitude	Longitude
A	4° 35.40′	114° 3.84′
B	4° 42.30′	114° 3.96′
C	4°48.00′	113° 58.08′
D	4° 34.74′	113° 43.32′
E	4° 22.80′	114° 0.60′
F	4° 35.40′	113° 59.16′

Area:

- 852 km^2 (85,200 hectare)



For Inquiry

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Proposed Area for Fisheries Refugia Management for Tiger Shrimp at Kuala Baram, Miri

Pengenalan

Fisheries Refugia Plan for Tiger Shrimp is an initiatives from Fisheries Department with the purpose to preserve the only area with the biggest source of tiger shrimp in Sarawak.

The border establishment of the tiger shrimp fisheries refugia at Kuala Baram, Miri was based on the critical habitat during the life cycle of the tiger shrimp.

The larvae of tiger shrimp are planktonic dan they inhabit the offshore area for about 14 to 20 days throughout the larval phases hari.

The postlarvae and juvenile then move to the estuary and become benthic for 6 months before they entered the sub-adult phase followed by adult phase. The adult spawners then return to offshore for spawning.

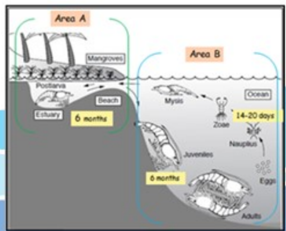
Refugia Management Plan Area

Area A:

- Nursery Ground
- Sungai Pasu, Sungai Lutong, Sungai Miri, Sungai Bakam and Sungai Sibuti

Area B:

- Spawning Ground
- Kuala Baram waters up to 12 nautical miles from the shore (water depth up to 50m).
- Post larvae, juvenile and spawners.



Harvesting Method for Tiger Shrimp

- Common harvesting method for tiger shrimp include drift net, hook & line, trammel net and trawl net:
- Common area for tiger shrimp harvesting:
  - **Kampung Kuala Baram**
  - **Kampung Pengkalan Lutong**
  - **Kamung Pulau Melayu**
  - **Kampung Piasau Utara**
  - **Kampung Kuala Bakam**

Seasonal Forecast Modelling

❑ Importance

- To understand the risk of climate change on the marine ecosystem at Kuala Baram for and effective management plan.

❑ Modelling Method

- An enhanced suite of marine ecosystem model from the Fisheries and Marine Ecosystem Model Intercomparison Project (Fish-MIP) was used to predict the effect of clmate change on the marine ecosystem and subsequently *P. monodon* population in Kuala Baram in the future.
- 10 years forecast development.
- The model explains how the variations of temperature and chlorophyll-a can predict the response of adult tiger shrimp stock at the offshore of Kuala Baram that depends on the phytoplankton as main food source.

For Inquiry

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Proposed Close Season for Capture at Fisheries Refugia Management Plan Area for Tiger Shrimp at Kuala Baram, Miri

Importance of Close Season

❑ To protect spawning female broodstock.

❑ To reduce the impact of environmental changes on the well-being of the shrimp.

- Climate change/environmental condition somewhat influence the shrimp behaviour such as migration pattern.

❑ To protect young shrimps

- Post larvae & juvenile.
- To allow them to grow before being captured.
- To allow new broodstocks to spawn at least once before being captured.

Seasonal Patterns Comparison of Tiger Shrimp with Seasonal Variabilities

❑ Focused on the relationship between the tiger shrimp season variabilities and important environmental parameters such as:

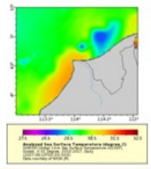
1. Hydrology Parameters

- Water temperature
- Salinity
- Chlorophyll-a (Indicator of food source)
- Suspended particulate matter (Indicator of river runoffs and nutrients)
- Rainfall
- Ocean current direction and speed
- Dissolved oxygen

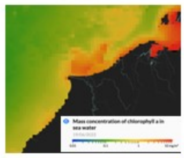
2. Environmental Parameters

- Monthly interval spanning over at least 2 years or a minimum of 1 year to cover all seasons.

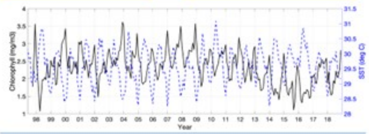
Proposed alternative data from the satelite data



Water Temperature



Chlorophyll a – Food Source



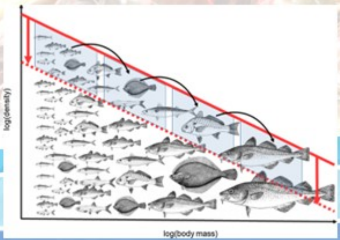
Example of time series data for sea surface temperature and chlorophyll a from the satellite.

Proposed Close Season for Capture

- For the protection of female broostock
  - Spawning season:
  - Julai – November
- To protect the population of post larvae and juvenile shrimp.
- Close season will be included in the license regulation.
- Closed for trawl net and trammel net

Ideal Equilibrium Community Size Spectrum

- **In an unexploited fish community**
  - The gradient is normal for increasing body mass and decreasing density (solid red line in the figure below).
- **Balanced harvest removes the cross section**
  - Reduces the overall density.
  - Balanced harvest will contribute little effect on this gradient (red dotted line)



For Inquiry

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Pusat Kecemerlangan Pendidikan Tinggi (HICoE)
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Proposed Landing Size for Capture at Tiger Shrimp Fisheries Refugia Management Plan Area at Kuala Baram, Miri

Introduction

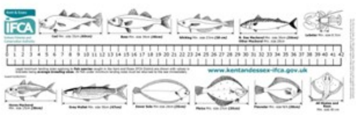
The increasing exploitation of wild fish stocks calls for a need for standardised and consistent fisheries management.

Age-based demographic description of Fish developed by Beverton and Holt (1957) was used in the past. However, the challenges involving this approach include:

- Unable to assess fish stocks due to limited data.
- Do not address the evolutionary side-effects of fishing .
- Do not incorporate the impact of density-dependent growth and/or cannibalism

Importance of Size Based Fisheries

- A common structuring variable.
- Directly related to food consumption, mortality, maturation, fecundity, fish gear selectivity, and population variation.
- Feasible and relatively easy to be conducted.



Method for Size Based Harvesting

1. Size at Sexual Maturity

- **Data required:**
  - Total Length
  - Body Weight
  - Individual maturity status

2. Gonad Maturation Stages

- **Data required:**
  - Time of maturation
  - Individual maturity status

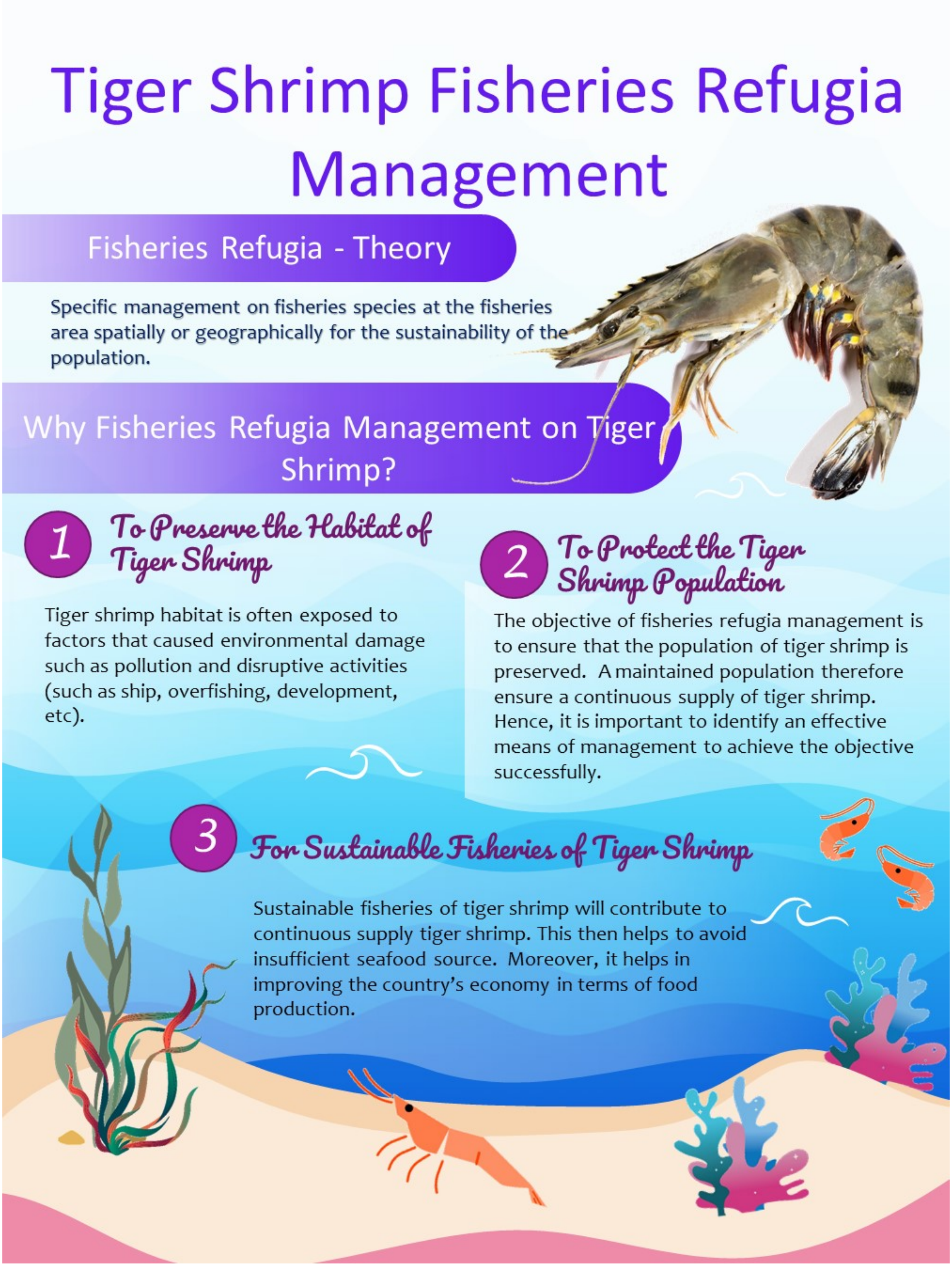
3. Length-Weight Relationship

- **Data required:**
  - Total Length
  - Body Weight

Proposed Landing Size for Capture

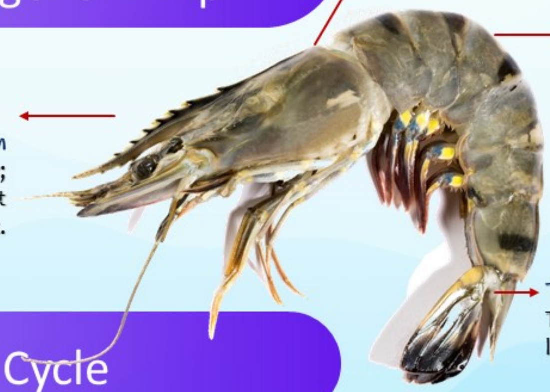
Sex	Body weight	Total Length
Betina	82 g	18.0 cm
Jantan	35 g	13.4 cm

Appendix F: Awareness Posters



Biology of Tiger Shrimp, *Penaeus monodon*

1 External Morphology of Tiger Shrimp



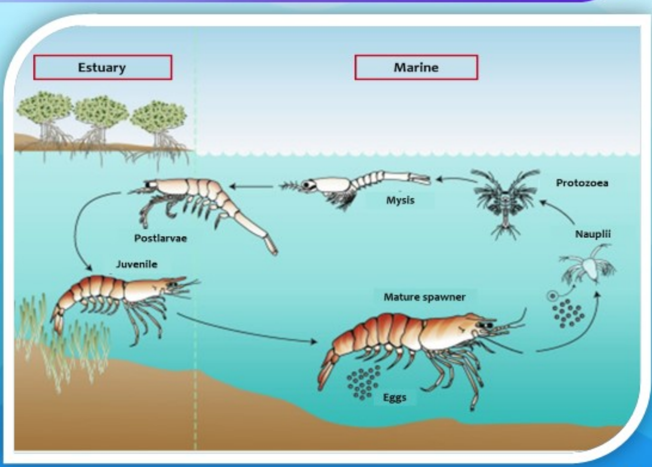
Hepatic Ridge
Long and curved.

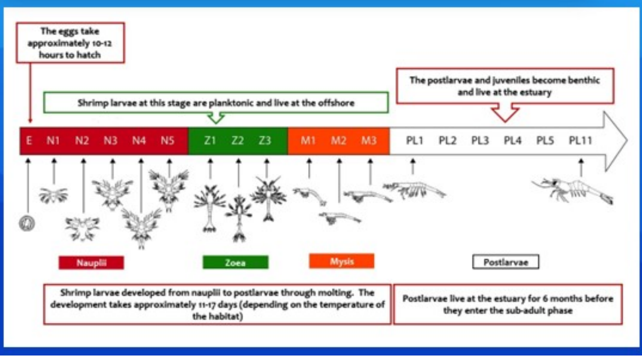
Colour
Presence of black and white stripes on the back and tail.

Rostrum
Curves down very slightly; rostral ridge lacks a distinct groove behind it.

Telson
Telson has a groove but is without lateral spines.

2 Life Cycle





The life cycle of tiger shrimp takes place in **2 areas:**

1. **Estuary**
2. **Offshore (Marine)**

Mating takes place at the offshore (**Marine**). Female broodstock then will developed and **produces eggs** at the marine area.

Shrimp larvae undergo developmental stages from **nauplii, zoea** and **mysis** at the **marine area** (≈ 11-17 days).

Postlarvae will then move to the **estuary** and develop into juvenile (≈ 6 months).

Juvenile shrimp then migrate to **offshore** and continue to grow until they reach maturity (approximately 5-6 months).

Landing Size Determination and Restriction on the Capture of Spawners at Kuala Baram, Miri

Importance of determination of landing size limit for capture

Capture of tiger shrimp without size limit will cause destruction of their life cycle.

Some of the complication that will arise without size limit fishing include:

1. Reduction of tiger shrimp population.
2. Smaller average size of matured shrimp.
3. Reduced shrimp quality (as food source).

Determination of landing size for shrimp capture

Total length of tiger shrimp at maturation:
Female : 18.0 cm (82g)
Male: 13.4 cm (35g)

Therefore, the proposed landing size allowed for capture for both shrimp

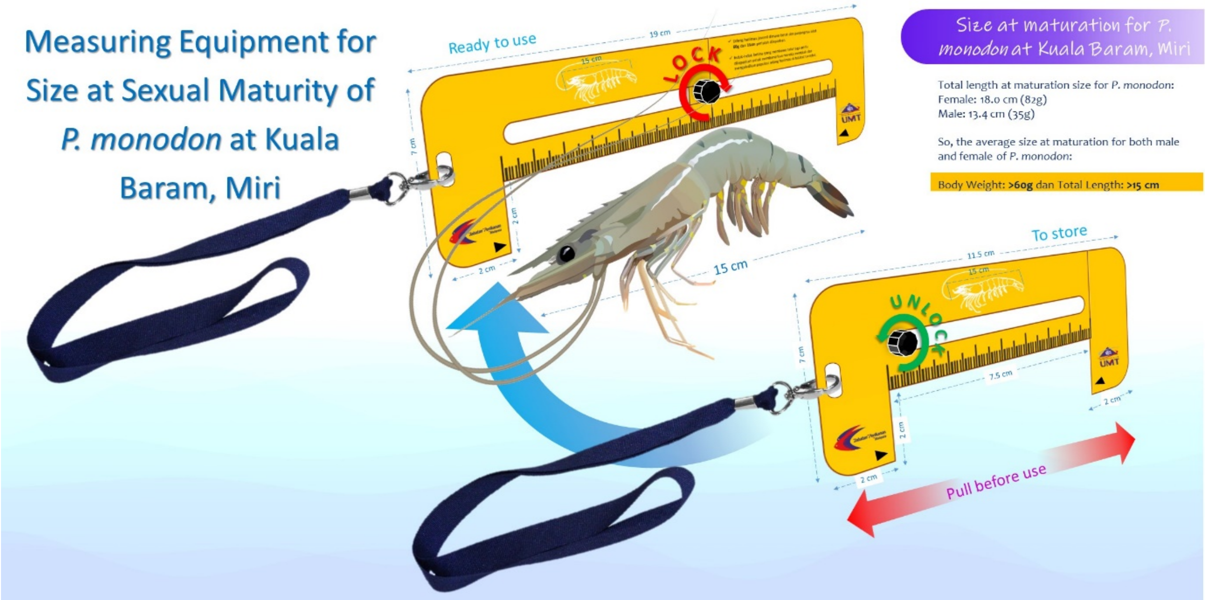
Body weight : **>90g** dan Total length: **>30 cm**

Juvenile shrimp and spawners should be released

Juvenile tiger shrimp with the weight and length that is below 60g and 15cm respectively should be released back into the water.

Spawners should also be released to allow them to reproduce and maintain the population of tiger shrimp at the habitat.

Appendix G: Proposed Measuring Equipment for Size at Sexual Maturity of *P. monodon*



Appendix H: Curriculum Vitae of Consultants

Consultant 1 (Lead Consultant)

PROF. DR. MHD IKHWANUDDIN ABDULLAH

EDUCATION

Dip./BSc. (UPM)
Malaysia

MSc./PhD. (Unimas)
Malaysia

CONTACT

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Field

Aquaculture

Expertise

Aquatic Invertebrates Culture and Biology

Specialization

- Hatchery and Seeding Production Technology

PUBLICATION

QR code link to SCOPUS personal page

RESEARCH INTEREST

My research primarily focuses on aquatic invertebrate culture, reproductive biology, breeding and reproduction. With respect to invertebrate aquaculture, I focus primarily on the culture and seed production of crustaceans from freshwater, marine and brackish environments. My research uses the understanding of invertebrate biology and physiology and translate them into the enhancement of seed and growout culture technology. The final goal of my research gears towards sustainable management strategies of aquaculture production. My previous projects involved crustacean species such as mud crab, blue swimming crab, spiny lobster, marine shrimp and freshwater prawn. Recently, my research focuses on the hatchery seed production of portunid crabs, ranging from understanding the fundamental knowledge of reproductive biology, broodstock management and breeding activities to the optimisation of larval rearing techniques that will pave the way for sustainable crab aquaculture development in the future.

PROFESSIONAL MEMBERSHIP

- National Shellfisheries Association, USA
- Asian Council of Science Editors
- Malaysian Fisheries Society
- Asean Fisheries Society

NETWORKING & RESEARCH COLLABORATION

- Shantou University, China
- Ginger and Coconut Development Sdn Bhd
- University of the Philippines Visayas, Philippines
- Southeast Asian Fisheries Development Center, Philippines
- Tokyo University of Marine Science and Technology, Japan
- Hasanuddin University, Indonesia
- Neocrab, Australia

EDITORIAL/ASSOCIATE EDITORIAL MEMBERSHIP

- Indonesian Aquaculture Journal
- Saudi Journal of Biological Sciences
- Journal of Sustainability Science and Management
- Frontiers in Marine Sciences

ACADEMIC RECOGNITION

- Adjunct professor - Universiti Malaysia Kelantan, Malaysia
- Guest Professor - National Taiwan Ocean University, Taiwan
- Visiting Professor - Shantou University, China

Consultant 2

PROF. DR. NUR AZURA SANUSI

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Field
Economics

Expertise
Financial Economics
Applied Econometrics

Specialization
Macroeconometrics
Islamic Financial Economics
Islamic Banking & Finance
Islamic Wealth Creation

PUBLICATION

QR code link to SCOPUS personal page

EDUCATION

B.Ec. (UKM)
Malaysia

Ph.D (UKM)
Malaysia

RESEARCH INTEREST

Nur Azura is at the forefront in social innovation, which is designed to help empowering people in improving quality of life. In research, she actively participated in more than 35 projects and committed as project leader for more than 15 projects worth more than RM5 million. In knowledge transfer, she has to date secured 16 grants amounting to approximately RM3.9 million, where she acted as principal investigator in 5 of such projects. Her current and past research projects are mainly in financial economics and she is currently focusing more into the community sustainability. Nationally, she serves as a resource person to the East Coast Economic Region Development Council on community sustainability. She is also a state task force member on the green financing research. She brings over 17 years of experience from research, teaching, education management, community product development, project management, consultancy and community engagement that focus on social innovation.

PROFESSIONAL MEMBERSHIP

- Member of International Council of Islamic Finance Educators (ICIFE)
- Member of Malaysian Consumer and Family Economics Association (MACFEA)
- Member of Malaysian Econometric Society

NETWORKING & RESEARCH COLLABORATION

- Terengganu Strategic & Integrity Institute
- Ministry of Higher Education, Malaysia
- National Hydraulic Research Institute of Malaysia
- East Coast Economic Region Development Council
- Forest Research Institute Malaysia
- Port of Tanjung Pelepas
- Universitas Trisakti, Indonesia
- Universitas Padjajaran, Indonesia

EDITORIAL/ASSOCIATE EDITORIAL MEMBERSHIP

- Journal of Business and Social Development
- Journal of Indonesian Treasury Review

ACADEMIC RECOGNITION

- Panel of appraiser – Malaysian Qualifications Agency (MQA)

Consultant 3

DR. KHOR WAI HO

EDUCATION

BSc. (UNIMAS)
Malaysia

Msc./PhD. (UMT)
Malaysia

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Field
Aquaculture

Expertise
Crustacean Breeding & Biotechnology

Specialization

- Larval rearing
- Reproductive biology
- Population health

RESEARCH INTEREST

My main research focus is on crustacean breeding and biotechnology. I work towards enhancing the culture (larval, juveniles and adults) of economically important crustacean species, especially portunid crabs, by applying various biotechnological tools to understand and manipulate the sex determination and differentiation processes. Further, to enhance growth, I am currently looking into the moulting mechanism and potential manipulation of this process in crustacean species. The inevitable effect of climate change on marine species, especially shellfish, also sparks my interest to understand the potential impact of changes in climate change-induced temperature and alkalinity have on the general growth and wellbeing of economically crustacean species, and how this would impact the crustacean fisheries and aquaculture.

PUBLICATION

QR code link to SCOPUS personal page

NETWORKING & RESEARCH COLLABORATION

- Hasanuddin University, Indonesia
- University of the Philippines Visayas, Philippines
- Shantou University, China
- Ningbo University, China
- Henan Normal University, China
- University of Bergen, Norway
- University of Copenhagen, Denmark
- Zoological Institute of the Russian Academy of Sciences, Russia

EDITORIAL/ASSOCIATE EDITORIAL MEMBERSHIP

- Frontiers in Physiology
- Frontiers in Marine Science

Consultant 4

DR. MOHD FAZHAN MOHD HANAFIAH

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Field
Aquaculture
Marine Biology and Ecology
Genetics

Expertise
Crustacean Breeding, Ecological studies and Genetics

Specialization

- Mud crab breeding and Grow-out culture
- Genomics studies
- Marine Biology and Ecology studies

PUBLICATION

QR code link to SCOPUS personal page

EDUCATION

BSc. (UNIMAS)
Malaysia

Msc. /PhD. (UMT)
Malaysia

RESEARCH INTEREST

My research focuses primarily on the breeding, grow-out culture, and genetic studies of crustaceans especially crabs and shrimps, to study their genetic inheritance, diversity, grow-out culture and feasibility to be the local brood stocks candidate for aquaculture production. I look into the phylogenetics and evolution of brachyuran crabs using various methods, including mitochondrial genes, nuclear genes, mitochondrial genome and gene families, and single copy gene derived from transcriptome data. Besides, I am also interested on the uniparental inheritance (maternal and paternal) of crustaceans in mitogenomic aspect. Furthermore, from the previous research, I described the population dynamics of all mud crab species in the wild and found the occurrence of presumed hybrid mud crabs in the equatorial region. I found and described four presumed hybrid groups that are morphologically distinct compared to the original four *Scylla* species. I also tested the feasibility of inter-species mating and discovered that crosses between *Scylla* species is easily induced in captivity. This further increases my interest to investigate the potential effect of climate change (increase in seawater temperature) in inducing the occurrence of presumed hybrids of *Scylla* in the wild. In conclusion, my research interest and focus are important in the selective breeding program of crustacean aquaculture and also important in the future prediction of crustacean aquaculture amid global warming.

NETWORKING & RESEARCH COLLABORATION

- Hasanuddin University, Indonesia
- University of the Philippines Visayas, Philippines
- Shantou University, China
- Ningbo University, China
- Henan Normal University, China
- University of Bergen, Norway
- University of Copenhagen, Denmark
- Zoological Institute of the Russian Academy of Sciences, Russia

Consultant 5

HADIL BIN RAJALI

EDUCATION

BSc. (USM) Malaysia	MSc. (University of Aberdeen) Scotland, UK

CONTACT

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Field-biology

Expertise-Fish stock assessment

Specialization-shrimp stock assessment

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RESEARCH INTEREST

Fish stock assessment involving swept area method for demersal fishes and shrimps and hydro-acoustic method for pelagic fishes. Population dynamics studies for all fishes, shrimps and prawns.

PUBLICATION

Google Scholar: hadil rajali

NETWORKING & RESEARCH COLLABORATION

- Fisheries Research Institute, Department of Fisheries Malaysia

EDITORIAL/ASSOCIATE EDITORIAL MEMBERSHIP

- Fisheries Research Institute, Department of Fisheries Malaysia

Consultant 6

DR. CHEAH WEE

EDUCATION

BSc./MSc. (USM) Malaysia	PhD. (UTas) Australia

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Field
Oceanography, air-sea-land interaction,

Expertise
Biological oceanography

Specialization
Earth observation, satellite remote sensing

RESEARCH INTEREST

I am an oceanographer interested in how hydrological processes affect biological activity in the ocean, especially under the context of ocean warming. My research involves field observations, synthesis of open datasets, satellite remote sensing and numerical models. My current research focuses on how environmental changes affect carbon fixation, nitrogen fixation in the Indian and Pacific Oceans. Beside the tropical ocean, I also study how carbon fluxes in the Southern Ocean respond to changes in environmental forcing and phytoplankton composition.

PUBLICATION

QR code link to SCOPUS personal page

PROFESSIONAL MEMBERSHIP

- International Association for Biological Oceanography
- Asia-Oceania Geosciences Society

NETWORKING & RESEARCH COLLABORATION

- University of Tasmania, Australia
- Australian Antarctic Division, Australia
- Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Germany
- First Institute of Oceanography, China
- Nagoya University, Japan
- National Institute for Polar Research, Japan
- Academia Sinica, Taiwan
- National Taiwan Ocean University, Taiwan

EDITORIAL/ASSOCIATE EDITORIAL MEMBERSHIP

- Frontiers in Marine Sciences

ACADEMIC RECOGNITION

- Scientific Committee on Oceanic Research (SCOR) Executive Committee, Early Career Scientist Representative, 2022-2024
- Third Place Winner for the Best Poster Award, Polar Research Symposium
- AUA Scholars Awards, Asian Universities Alliance (AUA)
- Best Oral Presentation (Asian Region), 34th Scientific Committee on Antarctic Research (SCAR) Open Science Conference
- Academia Sinica Postdoctoral Scholar Award