THE ESTABLISHMENT OF TIGER PRAWN *(Penaeus monodon)* REFUGIA :

Compilation of Research Findings on Broodstock, Juvenile, Female Maturation Stages and Socio-Economic Study

Nurridan binti Abdul Han
Fisheries Research Institute Bintawa
Department of Fisheries Malaysia

SEAFDEC/UNEP/GEF Fisheries *Refugia* Project

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

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Author :
Nurridan binti Abdul Han

Editors :
Jamil bin Musel
Norhanida binti Daud
Buniamin Kiprawi

2021

DEPARTMENT OF FISHERIES MALAYSIA

THE ESTABLISHMENT OF TIGER PRAWN
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First Edition

Project Leader of the Tiger Prawn Refugia Project Kuala Baram
Fisheries Research Institute
Sarawak and Labuan Division
Department of Fisheries Malaysia,
93744 Bintawa, Kuching, Sarawak.
Tel : 082-334144
Fax : 082-331281

ISBN 978-983-43977-1-5

Printed by:
Malien Press Sdn. Bhd.
G/FL Lot 184, Section 49, Jalan Abell, 93100 Kuching, Sarawak, Malaysia.
P. O. Box 3068, 93760 Kuching, Sarawak.

For citation purposes this document may be cited as:
Nurridan, A.H. (2021). The Establishment of Tiger Prawn *(Penaeus monodon)* Refugia: Compilation of Research Findings on Broodstock, Juvenile, Female Maturation Stages and Socio-Economic Study. In The Establishment of Tiger Prawn *(Penaeus monodon)* Refugia: Compilation of Research Findings on Broodstock, Juvenile, Female Maturation Stages and Socio-Economic Study, edited by Jamil, M, Norhanida, D & Buniamin, K. 1st Edition. Fisheries Research Institute Bintawa: Kuching, Sarawak. 114 p.

TABLE OF CONTENTS

PREFACE

By the Grace of Allah the Beneficent, the Merciful, and the Compassionate, I am able to complete this book "The Establishment of Tiger Prawn *(Penaeus monodon)* Refugia: Compilation of Research Findings on Broodstock, Juvenile, Female Maturation Stages and Socio-Economic Study".

The Fisheries Research Institute (FRI) Bintawa was given the trust and task as an agency that conducts research and disseminates scientific information on tiger prawns where this information is used in the project titled SEAFDEC/UNEP/GEF Fisheries Refugia Project: Establishment and Operation of a Regional System of Fisheries Refugia in the South China Sea and the Gulf of Thailand.

This book highlights the findings of research done in conjuction with the establishment of Tiger Prawn refugia in Kuala Baram, Miri, Sarawak. It will bring the readers to the Tiger Prawn journey where research is being carried out entailing the tiger prawn spawners (gravid adult tiger prawns), juvenile tiger prawns and the study of maturation stages of gravid tiger prawns. In addition, a study on socioeconomic factors was included to depict the health of the tiger prawn industry as well as reviewing fishermen's acceptance towards the refugia establishment.

This book contains a technical report that includes a complete biological study of tiger prawn broodstock and juvenile resources for the benefit and reference of other researchers, departmental management, and stakeholders to ensure tiger prawn fishery resources are maintained sustainably.

Apart from research on the biology, resources, and socio-economics of these tiger prawns, in 2018, a documentary titled *Udang Harimau Khazanah Negara* was broadcast on Radio Television Malaysia (RTM) TV1. The show highlights research activities related to tiger prawns as well as exposing the general public to the importance of protecting the species and informing fishermen in particular and the local community in general about the government's efforts through the Department of Fisheries Malaysia in its conservation. Images of research activities, including documentary filming, are inserted at the end of this book to guide the reader through the project's journey.

Thank you.

Nurridan binti Abdul Han

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ACKNOWLEDGEMENT

I wish to convey my sincere gratitude to the Director-General, Department of Fisheries Malaysia, Mr. Ahmad Tarmidzi bin Ramly, former Senior Director of Research, Dr. Zainoddin bin Jamari, Fisheries Research Institute, Department of Fisheries Malaysia, for their encouragement and valuable support in carrying out this work. A debt of gratitude is also due to, Mr. Bohari bin Leng, the Director of Department of Marine Fisheries Sarawak, Director of Fisheries Research Institute Bintawa, Mr. Jamil bin Musel, colleagues, family and friends directly and indirectly in supporting me throughout the project.

A heartfelt appreciation goes to Mr. Hadil bin Rajali, former deputy senior Director of Research, for his mandate, motivation, and enthusiasm that were inculcated into me to complete this study.

This project is jointly funded by grants from the SEAFDEC/UNEP/GEF Fisheries Refugia Project and the Malaysia Government developmental grants P21-30701011-23300-069.

Finally, I take this opportunity to thank certain individuals for their patience, understanding, assistance and team work : Madam Liza binti Long, Mr. Dokanear Kasto ak Muning, Mr. Buniamin Kiprawi, Cik Anis Ariffin, Mr. Kennedy Edward, Mr. Hassan bin Arshad, Mr. Adenan bin Pata, Mr. Faizal bin Udai, Mr. Sumady bin Derimi, Mr. Hady bin Asek (photographer), Mr. Ezni bin Rais, Mr. Nazrul bin Ahmad Zaidi and Mr. Mohd Zullkernean bin Jak'ba.

INTRODUCTION

The penaeids are made up of 225 species from 26 genera (Food and Agriculture Organization of the United Nations, FAO, 2008). It has been reported that 300 species of prawns have economic value, but only 100 of those are recorded in landings statistics worldwide (Chan, 1998), indicating their commercial value. The tiger prawn, *Penaeus monodon,* belongs to the Family Penaeidae and is one of the largest and most commercial commodities. Its body length can reach 270 mm, making it one of the largest prawns in the Family Penaeidae.

Since the 1980s, the prawn industry, particularly for tiger prawns, has been expanding. This prawn has now established itself as one of the most important aquaculture livestock, contributing significantly to the value of aquaculture landings. In ponds around the world, there are more than ten species of commercially farmed prawns, but tiger prawns *(P. monodon)* are among the most popular. Tiger prawns are farmed in tropical Asian countries and account for 60-70 percent of global livestock prawn production, up from 52 percent in 1998. However, because global marine fisheries are declining and resources are depleting (FAO, 2018), management mitigation measures were implemented to address these issues including refugia. Refugia is stated as a new tool to sustainable management for fisheries in Malaysian waters.

The refugia concept is defined as *"Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use"* (UNEP, 2005).

It focuses on the nature of the particular habitat and its critical significance to the life-history of the fished species. The refugia concept covers specific areas of significance to the life cycle of fish species, should be defined in space and time, should not be no-take zones, and serve to safeguard spawning aggregations, nursery grounds, and migration routes.

Whereas, refugia's objective was to ensure that the fishery resources are exploited sustainably through protection of critical stages of their life cycle such as during migration, spawning and juvenile periods.

Tiger prawns in Kuala Baram was identified as the candidate for refugia management concept due to substantial landings of tiger prawn were found in Miri waters in Sarawak, though they can also be found in Kuching, Kabong, and Lawas. According to a study conducted by the Fisheries Research Institute Bintawa in Sarawak, the total potential of tiger prawns is found in the coastal waters of Bintulu to Miri. Subsequent studies found that the waters of Tanjung Batu to Kuala Baram in Miri are a breeding area for tiger prawns, and it was found that local fishermen have identified the area for obtaining tiger prawns.

As a consequence, a national consultation was held in Malaysia to identify priority locations for the establishment of fisheries refugia. Representatives from local government units, research institutes, law enforcement, fisher folk organisations (e.g., The Fishermen Association, PN), and non-governmental organisations are among those involved in this consultation project. The goal of these consultations was to introduce participants to the concept of fisheries refugia sites, which included: establishing a shared understanding of the concept of fisheries refugia among participants; and prioritising sites for inclusion in a national and regional fisheries refugia system. The consultation also took into account available information on areas critical to the life-cycles of demersal and pelagic species along Malaysia's South China Sea coast. Because the fisheries refugia concept focuses on the protection of fish populations during a specific space and time in their life cycle, complete scientific information about the fish's life stages must be obtained.

The objective of the establishment of refugia areas:

(1) The establishment of refugia areas aims to ensure a sustainable source of tiger prawns where resources in natural habitats are exploited in a controlled manner.

(2) Protect tiger prawn breeding areas through the enforcement of a closed season for any tiger prawn fishing activities during the breeding period

(3) Ensure that the tiger prawn broodstock is preserved through an effective management action plan, like refugia.

(4) Help increase the economic potential of the target group through the sustainable management of tiger prawns. The creation of refugia areas in Kuala Baram can help raise awareness of local communities on the importance of conserving ecosystems and fishery resources.

Site Characterization of the Tiger Prawn *(Penaeus monodon)* refugia in Kuala Baram, Miri, Sarawak

***Nurridan Abdul Han**

Fisheries Research Institute Bintawa, Department of Fisheries Malaysia,
Sarawak and Labuan Division, Jalan Perbadanan, Bintawa, 93744, Sarawak.
*E-mail: nurridan@dof.gov.my

Biological component

Biological features

Similar to all penaeid shrimp, the rostrum well developed and toothed dorsally and ventrally. Carapace without longitudinal or transverse sutures. Cervical and orbito-antennal sulci and antennal carinae always present. Hepatic and antennal spines pronounced. Pterygostomain angle round. Stylocerite at first antennular segment. Basial spines on first and second pereiopods and exopods on the first to fourth pereiopods usually present. No fixed subapical spines on telson. Adrostral sulcus and carina are short, not reaching posteriorly beyond midlength of carapace. Gastro frontal carina absent. Females have closed-type thelycum (Refer to Photo 1-B). Petasma in male symmetrical with thin median lobes (Refer to Photo 1-A). The most distinct features for identification of this species are: fifth pereiopods without exopod; hepatic carina horizontally straight; and gastro-orbital carina occupying the posterior half of the distance between hepatic spine and postorbital margin of carapace. Adults may reach 33 cm in length and females are commonly larger than males (Refer to photo 2 and 3)

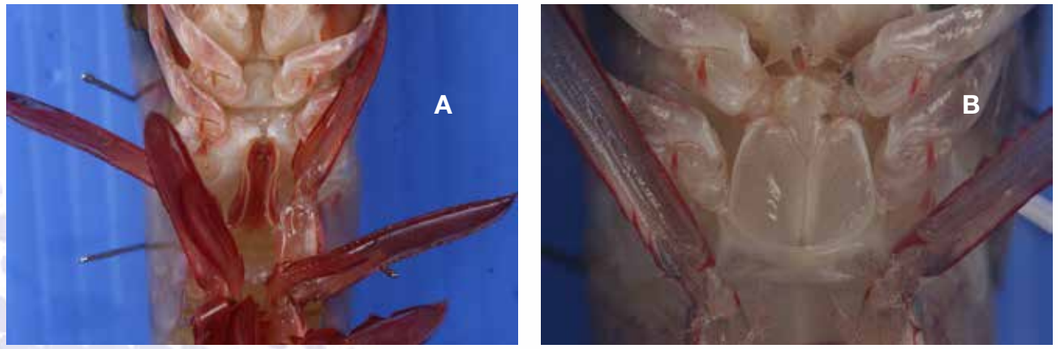

Photo 1: A-petasma-male genitalia, B-thelycum-female genitalia

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
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Photo 2: Female spawners weighing 231 grammes from Krokop market

Photo 3: Different size of gravid female *P. monodon*

Penaeus monodon can be found between the longitudes of 30°E and 155°E, and the latitudes of 35°N and 35°S. Its natural habitats span the Indo-Pacific, the Red Sea, Pakistan, the Malay Archipelago, the Philippines, Taiwan, Japan, Korea, Northern Australia, and Fiji (Pérez-Farfante and Kensley, 1997). According to Motoh (1981), tiger prawn's fishing grounds are largely in tropical countries, including Malaysia, Indonesia, and the Philippines.

Habitat and biology

It is one of the world's largest penaeid prawns, with global commercial significance. *P. monodon* mature adults only reproduce in tropical marine habitats up to 110 m depth on continental shelves (Holthuis, 1980), but the other larval stages, as well as the juvenile, adolescent, and sub-adult stages, grow in estuaries, coastal lagoons, and mangroves (Sandoval *et al.*, 2014). The life cycle of tiger prawn follows the same pattern of all penaeids prawn, starts with spawning in the sea and larvae will travel into the estuaries until pre-adult stages and go back to the sea to mature and spawn (Refer to Figure 1).

In the case of Sarawak, landings of the prawn increased in the state from October onwards, peaking during the monsoon months of January to March (Hadil, 1994). Tiger prawns were captured in relative abundance in coastal waters from Bintulu to Miri, notably off Kuala Suai, in water depths ranging from 10 to 20 metres with a mud-sandy substratum, according to previous surveys (Bejie, 1981, 1982, 1983).

According to observations and study conducted in 1998, tiger prawn spawners were found in water depths of more than 30 metres in Tg. Batu, Miri to Kuala Baram, Miri (Hadil and Faazaz, 1998). Since 1997, spawners have been collected by local trawlers. The information was confirmed by a resource survey done in 1999. (Hadil and Albert, 2001).

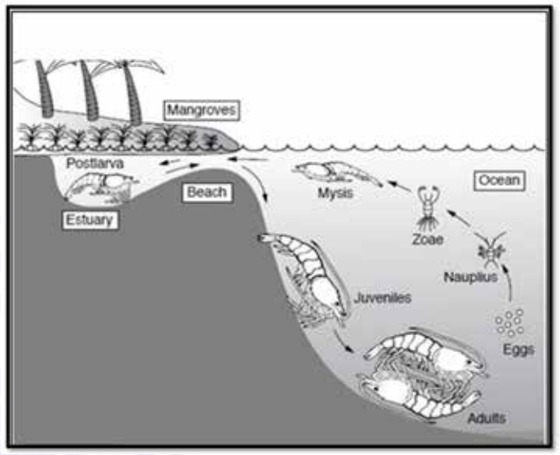


Figure 1: A diagrammatic of the life cycle of penaeids prawn (including *P. monodon*)

The offshore area of Kuala Baram, Miri, Sarawak, sloops into deep water (as close as 4 nautical miles), as is typical of a continental sloop area (Hadil and Faazaz,1998, Hadil and Albert, 2001, Hadil, 2004, Hadil, 2007, Hadil, 2014). The tiger prawn spawners or adults were found in this deeper water. Meanwhile, the juvenile tiger prawns were found in the nearby rivers, like *Sungai Pasu, Sungai Lutong, Sungai Bakam* and *Sungai Sibuti*. These rivers act as a nursery for the juvenile tiger prawns (Nurridan, 2021).

The out-rigged trawlers caught the adults tiger prawn usually at night, due to tiger prawn burrow themselves in the mud to protect themselves from predators and feed normally at night. For juveniles, artisanal fishermen collect juvenile tiger prawns by cast net.

Spawning season for tiger prawn starts from July to November each year, with August being the highest month. This maturation trends were also in line with study done in India that suggest fully matures ovaries occur throughout the year with August and March as peak spawning season (Kannan *et al.*, 2014). If refugia is to be implemented, where it will take into account the closure of the area off Kuala Baram during the spawning season, it is suggested that from August to October as a closed season to protect the gravid prawn from being caught and overexploited.

Ecological component

Marine Habitats

A tiger prawn refugia is proposed near the river mouth of Kuala Baram in Miri, Sarawak, to offset this diminishing situation, and the refugia site has been generally determined based on past and current research findings (Hadil & Faazaz, 1998, Hadil & Albert, 2001, Hadil, 2004, Hadil, 2007, Hadil, 2014). The refugia covering an area of approximately 852 km^2 in Kuala Baram area, Miri, Sarawak (Refer to Figure 2). (P1-N4 35.283, E114 04.359, P2-N4 47.202, E114 03.548, P3-N4 45.046, E113 50.527, P4-N4 36.671, E113 45.883, P5-N4 23.400, E113 58.200). The suggested location for the tiger prawn refugia is next to a mangrove forest with a river mouth nearby. As the region is adrift, the offshore area sloops into deeper depths.

The Sarawak basin covers a wide area both onshore and offshore which is divided into geological provinces, namely the West Baram Delta, Balingian, Central Luconia, Tinjar, Tatau, West Luconia and SW Luconia and SW Sarawak Provinces. The refugia site is placed under Baram Delta Basin, that was a tertiary basin, which developed in Late Eocene times after organic uplift and folding of Crestaceous to Eucene eugosylindrical sediments. Soft to firm silty clay, make up the bottom sediment type (Nagarajan *et al.*, 2015). There are numerous oil and gas projects of SHELL and PETRONAS located near the refugia area.

Besides the oil and gas, there are a few coral reef areas near refugia site, namely the Miri-Sibuti Coral Reef National Park and The Siwa Reef. The Miri-Sibuti Coral Reefs National Park is a gazetted National Park with water depth ranging from 7 to 50 m (23 to 164 ft) at the seaward edge, has an average visibility of 10 to 30 metres (33 to 98 ft) and estimated area coverage was 186,930 hectares. It comprises of multiple popular diving sites includes Luconia Area, Anemone Garden, Grouper Patch Reef, Atago Maru Wreck and Seafan Garden. Notably as the largest offshore national park created in the state of Sarawak.

The nearest patchy reef was Siwa Reef and is 7 to 13 m deep. Mostly composed of a diversity of massive corals. The live tissue of many of the hard corals was heavily covered with filamentous algae, indicating nutrient enrichment coming from outside the reef. Average live coral cover was between 20 and 30 %, and the large amount of algal growth indicated that the reef was under environmental stress. A total of 203 species, 66 genera of stony corals and 13 families of stony coral (198 species and 62 genera of zooxanthellate Scleractinia) was founded in the Sarawak waters (Daud, 2010).

Figure 2: Map showing the location of the tiger prawn refugia site (line with red colour), covering an area of approximately 852 km^2 in Kuala Baram area, Miri, Sarawak.

Oceanography

Winds

The general features of the coastal region of Sarawak come under the influences of the hydrography of South China Sea and the Sulu-Celebes Sea and is strongly influenced by the characteristics of the Monsoon periods and the currents are expected to be mainly wind-driven. There are four seasons affected the refugia site, that are (1) Northeast monsoon (November to March), (2) Inter Monsoon/Transition (April to May), (3) Southwest Monsoon (June to September) and (4) Inter-Monsoon/Transition (October to November).

Waves

Waves are primarily wind driven by the monsoons with the roughest weather arriving from the north-northeast during the northeast monsoon. In addition, tropical storms and typhoons in South China Sea can also produce severe weather, although much less predictable.

Currents

In the South China Sea, there are several significant mechanisms driving currents, these include: tidal currents (diurnal), surface wind driven currents, basin response currents derived from tropical storms or strong monsoonal surges and density driven currents (particularly near the outflow of large rivers, like Baram).

Water quality

Water quality at the refugia site was based on Marine Water Quality Standard (MWQS). Water quality like temperature, pH, salinity and dissolved oxygen were recorded using water checker (Table 1)

Table 1: Marine Water Quality Standard (MWQS) of all the six station (in refugia site)

Parameters	St 1	St2	St3	St4	St5	St6	MWQS (Class 3)
Temperature °C	30.50	30.43	29.90	30.20	31.00	30.38	≤2 °C#
pH@25°C	7.90	8.00	8.03	8.05	8.04	7.89	6.5-9.0
Dissolved oxygen, mg/L	3.45	4.56	4.90	5.22	4.77	3.85	> 3.0
Salinity, ppt	34.28	34.82	34.68	32.38	31.33	32.78	Not stated

Temperature in the marine environment can affect the population, species, and community-level activities of marine life (for example, affecting marine larval dispersal) as well as the rate of pollutant biodegradation. Meanwhile, pH is a valuable metric for assessing the chemical and biological state of seawater. All of the stations' pH levels are considered normal and within the standard range.

Nearly all aquatic life depends on dissoved oxygen (DO) to survive. The motion of waves and currents in sea water would allow oxygen from the atmosphere to dissolve in the water. Photosynthetic activity of phytoplankton, seaweeds, and seagrasses would also help to raise dissolved oxygen levels in seawater. The concentration of dissolved oxygen in all stations in refugia site was satisfactorily good and within the MWQS range.

Socio-economy

Fishermen community

Sarawak is the largest state in Malaysia with an area of 124,448.51 sq km and a perimeter of 2,991 km. Sarawak also has the largest Exclusive Economic Zone in Malaysia and a coastline length of approximately 1,035 km from Tanjung Datu to Merapoh. In addition, there are 23 estuaries gazetted in Sarawak. There are 15 Fisheries Districts in Sarawak with 175 fishing bases and 223 fishing villages. Fishing areas in Sarawak waters are of various types seabed. This affects the types of fishing gear that are appropriate to the location of the fishing activity carried out. Due to the uniqueness of sea bed and continental shelf in Sarawak, the fishing zone system in Sarawak slightly differ from other states in Malaysia. In Sarawak, including refugia site, there are 4 fishing zones namely Zone A (0-5 NM), Zone B (5-12 NM,), Zone C (12-30 NM) and Zone C2 (30 NM to EEZ boundary) (Refer to Table 2)

Table 2: Fishing zone in Sarawak waters depending on vessel, fishing gears and shoreline

Zone	Vessel (GRT)	Fishing gears / Operators	Shore line (NM)
A	0-<40	Traditional Fishermen & Traditional Anchovy Purse Seiner (Owner Operator)	0-5
B	0-<40	Trawlers and Purse Seiner (Owner Operator)	5-12 NM
C	40-<70	Trawlers and Purse Seiner (Owner operated and Non-Owner operated)	12-30 NM
C2	70 and above	Trawlers and Purse Seiner	30 NM to EEZ boundary

Commercial and artisanal fishermen participate in the tiger prawn fishery surrounding the refugia site. Trawls, purse-seines, drift nets, and other fishing gear were employed by the fishermen. Artisanal fishermen will catch a variety of fish, squids, prawns, and other marine species as a result. As a result, fishermen are not known as tiger shrimp fishermen (for instance). They will indirectly target tiger prawn as their major harvest because the waters around Kuala Baram are rich in tiger prawn resources. Other marine species, however, are just as vital as tiger prawn and will not be discarded. (Norhanida *et al.*, 2020).

A total of 112 fishers operating Drift nets *(Pukat Hanyut)*, 3-layered Drift nets *(Pukat Hanyut 3-lapis)*, fishing nets with rope and lead *(Pukat Tangsi)*, Pukat Tenggelam, Hooks and Line *(Pancing)* and trawl net (out-rigged boat) that operated from 5 nautical miles from the shore until 15 nautical miles offshore. They came from *Kampung Kuala Baram, Kampung Pengkalan Lutong, Kampung Pulau Melayu, Kampung Piasau Utara, Kampung Kuala Bakam* and Miri town (Refer to Table 2).

Table 3: Number of fishing license, fishing gears and fishing base engaging in the fishing operation near the refugia site.

Fishing base	Fishing Gears	No.of Licences
Kampung Kuala Baram	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	22
Kampung Pengkalan Lutong	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	20
Kampung Pulau Melayu	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	6
Kampung Piasau Utara	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line, trawlers	31
Kampung Bakam	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	26
Miri Town	Trawlers, Drift nets, hook and line, 3-layered Drift nets	7

Demography of Miri City

The refugia site situated off the coast of Kuala Baram, Miri, Sarawak, and is administered by Miri City. Miri is a coastal city in northeastern Sarawak, Malaysia, near the Brunei border on the island of Borneo. The city is located 798 kilometres (496 miles) northeast of Kuching and 329 kilometres (204 miles) southwest of Kota Kinabalu, with a total area of 997.43 square kilometres (385.11 square miles). Miri is Sarawak's second-largest city, with a population of 356,900 people as of 2021. The city is also the administrative centre of the Miri Division's Miri District.

Miri's climate is tropical rainforest. The southwest monsoon, which runs from April to September and is dry, and the northeast monsoon, which runs from October to March, are the two monsoon seasons. The yearly rainfall ranges between 250 and 380 cm (100 to 150 inches). Throughout the year, the air temperature ranges from 23 °C (73 °F) to 32 °C (90 °F). Temperatures can drop below 18 °C (64 °F) to 16 °C (61 °F) on rare occasions, notably in the months of November, December, and January. The lowest temperature ever recorded was 11 degrees Celsius (52 degrees Fahrenheit) in December 2010.

Miri City has a population of 234,541 people, according to the Malaysian census of 2010. Indigenous people (61,273), Malay (46,723), other indigenous tribes (24,119), Melanau (8,313), and Bidayuh make up the city's largest ethnic group (61.3 percent, 143,736). (3,308). Chinese (32.1 percent, 75,329), non-Malaysians (5.7 percent, 13,362), Indians (0.5 percent, 1134), and Others are the next groups (0.4 percent, 980). Bakong, Daliek, Miriek, Bruneian, and Kedayan people make up the majority of the Malay population. Miri has 19 out of 27 Sarawak ethnic groups, including Berawan, Lakiput (often pronounce as Kiput), Kedayan, Lun Bawang, Kayan, Kenyah, and Kelabit people. Miri's Chinese population is primarily Foochow, with large Hakka and Cantonese numbers, as well as a minor number of Teochews and Hainanese. A majority of non-Malaysians in Miri are Suluk and Bajau people from the southern Philippines, working at Baram Delta as fishermen. There are also illegal Suluk and Bajau people entering Miri using *Pulau Tikus* (near Baram Delta) as a transit point.

Demographic Characteristics of Fishers in refugia site (based on socio-economic survey respondents-Norhanida *et. al.*, 2020)

Males dominated the survey demographic, accounting for 99.1 percent of all respondents. Only the female respondents who were interviewed aided their husbands in fishing efforts. The percentages of people in each age group were 13.6 percent (20–39 years old), 54.5 percent (40–59 years old), and 31.8 percent (60–69 years old) (60 years old and above).

University degree holders (0.9 percent), certificate holders (0.9 percent), Secondary 5 (17.9%), Secondary 3 (21.4 percent), up to Primary 6 (41.1 percent), and no formal education

(0.9 percent) were the greatest levels of education acquired by respondents (15.2 percent). In general, it showed that the respondents' literacy rates were reasonably high, and that fishermen can read and write fairly well.

According to ethnic breakdown, the majority of respondents were Malays (38.4%), followed by Melanau (34.8%), Chinese (15.2%), Iban (10.7%), and Kedayan (10.7%). (0.9 percent). 83.9 percent of those polled were Mirians, while the rest came from other Sarawak districts for career opportunities and/or married Mirians. Majority of respondents were married with a coverage of 89.3%, followed by single respondents (8.9%) and single parents (1.8%).

The size of the respondents' houses is also a good indicator of their financial situation. Brick residential homes accounted for 42.0 percent of the total, followed by wooden houses (32.1 percent), and partially brick houses (32.1 percent) (25.9 percent). 69.1 percent of those polled claimed ownership of their homes. All respondents' homes were supplied with tap water and electricity.

The well-being of the respondents' household might be assessed by looking at the household appliances and vehicles. Motorcycles were the most commonly owned vehicle, accounting for 78.4 percent of all vehicles, followed by cars (66.1 percent). Refrigerator was possessed by 98.2 percent of respondents, followed by Washing Machine (92.0 percent) and Television (92.0 percent) (90.2 percent). The percentage of responders that own a mobile phone was 98.2%, making it the primary mode of contact for both work and personal matters.

In Kuala Baram, artisanal respondents' households spent an average of RM1,270.42 per month. Foodstuffs (RM731.73 month-1) were the most expensive item in a respondent's household, followed by home instalment payments (RM725.00 month-1), vehicle instalments (RM698.15 month-1), house rental payment (RM550.00 month-1), utility bills (RM223.19 month-1), and children's education expenses (RM223.19 month-1) (RM219.96 month-1). Cigarettes was the lowest expenditure for a respondent's household in the study areas at RM138.98 month-1.

Commercial respondents' households in Kuala Baram, on the other hand, spent an average of RM5,272.86 each month. Home instalment payments (RM2,433.00 month-1), food (RM2,357.14 month-1), children's school costs (RM1,900.00 month-1), vehicle instalment (RM1,400.00 month-1) and utility bills were among the expenses (RM821.43 month-1). Cigarettes was also the lowest expenditure for commercial respondent in the City of Miri at RM253.33 month-1. The main economic activities along the waters of Kuala Baram are fishermen (81.8 %) and the rest are from their working wife and children. The Monthly Fisheries Subsistence Allowances of RM300.00 provides additional household income to respondents. Only 25.9% of artisanal respondents regarded tiger shrimps as one of the most prized fish commodities.

Tiger Prawn Fisheries landing

Fishers that were involved in the tiger prawn fishery were divided into artisanal and commercial trawlers, mainly focused on usage of drift net, 3-layered drift net, hook and line and bottom trawling. While drift nets, 3-layered drift nets operate in coastal waters below 5 nautical miles, the bottom trawlers operate until 15 nautical miles to fish. In all cases, tiger prawns are considered as incidental catch, not targeted. However, the landing of tiger prawn has shown an undulating curve (Figure 3) and is not stable.

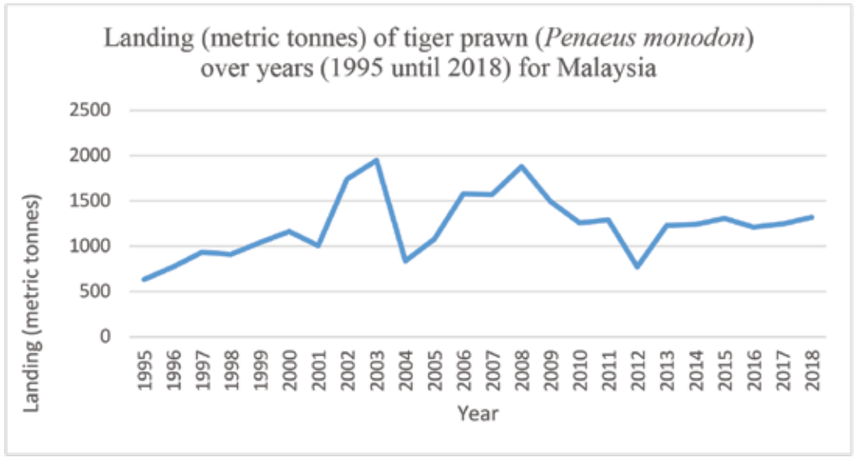


Figure 3: The annual landing (metric ton) of tiger prawn in Malaysia during a 23-years period (1995 – 2018) (data derived from the Annual Fisheries Statistics from year 1995-2018, Department of Fisheries Malaysia, 2018).

The catch rate, density, biomass and maximum sustainable yield of tiger prawn resource at Miri have been determined from previous study and is given in Table 3 (Hadil, 2014).

Table 4: The catch rate, density, biomass and maximum sustainable yield (MSY) of tiger prawn resource at Miri (Hadil, 2014).

Area Size (NM^2)	Catch Rate ($kg.hr^{-1}$)	Standard Deviation	Density ($kg.NM^{-2}$)	Biomas (metric ton)	MSY (metric ton)
296	1.99	0.523	52.44 (1:1.36 male:female)	15.52	23.00

In 2019, a resource study was done in the planned refugia area to validate and collect current distribution, density, and biomass of tiger prawn spawners. As a result, the catch rate ranged from 0.56 to 2.45 kg hr-1. The biomass of *P. monodon* in the proposed site was estimated to be 10.3 metric tonnes, with an average density of 13.92 kg/km^2.

An improved biomass estimate based on the average of several research would result in a more accurate landing stock. According to the results of this investigation, the projected refugia site contains a high density of tiger prawns with spawning females, which is consistent with earlier research (Hadil, 2014).

With the new legislation of shifting the trawling area farther up, areas less than 5 nautical miles are now considered protected from trawling activities, with large concentrations of tiger prawn spawners in the range of 4.47 – 5.76 nautical miles. The tiger prawn resources in this designated refugia area should be maintained at the current level, keeping in mind the precautionary approach to fishing. In order to assess the efficiency of management measures, such as refugia, an annual experimental survey and monitoring of commercial fishing boat performance should be carried out to ensure the current status of known fisheries. Furthermore, new and additional information is made available for the formulation of new and refinement of the old ones.

The Study of Tiger Prawn *(Penaeus monodon)* spawners, distribution, density and biomass in Kuala Baram, Miri Sarawak in 2019

***Nurridan Abdul Han**

Fisheries Research Institute Bintawa, Department of Fisheries Malaysia, Sarawak and Labuan Division, Jalan Perbadanan, Bintawa, 93744, Sarawak.
*E-mail: nurridan@dof.gov.my

Abstract

This study was carried out to validate the distribution, density and biomass of tiger prawn (Penaeus monodon) spawners at the proposed refugia site in Kuala Baram, Miri, Sarawak. The study was conducted from 24 August – 26 August 2019 using a Miri fisherman's out-rigged boat. A total of 6 locations were completed covering an estimated area of 370 km^2.

The density of tiger prawns was calculated using the Swept Area Method. A total of 6 hauls were recorded from this study. A total of 95 tails (9,027.2 gm) of tiger prawns were caught. The catch included 51 male and 44 female tiger prawns. The size of male tiger prawns caught ranged from 196 mm – 234 mm in total length and weighed from 53.4 gm – 116.8 gm. Females had total lengths ranging from 221 mm to 284 mm and weighed between 87.4 gm and 189.8 gm.

The study showed that the majority (45.5%) of the spawners had shed their eggs and 15.9% were ready to spawn. The catch rate obtained was from 0.56 – 2.45 kg hr^{-1}. The average density of P. monodon in the proposed site was 13.92 kg/km2 and the biomass was estimated at 10.3 metric ton.

Keywords : *refugia, out-rigged boat, density, biomass, spawners*

Introduction

Apart from unregulated coastal development, habitat destruction, and environmental deterioration in the area, the tiger prawn *(P. monodon)* population in Kuala Baram has been designated as the last frontier. Overfishing, the use of harmful or unsustainable gears and methods have all contributed to a decrease in total landings from 1995 to 2018. (Nurulhuda *et al.*, 2014, SEAFDEC, 2014).

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

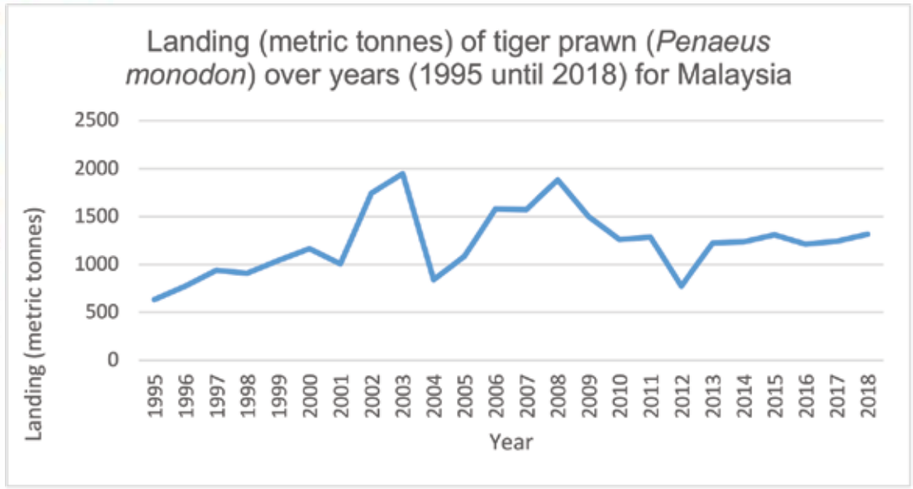


Figure 1: The annual landing (metric ton) of tiger prawn in Malaysia during a 23-years period (1995 – 2018) (data derived from the Annual Fisheries Statistics from year 1995-2018, Department of Fisheries Malaysia, 2018)

A tiger prawn refugia is proposed near the river mouth of Kuala Baram in Miri, Sarawak, to offset this diminishing situation, and the refugia site has been generally determined based on past and current research findings (Hadil & Faazaz, 1998, Hadil & Albert, 2001, Hadil, 2004, Hadil, 2007, Hadil, 2014). The suggested location for the tiger prawn refugia is next to a mangrove forest with a river mouth nearby. As the region is adrift, the offshore area sloops into deeper depths.

This study is a continuation of the previous study and to validate the distribution, density and biomass of tiger prawn spawners in the proposed refugia area. The objective of the study was to obtain information on the current distribution, density and biomass of tiger prawn spawners in the proposed refugia area.

Materials and Methods

The tiger prawn study was carried out in the proposed refugia site in Kuala Baram waters, Miri, Sarawak (Figure 2), which covers an area of 370 km^2. An out-rigged trawler, SF3-221 was deployed to do the task. The sampling commenced from 24 until 26 August 2019 and four Fisheries Research Institute Bintawa (FRIB) personnel were assigned onboard.

Figure 2: Map showing stations in the 2019 tiger prawn spawners study (station 1-6), and previous study in 2014 (stations 7-10).

Samples were taken using a bottom trawl. The trawling duration ranged from 2.0 to 2.25 hours with an average speed of 2.0 knots. The trawling duration and speed varied because of the limited area to maneuver, since a big portion of the coastal waters off Kuala Baram are oilfields. The initial and final locations of the trawl were recorded. Water depth and water quality (temperature, pH, dissolved oxygen and salinity) were also recorded. Once the catch was landed onboard the vessel, large-sized fish and prawns as well as dangerous and poisonous specimens were sorted out. All commercial species, irrespective of size, were weighed and recorded. Tiger prawns caught were weighed and measured to the nearest millimeter in terms of total length and carapace length.The female prawn egg maturity stage was determined based on criteria mentioned by Primavera (1988). All catch data were processed and analyzed to produce catch rates, species composition using the software Microsoft Excel.

The "swept" area method was used to determine the density of tiger prawn per square nautical mile. The trawl sweeps as well path, which is called the "swept area", or the "effective path swept". The swept area, can be estimated using the equation below:
a= D*h*x, D= V*t,
where V is the velocity of the trawl over the ground during trawling, t is the time spent trawling, h is the length of the headrope and x is that fraction of the headrope which is equal to the width of the path swept by the trawl. For Southeast Asia the values of x from 0.4 to 0.66 were suggested (Shindo 1973, SCSP 1978). Pauly (1980) suggests 0.5 as the best compromise x value for tropical waters. In this study, the value 0.5 was adopted.

The density of the tiger prawn was calculated from the catch rates recorded in kg/hour from this survey. If the weight of catch per haul is Cw, then Cw/t is the catch per hour when it is the duration the trawl haul. If "a" is the area swept by the trawl haul, the a/t represents the area swept per hour. In this survey, trawling for duration of one hour with a trawl net having a headrope length of 24.8 m covered the swept area. Thus for SF3-221, since two nets were used at the same time the total headrope used in the calculation of biomass was 49.6 m. One nautical mile is equals to 1852 meters.

The weight of catch per unit area is:
(Cw/t)/ (a/t) = Cw/a kg per sq. nm
The mean weight of catch per unit area (Cw/a) divided by q (catchability coefficient) gives the average biomass per unit area. The catchability coefficient represents the amount of the tiger prawn caught by the trawl relative to the amount that escaped being caught. When q = 1.0, all the prawn in the path of the trawl was assumed to be caught. Thus biomass, B, of the whole area study, A is:
B = (Cw/a)/q *A

Results

During the three days of research, a total of six hauls were recorded from six different locations. Location, water depth and water quality were presented in Table 1. *P. monodon* was caught in locations 1, 2, and 3, with the highest concentration in location 3. These three locations from the tip of Kuala Baram was in the range of 8.27 – 10.67 km (4.47 – 5.76 nm).

Table 1: This table depicts the trawl station, water depth, and water quality of the study site in the 2019 tiger prawn spawners study.

Station	Initial trawl	End trawl	Water depth (m)	Water parameter	Remarks
1	04° 36.821N 113°58.711E	04° 41.099N 113° 55.131E	10.2	Temperature : 30.50° C pH : 7.90 DO : 3.45 mg/l Salinity : 34.28 ppt	13 tail *P. monodon* catch, 8M,5F
2	04° 34.264N 113°54.297E	04° 38.340N 113° 53.764E	10.2	Temperature : 30.43° C pH : 8.00 DO : 4.56 mg/l Salinity : 34.82 ppt	29 tail *P. monodon* catch, 16M,13F

Station	Initial trawl	End trawl	Water depth (m)	Water parameter	Remarks
3	04° 32.313N 113°54.453E	04° 36.115N 113° 53.575E	10.5	Temperature: 29.90° C pH : 8.03 DO : 4.90 mg/l Salinity : 34.68 ppt	53 tail *P. monodon* catch, 27M,26F
4	04° 39.430N 113°58.020E	04° 36.926N 114° 02.159E	10.6	Temperature: 30.20° C pH : 8.05 DO : 5.22 mg/l Salinity : 32.38 ppt	No catch of *P. monodon*
5	04° 40.002N 113°57.921E	04° 39.373N 114° 02.932E	10.6	Temperature : 31.00° C pH : 8.04 DO : 4.77 mg/l Salinity : 31.33 ppt	No catch of *P. monodon*
6	04° 42.631N 114°03.212E	04° 43.721N 113° 59.171E	10.4	Temperature: 30.38° C pH : 7.89 DO : 3.85 mg/l Salinity: 32.78 ppt	No catch of *P. monodon*

Table 2 and Figure 3 show the overall catch composition obtained by the trawler SF3-221. The catch was dominated by fish (80.67%), Penaeid prawns of other species (14.24%), crabs (3.12%), molluscs (1.36%) and Tiger Prawns (0.61%). A total of 41 species were caught from 26 families and the most dominant was *Leiognathus equulus* (Family Leiognathidae) with 148.2 kg (10.06%).

Table 2 : This table depicts the overall catch composition of the trawler SF3-221 during the 2019 study of tiger prawn spawners.

No.	Species	Family	Total catch (kg)
1.	*Penaeus monodon*	Penaeidae	9.03
2.	*Penaeus semisulcatus*	Penaeidae	15.3
3.	*Fenneropenaeus merguensis*	Penaeidae	34.5
4.	*Metapenaeus affinis*	Penaeidae	50.0
5.	*Metapenaeus ensis*	Penaeidae	40.0

No.	Species	Family	Total catch (kg)
6.	*Metapenaeus brevicornis*	Penaeidae	70.0
7.	*Nemipterus peronii*	Nemipteridae	88.2
8.	*Nemiperus bathybius*	Nemipteridae	50.1
9.	*Nemipterus nematophorus*	Nemipteridae	53.0
10.	*Lactarius lactarius*	Lactariidae	122.4
11.	*Epinephelus coioides*	Serranidae	15.2
12.	*Psettodes erumei*	Psettodidae	20.3
13.	*Pseudohambus malayanus*	Paralichthyidae	10.3
14.	*Saurida tumbil*	Synodontidae	50.8
15.	*Saurida undosquomis*	Synodontidae	43.1
16.	*Upeneus sulphureus*	Mullidae	47.8
17.	*Diagramma pictum*	Haemulidae	15.9
18.	*Priacanthus tayenus*	Priacanthidae	70.5
19.	*Cynoglossus arel*	Cynoglossidae	15.0
20.	*Cynoglossus bilineatus*	Cynoglossidae	17.3
21.	*Maculabatis gerradi*	Dasyatidae	10.6
22.	*Gerres abbreviatus*	Gerreidae	21.5
23.	*Otolithes ruber*	Sciaenidae	100.0
24.	*Johnius belangerii*	Sciaenidae	10.3
25.	*Nibea soldado*	Sciaenidae	45.4
26.	*Anadontostoma chacunda*	Clupeidae	33.3
27.	*Ilisha elongata*	Pristigasteridae	15.0
28.	*Sphyraena jello*	Sphyraenidae	20.8
29.	*Drepane longimana*	Drepanidae	15.0
30.	*Terapon jarbua*	Terapontidae	43.2
31.	*Arius maculatus*	Ariidae	10.0
32.	*Muraenesox cinereus*	Muraenesocidae	12.0
33.	*Trichiurus lepturus*	Trichiuridae	23.2
34.	*Carangoides malabaricus*	Carangidae	25.0
35.	*Tentoriceps cristatus*	Trichiuridae	10.4

No.	Species	Family	Total catch (kg)
36.	*Leiognathus equulus*	Leiognathidae	148.2
37.	*Pomadasys kaakan*	Haemulidae	25.1
38.	*Portunus pelagicus*	Portunidae	20.3
39.	*Portunus sanguinolentus*	Portunidae	16.7
40.	*Charybdis natator*	Portunidae	9.0
41.	*Sepia aculeata*	Sepiidae	20.1
		TOTAL	**1473.83**

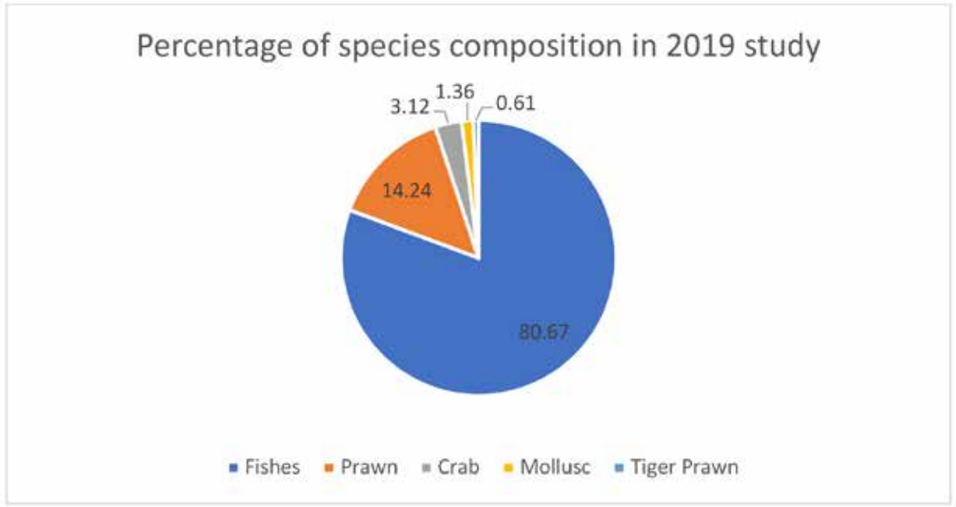


Figure 3: This figure shows the percentage of species composition in the *P. monodon* study in 2019.

A total of 95 tails 9,027.2 gm) of *P. monodon* were caught within the 10 m water depth. The catch included 51 males and 44 females tiger prawn. The size of male prawn caught ranges from 196 mm – 234 mm in total length and weighed from 53.4 gm – 116.8 gm. Whereas, for female, for total length, it ranged from 221mm – 284 mm and weighed at 87.4 gm – 189.8 gm. The study showed that majority (45 %) of the spawners had shed their eggs and 16 % was ready to spawn.

The carapace length ranges from 45 mm – 59 mm for male, whereas, for female, it ranges from 54 mm – 72 mm. According to Motoh (1981), the minimum size at maturity was 37 mm carapace length for male and 47 mm carapace length for female.

The maturity stages for female *P. monodon* caught were 13.6 % stage I, 20.5 % stage II, 4.5 % stage III, 15.9 % stage IV and 45.5 % stage V. The study shows that majority of the spawners (45.5 %) had shed their eggs to spawn and 15.9 were ready to spawn (refer to Figure 4). The catch rate obtained was from 0.56 – 2.45 kg hr^{-1}, where location 3 was the highest at 2.44 kg hr^{-1}, followed by station 2 and station 1 at 1.14 and 0.56 respectively.

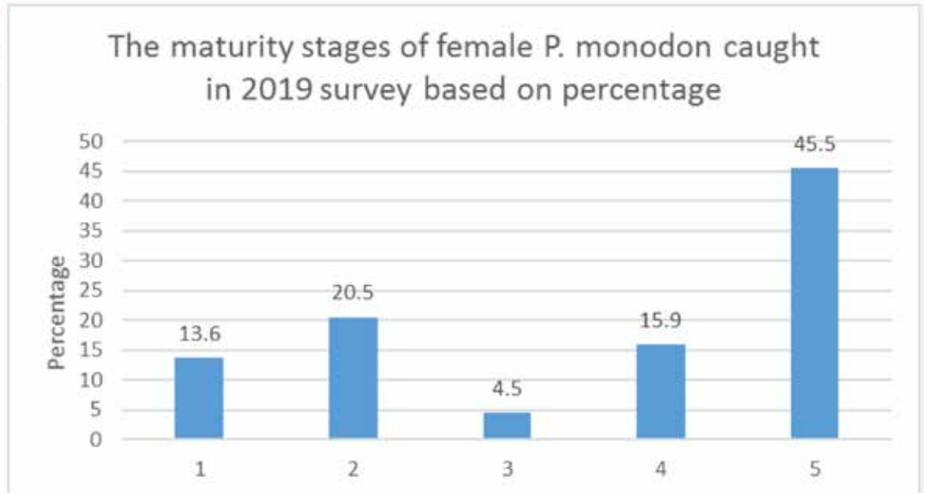


Figure 4: The maturity stages of female P.monodon caught in 2019 study based on percentage.

Discussion

The average density of *P. monodon* on the proposed site was 13.92 kg/km^2 and biomass was estimated at 10.3 ton. The biomass of *P. monodon* resources estimated was based only on this study over a limited period of time. A better biomass estimate using the average results from a series of studies would provide a better actual landing stock.

The findings of this study revealed that the proposed refugia site has a high density of tiger prawns with spawning females and in line with previous study (Hadil, 2014). Further discussions and consultations with many authorities and stakeholders will be required to determine the actual size of the tiger prawn refugia area.

Conclusion

With the new regulation of shifting further up the trawling area, those areas of less than 5 NM are considered protected from trawling activities, where the stations of high concentration of tiger prawn spawners are in the range of 4.47 – 5.76 NM.

The tiger prawn resources in this designated refugia area should be maintained at the current level, keeping in mind the precautionary approach to fishing. In order to assess the efficiency of management measures, such as refugia, an annual experimental survey and monitoring of commercial fishing boat performance should be carried out to ensure the current status of known fisheries. Furthermore, new and additional information is made available for the formulation of new and refinement of the old ones.

Acknowledgements

I'd like to express my appreciation to the staff of the Fisheries Research Institute of Bintawa and all staff of Department of Fisheries, Malaysia who took part and assist in this brief study. A lot of gratitude and thanks to Mr. Wong Hou Kiew, the boat owner of SF3-221 and all his fishing crew for their kind cooperation in participating in this survey. The study was funded through the development grants P21-30701011-23300-069 and the SEAFDEC/UNEP/GEF Fisheries Refugia Project Grant.

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

Photo 1: Both nets are hauled up by the out-rigged boat, SF3-221.

Photo 2: During the 2019 spawners study, tiger prawn spawners were captured.

Photo 3: Mixture of species caught during the 2019 spawners' study.

Photo 4: Maturation stage 4 for female tiger prawns.

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :

Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

Photo 5: The most dominant species was *Leiognathus equulus* in the 2019 spawners' study.

Photo 6: Species sorting on the boat.

Photo 7: The petasma, genital organ of male tiger prawn.

Photo 8: The thelycum, genital organ of female tiger prawn.

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

Photo 9: *Epinephelus coioides,* one of the commercial species caught in the 2019 study.

Photo 10: *Nemipterus peronii,* one of the commercial species caught in the 2019 study

The study of juvenile tiger prawn *(Penaeus monodon)*, distribution, density and biomass of juvenile *P. monodon* in *Sg. Pasu, Sg. Lutong* and *Sg. Bakam* in Miri, Sarawak

***Nurridan Abdul Han**

Fisheries Research Institute Bintawa, Department of Fisheries Malaysia, Sarawak and Labuan Division, Jalan Perbadanan, Bintawa, 93744, Sarawak.
*E-mail: nurridan@dof.gov.my

Abstract

A refugia idea based on a marine environment conservation strategy was proposed to ensure the sustainability of fishery resources. In the deeper waters of Kuala Baram, a survey for tiger prawn spawning stock was conducted. It is vital to do study on juvenile tiger prawns in order to obtain complete knowledge about the life cycle.The study was conducted using local fishing boats and cast net as a means of sampling the juveniles. Seven sampling trips spanning Sg. Pasu, Sg. Lutong, and Sg. Bakam (Sg=sungai=river) yielded a total of 1,100 castings. A total of 79 juvenile tiger prawn tails (324.8 gm) were caught. A total of 38 male and 41 female juvenile tiger prawns were caught.The average density was 6.8 g/m^2, 1.66 g/m^2 and 1.20 gm/m^2 for Sg. Pasu, lutong and Bakam 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 Sg.Pasu, followed by Sg, Bakam (25.33 kg) and Sg.Lutong (4.80 kg) respectively. The size of male tiger prawn caught ranged from 65 mm – 135 mm in total length and weighed from 2.8 gm – 13.4 gm. Whereas, for female, for total length, it ranged from 4.60 mm – 174 mm and weighed at 0.4 gm – 35.0 gm. The goal of this refugia project is to have this site designated as a fisheries refugia, allowing for the sustainable management of tiger prawn wild resources through spatial and seasonal closure during critical stages of their life cycle.

Keywords : *Juvenile, cast net, refugia, biomass, 'sg'=sungai=river*

Introduction

The penaeids are a group of 225 species belonging to 26 genera (Food and Agriculture Organization of the United Nations, FAO, 2008). According to reports, there are 300 species of prawns with economic value, however only 100 species are registered in statistics landings globally (Chan, 1998), indicating their commercial worth. The tiger prawn, Penaeus monodon Fabricius, belongs to the Penaeidae family and is one of the largest and most commercially valuable commodities. *Penaeus monodon*, with a body length of up to 270mm,

is one of the largest prawns in the Penaeidae family. Due to marine fisheries in the world are in the trend of declining and resources depletion (FAO, 2018), hence, management mitigation measure were introduced to curb these problems including refugia.

The refugia concept is defined as *"Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use"* (UNEP, 2005).

According to observations and studies conducted in 1998 (Hadil and Faazaz, 1998), tiger prawn spawners were found in water depths greater than 30 meters in Tg. Batu, Miri to Kuala Baram, Miri. Since 1997, spawners have been collected by local trawlers. The data was confirmed by a resource survey done in 1999 (Hadil and Albert, 2001) and 2012 (Hadil and Albert, 2012). (Hadil 2014). It is vital to perform study on juvenile tiger prawn in order to obtain complete information about the life cycle; therefore, this paper will focus on juvenile tiger prawn.

Materials and Method

With the assistance of local fisherman, juvenile tiger prawn surveys were conducted in March, June, and November 2020 at three important rivers inhabited by juvenile tiger prawn, namely the Sg. Pasu, Sg. Lutong, and Sg. Bakam (Figure 1, 2, 3). Sampling was carried out using a random sampling method at selected stations, either near the river mouth, in the middle of the river, or farther upstream. Within 7 months of the study, 220 stations had been completed.

Figure 1: Location in *Sg. Pasu* where juvenile tiger prawns were found (10 stations).

Figure 2: Location in *Sg. Lutong* where juvenile tiger prawns were found (4 stations).

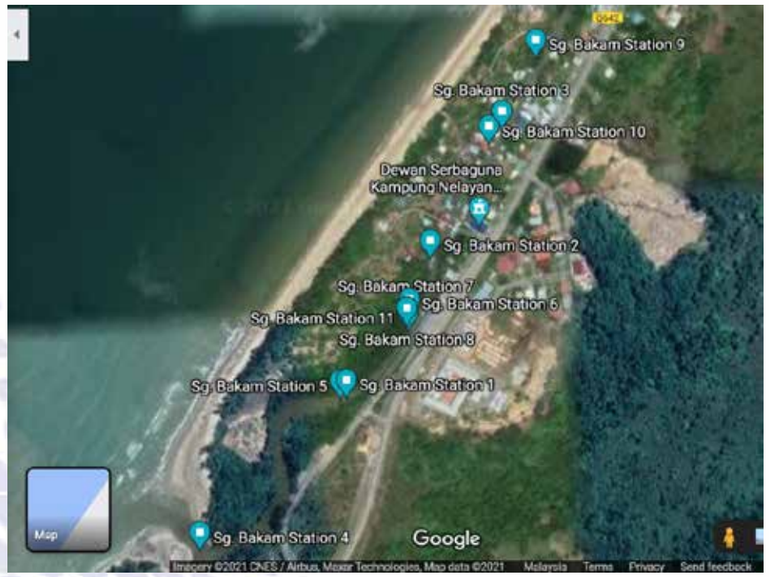


Figure 3: Location in *Sg. Bakam* where juvenile tiger prawns were found (11 stations).

Fishing was carried out during low and high tide. A cast net with 1.8 metre in length and 2.1 metres in diameter made of polyethylene net with mesh size of 19 mm (0.75 inch) was casted at each station to catch prawn. The sampling methodology adopted was the total removals methods (Welcomme 1983) where the catches usually consist of both prawns and fish. The cast net was throwed at the station then pulled and hauled up. All specimens collected were identified (Annie Lim et al.,) counted and weighed. The juvenile tiger prawn were sexed (male or female) based on presence or absence of the male genitalia (petasma) and female genitalia (thelycum), total length (TL; mm), carapace length (CL;mm) and weight (g) were measured.

To estimate the current biomass, the catch of prawns harvested from the 1.8 m cast net was then equated to the total length of the river. The total area of the cast net was calculated using

$A=\pi r\text{^}2$.

The simple equation for estimating the current biomass, where, A=area, r^2 = radius

In the estimation of prawn biomass, it was assumed that the distribution of the prawn catch per 1.8 m cast net from different rivers is normal (Mordkoff 2016). In order to normalize all the 1.8 m cast net catches, log transformation (Hadil *et al.,* 2017) was carried out.

Results

During March, June to November 2020, a total of 1100 casting activities utilising cast net were completed. Tables 1, 2, and 3 illustrate the locations of juvenile tiger prawns in each of the three rivers, as well as water quality data. A total of 79 tails (324.8 gm) of juvenile tiger prawn were caught. The catch included 38 males and 41 females juvenile tiger prawn. The size of male tiger prawn caught ranged from 65 mm – 135 mm in total length and weighed from 2.8 gm – 13.4 gm. Whereas, for female, for total length, it ranged from 4.60 mm – 174 mm and weighed at 0.4 gm – 35.0 gm. There were 63 species including *Penaeus monodon* caught in all the 3 rivers sampled. Apart from *P. monodon, Fenneropenaeus merguensis, F. indicus, Metapenaeus lysianassa, M.brevicornis, M. affinis, M. ensis* (prawn from the Family Penaeidae), *Macrobrachium rosenbergii* and *Macrobrachium* sp. (prawn from Family Paleomonidae) and the rest caught were fin-fish.

Table 1 : This table shows the location where juvenile tiger prawns were found, water quality and catch in *Sg. Pasu* from March, June-November 2020.

Location	Date	Station	Water Parameter	Remarks
Sg. Pasu Station 1	15 March 2020	04°31.3224N 113° 59.5388E	Temperature: 30.6° C pH : 5.32 DO: 7.71 mg/l Salinity: 30.15 ppt	8 tails of *P. monodon*, all male
Sg. Pasu Station 2	16 March 2020	04° 31.3343N 113° 59.4996E	Temperature: 26.00° C pH : 5.37 DO: 7.50 mg/l Salinity: 30.01 ppt	14 tails of *P. monodon*, all male
Sg. Pasu Station 3	16 March 2020	04° 31.2573 113° 59.6539	Temperature: 27.90° C pH : 5.49 DO: 5.75 mg/l Salinity: 19.44 ppt	3 tails *P. monodon*, all female
Sg. Pasu Station 4	17 March 2020	04° 31.2963 113° 59.6286	Temperature: 28.05 °C pH : 5.48 DO: 4.29 mg/l Salinity: 17.86 ppt	1 tail, female
Sg. Pasu Station 5	12 September 2020	04° 31.231N 113° 59.573E	Temperature: 27.30° C pH : 8.06 DO: 2.97 mg/l Salinity: 2.05 ppt	9 tail, 7M, 2F
Sg. Pasu Station 6	21 October 2020	04° 31.296N 113° 59.446E	Temperature: 29.9° C pH : 7.21 DO: 2.70 mg/l Salinity: 10.2 ppt	3 tail, 1M, 2F
Sg. Pasu Station 7	23 October 2020	04 3°1.270N 113° 59.646E	Temperature: 28.50 °C pH : 7.72 DO: 3.83 mg/l Salinity: 14.08 ppt	1 tail, F
Sg. Pasu Station 8	23 October 2020	04° 31.301N 113° 59.447E	Temperature: 28.65° C pH : 7.19 DO: 3.55 mg/l Salinity: 11.79 ppt	1 tail, F

Location	Date	Station	Water Parameter	Remarks
Sg. Pasu Station 9	1 November 2020	04° 31.326N 113° 59.648E	Temperature: 27.1° C pH : 7.51 DO: 1.06 mg/l Salinity: 1.90 ppt	2 tails, 2F
Sg. Pasu Station 10	1 November 2020	04 °31.302N 113° 59.556E	Temperature: 27.20° C pH : 7.82 DO: 4.46 mg/l Salinity: 1.24 ppt	1 tail, 1F

Table 2 : This table shows the location where juvenile tiger prawns were found, water quality and catch in *Sg. Lutong* from October-November 2020.

Location	Date	Station	Water Parameter	Remarks
Sg. Lutong Station 1	30 October 2020	04° 28.453N 114° 00.026E	Temperature: 28.6° C pH : 7.91 DO: 3.91 mg/l Salinity: 29.65 ppt	2 tails of *P. monodon*, both female
Sg. Lutong Station 2	3 November 2020	04° 28.278N 114° 00.030E	Temperature: 31.58° C pH : 8.15 DO: 4.27 mg/l Salinity: 6.44 ppt	1 tail of *P. monodon*, 1F
Sg. Lutong Station 3	4 November 2020	04° 28.459N 114° 00.020E	Temperature: 33.10 °C pH : 8.11 DO: 1.53 mg/l Salinity: 6.09 ppt	4 tails *P. monodon*, 2M, 2F
Sg. Lutong Station 4	5 November 2020	04° 28.275N 114° 00.030E	Temperature: 31.35° C pH : 8.30 DO: 2.83 mg/l Salinity: 7.12 ppt	1 tail, male

Table 3 : This table shows the location where juvenile tiger prawns were found, water quality and catch in *Sg. Bakam* from September-November 2020.

Location	Date	Station	Water Parameter	Remarks
Sg. Bakam Station 1	17 September 2020	04 °15.046N 113° 55.573E	Temperature: 26.8° C pH : 7.50 DO: 5.05 mg/l Salinity: 2.62 ppt	2 tails of *P. monodon*, both female
Sg. Bakam Station 2	18 September 2020	04 °15.165N 113° 55.645E	Temperature: 28.00° C pH : 7.18 DO: 5.10 mg/l Salinity: 3.09 ppt	2 tails of *P. monodon*, both female
Sg. Bakam Station 3	18 September 2020	04° 15.275N 113 °55.706E	Temperature: 27.4° C pH : 7.01 DO: 4.58 mg/l Salinity: 2.49 ppt	1 tail *P. monodon*, 1F
Sg. Bakam Station 4	24 October 2020	04° 14.916N 113° 55.448E	Temperature: 27.60° C pH : 7.40 DO: 4.21 mg/l Salinity: 0.91 ppt	1 tail, female
Sg. Bakam Station 5	25 October 2020	04° 15.045N 113° 55.568E	Temperature: 27.53°C pH : 7.54 DO: 3.44 mg/l Salinity: 2.34 ppt	1 tail, 1 male
Sg. Bakam Station 6	25 October 2020	04° 15.115N 113 °55.627E	Temperature: 27.40°C pH : 7.52 DO: 3.37 mg/l Salinity: 2.34 ppt	1 tail, female
Sg. Bakam Station 7	26 October 2020	04° 15.108N 113 °55.624E	Temperature: 26.15°C pH : 7.39 DO: 3.69 mg/l Salinity: 1.93 ppt	2 tail, both male
Sg. Bakam Station 8	10 November 2020	04° 15.107N 113° 55.625E	Temperature: 25.88°C pH : 7.84 DO: 4.10 mg/l Salinity: 0.48 ppt	1 tail, female

Location	Date	Station	Water Parameter	Remarks
Sg. Bakam Station 9	11 November 2020	04 °15.336N 113° 55.735E	Temperature: 29.08°C pH : 7.70 DO: 4.58 mg/l Salinity: 0.25 ppt	3 tails, 2M, 1F
Sg. Bakam Station 10	12 November 2020	04 °15.262N 113° 55.695E	Temperature: 29.15 ° C pH : 7.50 DO: 4.41 mg/l Salinity: 0.61 ppt	2 tails, both female
Sg. Bakam Station 11	12 November 2020	04° 15.103N 113° 55.626E	Temperature: 27.28 ° C pH : 7.62 DO: 5.08 mg/l Salinity: 1.93 ppt	2 tails, both female

Prawn biomass was estimated based on adjusted mean catch, AMC obtained from cast net sampling. Biomass estimates of juvenile tiger prawns from the 3 rivers sampled calculated were summarized in Table 4. With an AMC of 1.60 kg of tiger prawns per 1.2 metres radius of cast net, Sg. Pasu river is the most productive, followed by Sg. Bakam river and Sg. Lutong river respectively. Whereas, the biomass (kg) estimated was 31.94, 25.33 and 4.80 for Sg. Pasu, Bakam and Lutong respectively.

Table 4 : Estimated biomass of juvenile tiger prawn in *Sg. Pasu, Sg. Bakam* and *Sg. Lutong*

No.	River	Length (km)	AMC (kg)	Variance of AMC	Biomass (kg)
1.	Sg. Pasu	1.0-1.2	1.6	4.43	31.94
2.	Sg. Bakam	3.0-3.5	1.62	1.20	25.33
3.	Sg. Lutong	1.2-1.5	0.95	0.40	4.80

Discussion

The results of these survey indicated that the value of *P. monodon* (in terms of numbers) are significant compare to total species caught in the survey. Among the three rivers, Sg. Pasu river was the nearest nursery grounds, adjacent to Kuala Baram, where adjusted mean catch (AMC) calculated as the highest. In terms of biomass, Sg. Pasu river showed the highest biomass, 31.94 kg, followed by Sg. Bakam and Sg. Lutong respectively at 25.33 and 4.80. Juvenile and adult of commercial species such as *Lates calcarifer, Lutjanus argentimaculatus, L. johnii, Carangoides malabaricus, C. sexfasciatus, C. ignolis, Plectorhinchus gibbosus, Pomadasys kaakan, F. merguensis, F. indicus, M. affinis, M. ensis, M. brevicornis* and *Macrobrachium rosenbergii* were also found inhabiting the same area with tiger prawn.

Conclusion

A total of 1,100 casts were recorded from 7 months survey trips. A total of 79 tails (324.8 gm) of juvenile tiger prawn were caught. The catch included 38 males and 41 females juvenile tiger prawn. The size of male tiger prawn caught ranged from 65 mm – 135 mm in total length and weighed from 2.8 gm – 13.4 gm. Whereas, for female, for total length, it ranged from 4.60 mm – 174 mm and weighed at 0.4 gm – 35.0 gm. This revealed that the juvenile *P. monodon* uses these three rivers, namely Sg. Pasu, Sg. Bakam, and Sg. Lutong, as a nursery. To ensure the survival of tiger prawn's life cycle, these nursery grounds must be preserved and conserved.

Acknowledgements

I'd like to express my appreciation to the staff of the Fisheries Research Institute of Bintawa and all Department of Fisheries, Malaysia who help me in this study. A lot of gratitude and thanks to all the boat owner for their kind cooperation in participating in this study. The study was funded through the development grants P21-30701011-23300-069 and the SEAFDEC/UNEP/GEF Fisheries Refugia Project Grant.

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

Photo 1: Cast net been thrown at the mouth of *Sg. Bakam*.

Photo 2: Identification with morphometric data collected during field trips.

Photo 3: In the study, juvenile tiger prawns of various sizes were caught.

Photo 4: Berried female giant fresh water prawn, *Macrobrachium rosenbergii,* together with juvenil *P. monodon* inhabiting *Sg. Bakam*.

Photo 5: The latest nursery river for *P. monodon*, *Sg. Bakam.*

Photo 6: *Lutjanus argentimaculatus* is one of the commercial species discovered in the study.

Maturation and Spawning of female adult *Penaeus monodon* in Kuala Baram, Miri, Sarawak

***Nurridan Abdul Han**

Fisheries Research Institute Bintawa, Department of Fisheries Malaysia,
Sarawak and Labuan Division, Jalan Perbadanan, Bintawa, 93744, Sarawak.
*E-mail: nurridan@dof.gov.my

Abstract

The goal of the refugia was to ensure that fishing resources were utilized sustainably by protecting them throughout critical phases of their life cycle, such as migrating, spawning, and juvenile phases. It is vital to do research on ovarian maturation phases in order to obtain complete information on the spawning season of P. monodon *in Kuala Baram, Miri, Sarawak. Hence, this study will focus on it. From June to November 2020, gravid female samples were purchased at two separate locations, namely Hock Hai Kim Cold Storage jetty and Krokop market in Miri, Sarawak. The visualization technique to observe stages of ovary maturation was also explicitly used. The determination of ovarian development is made by illuminating the internal body organs of the female by means of a torch light being passed along her side. With a total of 290 individuals procured within the six months of sampling, stage 4 has recorded as the most prominent catch, followed by stage 3, 2, 5 and 1 respectively. Stage 4 started to increase from July to Nov 2020, and August experienced the peak of the increase in stage 4. If a refugia is to be implemented, it is advised that a closed season be established from August to October to protect the gravid prawns from being caught and overexploited during the spawning season.*

Keywords : *gravid, ovary, maturation, refugia, overexploited*

Introduction

The tiger prawn, *Penaeus monodon* Fabricius falls under the Family Penaeidae and was identified as one of the largest and the most commercial commodity. *P. monodon*, with body length reaches 270 mm can be considered as one of the largest prawn under Family Penaeidae. The age of first breeding in *P. monodon* is unknown. However, it is apparent that they go through a period of adolescence before passing through puberty and finally becoming sexually mature (Ayub and Ahmed, 2002). Anecdotal evidence supports the conclusion that a combination of age and body size influences the onset of sexual maturity.

The average size of *P. monodon* broodstock varies according to geographic location and may have a genetic as well as an environmental basis. Large males, 80 grams or larger, are preferred by hatcheries for captive matings as they generally produce higher hatch rates compared to those obtained from smaller males typically utilized as broodstock as matings with large males results in higher fertilization rates compared to small males (Pratoomchat *et al.* 1993). In Australia, wild female broodstock are typically within the range of 110 to 160 grams, whereas in the more equatorial regions of Thailand broodstock range from 150 to well over 200 grams. Commercial hatcheries prefer larger females to smaller ones in order to maximize egg production per spawner utilized.

In female penaeid prawns the ovaries are paired, but partially fused in the cephalothorax (head and thorax region), and consist of a number of lateral lobes which continue along the entire length of the tail. The determination of ovarian development by hatchery technicians is made by illuminating the internal body organs of the female by means of a bright underwater torch beam being passed along her side. However, due to the density of the cephalothorax, the only portion of the ovary seen by illumination is that within the tail. This appears as a dark shadow, due to the dense lipid composition and pigmentation, and can be ranked through a series of developmental stages from I to V.

In order to get the complete information on the spawning season of *P. monodon* in Kuala Baram, Miri, Sarawak, it is necessary that research on ovarian maturation stages conducted, therefore, this report will focused on ovarian maturation of *P. monodon* in Kuala Baram, the earmarked area for refugia.

The objective of this study is to determine the spawning month of *P. monodon* to come up with crucial information, therefore refugia management can prosecute.

Materials and Method

The ovarian maturation stages of gravid/adult female surveys in 2020 were conducted at 2 different sites, namely Hock Hai Kim Cold Storage jetty and Krokop market in Miri, Sarawak. Hock Hai Kim Cold Storage jetty was privately owned by trawl operators whereas, samples from Krokop market originated from trawl operators from 'Lembaga Kemajuan Ikan Malaysia (LKIM) jetty.

Samples were bought from the operators and fish monger, with price ranging from RM85 to RM100 per kilogram. Around 100-150 tails of adult *P. monodon* were bought, measured length and weight. Approximately 30-70 tails of gravid female were dissected to get/collect the gonad. Thereupon, Gonadosomatic Index, abbreviated as GSI was calculated. GSI is the calculation of the gonad mass as a proportion of the total body mass. It is represented by the formula:

$$GSI = [\text{gonad weight} / \text{total tissue weight}] \times 100$$

It is a tool for measuring the sexual maturity of animals in correlation to ovary development and testes development (in this study, ovary development).

Beside the GSI to estimate the sexual maturity, the visualization technique to observe stages of ovary maturation were also explicitly used. The determination of ovarian development is made by illuminating the internal body organs of the female by means of a torch light being passed along her side. The maturation of the ovary has been categorised into five stages, the classification of which is based on ovum size, gonad expansion and coloration (Motoh, 1981).

Results

A total of 290 tail of gravid female *P. monodon* were weighted and GSI were calculated from June until November 2020.

The maturity stage of tiger prawn in Kuala Baram were presented in Figure 1. With a total of 290 individuals (Table 1) caught within the six months of sampling, stage 4 has recorded as the most prominent catch, followed by stage 3, 2, 5 and 1 respectively. Stage 4 classified as ripe stage (mature), It is diamond in shape, expanding through the exoskeleton of the first abdominal segment. The isolated ovary appears dark olive green, filling up all the available space in the body cavity (Primavera, 1988).

From the observation (Figure 1), stage 4 started to increase from July to Nov 2020, and August experienced the peak of increase in stage 4.

Table 1 : The maturity stage of tiger prawn prawn caught in Kuala Baram

Month	Stage				
	1	**2**	**3**	**4**	**5**
June	4	10	11	8	13
July	3	7	9	13	10
Aug	15	15	11	16	7
Sept	8	11	15	14	12
Oct	6	7	9	15	3
Nov	6	9	6	15	2
Total	**42**	**59**	**61**	**81**	**47**

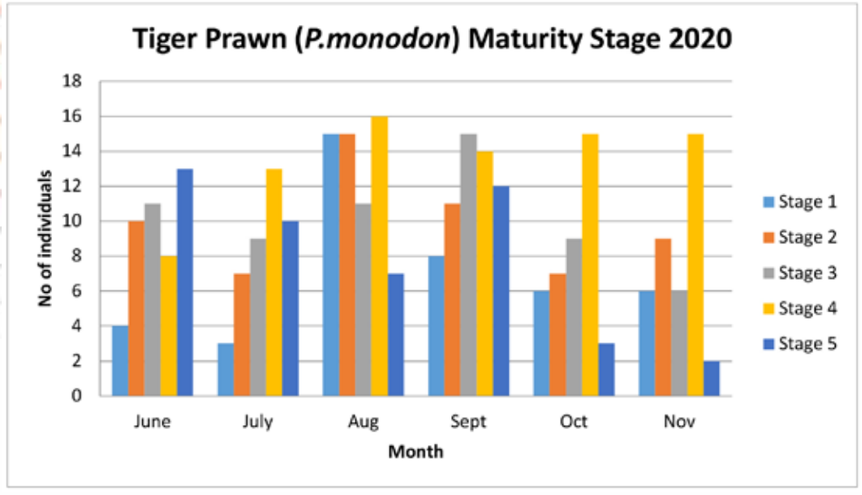


Figure 1: Bar graph of maturity stage of tiger prawn caught in Kuala Baram

Discussion

The findings of these surveys revealed that the gravid female of stage 4 dominated from July to November each year, with August being the highest month. This conclusion is consistent with prior findings (Hadil, 2018), which show that ovarian maturation peaks in August. The findings also in line with study done in India that suggest fully matures ovaries occur throughout the year with August and March as peak spawning season (Kannan *et al.,* 2014).

Conclusion

A total of 290 gravid female *P. monodon* were recorded from 6 survey trips from June until November, with stage 4 maturation stages began from July until November, with highest score was in the month of August. In conclusion, if refugia is to be implemented, where it will take into account the closure of the area off Kuala Baram during the spawning season, it is suggested that from August to October as a closed season to protect the gravid prawn from being caught and overexploited.

Acknowledgements

I'd like to express my appreciation to the staff of the Fisheries Research Institute of Bintawa and all Department of Fisheries, Malaysia who help me in this study. The study was funded through the development grants P21-30701011-23300-069 and the SEAFDEC/UNEP/GEF Fisheries Refugia Project Grant.

Photo 1: Samples of gravid female *P. monodon* from Krokop Market

Photo 2: Sample selection of gravid female *P. monodon* in Krokop market

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :

Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

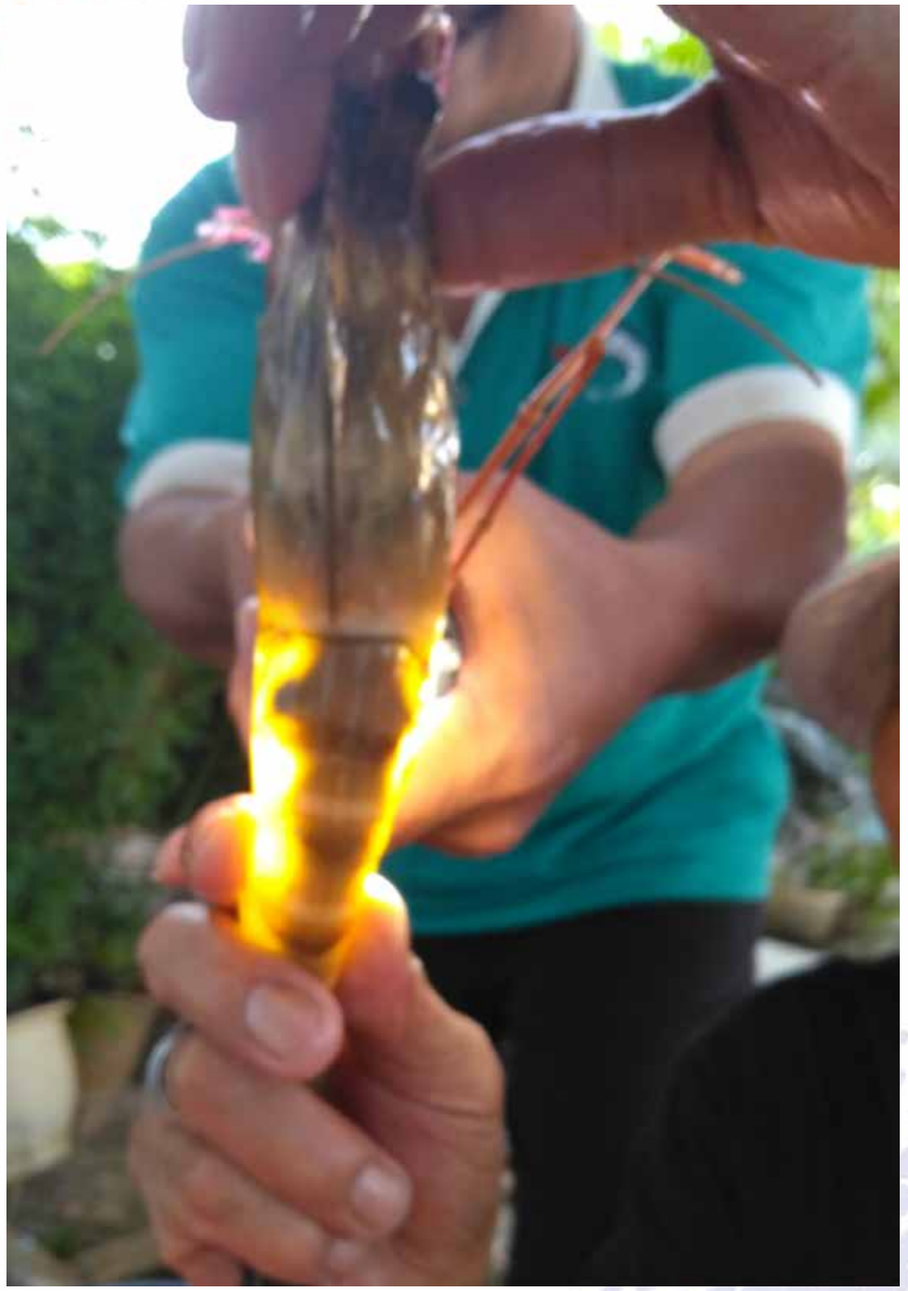


Photo 3: The determination of ovarian development in gravid female *P. monodon* is made by illuminating the internal body organs of the female by means of a torch light being passed along her side.

Photo 4: A few stages of gravid female *P. monodon*, A : stage 5, B : stage 1, C : stage 3, D : stage 2

Photo 5: Gravid females of *P. monodon* were dissected to get/collect the gonad.

Photo 6: Weighing gonad using weighing machine, Toledo.

◄ **Photo 7:**
A gravid female *P. monodon*, already dissected, disposing its gonad and intestine

► **Photo 8:**
Stage 4 gravid female *P. monodon*

◄ **Photo 9:**
Gonad, stage 2

► **Photo 10:**
Intestine of *P. monodon*

◄ **Photo 11:**
Showing, right: male, left: female of *P. monodon*

► **Photo 12:**
Gonad and intestine of gravid female *P. monodon* being separated

Photo 13: Female spawners weighing 231 gram from Krokop market

Photo 14: Different size of gravid female *P. monodon*

Refugia as a new tool for fisheries management in Malaysian waters?

***Nurridan Abdul Han**

Fisheries Research Institute Bintawa, Department of Fisheries Malaysia, Sarawak and Labuan Division, Jalan Perbadanan, Bintawa, 93744, Sarawak.
*E-mail: nurridan@dof.gov.my

Abstract

In order to maintain the sustainability of fishery resources, a refugia concept based on a marine environment conservation approach was introduced. The concept of refugia has been defined by UNEP: Regional Working Group - Fisheries as "Spatially and geographically marine or coastal areas in which specific management measures are applied to sustain important species (fisheries resources) during critical stages of their life cycle, for their sustainable use. As for spawners, it was estimated that the catch rate for tiger prawn spawners in the studied area was 1.99 kg hr^{-1}, density was 52.44 kg Nm^{-2} whereas for biomass, it was estimated 15.52 metric tonnes and Maximum Sustainable Yield (MSY) was 23 metric tonnes. Beside the catch rate, biomass and MSY, the gonad studies showed that peak breading season during the July-August period when the percentage of stage-IV gonad was the highest. In order to get the complete information of the life cycle, it is necessary that research on juvenile tiger prawn should be carried out. The overall mean catch rate for Pasu, Lutong and Sibuti rivers was estimated 1.20 kg (male- 52.85 % and female 47.14%) equivalent to 70 tails of prawn (37 tails male and 33 tails female). Biomass estimate are directly proportional to the catch rate and the length of the river with the highest biomass at 15.23 kg contributed by Sibuti river, followed by Pasu river (11.73 kg) and Lutong river (10.00 kg) respectively. In terms of total length (in cm) the juvenile tiger prawns ranges from 6.5-37.3 cm with body weight ranges from 1.6 - 218 gram. The targeted outcome of this refugia project is to have this site gazetted as fisheries refugia so that the wild resources of tiger prawn are sustainably managed through spatial and seasonal closure during the critical phases of their life cycle.

Keywords : *Refugia, tiger prawn, closure, critical, cast net*

Introduction

The state of marine fisheries in the world are in the trend of declining and resources depletion (FAO, 2018). The overwhelming threats to fish stock such as overexploitation, overcapacity, the usage of destructive and unsustainable fishing gears, habitat destruction, pollution and illegal fishing has lead to habitat destruction and depletion of fish stocks (Nurulhuda *et al.*, 2014, SEAFDEC, 2014). Hence, management mitigation measure was introduced to curb

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

these problems including refugia. Refugia is stated as a new tool to sustainable management for fisheries in Malaysian waters.

The refugia concept is defined as *"Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use"* (UNEP, 2005).

It focuses on the nature of the particular habitat and its critical significance to the life-history of the fished species. Refugia concept cover specific areas of significance to the life-cycle of fish species, should be defined in space and time, should not be no-take zones and serve to safeguard spawning aggregations, nursery grounds, and migration routes.

Whereas, refugia objective was to ensure that the fishery resources are exploited sustainably through protection of critical stages of their life cycle such as during migration, spawning and juvenile periods.

There are two proposed fishery refugia sites in Malaysia, namely the Lobster (*Panulirus spp.*) Refugia in Tanjung Leman, Johor and the Tiger Prawn (*Penaeus monodon*) in Kuala Baram, Miri, Sarawak (Figure 1). For the lobster refugia in Tanjung Leman, the actual site has not been determined yet as scientific data gathering is still ongoing and the Department of Fisheries Malaysia will only announce the refugia area once the spawning site of the spiny lobster has been determined. The main fishing area for spiny lobsters spans from southern Pahang to the tip of east Johor (Sungai Rengit). Landing data of spiny lobsters caught by fishermen has been collected in some jetties such as Endau, Tanjung Leman and Sedili (Figure 2).

As for the tiger prawn refugia, the proposed site is located at the river mouth of Kuala Baram in Miri, Sarawak and the refugia area has been roughly determined by researchers studying the tiger prawn resources (Figure 3). The proposed site for the tiger prawn refugia is located near a mangrove swamp with a river mouth and nearby the border of Brunei Darussalam. The offshore area sloop into deep water as characteristic of a continental sloop area (Hadil and Faazaz,1998, Hadil and Albert, 2001, Hadil, 2004, Hadil, 2007, Hadil, 2014).

Figure 1: The locations of the proposed Lobster Refugia at Tanjung Leman, Johor (Site 1) and Tiger Prawn Refugia at Kuala Baram, Sarawak (Site 2)

Figure 2: The spiny lobster fishery area at South Pahang-East Johor waters

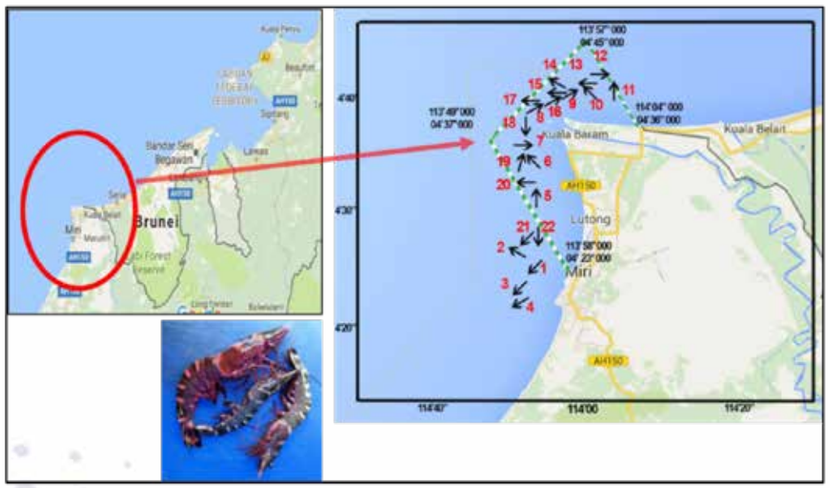


Figure 3: The proposed tiger prawn refugia area at Kuala Baram, Miri, Sarawak

The national coordination mechanism follows closely the suggested layout by the Regional Refugia Project Steering Committee where there are 3 levels of coordination, namely the National Fisheries Refugia Committee, the National Scientific and Technical Committee and two site based Fisheries Refugia Committees at Tanjung Leman and Kuala Baram (Figure 4). The Chairman for the National Fisheries Refugia Committee is the Director General of Fisheries Malaysia while the Chairman for the National Scientific and Technical Committee is the Director of the Fisheries Research Institute (DOFM).

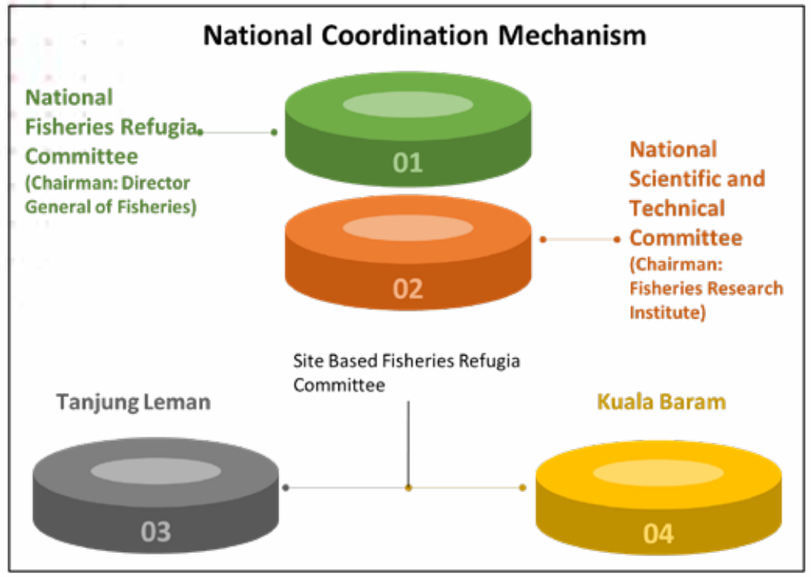


Figure 4: The national coordination mechanism for the execution of the SEAFDEC/ UNEP/GEF Fisheries Refugia Project in Malaysia

Problem statement

What is refugia?
Why the need of refugia for management?
Why apply refugia for tiger prawn?

Objective

The objectives is to ensure that the fishery resources are exploited sustainably through protection of critical stages of their life cycle such as during migration, spawning and juvenile periods. This paper focuses on refugia for tiger prawn (Penaeus monodon) in Kuala Baram, Miri, Sarawak.

Literature review

Tiger prawn, *Penaeus monodon* is the largest of the penaeid prawn, native Arabian Peninsula, Indo-West Pacific, Indian Ocean, coast of Australia, Indonesia, southeast Asia, and South Africa. The juveniles were found in estuaries, mangrove and lagoons, very tolerance with to high range of salinity water (2-30 ppt) and the adult go to deeper water (20-50 m). In Sarawak, landings of the prawn increase from October onwards and reached peak during

the monsoon months of January to March (Hadil, 1994). Past surveys indicated that the species was caught in relative abundance in coastal waters from Bintulu to Miri specifically off Kuala Suai in water depths ranging from 10 to 20 m with mud-sandy substratum (Bejie, 1981, 1982, 1983).

Based on observation and research done in 1998 location for tiger prawn spawners were located in water depth (> 30 m) in Tg. Batu, Miri to Kuala Baram, Miri (Hadil and Faazaz, 1998). Local trawlers have been operating since 1997 to collect spawners. The data was verified by resourse survey that have been conducted in 1999 (Hadil and Albert, 2001).

Methodology

The methodology were divided into two components: the adult/spawner and the juvenile tiger prawn which include off shore Kuala Baram and rivers nearby Kuala Baram.

Site

The area surveyed extended seaward beyond the coast to the 50 m depth contour in Kuala Baram with the farthest trawl station at about 12 Nautical Mile (NM) offshore (Figure 5). Beside the adult/spawners, the juvenile tiger prawn surveys were carried out at 3 major rivers inhabited by juvenile tiger prawn namely Pasu, Lutong and Sibuti rivers respectively (Figure 6) from March to April 2019.

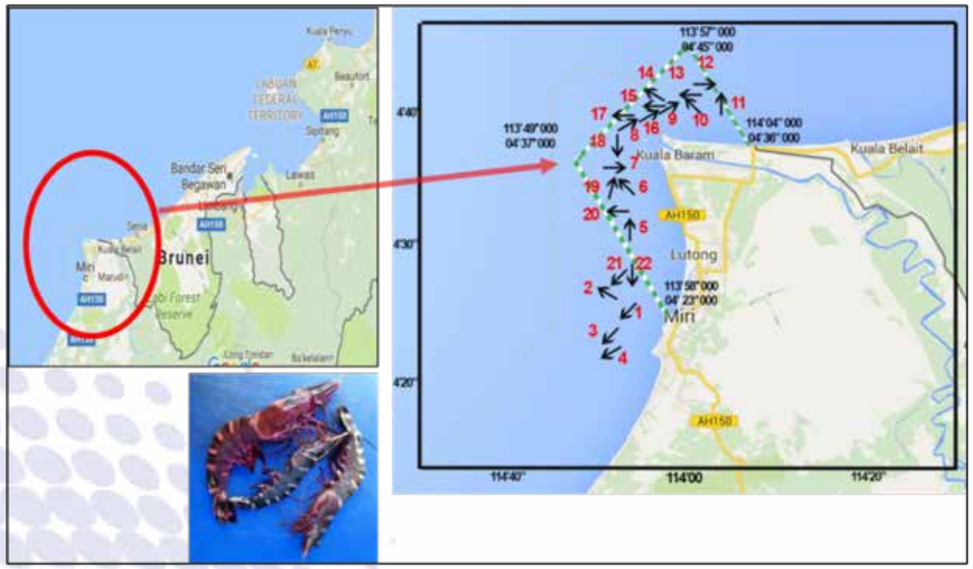


Figure 5: The proposed tiger prawn refugia area at Kuala Baram, Miri, Sarawak

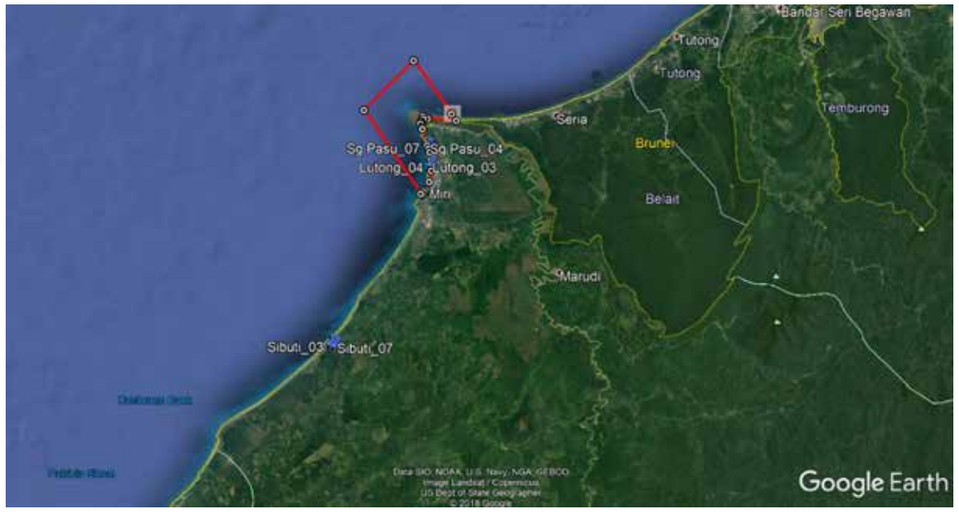


Figure 6: Three major rivers, Pasu, Lutong and Sibuti rivers as nursery ground for juvenile tiger prawn (study done in 2019)

Vessel and gear

For the adult study, sampling was carried out using commercial trawlers of 25 Gross Registered Tonnages (GRT). One or two researchers were placed on-board the vessel during the sampling trips and another two or three researchers were stationed at the port of call for the detailed processing of the biological samples. The net used was prawn net specifically designed to fish for a variety of near bottom dwelling species. The net was made of polyethylene with a code end mesh size of 38 mm. Total length of the net was measured at 35.3 m with a headrope of 23.5 m, ground rope of 24.7 m and a circumference of 33.6 m. Whereas for juvenile, Fishing was carried out during low and high tide. A cast net with 1.8 metre in length and 2.1 metres in diameter made of polyethylene net with mesh size of 19 mm (0.75 inch) was casted at each station to catch prawn (Figure 6). The sampling methodology adopted was the total removals methods (Welcomme, 1983) where the catches usually consist of both prawns and fish. The cast net was throwed at the station then pulled and hauled up. Swept area method (Sparre and Venema, 1998) which is one of the simple holistic methods was adopted for the survey of prawn resource. The head rope lengths were recorded for the calculation of the area swept.

Whereas, for the juvenile, the juveniles were caught using cast net 1.8 m in diameter. To estimate the current biomass, the catch of prawns harvested from the 1.8 m cast net was then equated to the total length of the river. The total area of the cast net was calculated using
$A=\pi r^{\wedge 2}$.

The simple equation for estimating the current biomass, where, A=area, r^2 = radius

In the estimation of prawn biomass, it was assumed that distribution of the prawn catch rates by sub-area or each river is normal (Mordkoff, 2016). Therefore, in order to normalize all the catch rates, log transformation was carried out. Log transformation of the variable is the usual method for *stabilizing* the variance (Sokal and Rohlf, 1969; Zars, 1974; Neter *et al.*, 1990). A value of 1 was added to all the catch rate values before log-transforming the data, to compensate for any zero value in the catch rate data set. Catch rates at every trawl or barrier net stations by sub-area were then transformed to natural log. Subsequently, the steps as mention below (Table 1) will be followed to arrive at adjusted mean catch rate.

Table 1: Steps in obtaining adjusted mean catch and its variance

	Order of transformation	Formula guideline
1	Catch rate (original count)	C_i
2	Log transformed catch rate	$X_i=Log_e (C_i+1)$
3	Arithmetic mean of transformed catch rate	$M=(Sum X_i) / N$
4	Variance of transformed catch rate	$VarX_i= Var(X1,X2,X3……..Xi)$
5	Derived mean catch rate	$Md=(ExpM)-1$
6	Adjusted mean catch rate	$M_a=Md*Exp((VarX_i)/2)$ Var
7	Variance of adjusted mean catch rate	$Ma=(Ma)2*Exp(VarX_i)* \frac{(Exp(VarX!))-1}{N}$

Findings

Due to the deterioration of spawning and nursery habitat, a tiger prawn refugia is proposed at the river mouth of Kuala Baram in Miri, Sarawak and the refugia site has been roughly identified based on past and current research findings (Hadil and Faazaz,1998, Hadil and Albert, 2001, Hadil, 2004, Hadil, 2007, Hadil, 2014). The proposed site for the tiger prawn refugia is located near a mangrove forest with an adjoining river mouth. The offshore area sloops into deeper depth as the area is adjacent to the continental sloop. In the vicinity of the refugia area is the Miri-Sibuti Coral Reefs National Park.

The catch rate, density, biomass and maximum sustainable yield of tiger prawn resource at Miri have been determined from previous study and is given in table (Hadil, 2014).

Table 2: The catch rate, density, biomass and maximum sustainable yield (MSY) of tiger prawn resource at Miri (Hadil, 2014).

Area Size (NM^2)	Catch Rate ($kg.hr^{-1}$)	Standard Deviation	Density ($kg.NM^{-2}$)	Biomas (metric ton)	MSY (metric ton)
296	1.99	0.523	52.44 (1:1.36 male:female)	15.52	23.00

Beside the catch rate, biomass and MSY, the gonad studies showed that peak breading season during the July-August period when the percentage of stage-IV gonad was the highest (Figure 7). This information is crucial to the determination of the closing season of the tiger prawn refugia which enable the protection of tiger prawn during their spawning period.

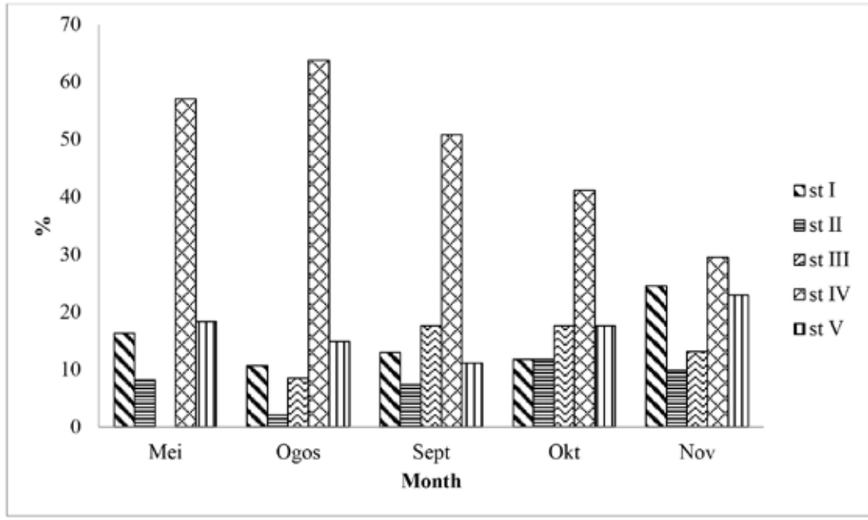


Figure 7: Stages of gonad development (Stage I – V) of female tiger prawn caught during the survey according to month (stage = st). (Adapted from Siow *et al.,* 2019).

Likewise, a study on juveniles has been carried out in the Pasu, Lutong and Sibuti rivers to estimate the catch rate, density and biomass of juvenile tiger prawns. A total of 375 casting activities using a cast net were carried out between March and April 2019. The catches of the cast net at the surveyed location were listed in Table 3. There were 25 species, including *Penaeus monodon,* caught in all the 3 rivers sampled. Besides *P. monodon, Fenneropenaeus merguensis, F. indicus, Metapenaeus lysianassa* (prawn from the Family Penaeidae), *Macrobrachium rosenbergii* (prawn from the Family Paleomonidae), the other 20 species caught were fin-fish.

In terms of catch composition (Table 3), *P. monodon* constituted 39.0% of the total catch followed by Banana prawn, *F. merguensis* – 18.4%, Longarm Mullet, *Moolgarda cunnesius* -7.1%, Indo-Pacific Tarpon, *Megalops cyprinoides* – 5.6%, Tade grey Mullet, *Chelon planiceps* – 5.5%, Indian white prawn, *F. indicus* – 4.9%, Tiger-toothed croaker, *Otolithes ruber* – 3.1%, Spotted scad, *Scatophagus argus* – 2.2% and the remainder 17 species each contributed < 1%.

Prawn biomass was estimated based on adjusted mean catch, AMC obtained from cast net sampling. Biomass estimates of tiger prawns from the 3 rivers sampled calculated were summarized in Table 4. With an AMC of 10.61 kg of tiger prawns per 1.2 metres radius of cast net, Pasu river is the most productive, followed by Sibuti river and Lutong river respectively. The total biomass estimated for tiger prawns in all 3 rivers was 15.90 kg.

Table 3: Percentage catch composition and total catch in terms of weight, wt. (g) and numbers, no.tails over 375 casting operations at Pasu. Lutong and Sibuti rivers, Miri surveys in March and April 2019.

No.	Species	Weight (g)	No.tails	Percentage (%)
1.	*Penaeus monodon*	2415.2	70	39.02
2.	*Fenneropenaeus merguensis*	1140	93	18.40
3.	*Moolgarda cunnesius*	439.4	11	7.1
4.	*Megalops cyprinoides*	345	2	5.6
5.	*Chelon planiceps*	339.4	11	5.5
6.	*F. indicus*	302.4	47	4.9
7.	*Toxotes chatareus*	194.2	6	3.13
8	*Otolithes ruber*	189.6	10	3.06
9.	*Scatophagus argus*	138.2	55	2.20
10.	*Lutjanus johni*	127	2	2.05
11.	*Oxyeleotris sp.*	116.1	4	1.8
12.	*Coilia boernensis*	44.5	2	0.71
13.	*Eubleekeria splendens*	54.0	10	0.87
14.	*Thryssa setirostris*	4.2	1	0.06
15.	*Encrasicholina punctifer*	31.8	4	0.51
16.	*Macrobrachium rosenbergii*	20.8	8	0.33
17.	*Raconda russeliana*	51.6	3	0.83

No.	Species	Weight (g)	No.tails	Percentage (%)
18.	*Plectorhinchus chaetodonoides*	6.2	1	0.10
19.	*Pomadasys kaakan*	29.6	3	0.47
20.	*Gerres erythrourus*	34.6	5	0.56
21.	*Sillago sihama*	116.4	1	1.88
22.	*Carangoides malabaricus*	33.2	1	0.53
23.	*Amblygaster sirm*	10.6	1	0.17
24.	*Scomberoides tala*	9.4	1	0.15
25.	*Metapenaeus lysianassa*	4.33	3	0.07
	Total	**6197.73**	**355**	**100**

Table 4: Estimated biomass of juvenile tiger prawn in Pasu, Lutong and Sibuti rivers

No	River	Length (km)	AMC (kg)	Variance of AMC	Biomass (kg)
1.	Pasu river	1.0	10.61	9.67	11.73
2.	Lutong river	1.2	3.34	5.94	20.77
3.	Sibuti river	3.0	5.85	82.21	15.22

Discussion

The establishment of fish refugia encompasses on four main component, (1) the identification and management of fisheries and critical habitat linkages at priority fisheries refugia, (2) the improvement of management of critical habitats for fish stocks of transboundary significance via national and regional actions to strengthen the enabling environment and knowledge-base for fisheries refugia management, (3) the management and dissemination of information in support of national and regional-level implementation of the fisheries refugia and (4) the cooperation and coordination exercises at the national and regional levels for management of integrated fish stock and critical habitat. The success of the fish refugia establishment more dependant on the acceptance of the fisherfolk or stakeholders on the usage and benefit of refugia. By emphasising the sustainable use aspects of refugia rather than the no-take zone approach adopted, and also the critical fish stock concept and the habitat linkages provide suitable platform for interaction between local authorities and the stakeholders (Paterson *et al.*, 2013).

Conclusion

Fish refugia is actually part and parcel of fisheries management namely ecosystem approach fisheries management that integrate building up healthy ecosystem to manage resources, in this context, the tiger prawn to sustainable wellbeing. This resource survey shown that the juvenile tiger prawn, *Penaeus monodon* resource in Miri, Sarawak was located in the nursery ground, in this case, Pasu, Lutong and Sibuti rivers to complete its life cycle. Therefore, regulation of fishing effort of gears which is primarily responsible on exploitation of these precious juvenile has to be enforced. Thus, it is recommended that these nursery ground to be gazetted as refugia site for sustainable fisheries of tiger prawn.

The Pre-Effect Analysis on the Pre-Establishment of Tiger Prawn Refugia towards the Socio-economy of Fishers in Kuala Baram Waters off Miri, Sarawak 2020

NORHANIDA, D.[1], NURRIDAN, A.H.[2] AND NUR SHAHIRAH, M.G.[3]

[1]Fisheries Research Institute, Penang
[2]Fisheries Research Institute, Sarawak & Labuan Division, Bintawa, Sarawak
[3]Universiti Teknologi MARA, Seremban Campus, Negeri Sembilan
Corresponding author : norhanidaud@yahoo.com

Abstract

The study aims to obtain the views of fishers who are directly and indirectly involved in tiger prawn (Penaeus monodon) *fishery in the waters off Kuala Baram, Miri, Sarawak. The study found out that 61% of respondents (n=112) did not have a clue on the establishment of refugia planned for tiger prawn. Nevertheless, the Department of Fisheries's plans to establish tiger prawn's refugia have been well-received by 92% of the respondents interviewed. The Cronbach's Alpha scores obtained from the Reliability Test conducted on respondents' responses on perceptions (0.808) showed consistent results and interpreted as ''GOOD". In other words, respondents along the coast of Kuala Baram agreed with the establishment of refugia for tiger prawn. Results from this study may have direct implications for the decision-makers of the Department, however, they also may serve as a baseline for future social and economic studies of the tiger prawn in the Sarawak Waters.*

Keywords: *Tiger prawn fishery, Penaeus monodon, refugia, Kuala Baram, Reliability Test*

Introduction

Miri, in particular is an active area for catching tiger prawn starting from Kuala Baram to Kuala Bakam (please refer to **Map 1**). It has mangrove areas with a relatively sloping platform area, as well as an area that plunges far enough to allow water with high salinity to reach the beach.

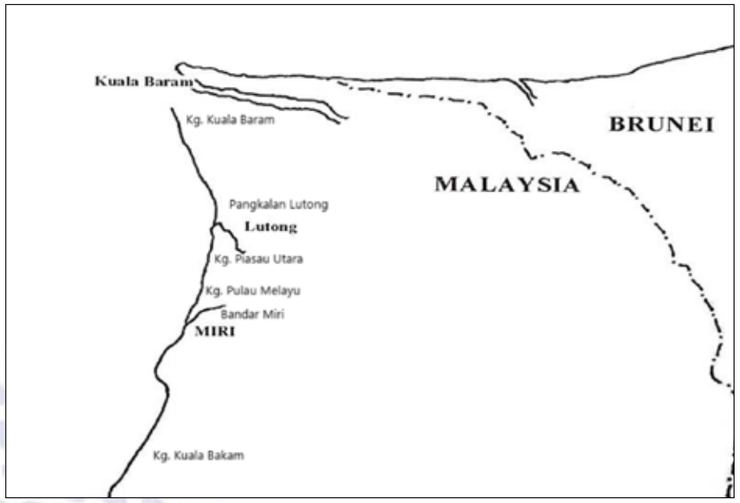
The results of studies conducted by the Fisheries Research Institute, Sarawak and Labuan Division, Bintawa indicated that the catch rate by trawlers was 1.300 kg per hour. The exploitation rate of the catch of tiger prawn was approximately 20% per year. Miri has the potential to produce 47 million males and 88,000 females of tiger prawn, worth of RM5 million and RM22 million a year respectively.

The concept of fisheries refugia has been defined by United Nations Environment Programme (UNEP) as :-

"Spatially and geographically marine or coastal areas in which specific management measures are applied to sustain important species (fisheries resources) during critical stages of their life cycle, for their sustainable use"

and is being developed as a new approach to identify key areas for integrated habitat management and fisheries. Refugia in this context are not a 'Fishing Prohibition Zone'. The establishment of these refugia uses the approach of using resources sustainably for the benefit of present and future generations. With the existence of a closed area, it can protect a species or several groups of species during a critical stage in the life cycle of the said-species.

In Malaysia, consultations have been conducted to identify priority areas for the establishment of fishery refugees, the consultation is comprised of representatives of local government agencies, research institutions, institutions of higher learning, law enforcement agencies, fishers' associations and non-governmental organizations. The two refugia locations that have been selected are in Tanjung Leman, Johore (prawn) and Kuala Baram, Miri, Sarawak (tiger prawn). In this regard, a management plan should be prepared as the focal reference in planning the development of the tiger prawn fishery in Kuala Baram and particularly in the state of Sarawak.



Map 1: Study locations in Kuala Baram, Miri, Sarawak

Because tiger prawn is a high-value fishery resources, relevant fisheries information is essential for more effective management. This includes information on catch, catch composition, species distribution, exploitation stage and season.

Research Objectives

The objectives of this study was to provide a social and economic characterization of the tiger prawn fishers. In doing so, variables pertaining to the following were assessed in aggregate for all respondents as follows:

(i) to evaluate the socio-economic impact on the fishers of Kuala Baram before the establishment of tiger prawn's refugia in the specific area to be determined later,
(ii) to determine the exploitation status of tiger prawn fishery in Kuala Baram such as the number of fishers, fishing equipment, vessels, catch rate, etc,
(iii) to determine the economics of the tiger prawn fishery in respect of expenditure and revenue; and
(iv) to verify the acceptance of fishers towards prawn refugia to be proposed at Kuala Baram for tiger prawn.

Scope of Study

The scope of the study is to study the profile of tiger prawns' fishers in order to obtain information on

(i) the respondents' background such as place of origin, marital status, ethnicity, level of education, residence, basic facilities and property ownership,
(ii) catch operations such as fishing gears, fishing areas, duration, operational costs, catch and species composition,
(iii) the marketing and distribution of tiger prawns,
(iv) respondents' main occupation and additional incomes,
(v) income distribution, household income and expenditures; and
(vi) other related information.

Significance of the Study

By implementing this study, the number of tiger prawns' fishers in Sarawak, could be verified. Other than that, the market, cost and returns of tiger prawn fishery shall be determined so as issues and obstacles could be addressed. The overall goal was to determine the dependence of the fishers and his/her household on fishing in general and on tiger prawn fishery in particular.

METHODOLOGY

The primary goal of this study was to obtain the social and economic information about tiger prawn fishery in Sarawak. Therefore, the methods for conducting the study were questionnaires, focus group discussions and key informant interviews.

Questionnaire Development and Design

A structured questionnaire was developed to collect social and economic information from tiger prawn fishers mostly comprised of owners and owner-operators. Majority of the questions were close-ended and collected quantitative data. However, open-ended questions provided respondents the chance to comment on contentions issues.

The questionnaire was divided into six sections :
(i) the project information,
(ii) the respondents' profile,
(iii) fishers' household income,
(iv) fishing operations in general ; and
(v) tiger prawns' capture operations.

Questions pertaining to the aspect of fishers' level of awereness on the proposed refugia at waters off Kuala Baram were also asked, including the benefits of refugia, and social and environmental protection offered by refugia.

Research Design

First and foremost, information on the number of fishers of Miri, particularly at Kuala Baram and their respective vessels were acquired. The Fisheries District Offices of Miri planned and came up with the interview appointments with the fishers/respondents by setting up the date, time and venues. At the designated date and time, the project leader with a group of local enumerators will be at the location, acommpanied by the Fisheries District staff to conduct face-to-face interview. The enumerators would then jot down the answers from the respondents in the questionnaires. The process took about 20 – 30 minutes per questionnaire, based on the information given by the respondents. Small tokens were awarded to the respondents as appreciation for the co-operation given. Data were keyed-in the Microsoft Excel which were then transported to SPSS for analysis.

Formal and informal key informant interviews and focus group discussions provided the opportunity to obtain additional in-depth information on the fishery. They permitted respondents to clarify statements or to further elaborate on brief comments.

Questionnaire responses were coded and entered into data tables. Data were then analysed using SPSS for Windows. Secondary data sources consisted mainly of records and reports, ranging from fisheries statistics to registration records to the reports of similar studies and consultations. The information from these sources were included int the results and discussions.

Locations

A total of six locations were selected for this study namely Kampung Kuala Baram, Pangkalan Lutong, Kampung Pulau Melayu, Bandar Miri (trawlers only), Kampung Piasau Utara and Kampung Kuala Bakam.

RESULTS AND ANALYSIS

This section presents the results from the fishers ; the respondents' questionnaire examines the basic of the tiger prawn fishery such as information on the boats, local knowledge of tiger prawn, gear used and fishing effort. Income, operating costs, bot maintenance and marketing are also examined. The respondents' attitudes and perceptions with respect yo the resource, its' management and the tiger prawn refugia proposal are examined as well.

Tiger Prawn Fishery Overview

The real senario of fishers in Malaysia are divided into two categories ; commercial fishers or artisanal fishers. The fishers in question are further divided into fishing gears used by them such as Trawls, Purse-seines, Drift nets, etc. Accordingly, artisanal fishers will catch variety of fish, squids, prawns and other marine species. Therefore, fishers are not referred to as tiger prawn fishers (for instance). Because the waters of Kuala Baram is rich in tiger prawn resources, they will indirectly target tiger prawn as their primary catch. However, the capture of other marine species is as important as tiger prawn and will not be discarded.

Table 1 : Tiger prawns' landings statistics in Sarawak

Year	Landings (tonnes)	Mean Ex-vessel price in Sarawak (RM)	Fishing gears
2006	34	n.a.	n.a.
2007	22	n.a.	n.a.
2008	688	n.a.	Bag nets, Trawls & Drift nets
2009	8	n.a.	Trawls
2010	3	n.a.	Trawls
2011	5	28.49	Drift nets & Trawls
2012	3	29.29	Drift nets
2013	40	n.a.	Drift nets & Trawls

Year	Landings (tonnes)	Mean Ex-vessel price in Sarawak (RM)	Fishing gears
2014	11	30.06	Trawls & Drift nets
2015	29	34.57	Trawls & Drift nets
2016	22	31.78	Trawls & Drift nets
2017	10	32.38	Trawls
2018	10	n.a.	Trawls
2019	11	34.44	Trawls

Notes :
n.a. : data not available
USD1.00 ~ RM4.01 (January, 2021)

Based on the Department of Fisheries' Statistics from 2006, the highest landings was recorded in 2008 with 688 tonnes, caught by Bag nets, Trawls and Drift nets **(Table 1)**. After that, the landing of tiger prawns showed a sharp decline until 2019. Starting from 2017, tiger prawns were caught by trawlers and no landing of tiger prawns by artisanal fishers were recorded. The ex-vessel price of tiger prawns have not changed much from RM28.49 per kilogram in 2011 to RM34.44 in 2019.

Fishing Gears

Artisanal fishers

The average boat length and gross rate tonnage (GRT) used by artisanal respondents at Kampung Kuala Baram (n=22), Pangkalan Lutong (n=20), Kampung Pulau Melayu (n=6), Kampung Piasau Utara (n=31) and Kampung Kuala Bakam (n=26) are 26.05 ft and 2.978 GRT respectively; and empowered by 43.22 horsepower engines. The fishing gears used by the respondents comprises of Drift nets *(Pukat Hanyut)*, 3-layered Drift nets *(Pukat Hanyut 3-lapis)*, *Pukat Tangsi* (fishing nets with rope and lead), *Pukat Tenggelam* and Hooks and Line *(Pancing)*.

Commercial fishers

The mean of vessel length and gross rate tonnage used by Trawlers (n=7) in Miri are 62.24 ft and 45.000 GRT respectively; and empowered by 326.25 horsepower engines.

Catch and Effort

Artisanal fishers

The average overall catch of the artisanal respondents was 51.981 kg per trip with operational cost approximately at RM151.57 per trip. The average catch was valued at RM541.47 per trip. The composition of tiger prawns ranged between 4.01 – 12.45% of the total catch (kg) per trip. Respondents engaged in the fishing acitivities approximately 18.90 days monthly **(Table 2)**.

Of the interviews conducted, 25.9% of overall artisanal respondents informed that they were targeting tiger prawns as one the main catch. On the other hand, the remaining respondents (74.1%) indicated that tiger prawns were not the main catch because the resources were not distributed extensively in their respective operating areas.

Table 2 : The information on the fishing operations of atisanal fishers in Kuala Baram

Fishing base	Catch weight (kg/trip)	Overall value of catch (RM/trip)	Operational cost (RM/trip)	% of tiger prawns	# of operating days (per month)
Kg. Kuala Baram	42.636	343.18	99.84	7.49	17.77
Pangkalan Lutong	61.750	585.00	175.45	12.45	19.80
Kg. Pulau Melayu	48.333	446.67	142.33		15.00
Kg. Piasau Utara	42.419	673.35	186.10	4.01	18.90
Kg. Kuala Baram	64.615	540.38	138.36	10.40	20.08
Overall weighted average	***51.615***	***541.47***	***151.57***	***9.29***	***18.90***

Notes :
USD1.00 ~ RM4.01 (January, 2021)

Commercial fishers

The average overall catch of Trawlers (n=7) of Miri was 5,428.571 kg per trip as indicated in **Table 3**. The mean operating cost of a Trawl vessel was RM8,267.86 with catch valued at RM16,628.57 per trip. On average, the composition of tiger prawns caught by commercial respondents was 0.86% (or nearly 46.686 kg) of overall catch. Unlike artisanal fishers, trawling operations last between 5 to 10 days for one (1) fishing trip.

Table 3 : The information on the fishing operations of trawl fishery in Kuala Baram

Miri	Catch weight (kg/trip)	Overall value of catch (RM/trip)	Operational cost (RM/trip)	% of tiger prawns	# fishing trips (per month)	# days of one fishing trip
Trawl_01	700.000	7,000.00	1,200.00		3	5
Trawl_02	500.000	10,000.00	4,705.00		4	5
Trawl_03	5,000.000	25,000.00	8,500.00	0.60	2	7
Trawl_04	8,000.000	20,000.00	14,580.00	0.03	2	10
Trawl_05	1,800.000	14,400.00	13,940.00	3.00	2	5
Trawl_06	7,000.000	15,000.00	5,900.00	0.29	2	10
Trawl_07	15,0000.000	25,000.00	9,050.00	0.40	2	10
Overall weighted average	***5,428.571***	***16,628.57***	***8,267.86***	***0.86***	***4.43***	***7.43***

Distance of Fishing Areas

Respondents from the six designated areas estimated that the distribution of tiger prawns between 1 to 15 nautical miles from the coastline **(Table 04)**. Based on ecological knowledge, 86% of overall respondents admitted that they were not very knowledgeable about the tiger prawn habitats and spawning ground in the waters of Kuala Baram. The distribution of tiger prawns near to the islands scattered in the waters of Kuala Baram was informed by 9% of respondents, followed by waters of Tanjung Batu (2%) and in the waters neighbouring Miri – Brunei (1%). The remaining respondents (2%) acknowledged that tiger prawns live flourishly in the muddy seabed areas.

Table 4 : Distance of tiger prawn fishery in Kuala Baram

Fishing base	Distance from coastline (nautical miles)		
	Minimum	Maximum	Average
Kampung Kuala Baram	2.00	4.00	3.82
Pangkalan Lutong	2.00	7.00	3.32
Kampung Pulau Melayu	6.00		6.00

Fishing base	Distance from coastline (nautical miles)		
	Minimum	Maximum	Average
Miri (trawls only)	5.00	7.00	5.67
Kampung Piasau Utara	1.00	9.00	4.00
Kampung Kuala Bakam	2.00	15.00	9.40

Demographic Characteristics of Respondents and Respondents' Households

Respondents were mostly dominated by males, who represented 99.1% of the survey population. The interviewed female respondents assisted their spouses in fishing operations only. The percentages of age groups were 13.6% (20 to 39 years old), 54.5% (40 to 59 years old) and 31.8% (60 years old and above).

In order of prominence, the highest level of education attained by respondents were university degree holders (0.9%), diploma holders (0.9%), Secondary 5 (17.9%), Secondary 3 (21.4%), up to Primary 6 (41.1%), no formal eduction (15.2%). Generally, it indicated that the literacy rates among the respondents were quite high; and fishers are able to read and write reasonably well.

Based on ethnic breakdown, majority of the respondents were Malays (38.4%), followed by Melanau (34.8%), Chinese (15.2%), Iban (10.7%) and Kedayan (0.9%). 83.9% of respondents were native to Miri while the rest came from other districts of Sarawak because of job opportunities and / or married the Mirians.

Majority of respondents were married with a coverage of 89.3%, followed by single respondents (8.9%) and single parents (1.8%).

The built-up of the respondents' residences is also an indicator of the household economic status. The percentage distribution of brick residential homes was 42.0%, wooden house (32.1%) and partially brick house (25.9%). 69.1% of respondents were the possessor of their residences. All respondents' homes were supplied with tap water and electricity.

The well-being of respondents' household could be measured by observing the home appliances and vehicles. Vehicle ownership indicated that Motorcycle was the most owned vehicle at 78.4% followed by Car (66.1%). In terms of home appliances, 98.2% of respondents owned Refigerator, followed by Washing Machine (92.0%) and Television (90.2%). The percentage of respondents owing mobile telephone was 98.2%, making it the main communication tool used for work and personal matters.

Artisanal respondents' household in Kuala Baram spent an average of RM1,270.42 per month. The highest expenditure of a respondent's household was foodstuff (RM731.73 month^{-1}), followed by home installment payment (RM725.00 month^{-1}), vehicle installments (RM698.15 month^{-1}), house rental payment (RM550.00 month^{-1}), utility bills (RM223.19 month^{-1}), children educations' expenses (RM219.96 month^{-1}). Cigarettes was the lowest expenditure for a respondent's household in the study areas at RM138.98 month^{-1}.

On the other hand, commercial respondents' household in Kuala Baram spent an average of RM5,272.86 per month. These expenditures included home installment payment (RM2,433.00 month^{-1}), foodstuff (RM2,357.14 month^{-1}), childrens' education expenses (RM1,900.00 month^{-1}), vehicle installment (RM1,400.00 month^{-1}) and utility bills (RM821.43 month^{-1}). Cigarettes was also the lowest expenditure for commercial respondent in the City of Miri at RM253.33 month^{-1}.

Economic Profile of Fishers in Kuala Baram

Nearly all respondents (81.8%) along the waters of Kuala Baram regarded fishing as the major source of income. In addition, household expeditures were also supported by the income of their working wives and children as well. The Monthly Fisheries Subsistence Allowances of RM300.00 provides additional household income to respondents. Only 25.9% of artisanal respondents regarded tiger prawns as one of the most prized fish commodity.

Tiger prawn is the largest of the panaeid found in Sarawak, but were caught in small quantities (Hadil, 2007). The tiger prawn catching season runs actively from October onwards and reached the peak during the moonson months of January to March.

Capital Investment

Most of the respondents have made a significant investment in the fishery and are highly dependent on it for personal income. The majority respondents of artisanal fishers interviewed were Owner-Operators (94.3%),followed by Crews (3.8%) and Skippers (1.9%). The mean estimated current market value of boat, engine and fishing gears was RM25,603.97 as shown in **Table 05**.

Table 05 : Start-up capital for the acquisition of boat, engine and fishing gears for artisanal fishers of Kuala Baram

Major Fishing Gear	Boat (RM)	Engine (RM)	Major Gear (RM)	Secondary Gear (RM)	Total Capital (RM)
Drift net	9,319.40	11,015.15	4,377.88	1,656.67	26,038.68
3-Layered Drift net	7,252.63	10,005.56	3,700.00	2,450.00	24,542.89
Pukat Tangsi	9,075.00	11,025.00	3,285.00	450.00	25,660.00
Pukat Tenggelam	9,100.00	11,983.33	3,933.33	2,200.00	26,433.33
Hooks & Lines	9,240.00	13,20.00	1,710.00		22,684.00
Overall average	***8,903.96***	***11,001.01***	***4,045.30***	***1,806.82***	***25,603.97***

The mean estimated current market value of vessels, engines and supporting equipment for Trawl was RM518,571 as shown in **Table 06**.

Table 06 : Start-up capital for the acquisition of boat, engine and fishing gears for Trawlers at Miri City

# of vessel	Body of vessel (RM)	Engine (RM)	Trawl net (RM)	Supporting equipment (RM)	Total capital (RM)
Trawl_01	130,000	90,000	20,000	8,000	240,000
Trawl_02	120,000	100,000	15,000	8,000	235,000
Trawl_03	300,000	100,000	20,000	0.00	420,000
Trawl_04	450,000	160,000	10,000	60,000	680,000
Trawl_05	600,000	130,000	25,000	50,000	805,000
Trawl_06	300,000	150,000	25,000	50,000	525,000
Trawl_07	500,000	150,000	25,000	50,000	725,000
Overall average	***342,857***	***125,714***	***20,000***	***37,667***	***518,571***

Revenue

Artisanal fishers of Kuala Baram

The monthly average weighted income of respondents from fishing activities alone was RM2,256.03; in which respondents using *Pukat Tenggelam* recorded the highest revenue at RM3,184.00 per month, followed by Drift Nets (RM3,134.00), Longlines (RM3,081.67), Hooks and Lines (RM2,31.00) and *Pukat Tangsi* (RM1,935.29) as shown in **Table 07**.

Table 07 : Average revenue solely from artisanal fishing activities (RM per month)

Fishing base	Drift net	*Pukat Tangsi*	*Pukat Tenggelam*	Hooks and Lines	Longlines	Average income
Kampung Kuala Baram	1,200.00	2,080.00	0.00	1,075.00	3,622.50	1,928.75
Pangkalan Lutong	0.00	1,775.00	3,142.00	2,800.00	2,000.00	2,448.67
Kampung Pulau Melayu	0.00	1,475.00	0.00	0.00	0.00	1,475.00
Kampung Piasau Utara	0.00	1,583.330	3,000.00	2,538.18	0.00	2,116.80
Kampung Kuala Bakam	5,068.00	2,600.00	3,412.50	0.00	0.00	2,941.08
Overall average	***3,134.00***	***1,935.29***	***3,184.83***	***2,311.00***	***3,081.67***	***2,256.03***

Note : USD1 ~ RM4.01 (January 2021)

Trawlers of Miri

The monthly average weighted income of trawlers from fishing activities was RM33,285.71, ranging from RM15,000 to RM60,000 as indicated in **Table 08**.

Table 08 : Average monthly revenue solely from Trawl fishery in Miri (RM)

# Trawl	01	02	03	04	05	06	07
Owner-operator	20,000		50,000	50,000	60,000	15,000	30,000
Skipper		8,000					

Note : USD1 ~ RM4.01 (January 2021)

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

Opinions and Perceptions on Fisheries Management

In order to obtain respondents' perspective on the proposed tiger prawn refugia at Kuala Baram, several related questions were also asked. The series of questions were categorized into three sections, i.e. (i) the level of awareness, (ii) the benefits of refugia, and (iii) social and environmental protection.

Level of awareness

Under the Establishment and Operation of a Regional System of Fisheries Refugia in the South China Sea and Gulf of Thailand, the Department of Fisheries intends to establish a refugia for tiger prawn at Kuala Baram. Therefore, 61.0% respondents noted that they were not well aware of the plan as indicated in **Figure 1**.

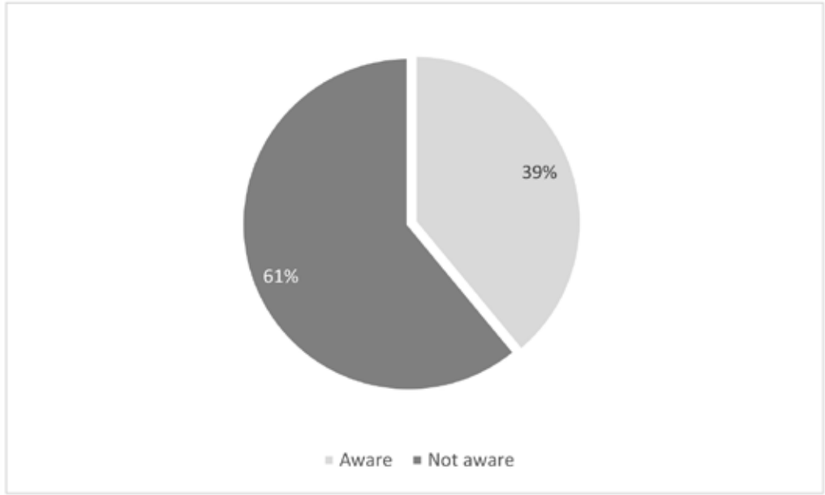


Figure 1: Proposed establishment of tiger prawn refugia at Kuala Baram, Miri, Sarawak

From the interviews, 92.0% of the respondents **(Figure 2)** agreed with the proposed location, compared to 7.0% of respondents. Only 3% from the overall respondents remained neutral.

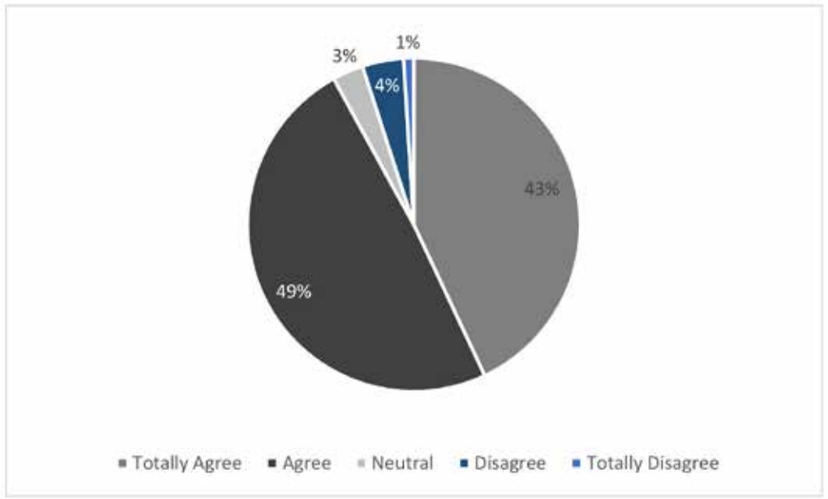


Figure 2: Kuala Baram, Miri as the site for tiger prawn refugia

A total of 90.0% respondents agreed with the proposal to enforce a ban on tiger prawn capture during their breeding season. Respectively, 9.0% respondents disagreed as well as 1.0% respondents remained neutral on this matter **(Figure 3)**.

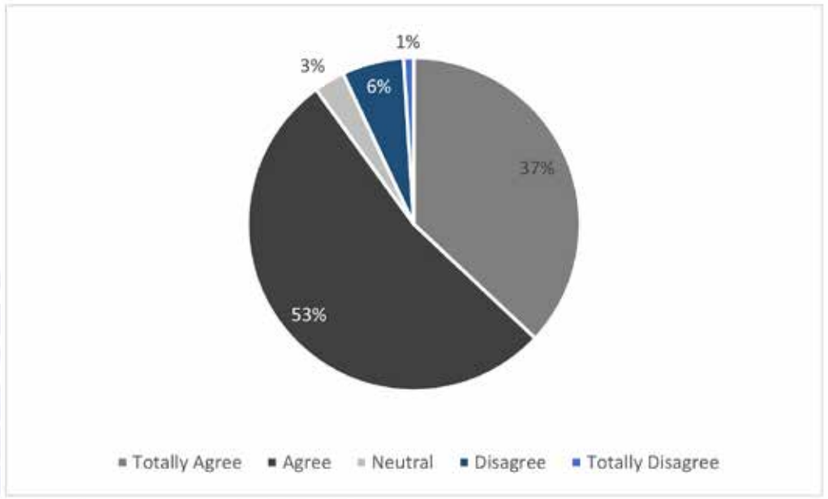


Figure 3: Prohibition of tiger prawn fishery during the breeding season

To ensure the success of this program, fishers' co-operation is very important. In this regard, the Department of Fisheries would like to propose that fishers in the vicinity of Kuala Baram to assist in maintaining the refugia, once after they are formally established. The fisheries authority has limited capacity to manage the tiger prawns' refugia. Therefore, 95.0% respondents agreed to jointly-maintained the refugia as opposed by 3.0% of the respondents **(Figure 4)**.

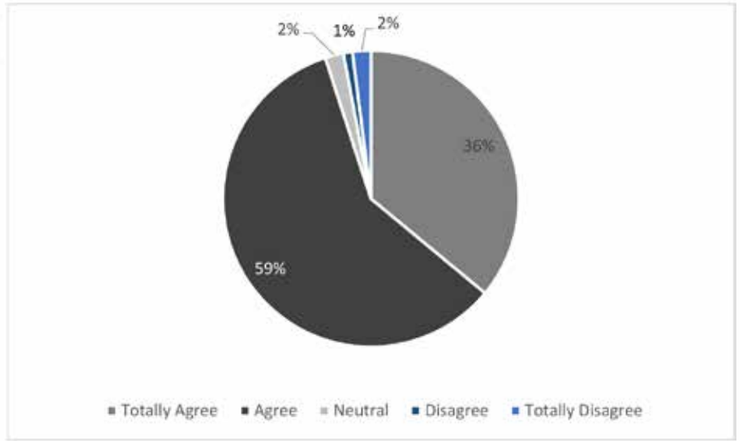


Figure 4: Respondents' responsibility to maintain the refugia

With regards to the prohibition of fishing in the areas that would be gazette as prawn refugia, nearly 84.0% of respondents believed that it should be enforced. However, 14.0% of respondents opposed to the proposal and remained neutral were 2.0% respectively **(Figure 4.1)**.

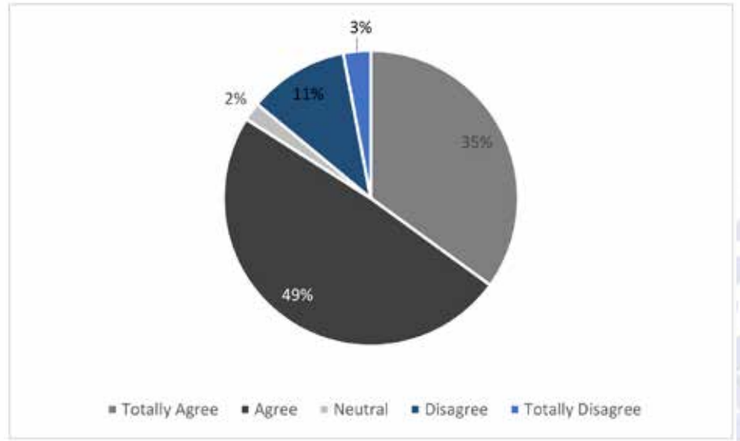


Figure 4.1: The site of the refugia should be 'no-fishing zone'

The respondents had expressed the view that the fisheries authority / government should have presented these issues to the stakeholders and consulted with them before any fishery-related programs could be implemented. The opinion was keenly expressed by 99.0% of respondents from the interview **(Figure 5)**.

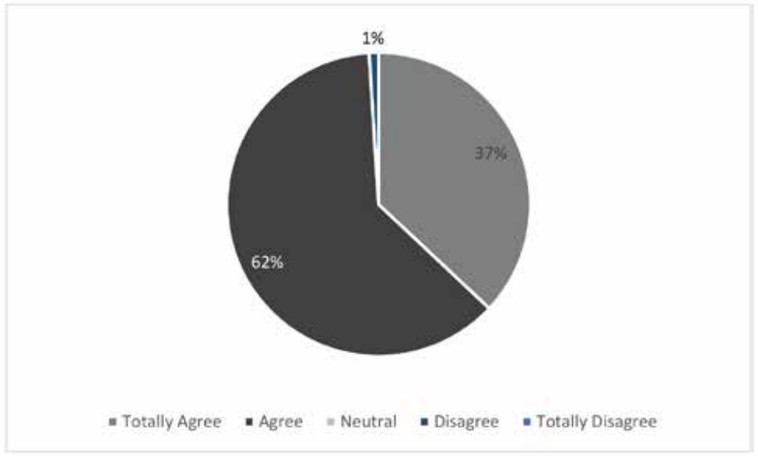


Figure 5: Need for discussion / consultation between DoF and fishers regarding the establishment of tiger prawn refugia

The Benefits of Refugia

As many as 90.0% of respondents agreed that the establishment of refugia can help increase fisher's income. Only a small percentage of respondents (2.0%) disagreed with the statement as indicated in **Figure 6**.

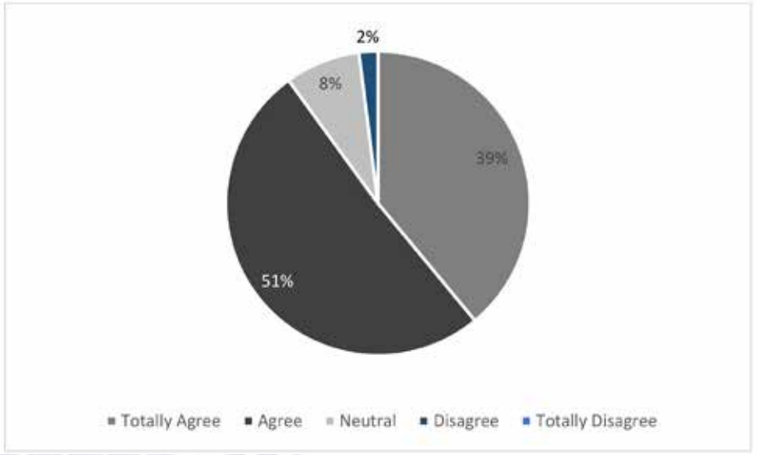


Figure 6: Refugia establishment could assist in increasing the fishers' income

As many as 94.0% of respondents agreed that fishers, especially artisanal fishers along the coast of Kuala Baram will benefit from the establishment of refugia. However, 4.0% of the respondents remained mum on this matter while 2.0% of the respondents were being skeptical of the statement **(Figure 7)**.

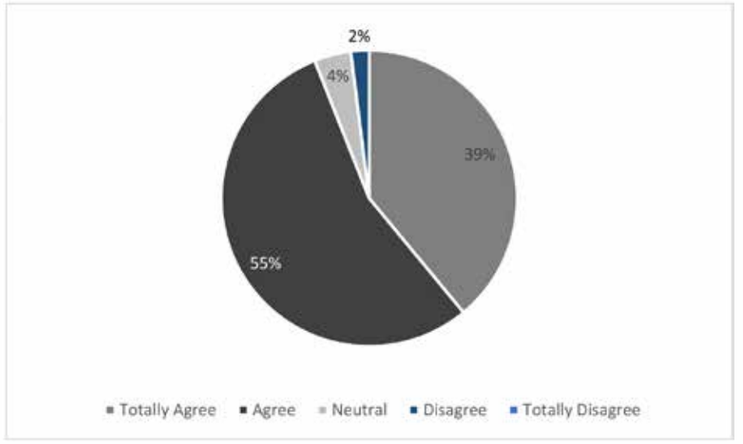


Figure 7: Artisanal fishers will benefit from the establishment of refugia

As many as 92.0% of the respondents were optimistic that the number of tiger prawn would eventually increase after the establishment of the refugia. However, this view was not enthusiastically shared by 3.0% of the respondents while 5.0% of the respondents remained neutral on this statement **(Figure 8)**.

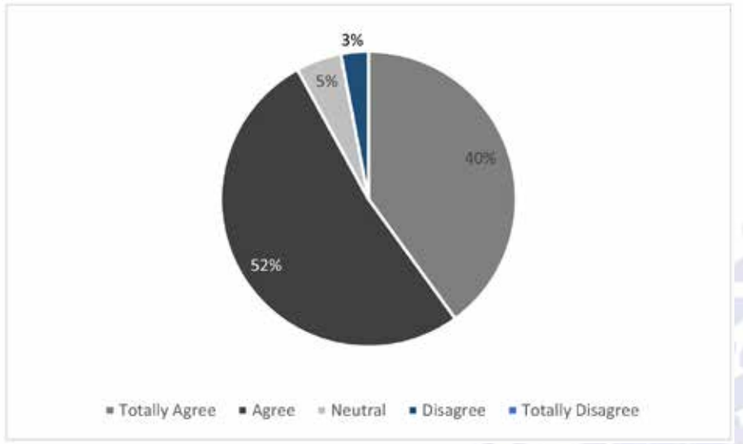


Figure 8: Refugia will increase the number of tiger prawns

Nearly 92.0% of the respondents believed that the quality of tiger prawn will be improved (bigger size) due to the establishment of refugia in the waters of Kuala Baram as indicated in **Figure 9**.

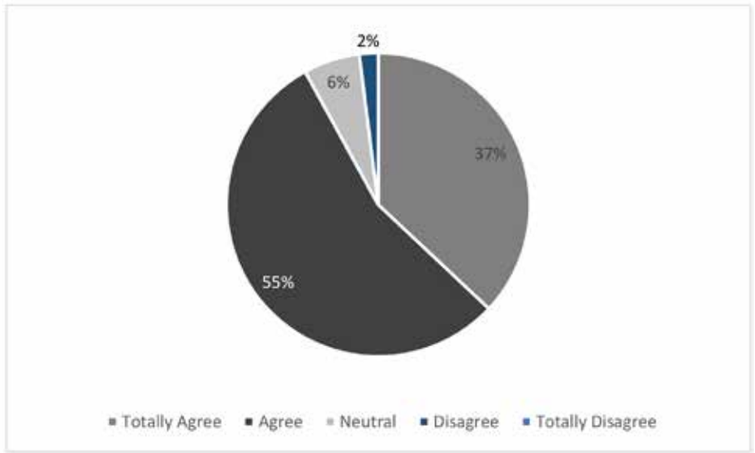


Figure 9: The quality of tiger prawn will be improved

A total of 92.0% of the respondents welcomed the establishment of more refugia along the coast of Kuala Baram in the future as it would boost the tiger prawn resources and thus, increasing the income of artisanal fishers. As many as 5.0% respondents expressed their disagreement on the statement while 3.0% of respondents remained neutral **(Figure 10)**.

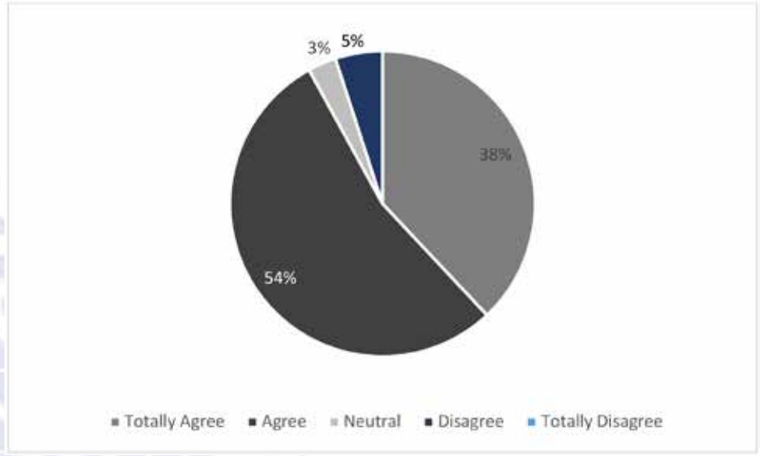


Figure 10: More refugia need to be built/established

Social and Environmental Protection

The establishment of tiger prawn's refugia will affect human rights such as dignity, culture and uniqueness of the fishing community were strongly opposed by 92.0% of the respondents interviewed. 4.0% of the respondents remained neutral respondents agreed with the statement respectively **(Figure 11)**.

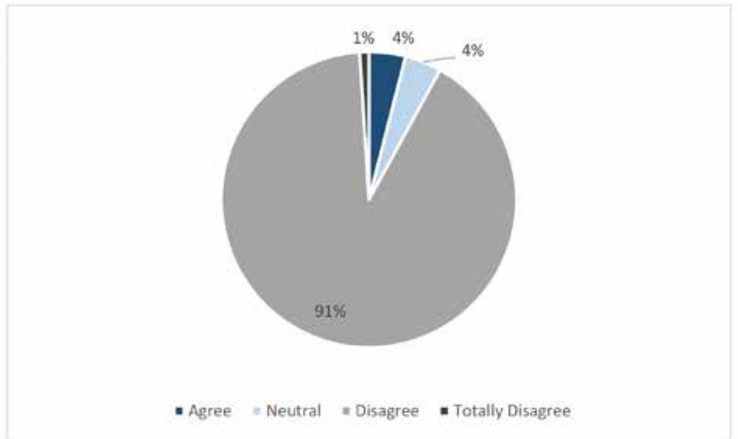


Figure 11: Refugia affects human rights

The establishment of prawn's refugia causes social conflict over fishers' access to fishery resources were shared equally by both the dissenting (2.0%) and the neutral respondents (3.0%) as shown in **Figure 12**.

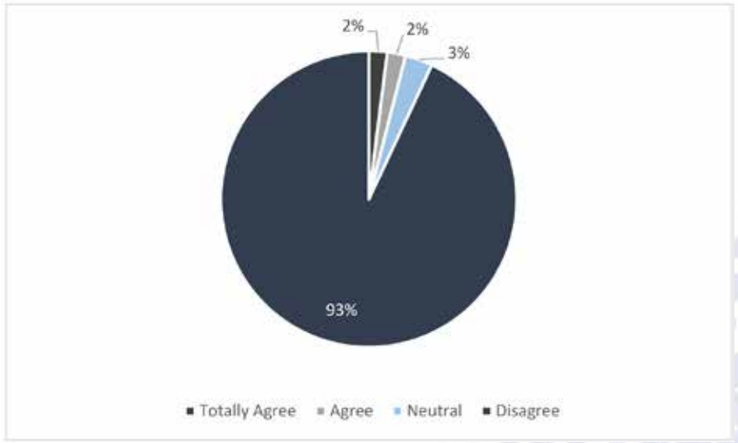


Figure 12: Refugia causes social conflict on fishers' access to fishery resources

As many as 88.0% of respondents felt that the establishment of tiger prawn's refugia will not change the utilization of land, sea and fishery resources. However, this statement was supported by 8.0% respondents while 4.0% respondents remained silent **(Figure 13)**.

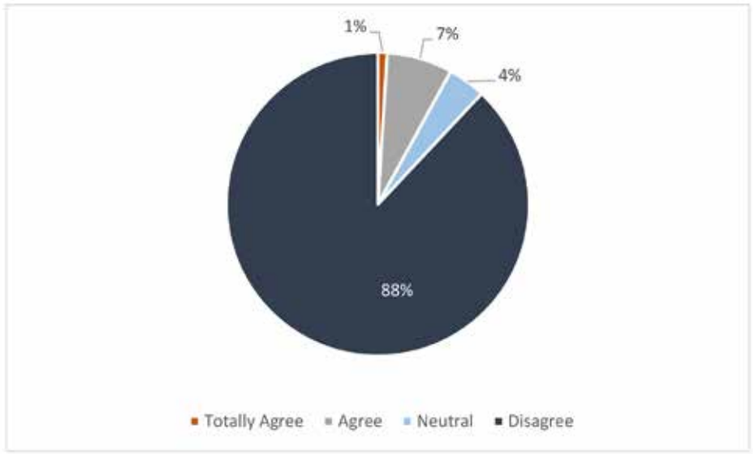


Figure 13: Refugia changes the use of land, sea and fishery resources

As many as 89.0% of the respondents disagreed on the establishment of refugia will cause displacement of local communities to other areas. 1.0% of the respondents remained neutral, while the rest of the respondent agreed with the statement **(Figure 14)**.

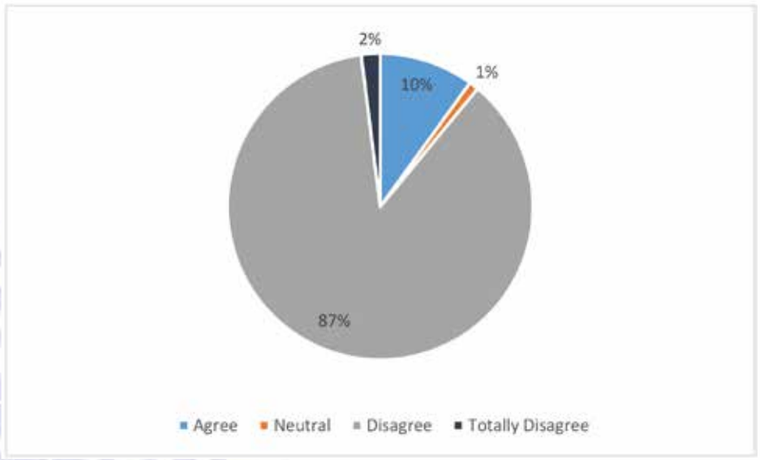


Figure 14: Refugia causes local residents to be relocated to other areas

91.0% of the respondents did not consider that the establishment of refugia will cause the dwindling number of fishers, or fishers will lose their jobs, thus affecting their livelihood. On the contrary, less than 10% of respondents believed that refugia will reduce the number of fishers **(Figure 15)**.

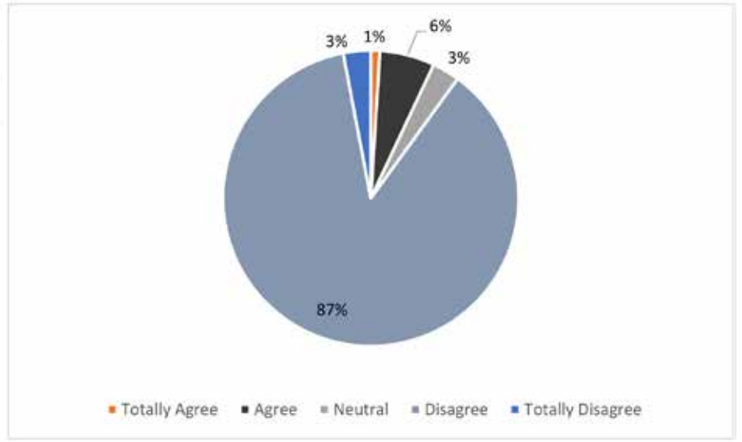


Figure 15: Refugia causes fishers to lose their jobs

The establishment of tiger prawn's refugia proposed by the Department of Fisheries was not considered by respondents (84.0%) to cause a decline in eco-tourism and recreational fisheries. Only 11.0% of respondents insisted that it would upset the eco-tourism as well as recreational fishing **(Figure 16)**.

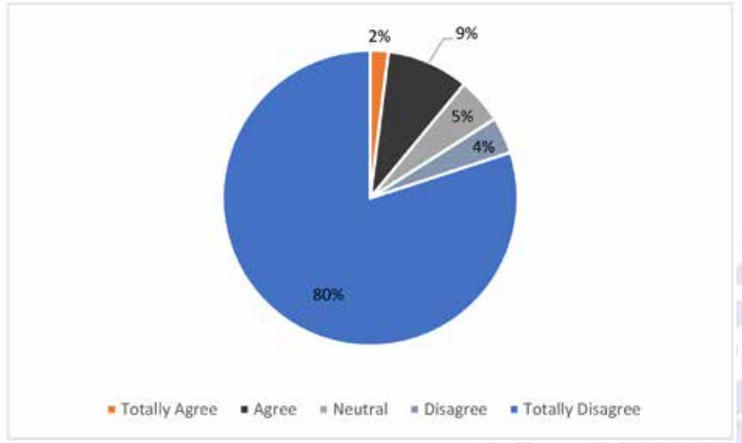


Figure 16: Refugia affects eco-tourism and recreational fisheries

Only 4.0% of the respondents believed that the refugia will lead to a deterioration on the livelihood of the fishers as well as the local communities. This statement was strongly rejected by 92.0% of respondents while the rest of the respondents had no comment or opinion on this matter **(Figure 17)**.

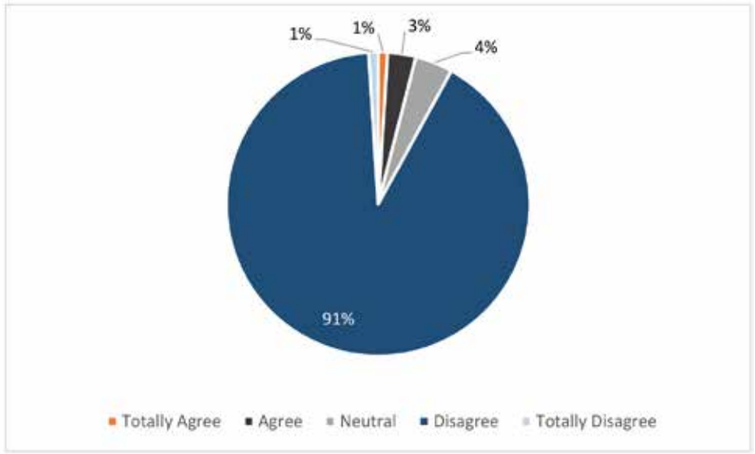


Figure 17: Refugia deteriorates the livelihood of fishers

96.0% of respondents disagreed that the establishment of the refugia will have a disproportionate impact on women, the disabled and the poor as indicated in **Figure 18**.

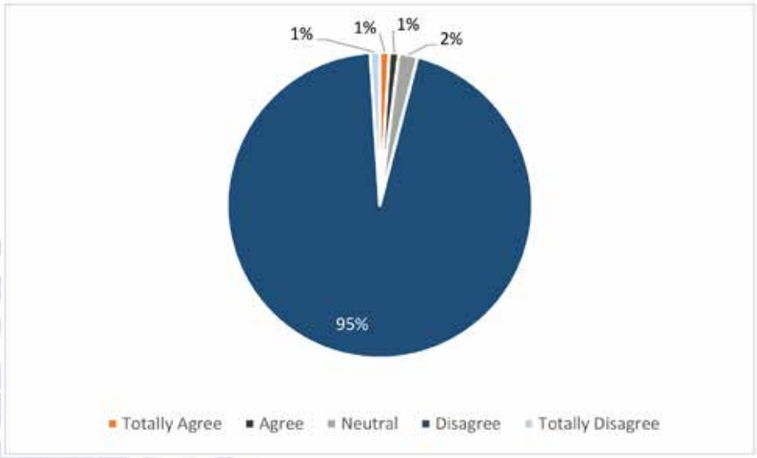


Figure 18: Refugia causes unbalanced impact on women, disabled and the poor

98.0% of the respondents were reluctant to agree with the statement that refugia would affect the cultural heritage of the local communities along waters of Kuala Baram while only 1.0% of the respondents thought otherwise. 1.0% of the respondents remained neutral **(Figure 19)**.

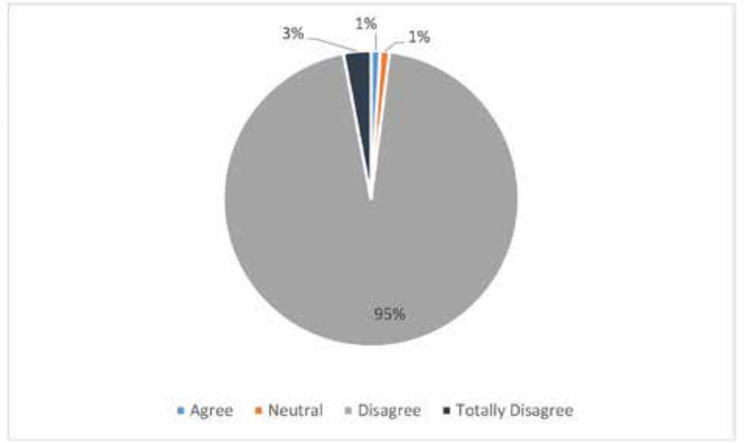


Figure 19: Refugia affects the cultural heritage of local communities

Reliability Test

Descriptive analyses were used to obtain the demographic profile. Since the questionnaires on the perceptions on issues regarding the establishment of tiger prawn's refugia consisted of Likert Scale (1 = Strong Agree, 2 = Agree, 3 = Neutral and 4 = Disagree), Cronbach's Alpha for each variable should be counted in order to measure the internal consistency of the questionnaires. According to Cronbach (1951), the thumb of rule for the interpretation of Reliability Test is indicated as follows:

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

The reliability of **0.7 or higher** are required and the **Table 06** indicated the score of the reliability rest for each variable.

Table 6 : Reliable Statistics for Variables

Variable		Scale Mean if Item Deleted	Scale Variance If Item Deleted	Corrected Item - Total Correlation	Alfa Cronbach
Keywords	**Item**				
Level of Awareness					
Aware	1.1	52.22	36.355	-.269	**.826**
Agree	1.2	52.12	28.770	-.653	**.780**
Prohibit_catch	1.3	52.04	28.251	.712	**.775**
Maintained	1.4	52.13	28.291	.827	**.773**
Prohibit_area	1.5	51.86	28.520	.496	**.793**
Confer	1.6	52.18	30.653	.691	**.785**
Benefits of Refugia					
Increase_income	2.1	52.11	29.124	.730	**.777**
Knowledge	2.2	52.15	29.734	.706	**.780**
Prawn_resources	2.3	52.13	28.777	.774	**.774**
Prawn_quality	2.4	52.10	29.206	.756	**.777**
More_refugia	2.5	52.08	29.912	.549	**.788**
Social and Environmental Protection					
Human_rights	3.1	49.94	35.645	-.160	**.820**
Social_conflict	3.2	49.97	35.252	-.084	**.821**
Change	3.3	50.03	33.324	.178	**.810**
Relocation	3.4	50.02	34.594	.003	**.819**
Unemployed	3.5	49.98	33.585	.151	**.811**
Eco_tourism	3.6	50.12	33.941	.170	**.817**
Standand_of_living	3.7	49.93	34.499	.059	**.812**
Impact	3.8	49.88	34.255	.180	**.807**
Heritage	3.9	49.82	34.959	-.010	**.812**

Based on **Table 06**, the Reliability Test of Cronbach's Alpha for each variable are greater than 0.7, thus, the overall for the Reliability test for the variables can be further shown as below:

Cronbach's Alpha	Cronbach's Alpha based on Standardized Item	No of Item
0.819	0.799	22

In conclusion, the results indicated that the Cronbach's Alpha is **0.819** which is **GOOD**, based on the rule of thumb for interpreted Reliability Test.

Discussions and Conclusions

Marine Protected Area (MPA) is an ecosystem-based management tool established to protect sensitive habitats, fauna and related ecosystem services. MPA is established to create an area or location where biodiversity and abundance of marine can be restored and preserved. In other cases, MPA is established based on the requirements of fisheries management, as protection to nursery and breeding areas so that fisheries resources are biologically protected.

Compared to Refugia, as outlined by *SEAFDEC / UNEP / GEF Project : Establishment and Operation of a Regional System of Fisheries Refugia in the South China Sea and Gulf of Thailand,* Refugia is geographically and spatially defined area, where specific management measures are used to maintain important species (fishery resources) during the critical stages of its life cycle, for the sustainability of the species.

Among the factors influencing fishing operations in Kuala Baram is the season. Most fishers of Kuala Baram actively carry out fishing activities during the intermediate monsoon season (or the transition season) which lasts between April to the end of May. After that, fishing activities are still actively implemented during the Northeast Monsoon (or rainy season) that hit Sarawak waters, between November to March. From the interviews conducted, fishers performed fewer fishing operations during the Southwest Monsoon season (late May to September), although it was a dry season.

Tiger prawns are mostly caught by respondents between February to March. It coincides with the tiger hrimps spawning season between January to March. Although it is the largest penaeid in Sarawak, the tiger prawns are mostly caught by trawlers.

Trawl is the most popular and efficient to catch prawns (including tiger prawns) although the usage of trawl have negative effect on marine biodiversity and the artisanal fisheries. According to the Food and Agriculture Organization of the United Nations (FAO), prawn trawlers' nets can inadvertently catch up to 25 times more non-targeted species than prawn.

Regarding the tiger prawn refugia, respondents also offered some suggestions and recommendations as follows:-

(i) conducting strict surveillance in the refugia areas from trawl encroachment and passage of large container ships,
(ii) providing care, monitoring and maintenance after the establishment of refugia,
(iii) monitoring the refugia areas from the encroachment of foreign fishers,
(iv) organizing trainings and campaigns related to Tiger Prawn's refugia to educate fishers and fishing community; and
(v) enforcing a ban on fishing during the spawning season of Tiger Prawns.

The fishers along the waters of Kuala Baram are very clear about the needs and benefits of refugia as the number of Tiger Prawns are declining at an alarming rate. They also realized that their income will increase if and only if they complied with the refugia's requirements. In this regard, fishers recognized the need for change and come to an understanding with the Department's measures in protecting fisheries resources, especially Tiger Prawns for the future. The awareness of these changes is reluctantly acknowledged by some fishers who insist in maintain their fishing methods or targeted species.

The fisheries stakeholders also provided some suggestions to help boost the fishing industry. Fishers proposed that there is a need for alternative for fishing; in terms of species, fishing gears, fishing techniques and fishing areas as measures of compliance with the establishment of refugia that would be influenced by the current prawn fishing. Fishers, especially young fishers need to be trained in mastering the various fishing techniques in to further developing this industry. Fishers no longer have to rely on the hereditary experience taught by their father or grandfather in human capital development and personal skills.

The results from the discussions with the respondents also suggested that fishers and the Department of Fisheries are also concerned about the negative potential of the socio-economic impact of refugia establishment. This is because the Department has limited capacity in managing the refugia (staff and finance). In this regard, the involvement of fishers in refugia's management is critical and urgently obligatory. It is also noted that high level of trust and understanding between the Department of Fisheries and the members of the fishing community was observed from this study. This linkage should be strengthened and extended throughout the Department of Fisheries so that fishers can rest assured that the Department is truly committed in ensuring the sustainability of fisheries resources and safeguarding the interests of fishers as well as future generations.

In return, fishers should be prepared at all time and encouraged to supply and share data of catch and effort voluntarily with the Department of Fisheries so that the resource of Tiger Prawns can be evaluated more accurately. Information on the status of the resources can be passed back to fishers for feedback, and allows both parties to make precise decisions on which fishers agree to comply with is as the authority agrees to enforce it.

Active participation of fishers and fishers' communities is critical for the sustainable utilization of fisheries resources. It will create a transition towards co-management where bot resource users (fishers) and government agencies (Department of Fisheries) can work together to address management issues and share decision-making responsibilities before any actions can be taken.

The Department of Fisheries has also designed and implemented several educational programs for fishers and the public on the importance of working together to safeguard fisheries resources and livelihood. Such programs can raise awareness of environmental

THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
Female Maturation Stages and Socio-Economic Study

issues, especially fisheries and thus, strengthen beneficial relationships. Socio-economic information is essential for long-term monitoring and is used to determine the status of resources and how management measures can influence the stakeholders.

Assuming the establishment of refugia is the best for conservation of tiger prawn, the impact on the stakeholders should be monitored periodically while mitigation measures are in place. This is the essence of adaptive management whereby the results of this socio-economic information can be used to reinforce the decisions made by top management. On-going monitoring of the economics of fisheries as these refugias are fully implemented is to look at the development and its impact on fishers, resources and the environment.

In refuting the allegation that the Department of Fisheries does not take fishers' support seriously, it may be time for fishers to begin keeping records of the catch and landing so that it can be shared with the Department; so that the Government of Malaysia can better appreciate the economic importance that fishers contributed to the national fisheries production.

Future Directions

Research

The scope of the study to be extended on (i) the distribution, ecology and biology of Tiger Prawns and (ii) stock assessment and population dynamics. Continuous monitoring on the economics of tiger prawn fishery would be obligatory when refugia is completely implemented to see what effect it is having. This should be done to provide data within a year of two after it has come completely into effect.

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THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :
Compilation of Research Findings on Broodstock, Juvenile,
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ICOSMaP 2019
29-31 October 2019, Kuantan, Pahang

FUNDAMENTAL STUDIES ON JUVENILE TIGER PRAWN (*Penaeus monodon*) RESOURCES IN MIRI RIVERS, SARAWAK IN LINE WITH FISHERIES REFUGIA CONCEPT

A. H. Nurridan[1]*, R. Hadil[2] and R. Richard[1]
1. FRI Bintawa, Jln Perbadanan, Bintawa, Kuching
2. FRI Batu Maung, Batu Maung, P. Pinang

*Email: nurridan@dof.gov.my

Introduction

- The fisheries refugia concept
  - adopted by Malaysia under the SEAFDEC-UNEP-GEF definition-"*spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use*".
- A tiger prawn refugia is proposed at the river mouth of Kuala Baram in Miri, Sarawak and the refugia site has been roughly identified based on past and current research findings
- Research objectives : focused on locating juvenile nursery area in mangrove and to determine initial juvenile resources in the targeted areas.

Materials and methods

- Location
  - 3 major rivers-Pasu, Lutong and Sibuti, inhabited by juvenile tiger prawn, *P. monodon* (Maps generated by Google Earth)

- Sampling method
  - Fishing was carried out during low and high tide (March-April 2019).
  - A cast net with 1.8 metre in length and 2.1 metre in diameter made of polyethylene net with mesh size of 19 mm (0.75 inch)

- Estimation method
  - the catch of prawns harvested from the 1.8 m cast net was then equated to the total length of the river. The total area of the cast net was calculated using $A = \pi r^2$, the simple equation for estimating the current biomass

The simple equation for estimating for the current biomass , Bc (kg) of prawn for each river system was:

$$Bc=(C/x) \times 2L$$

- Where;
- C= total prawn catch(kg) per casting (kg)
- x=radius of the cast net, in this case x=1.05 – 2.1 m
- L=total navigable length of river, in this case=1.0-3.0km
- 2= two sides of the river

Results and discussions

- A total of 375 cast using cast net were carried out between March and April 2019
- The catches of the cast net at the surveyed location were listed in Table 1 , where *P. monodon* lead at 39.0 % of total catch

No.	Species	Weight (g)	No. (ind.)	Percentage (%)
1.	*Penaeus monodon*	2425.0	70	39.00
2.	*Fenneropenaeus merguiensis*	1140	33	18.40
3.	*Mouigarda connesius*	430.4	12	7.1
4.	*Megalops cyprinoides*	341	1	5.6
5.	*Chelon planiceps*	339.4	12	5.5
6.	*P. indicus*	302.4	47	4.9
7.	*Toxotes chatareus*	194.2	6	3.13
8.	*Otolithes ruber*	189.6	10	3.06
9.	*Scatophagus argus*	138.2	55	2.20
10.	*Lutjanus johni*	127	3	2.05
11.	*Oryzeleotris sp.*	116.2	4	1.8
12.	*Collo boermensis*	44.5	2	0.71
13.	*Eubleekeria splendens*	34.0	10	0.87
14.	*Thryssa setirostris*	4.2	1	0.06
15.	*Encrasicholina punctifer*	31.8	4	0.51
16.	*Macrobrachium rosenbergii*	20.8	8	0.33
17.	*Raconda russeliana*	51.8	3	0.83
18.	*Plectorhinchus chaetodonoides*	6.2	1	0.10
19.	*Pomadasys kaakan*	29.0	3	0.47
20.	*Gerres erythrourus*	34.6	3	0.56
21.	*Siliago sihama*	116.4	1	1.88
22.	*Carangoides malabaricus*	33.0	1	0.53
23.	*Ambiygaster sirm*	10.8	1	0.17
24.	*Scomberoides tala*	9.4	1	0.15
25.	*Metaperaeus lysianassa*	4.33	3	0.07
	Total	6237.73	355	100

Table 1 : Percentage catch composition and total catch in terms of weight, wt. (g) and numbers, no.(ind) over 375 casting operations at Pasu, Lutong and Sibuti rivers, Miri surveys in March and April 2019.

- Prawn biomass was estimated based on adjusted mean catch, AMC obtained from cast net sampling.
- Biomass estimation of tiger prawns from the 3 rivers sampled calculated were summarized in Table 2.
- AMC of 10.61 kg of tiger prawns per 1.2 metres diameter of cast net, Pasu river is the most productive, followed by Sibuti river and Lutong river respectively
- The total biomass estimated for tiger prawns in all 3 rivers was 15.90 kg.

No.	River	Length (km)	AMC (kg)	Variance of AMC	Biomass (kg)
1.	Pasu river	2.0	10.61	9.67	11.73
2.	Lutong river	1.1	3.34	5.04	10.77
3.	Sibuti river	3.0	5.83	81.21	15.41

Table 2: Biomass estimation of tiger prawns from the 3 rivers.

Conclusion

This resource survey shown that the juvenile tiger prawn, *Penaeus monodon* resource in Miri, Sarawak is located in the nursery ground, in this case, Pasu, Lutong and Sibuti rivers to complete its life cycle. Therefore, regulation of fishing effort of gears which is primarily responsible on exploitation of these precious juvenile has to be enforced. Thus, it is recommended that these nursery ground to be gazetted as refugia site for sustainable fisheries of tiger prawn.

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THE ESTABLISHMENT OF TIGER PRAWN
(Penaeus monodon) REFUGIA :

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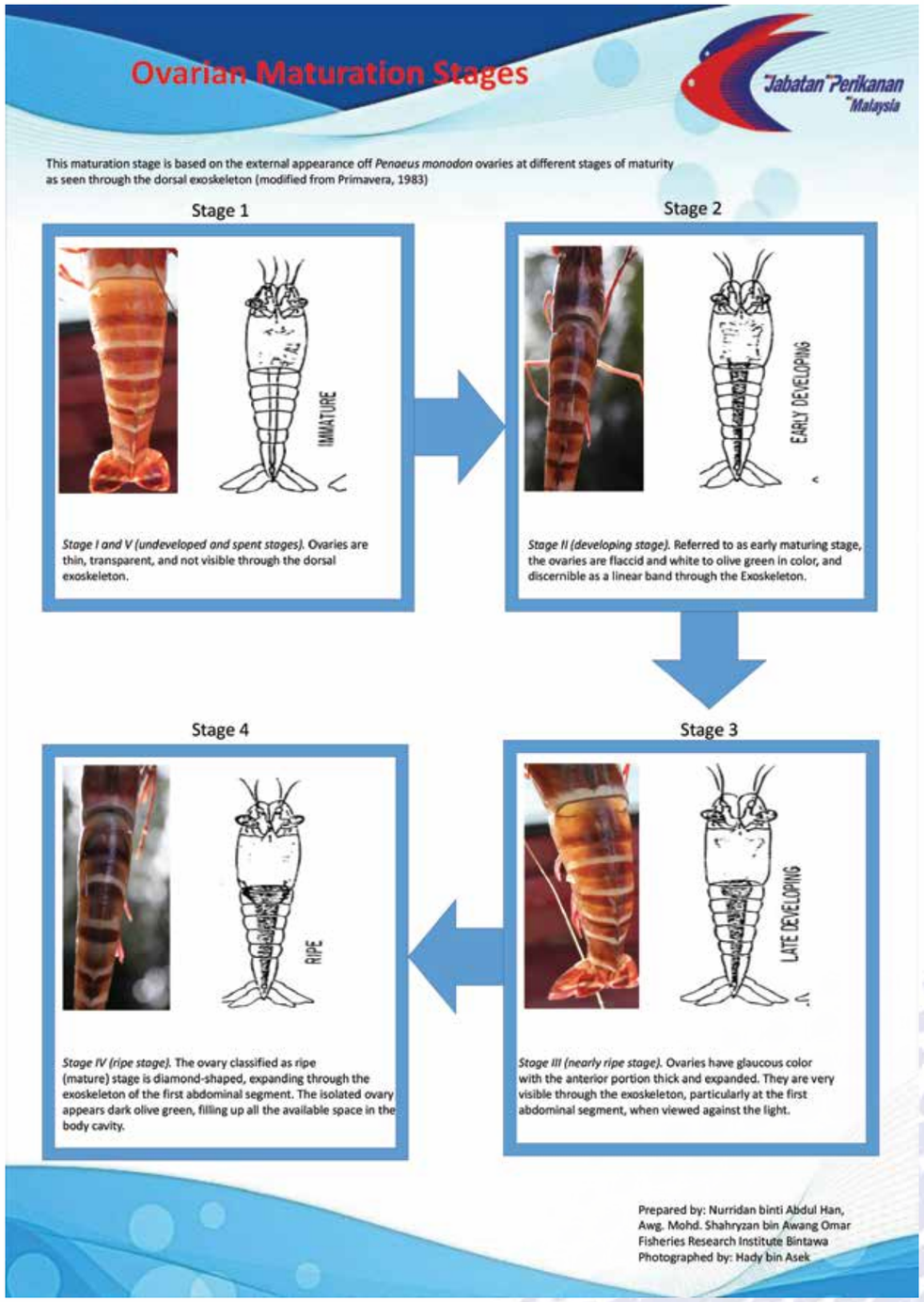
TAPAK NURSERI JUVENIL UDANG HARIMAU *(Penaeus monodon)*
NURSERY GROUND FOR JUVENILE TIGER PRAWN *(Penaeus monodon)*
Jabatan Perikanan Malaysia
Pandangan landskap Sungai Pasu
Landscape view of Pasu river
Pandangan landskap Sungai Lutong
Landcape view of Lutong River
Pandangan Sg. Pasu dari Google Earth
Google Earth view of Pasu River
Pandangan Sg. Lutong dari Google Earth
Google Earth view of Lutong River
Peta sungai-sungai Miri
Rivers of Miri map
Pandangan Sg. Sibuti dari Google Earth
Google Earth view of Sibuti River
Pandangan landskap Sungai Sibuti
Landscape view of Sibuti River
Disediakan oleh/
Prepared by:
Nurridan binti Abdul Han
Dokanaer Kasto anak Muning
Gambar oleh/Photo by:
Hady bin Asek


Ovarian Maturation Stages
Jabatan Perikanan Malaysia
This maturation stage is based on the external appearance off *Penaeus monodon* ovaries at different stages of maturity as seen through the dorsal exoskeleton (modified from Primavera, 1983)
Stage 1
IMMATURE
Stage I and V (undeveloped and spent stages). Ovaries are thin, transparent, and not visible through the dorsal exoskeleton.
Stage 2
EARLY DEVELOPING
Stage II (developing stage). Referred to as early maturing stage, the ovaries are flaccid and white to olive green in color, and discernible as a linear band through the Exoskeleton.
Stage 3
LATE DEVELOPING
Stage III (nearly ripe stage). Ovaries have glaucous color with the anterior portion thick and expanded. They are very visible through the exoskeleton, particularly at the first abdominal segment, when viewed against the light.
Stage 4
RIPE
Stage IV (ripe stage). The ovary classified as ripe (mature) stage is diamond-shaped, expanding through the exoskeleton of the first abdominal segment. The isolated ovary appears dark olive green, filling up all the available space in the body cavity.
Prepared by: Nurridan binti Abdul Han,
Awg. Mohd. Shahryzan bin Awang Omar
Fisheries Research Institute Bintawa
Photographed by: Hady bin Asek

Pamphlet explaining the concept and importance of refugia (in *Bahasa Melayu*)

PHOTOGRAPH SHOWING THE NURSERY GROUNDS FOR JUVENILE TIGER PRAWN

Mouth of Pasu River, adjacent to Kuala Baram

Pasu River : width (10-25 metres)

Upstream view (Pasu River)

PHOTOGRAPH SHOWING THE NURSERY GROUNDS FOR JUVENILE TIGER PRAWN

Lutong River :
milky tea colour

Upstream view
(Lutong River)

Sibuti River

PHOTOGRAPH SHOWING THE NURSERY GROUNDS FOR JUVENILE TIGER PRAWN

The mouth of the
Bakam river

Upstream view of
Bakam River

View of a massive *Rhizophora* in
comparison to a human

PHOTOGRAPH DEPICTING ACTIVITIES RELATED TO THE FILMING OF RADIO TELEVISION MALAYSIA 1 (RTM1)'S DOCUMENTARY "SIMFONI ALAM" IN OCTOBER 2018

Discussion with the fishermen, Mr. Ting

Filming at the Jetty

Filming at the Baram River

PHOTOGRAPH DEPICTING ACTIVITIES RELATED TO THE FILMING OF RADIO TELEVISION MALAYSIA 1 (RTM1)'S DOCUMENTARY "SIMFONI ALAM" IN OCTOBER 2018

PHOTOGRAPH DEPICTING ACTIVITIES RELATED TO THE FILMING OF RADIO TELEVISION MALAYSIA 1 (RTM1)'S DOCUMENTARY "SIMFONI ALAM" IN OCTOBER 2018

Filming in a fishermen's boat at Kuala Baram

The documentary was aired on RTM TV1 on December 4, 2018

A Socio-economic survey conducted in July 2020

PHOTOGRAPHS RELATED TO RESEARCH ACTIVITIES

Water parameters were monitored using a water checker

The juvenile tiger prawn was caught using a cast net

PHOTOGRAPHS RELATED TO RESEARCH ACTIVITIES

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PHOTOGRAPHS RELATED TO RESEARCH ACTIVITIES

The measurement of the cast net

Species composition were trawled together with tiger prawn

PHOTOGRAPHS RELATED TO RESEARCH ACTIVITIES

A 271-gramme-weight tiger prawn

Tiger Prawn Refugia Gallery in Marine Fisheries Office, Miri

Different sizes of juvenile tiger prawns

THE COMPOSITION OF SPECIES TRAWLED TOGETHER WITH *Penaeus monodon* BROODSTOCK (SPAWNERS) AND JUVENILE (USING CAST NET)

Pomadasys kaakan

Broodstock of *Penaeus monodon*

Fenneropenaeus merguensis

THE COMPOSITION OF SPECIES TRAWLED TOGETHER WITH *Penaeus monodon* BROODSTOCK (SPAWNERS) AND JUVENILE (USING CAST NET)

Anadontostoma chacunda

Leiognathus equulus

Lactarius lactarius

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THE COMPOSITION OF SPECIES TRAWLED TOGETHER WITH *Penaeus monodon* BROODSTOCK (SPAWNERS) AND JUVENILE (USING CAST NET)

Terapon jarbua

Upeneus sulphureus

Pseudorhambus malayanus

THE COMPOSITION OF SPECIES TRAWLED TOGETHER WITH *Penaeus monodon* BROODSTOCK (SPAWNERS) AND JUVENILE (USING CAST NET)

Nibea soldado

Otolithes ruber

Portunus sanguinolentus

THE COMPOSITION OF SPECIES TRAWLED TOGETHER WITH *Penaeus monodon* BROODSTOCK (SPAWNERS) AND JUVENILE (USING CAST NET)

Juvenile
Penaeus monodon

Scatophagus argus

Toxotes jaculatrix

ISBN 978-983-43977-1-5