



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

SITE CHARACTERIZATION OF THE TIGER PRAWN (*Penaeus monodon*) REFUGIA IN KUALA BARAM, MIRI, SARAWAK

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

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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. Pterygostomian angle round. Stylocerite at first antennular segment. Basial spines on first and second pereopods and exopods on the first to fourth pereopods usually present. No fixed subapical spines on telson. Adrostral sulcus and carina are short, not reaching posteriorly beyond midlength of carapace. Gastrofrontal 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 pereopods without exopod; hepatic carina horizontally straight; and gastroorbital 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)

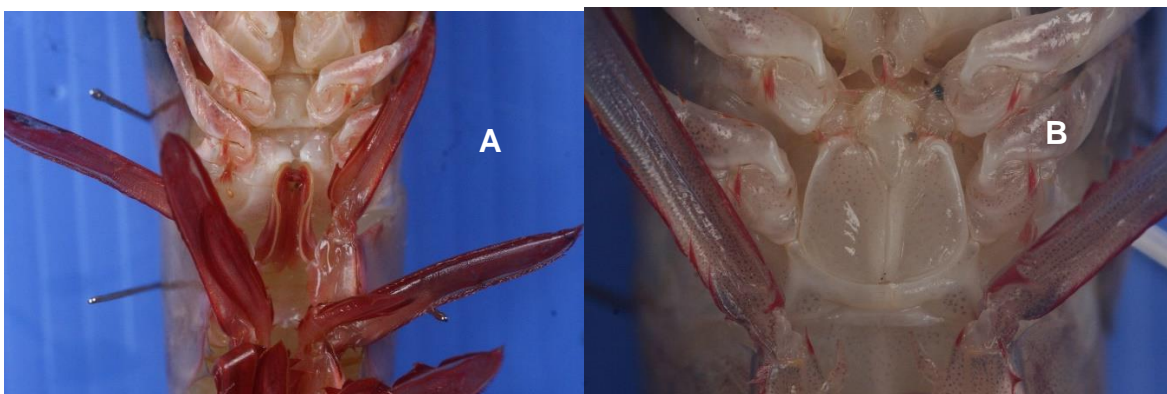


Photo 1: A-petasma-male genitalia, B-thelycum-female genitalia



Photo 2: Female spawners weighing 231 gram 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).

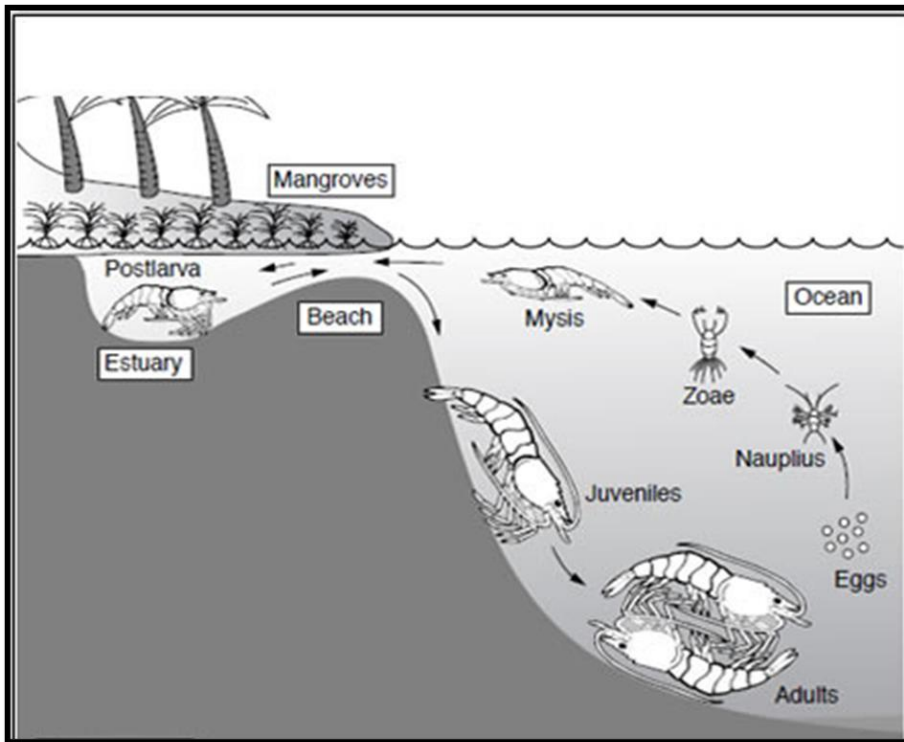


Figure 1 : A diagrammatic of the life cycle of penaeids prawn (including *P.monodon*)

The offshore area of Kuala Baram, Miri, Sarawak, slopes 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 km² 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 slopes 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 Cretaceous to Eocene 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 Reef's 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 km² 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 dissolved 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
<i>Kampung Kuala Baram</i>	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	22
<i>Kampung Pengkalan Lutong</i>	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	20
<i>Kampung Pulau Melayu</i>	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line	6
<i>Kampung Piasau Utara</i>	Drift nets, 3-layered Drift nets, fishing nets with rope and lead, Hooks and Line, trawlers	31
<i>Kampung Bakam</i>	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.

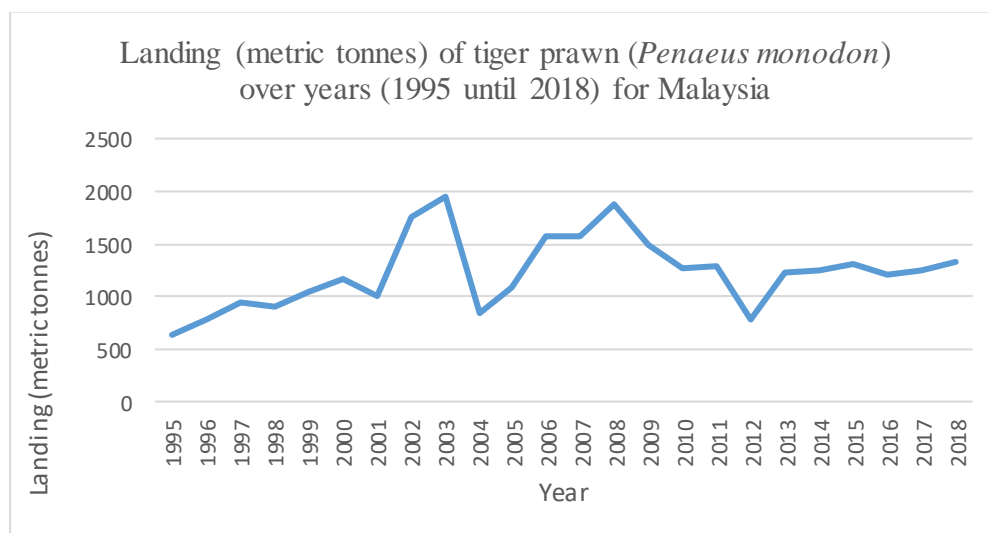


Figure 3: The annual landing (metric ton) of tiger prawn in Malaysia during a 23-years period (1995 – 2018) (data derived from the Annual Fisheries Statistics from year 1995-2018, Department of Fisheries Malaysia, 2018).

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)	Biomass (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/km².

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.

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