Resource Assessment of the Tiger Shrimp, *Penaeus Monodon* of Kuala Baram, Miri-Sarawak

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Abstract. - Two commercial trawlers, a twin–outrigger trawler (SF3-779), and a stern trawler (SF3-118) were chartered to carry out the survey for the assessment of the tiger shrimp resource. The survey area extended to the 50 m depth contour line from Tanjong Baram to Kuala Bakam, Miri. The total area covered was estimated to be 295.5 nm^2. A total of 23 stations were completed; 13 stations surveyed by SF3-779 in depth stratum 11-50 m and the other 10 stations by SF3-118 for the depth stratum 5-10 m. A total of 131 tails of *Penaeus monodon* were caught by SF3-779 in the more than 10 m depth stratum. The catch included 51 male and 80 female shrimps. The average catch rate obtained was 0.22 kg hr^{-1} for male shrimp and 0.47 kg hr^{-1} for female shrimp. *Penaeus monodon* occupied only 0.4% - 5.6% of the catch with an average of 2.16%. The other penaeid shrimps contributed an average of 5.74% to the total catch. The rest of the catch (92.10%) consisted of fish. In the shallower waters (5-10 m), SF3-118 caught only 7 male and 1 female tiger shrimps throughout the 10 stations sampled. The average catch rate obtained for the tiger shrimp was 0.03 kg hr^{-1} and 0.006 kg hr^{-1} for the male and female shrimp respectively. *Penaeus monodon* catch contributed an average 0.75% of the total catch. The rest of the catch was attributed to other penaied shrimp (10.16%) and fish (89.09%). The male shrimp size ranged from 28.3 mm (103.5 mm total length and weight 20 g) to 59.3 mm carapace length (220.7 mm total length and weight 156 g). The size of female shrimps caught ranged from 37.0 mm carapace length (163 mm total length and weight 30 g) to 75.0 mm carapace length (282 mm total length and weight 210 g). The survey shows that the majority (68.9%) of the broodstocks was ready to spawn and 9.9% already shed their eggs. About 62.5% of the tiger shrimp resources were found in the area 11 to 50 m deep with the rest caught in the shallow waters, 5 to 10 m deep. The biomass estimated were 2,695 kg for male and 3,076 kg for female shrimps based on catchability coefficient (q) of 1.0. At current yield (1,987 kg for male and 3,749 kg for female shrimps) and current biomasses derived, the Maximum Sustainable Yields were 4,362 kg and 5,720 kg for male and female tiger shrimps, respectively. The exploitation rate (E) was 0.4 per year for both male and female shrimps. The E values obtained indicate that the tiger shrimp resource has not been exploited optimally, E=0.5 per year. The tiger shrimp, *P. monodon* resource on the coast of Miri, specifically off Kuala Baram should, however, be sustained at the present level.

Keywords: *Penaeus monodon*, biomass, maximum sustainable yield

Abstrak. - Dua bot pukat tunda komersial, SF3-779 dan SF3-118 telah disewa khas bagi menjalankan survei udang harimau. Kawasan survei udang harimau ialah dari Tanjong Baram ke Kuala Bakam, Miri merangkumi persisiran pantai hingga ke kedalaman 50 m. Keluasan kawasan survei ialah kurang lebih 295.5 batu nautika persegi. Dua puluh tiga stesen menunda telah dijalankan; 13 stesen dibuat oleh bot SF3-779 di kedalaman air 11 - 50 m dan 10 stesen di kendalikan oleh bot SF3-118 di kedalaman air 5-10 m. Sebanyak 131 ekor (51 jantan dan 80 betina) *P. monodon* berjaya ditangkap oleh bot SF3-779 dimana kadar tangkapan ialah 0.22 kg jam^{-1} bagi udang jantan dan 0.47 kg jam^{-1} bagi udang betina. Tangkapan *P. monodon* merupakan antara 0.4% - 5.6% (purata 2.16%) dari hasil tangkapan keseluruhan (5.74% spesis udang lain dan 92.1% ikan). Manakala bagi kawasan perairan cetek, bot SF3-118 berjaya mendaratkan sebanyak 7 ekor udang jantan dan seekor udang betina dengan kadar tangkapan masing-masing 0.03 kg jam^{-1} dan 0.006 kg jam^{-1} dimana tangkapan *P. monodon* merupakan hanya 0.75% dari tangkapan keseluruhan (10.16% spesis udang lain dan 89.09% ikan). Saiz *P. monodon* jantan yang didaratkan ialah dalam julat 28.3 mm (103.5 mm panjang badan dan mempunyai berat 20 g) hingga 59.3 mm panjang karapas (220.7 mm dan berat 156 g). Bagi *P. monodon* betina, saiz yang didaratkan ialah dari 37.0 mm panjang karapas (163 mm panjang badan dan berat 30 g) hingga 75.0 mm

panjang karapas (282 mm panjang badan dan berat 210 g). Survei ini menunjukkan bahawa kebanyakan (68.9%) dari induk *P. monodon* betina bersedia menetaskan telor, manakala 9.9% telah menghempaskan telor. Kira-kira 90% dari sumber *P. monodon* didapati di perairan sedalam 11 - 50 m. Anggaran biomas adalah 2,695 kg bagi *P. monodon* jantan dan 3,076 kg bagi *P. monodon* betina berdasar kepada koeffisien keupayaan tangkapan (q), bernilai 1.0. Pada tahap pendaratan semasa (1,987 kg bagi udang jantan dan 3,749 kg bagi udang betina) dan dari anggaran biomas, Hasil Mampan Maksima, ialah 4,362 kg dan 5,720 kg masing-masing bagi *P. monodon* jantan dan betina. Kadar eksploitasi (E) adalah 0.4 setahun bagi kedua-dua *P. monodon* jantan dan betina. Kadar eksploitasi masih lagi rendah dengan mengambil kira tahap optimum ialah E = 0.5 setahun. Dengan keputusan ini, sumber *P. monodon* di perairan laut Miri, khasnya Kuala Baram perlulah dikekalkan pada tahap eksploitasi sekarang.

Introduction

Shrimp surveys carried out since 1980 (Bejie, 1981, 1982 and 1983; Yong, 1990; Hadil 1994a) indicated that the majority (80%) of the shrimps were caught in waters from 6 to 20 meters deep in Sarawak. Results of these surveys suggested that shrimps were more abundant in the Kuching Bay.

Twenty-one species of penaeid shrimps were recognized in Sarawak waters (Tamaei, 1979; Hadil, 1994b). Eventhough, the concentration of the shrimp resource is in the coastal waters of western Sarawak, species distribution is more diverse. Tiger shrimp, *P. monodon* is the largest of the penaeids found, but were caught in small quantities (Hadil, 1994b). Landings of shrimps increase from October onward and reach the peak during the monsoon months of January to March (Hadil, 1994b). Past surveys (Bejie, 1981, 1982 and 1983; Hadil, 1994a) 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 bottom. Occasionally, *P. monodon* was caught in Kuching Bay (Hadil, 1994b).

Hadil and Faazaz (1998) have identified the area of more than 30 m off Tanjong Batu to Kuala Baram as a potential tiger shrimp sanctuary. This area has been used as a tiger shrimp broodstock collection area since 1997 by the local trawlers.

The State Government of Sarawak has initiated the setting up of the task force to look into the possibility of utilizing the state own broodstock resource for the fast growing shrimp aquaculture industry. Two commercial trawlers, a twin–outriggered trawler (SF3-779) and a manually operated stern trawler (SF3-118) were chartered to carry out the survey in July 1999. This paper presents the results of the assessment of the resource based on the data obtained during the survey.

Materials and Methods

Description of the survey area

The survey area extended to the 50 m depth contour line from Tanjong Baram to Kuala Bakam, Miri (Figs. 1 and 2). The total area covered was estimated to be 295.5 nm^2, which comprised 168.5 nm^2 surveyed by stern trawler SF3-779 and 92 nm^2 surveyed by twin-out rigger trawler SF3-118. The remaining areas which are the restricted areas of the west Lutong and Baram oilfields were not taken into account in the biomass estimation.

Fishing vessel and fishing gear specifications

Trawlers SF3-779 and SF3-118 were deployed to survey the shallow (5-10 m) and the deeper (10-50 m) parts of the survey area respectively. Some of the principal details of the vessels and the equipment are given below ;

Principal characteristic	**SF3-118**	**SF3-779**
Hull	wooden	wooden
Length overall (m)	12.8	18
Breadth (m)	3.0	4.2
Gross tonnage (tons)	15	62
Main engine	16hp. Yanmar diesel	315hp Nissan diesel
Type of vessel	Stern trawler	Twin-outrigger trawler

The designs of the trawl net and otterboard used and some of their principal features are shown in Figs. 3, 4, 5 and 6. The nets were made of polyethylene with a cod-end mesh size of 63 mm and 50 mm for SF3-779 and SF3-118 respectively.

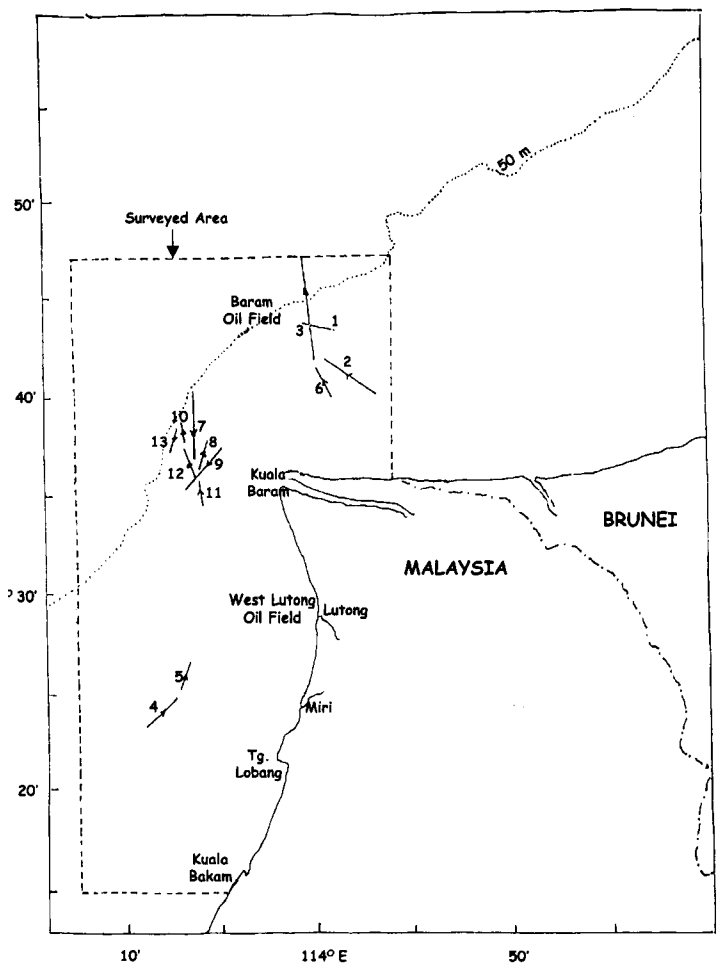


Figure 1 : Trawl stations and directions of trawling by out-rigger trawler, SF3-779 to survey for tiger shrimps off Kuala Baram in July/August 1999

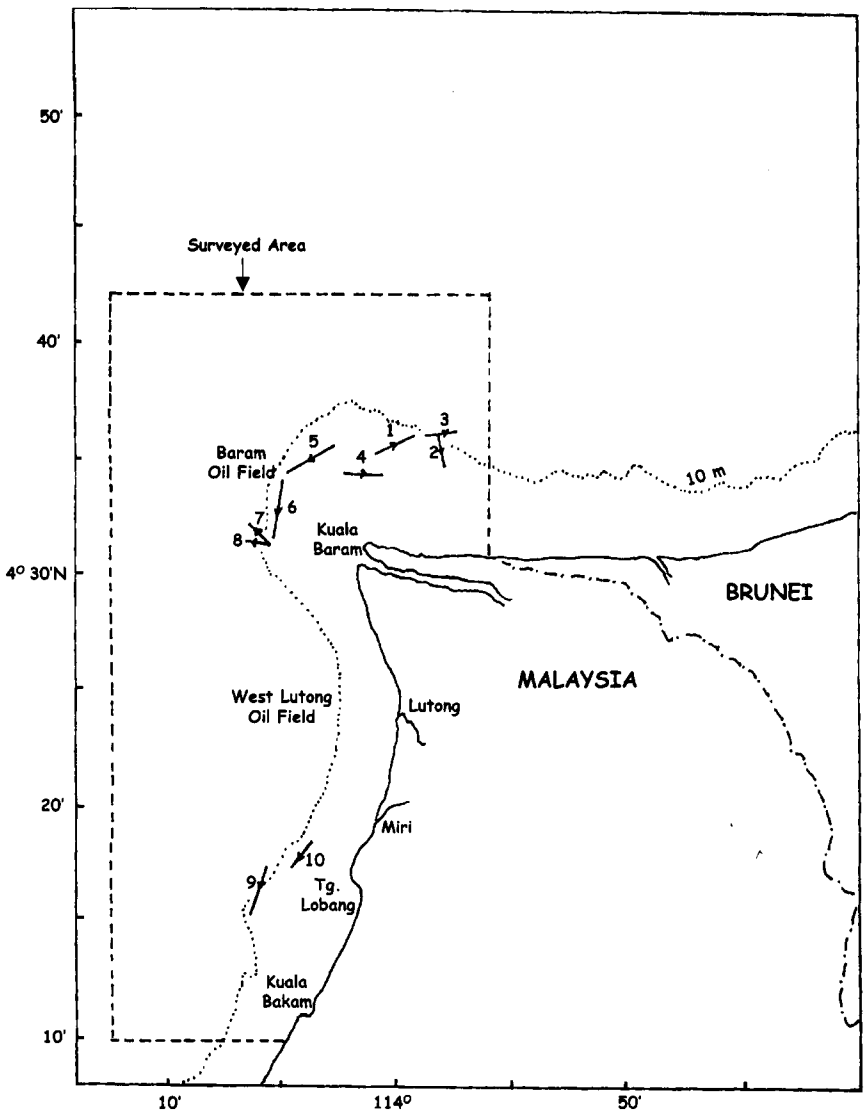
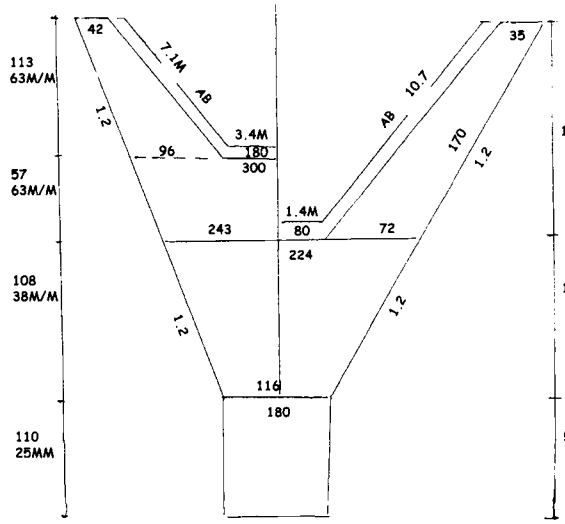


Figure 2 : Trawl stations and direction of trawling by stern trawler, SF3-779 to survey for tiger shrimp off Kuala Baram in July/August 1999



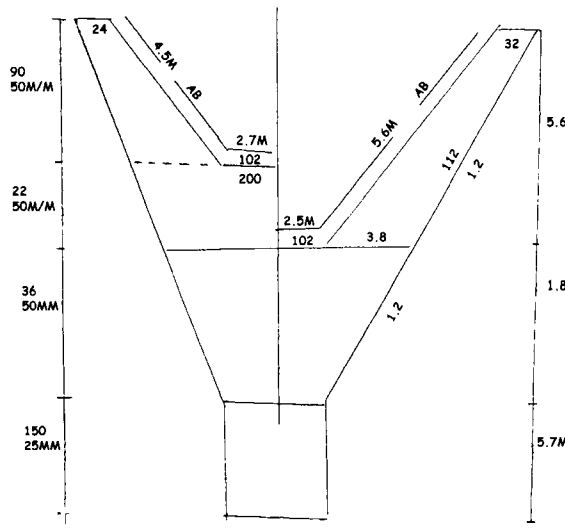
Boat particulars :-

Length	- 18 m
Breadth	- 4.2 m
Net tonnage	- 62 ton
Engine	- 315 hp. (Nissan)

Net particulars :-

Net length	- 17.8 m
Headrope length	- 17.6 m
Groundrope length	- 21.8 m
Mesh size	- 63 mm
Net material	- Polyethelene (P.E.)
Float size	- 4 1/2"Ø x 55 kg
Chain for groundrope	- 5/8 x 55 kg

Figure 3 : Shrimp trawler net design of out-rigger trawler, SF3-779 used to survey tiger shrimp resource off Kuala Baram in July/August 1999



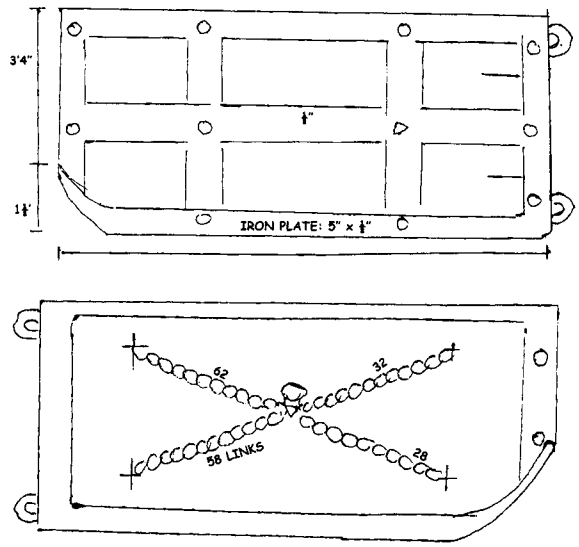
Boat particulars :-

Length	- 12.8 m
Breadth	- 3 m
Net tonnage	- 15 ton

Net particulars :-

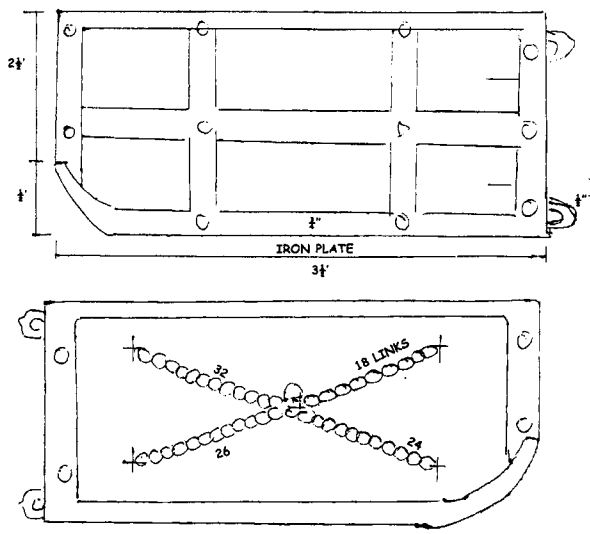
Net length	- 13.4 m
Headrope length	- 11.7 m
Groundrope length	- 13.7 m
Mesh size	- 50 mm
Net material	- Polyethelene (P.E.)
Float size	- 4 1/2"Ø (No. 6)

Figure 4 : Shrimp trawl net design of stern trawler, SF3-188 used to survey tiger shrimp resource off Kuala Baram in July/August 1999



Material :
- Melakak wood
- 1" x 6"
- the whole board is enclosed with iron plates of 5" width and 1/2" thickness
- Stainless steel short-link chain - 1/2" diameter

Figure 5 : Otter-board design of out-rigger trawler SF3-779 used to survey tiger shrimp resource off Kuala Baram in July/August 1999



Material :
- Melakak wood
- 1" x 4" x 3"
- the whole board is enclosed with iron plates of 5" width and 1/2" thickness
- Stainless steel short-link chain - 1/2" diameter

Figure 6 : Otter-board design of stern trawler SF3-188 used to survey tiger shrimp resource off Kuala Baram in July/August 1999

Survey design and sampling stations

The survey method used followed the standard method outlined in Mackett (1973) and Sparre and Venema (1992). Sampling was conducted using the stratified random sampling technique. Within each stratum (5 - 10 m and 11 - 50 m), trawl stations were selected randomly. A total of 23 stations were completed; 13 stations surveyed by SF3-779 and the other 10 stations by SF3-118 (Appendices 1 and 2). The distribution of stations is shown in Figs. 1 and 2. Fishing were carried out both during day and night times.

Sampling procedure

Samples were taken using the bottom trawl. The trawling duration ranged from 49 minutes to 2.95 hours with an average speed of 3.23 and 2.43 knots for vessels SF3-779 and SF3-118 respectively (Appendices 1 and 2). The trawling duration and speed varied because of the limited area to maneuver since a big portion of the coastal waters off Kuala Baram and Lutong were oilfields (Figs. 1 and 2). Once the catch was landed onboard the vessel, large size fish and shrimps as well as dangerous and poisonous specimens were sorted. All commercial species irrespective of size were weighed and recorded. Tiger shrimp caught were weighed and measured to the nearest millimeter in term of total length and carapace length. Length measurements were taken and recorded on to length frequency forms by station. The female shrimp egg maturity stage was determined based on the criteria mentioned by Motoh (1981). All catch data were processed and analyzed to produce catch rates and species composition using the software Microsoft Excel.

Data Analysis

Biomass determination

The "swept" area method was used to determine the density of tiger shrimp per square nautical mile. The trawl sweeps a well define path, which is called the "swept area", or the "effective path swept". The swept area, "a" can be estimated using the equation below:

$a = D*h*x, \quad D = V*t,$

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 shrimp was calculated from the catch rates recorded in kg hr^{-1} from this survey. If the weight of catch per haul is Cw, then Cw/t is the catch per hour when t is the duration at the trawl haul. If "a" is the area swept by the trawl haul, then a/t represents the area swept per hour. In this survey, trawling was for a duration of one hour with a trawl net having a headrope length of 17.6 m and 11.7 m for SF3-779 and SF3-118 respectively. Thus for SF3-779, since two nets were used at the same time the total headrope used in the calculation of biomass was 35.2 m (1 nm = 1,852 m). The catch weight per unit area is

$(Cw/t)/(a/t) = Cw/a$ kg nm^2

The mean weight of catch per unit area ($\overline{Cw}/a$) divided by q (catchability coefficient) gives the average biomass per unit area. The catchability coefficient represents the amount of the shrimp caught by the trawl relative to the amount that escaped being caught. When q = 1.0, all the shrimp in the path of the trawl was assumed to be caught. Thus biomass (B) of the whole survey area, A is:

$$B = (\overline{Cw}/a)/q * A$$

Estimation of exploitable potential

This tiger shrimp resource has been exploited since the introduction of the trawl in early seventies (Hadil, 1994a), but was not prominent due to the fact that shrimp farming was not really popular then. For stocks that are exploited, the maximum sustainable yield, MSY was calculated using the equations proposed by Cadima (in Sparre and Venema 1992) as given below.

$$MSY = 0.5*(Y+MBc)$$

In this equation, Y is the current yield, M is the natural mortality coefficient and Bc is the current biomass determined.

In the determination of MSY, the value of q equals to 1.0 was used on the assumption that commercial trawler catches all along its swept area. The natural mortality coefficient used was 2.5 based on the value recommended by Garcia (1985). The current yield at 5,736 kg (Table 1) taken from the area surveyed was estimated from the landings of commercial trawlers of all size categories in Miri, Sarawak (Anon., 1999). Based on the current survey results (total catch of *P. monodon* from the two vessels), the ratio of male to female shrimp in term of weight was 0.53 to 1.00.

Table 1 : Landings (kilogram) of *Penaeus monodon* by trawlers in Miri, Sarawak in 1999

Year	Month												Total (kg)
	Jan	Feb	Mac	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	
1999	630	704	1140	680	545	340	468	298	208	216	307	200	5736

** Source : Annual Fisheries Statistics For 1999 (Anon., 1999)

*Estimation of Exploitation rate (*E)

Exploitation rate (E) is a fraction of the total death (Z) caused by fishing (F). Since F=Y/Bc and Z=F+M, the exploitation rate can be estimated following the equation below:

$$E = (Y/Bc)/(Y/Bc+M)$$

Morphometric relationship analysis

The length frequency data for the shrimp were analysed using FiSAT Version 1.10 program (FAO-ICLARM Stock Assessment Tools). The relationships between weight and total length (TL) and between carapace length (CL) and total length were also done using the same program.

Results and Discussion

A total of 23 hauls (Appendices 1 and 2) was successfully conducted from 29th July 1999 to 3rd August 1999.

Catch composition

Tables 2 and 3 show the overall catch composition obtained by trawlers SF3-779 and SF3-118 respectively. The dominant penaeid shrimps caught by SF3-779 in the deeper waters were *P. monodon* at 13.22 kg followed by *Metapenaeus affinis* at 9.01 kg. Several species of fish and cephalopods were caught and the dominant species in term of weight and numbers were *Leiognathus bindus* (3.25 kg), *Sepia* spp. (14.06 kg), *Ariomma indica* (5.6 kg), *Muraenesox cinereus* (5.23 kg) and Teraponidae (2.27 kg) and others in meager quantity.

Table 2 : Catch composition of dominant shrimp and fish species caught by SF3-779 in July/August off Kuala Baram

Species	Total Catch (kg)
SHRIMP	
Penaeus monodon (M)	4.25
Penaeus monodon (F)	8.97
Metapenaeus affinis (M)	1.05
Metapenaeus affinis (F)	7.96
Mixed shrimp species	3.62

Species	Total Catch (kg)
FISH	
Leiognathus bindus	3.25
Teraponidae	2.27
Ariomma indica	5.60
Muraenesox cinereus	5.23
Sepia sp.	14.06
Mixed Fish	98.84

Table 3 : Catch composition of dominant shrimp and fish species caught by SF3-118 in July/August off Kuala Baram

Species	Total Catch (kg)
SHRIMP	
Penaeus monodon (M)	0.56
Penaeus monodon (F)	0.12
Metapenaeus affinis (M)	1.69
Metapenaeus affinis (F)	2.41
Penaeus merguensis (M)	0.79
Penaeus merguensis (F)	1.53
Mixed shrimp species	3.75

Species	Total Catch (kg)
FISH	
Gizza minuta	5.25
Leiognathus equulus	12.22
Opisthopterus tardoore	5.81
Sciaenidae	6.79
Jellyfish	54.10
Mixed fish species	42.38

The dominant shrimps caught in the shallow waters by SF3-118 were *M. affinis* (4.01 kg) and *P. merguiensis* (2.33 kg). The other component of the catch comprises smaller size fish, which include jellyfish (54.1 kg), *Leiognathus equulus* (12.22 kg), Sciaenidae (6.79 kg), *Opisthopterus tardoore* (5.81 kg), *Gizza minuta* (5.25 kg) and others in small quantities.

The assemblage of shrimps and fishes shows a simple differentiation in species composition from shallower to deeper waters. Presumably, the reason for this was due to the fact that the food availability was different between the shoreline with mangrove fringes and that of the open sea with muddy bottoms.

Catch rates

In order to avoid biases, the catch data of SF3-779 and SF3-118 were converted to kilogrammes per hour and log-tranformed to obtained the average catch rate from normal distribution.

A total of 131 tails of *P. monodon* were caught by SF3-779 (Table 4) in the greater than 10 m deep stratum. The catch includes 51 and 80 male and female shrimps respectively. The catch ranged from 1 tail per station to 25 tails per station. The high numbers of *P. monodon* caught were at stations 7, 9, 10 and 11, where the numbers caught ranged from 18 to 25 tails per station. The average catch rate obtained was 0.22 kg hr^{-1} for male shrimp and 0.47 kg hr^{-1} for female shrimp. The average numbers caught per hour were 2.7 tails and 4.2 tails for male and female tiger shrimps respectively. The average catch rates obtained for other peneaid shrimps and fish were 2.14 kg hr^{-1} and 28.91 kg hr^{-1} respectively. *Penaeus monodon* only occupied 0.4 - 5.6% of the catch with an average of 2.16%. The other penaeid shrimps contributed an average of 5.74% to the total catch. The rest of the catch composition was fish (92.10%).

In the shallower waters (5 - 10 m), SF3-118 caught only 7 males and 1 female tiger shrimps throughout the 10 stations sampled (Table 5). There were only 5 stations that landed between one and two tails of tiger shrimp per haul. The average catch rates obtained for the tiger shrimp were 0.03 kg hr^{-1} and 0.006 kg hr^{-1} for the male and female shrimps respectively. In term of numbers caught, the figures were relatively small; 0.4 tail for male and 0.05 tail for the female shrimps. *Penaeus monodon* catch contributed an average 0.75% to the total catch. The rest of the catch was attributed to the other penaeid shrimps (10.16%) and fish (89.09%).

There was obviously a variation in the average total catch rates recorded between the two strata (5 - 10 m and 11 - 50 m deep waters). This was due to the migration of bigger size and matured shrimp to the deeper waters for spawning. In this survey, the deeper stratum was found to be most productive. Therefore, the fishing grounds beyond the 10 m isobath were richer than the shallow waters.

Shrimp size and maturity stage

The male shrimp size ranged from 28.3 mm carapace length, (103.5 mm total length, and weighed 20 g) to 59.3 mm carapace length (220.7 mm total length and weighed 156 g). The size of female shrimps caught ranged from 37.0 mm carapace length (163 mm total length and weighed 30 g) to 75.0 mm carapace length (282 mm total length and weighed 210 g). Most of the female shrimps were distributed in the deeper waters and 77.8% were matured. According to Motoh (1981), the minimum size at maturity was 37 mm carapace length for male and 47 mm carapace length for female shrimp.

The morphometric analysis involving the relationship between total length and carapace length and between weight and total length followed the equations below:

Table 4 : Catch rates (by haul) of shrimps and fish caught by SF3-779 in July/August 1999 off Kuala Baram

Station	1		2		3		4		5		6		7		8		9		10		11		12		13		Total		Average Catch rate	
Date	29.07.99		29.07.99		29.07.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		03.08.99					
Fishing	1503-1612		1615-1812		1832-2025		0820-1030		1100-1219		1232-1335		1340-1442		1448-1554		1630-1756		11813-1902		1950-2117		2145-2348		0842-1020					
Substrate	Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud		Soft Mud		Mud		Mud					
Sea condition	Choppy		V. Choppy		Choppy		Choppy		Choppy		Choppy		Choppy		Choppy		Calm		Calm		Calm		Choppy		Rough					
Water colour	Greenish		Muddy		Muddy		Dark Green		Dark Green		Greenish		Greenish						Greenish		Green/Blue		Greenish		Greenish					
(Wt. in kg)	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails
P. monodon (M)			0.43	4	0.43	4	0.10	1			0.62	5	0.50	7	0.08	1	0.44	8	0.27	4	0.43	12	0.70	4	0.25	1	4.25	51	0.22	2.7
P. monodon (F)	0.20	1	0.56	4	0.44	3			0.14	1	0.26	2	1.45	11	0.48	4	2.06	16	2.11	16	0.83	13	0.44	9			8.97	80	0.47	4.2
Total	0.20	1	0.99	8	0.87	7	0.10	1	0.14	1	0.88	7	1.95	18	0.56	5	2.50	24	2.38	20	1.26	25	1.14	13	0.25	1	13.22	131	0.69	6.9
Other Shrimps	0.48		1.60		7.14		0.96		0.75		4.73		2.55		1.19		9.70		9.71		1.50		0.50				40.81		2.14	
Fish	12.50		15.00		58.00		12.00		25.00		80.00		70.00		20.00		90.00		70.00		60.00		40.00				552.50		28.91	
Total catch (Wet Wt.)	13.18		17.59		66.01		13.06		25.89		85.61		74.50		21.75		102.2		82.09		62.75		41.64		0.25		606.5		31.74	
% P. monodon	1.50		5.60		1.30		0.77		0.42		1.02		2.62		2.57		2.40		2.90		2.09		2.74				25.93		2.16%	
% Shrimp	3.64		9.11		10.82		7.35		2.26		5.52		0.08		5.47		9.49		11.40		2.50		1.2				68.84		5.74&	
Catch rates ($kghr^{-1}$)	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails
P. monodon (M)			0.22	2.05	0.23	2.13	0.05	0.46			0.59	4.76	0.49	6.80	0.07	0.91	0.31	5.59	0.33	4.87	0.30	8.28	0.34	1.95	0.15	0.61			0.23	2.41
P. monodon (F)	0.17	0.87	0.29	2.05	0.23	1.60			0.11	0.76	0.258	1.91	1.41	10.68	0.44	3.64	1.44	11.19	2.57	19.5	0.57	8.97	0.22	4.39					0.43	3.62

Average catch rates after log-transformed

Table 5 : Catch rates (by haul) of shrimps and fish caught by SF3-118 in July/August 1999 off Kuala Baram

Station	1		2		3		4		5		6		7		8		9		10		Total		Average Catch rate	
Date	29.07.99		29.07.99		29.07.99		02.08.99		02.08.99		02.08.99		02.08.99		02.08.99		03.08.99		03.08.99					
Fishing	1410-1536		1605-1806		1820-2000		0949-1143		1227-1342		1355-1513		1526-1720		1739-1908		0728-0846		0957-1022					
Substrate	Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud		Mud					
Sea condition	Choppy		V. Choppy		Choppy		Choppy		Choppy		Choppy		Calm		Calm		Choppy		Choppy					
Water colour	Greenish		Muddy		Muddy		Greenish		Greenish		Greenish		Greenish		Dark Green		Dark Green		Dark Green					
(Wt. in kg)	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails
P. monodon (M)	0.13	2	0.19	2									0.05		0.09	1			0.11	1	0.56	7	0.03	0.40
P. monodon (F)														0.12							0.12	1	0.01	0.05
Total	0.13	2	0.19	2									0.17		0.09	1			0.11		0.68	8	0.04	0.45
Other Shrimps	2.19	286	0.82	65	1.05	156	0.90	238	1.21	188	1.53	343	1.17	96	0.27	29			0.33	15	9.50		0.50	
Fish	4.71	57	11.20	73	8.27	68	2.55	116	16.95	107	25.98	333	40.21	4681	4.18	100	17.31	512	5.74	648	137.10		7.25	
Total catch	7.03	345	12.21	140	9.312	224	3.44	354	18.16	295	27.51	676	41.54	4777	4.54	130	17.31	512	6.18	663	147.3		7.79	
% P. monodon	1.85		1.52										0.4		1.98				1.78					
% Shrimp	31.08		6.72		11.26		26		6.67		5.57		2.915		6.02				5.34					
Catch rates ($kghr^{-1}$)	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails	Wt.	Tails
P. monodon (M)	0.09	1.4	0.09	0.99									0.03	0.5	0.06	0.68			0.26	2.38			0.12	1.02
P. monodon (F)													0.06	0.5									0.06	0.50

Average catch rates after log-transformed

Table 6 shows the outcome of the analysis using FiSAT software program.

Table 6 : Morphometric analysis on the relationship between total length and carapace length and between weight and total length of *P. monodon*

Parameters	Total Length (TL) Vs Carapace Length (CL)		Weight Vs Total Length (TL)	
	male	female	male	female
a	59.24	58.93	0.0009	0.0002
b	2.72	2.96	2.16	2.43
Correlation coefficient, r	0.56	0.97	0.71	0.82

The maturity stages of the female shrimp caught were 22.2% stage 1; 33.3% stage 2; 22.2% stage 3; 12.4% stage 4 and 9.9% stage 5 (spent). The survey shows that the majority (67.9%) of the broodstock was ready to spawn. Females at stage 2 and 3 were most suitable for hatchery use. Female at stage 4 is best suited for immediate spawning but the timing of their delivery to the hatchery is critical, considering the spawning of eggs at anytime.

Biomass estimates

In shallow waters, the density of male shrimp was 15.58 kg nm^{-2}. Since only one tail of female was caught in the shallow waters, the density was low at 7.79 kg nm^{-2}. The density of female shrimps resource in the shallow waters was half that of deeper waters (Table 7). However, the distribution of the male shrimps showed the reverse.

Table 7 : Abundance of *P. monodon* estimated by depth strata for July/August 1999 off Kuala Baram

Depth Stratum	No. of Station	Area (nm^2)	Catch Rate (kg hr^{-1})		Density (kg hr^{-1})		Total Biomass (kg)	
			Male	Female	Male	Female	Male	Female
5-10 m	10	92.0	0.120	0.060	15.58	7.79	1433	717
11-50 m	13	168.5	0.230	0.430	7.49	14.00	1262	2359
Total	23	260.5					2695	3076

Biomass estimates of the tiger shrimp resource off Kuala Baram, Sarawak calculated using the Swept Area method are summarized in Table 7. The biomass was 2,695 kg and 3,076 kg for male and female shrimps respectively. The biomass difference between the two depth strata (5-10 m and 11-50 m) was roughly in the ratio of 6:10. The 11-50 m stratum has a slightly bigger area. About 62.5% of the tiger shrimp resource was found in this stratum (Table 7).

The biomass of tiger shrimp estimated here was based on the results of only one survey conducted over a limited period. A better biomass estimate using the average result from a series of surveys conducted in different months in the same area would provide a better estimate of the actual standing stock. A series of surveys should cover the seasonal variation in the standing stock.

Exploitation potential

The available data on current yield (Y) taken from the survey area were the landings of commercial trawlers in 1999. Table 1 gives the landings of trawlers of all sizes categories in Miri, Sarawak. Out of the total 5,736 kg landed in 1999, the estimated yields of male and female shrimps following the ratio of 0.53 to 1.00 respectively in the current study, gives 1,987 kg and 3,749 kg of male and female shrimps, respectively.

No natural mortality (M) for tiger shrimp in Malaysian waters were ever recorded. However, by critically analysing all the available M values for penaeid shrimp, Garcia (1985) reported an average natural mortality rate of 2.4 ± 0.3 per year for adults. A compromised average value of 2.5 was taken for this study.

Table 8 gives the MSY for both male and female tiger shrimps at the current yield of 1,987 kg and 3,749 kg for male and female shrimp respectively. From the derived biomasses, the MSY was 4,362 kg and 5,720 kg for male and female tiger shrimps, respectively. In the present survey, the average weight were 80 g and 110 g for male and female shrimps, respectively. Based on Motoh (1981), these sizes were considered as being matured. In term of numbers, the MSY for male and female shrimps were estimated to be 54,525 and 52,000 tails, respectively.

Table 8 : Estimation of Maximum Sustainable Yield (MSY) of *P. monodon* resource for Kuala Baram area at yield of 1,987 kg and 3,749 kg for male and female shrimps respectively

Reference	**Male** **Bc=2695 kg** **q=1.0, m=2.5**	**Female** **Bc=3076 kg** **q=1.0, m=2.5**
Cadima (in Sparre & Venema, 1992)	4362 kg	5720 kg

These MSY estimates (Table 8), were derived by using assumptions for values like catchability coefficient (q), natural mortality (M) and yield from the fisheries (Y), which were estimated from the landings of commercial trawlers. In such a situation, a change in any of the three variables used, will change the estimate of MSY and potential yield.

The choice of average M value used also affects the MSY estimated. A monthly series of length frequency data were being collected from commercial trawlers in Kuala Baram and the M value derived from this data will be very useful in refining the future MSY value.

In the estimates of current tiger shrimps yield, the assumption made was the present survey results mirror the weight ratio between male and female shrimp in the commercial landings. Frequent surveys will certainly improve the ratio between male and female shrimps catch.

Exploitation rate

Table 9 shows the exploitation rates derived. The exploitation rate, E, was 0.4 per year for both male and female shrimps. The E values obtained indicate that the tiger shrimp resource has not been exploited optimally at E=0.5 per year. If the value stands at less than 0.5 per year, the broodstock resource can sustain further exploitation.

Table 9 : Estimation of exploitation rate (E) of *P. monodon* for Kuala Baram area in July/August 1999 At yield of 1,987 kg and 3,749 kg for male and female respectively

	Male	Female
Naturality Mortality (M)	2.5	2.5
Catchability coefficient (q)	1.0	1.0
Current biomass, Bc (kg)	2695	3076
Exploitation rate E	0.4	0.4

Conclusions

In order to sustain the tiger shrimp, *P. monodon,* resource on the coast of Miri, specifically off Kuala Baram, the present level of exploitation should be maintained.

The evaluation of any management measures requires continuous monitoring and research survey conducted annually following implementation and enforcement of that measure. Monitoring the performance of commercial fishing boats should be conducted parallel to this survey. This is to ensure that information on current status of the fisheries is well updated for the formulation and definition of the management measures for the penaeid shrimps fisheries.

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Appendix 1 : Trawl log for twin outrigger trawler SF3-779

Date	Station No.	Time net released	Start trawling		Position (Lat/Long)			Speed (knot)	Start trawling		Position (Lat/Long)			Time net lifted	Trawling time (hr)
			Time (hour)	Depth (m)					Time (hour)	Depth (m)					
29.07.99	1	1458	1503	35	04	43	36	3.2	1612	30.2	04	43	10	1609	1.15
					113	59	68				114	01	89		
29.07.99	2	1610	1615	20	04	42	29	3.2	1812	20	04	47	80	1812	1.95
					114	00	00				113	59	40		
29.07.99	3	1828	1832	20	04	42	29	3.2	2025	27	04	40	70	2025	1.88
					114	59	50				114	03	64		
02.08.99	4	815	820	28	04	23	52	3.3	1030	23	04	25	00	1036	2.31
					113	51	23				113	52	78		
02.08.99	5	1056	1100	27	04	25	23	3.2	1219	24	04	25	87	1224	1.31
					114	02	161				114	01	737		
02.08.99	7	1339	1340	28	04	40	16	3.1	1442	28	04	38	305	1443	1.03
					113	54	680				113	53	117		
02.08.99	8	1443	1448	30	04	37	856	3.4	1554	26	04	35	611	1556	1.10
					113	52	56				113	53	515		
02.08.99	9	1625	1630	34	04	35	646	3.4	1756	33	04	38	326	1808	1.43
					113	53	334				113	53	464		
02.08.99	10	1810	1813	31	04	38	350	3.4	1902	26	04	36	958	1905	0.82
					113	53	448				113	53	258		
02.08.99	11	1945	1950	27	04	37	142	3.2	2118	23	04	36	825	2120	1.45
					113	53	448				113	53	547		
02.08.99	12	2140	2145	48	04	37	173	3.1	2348	29	04	36	630	2400	2.05
					113	53	768				113	53	35		
03.08.99	13	840	842	-	04	37	173	3.1	1020	-	047	36	630	1024	1.63
					113	53	768				113	52	35		

Appendix 2 : Trawl log for stern trawler SF3-118

Date	Station No.	Time net released	Start trawling		Position (Lat/Long)			Speed (knot)	Direction (degrees)	Start trawling		Position (Lat/Long)			Time net lifted	Trawling time (hr)
			Time (hour)	Depth (m)						Time (hour)	Depth (m)					
29.07.99	1	1405	1410	8.1	04	38	473	2.8	67	1536	10.704	04	40	10	1553	1.43
					113	58	97					114	00	62		
	2	1601	1605	7.5	04	40	47	2.4	33	1806	10.4	04	40	29	1812	1.03
					114	00	79					114	01	82		
	3	1817	1820	10.9	04	40	31	2.2	137	2000	9.5	04	39	21	2007	2.55
					114	01	07					114	01	71		
02.08.99	4	945	949	6.3	04	38	78	2.5	30	1143	7	04	38	67	1154	2.95
					113	57	53					113	59	151		
	5	1334	1227	8.5	04	39	85	2.3	25.1	1342	10.2	04	38	43	1347	1.42
					113	57	15					113	54	91		
	6	1352	1355	9.9	04	38	49	2.4	324	1513	8.3	04	35	55	1515	1.70
					113	54	97					113	54	61		
	7	1523	1526	7.6	04	36	55	2.4	151	1720	10	04	35	95	1726	2.95
					113	54	71					113	54	36		
	8	1736	1739	9.0	04	36	07	2.3	36	1908	10.5	04	36	208	1916	2.25
					113	54	52					113	54	320		
03.08.99	9	726	728	12.9	04	23	05	2.5	184	846	10.3	04	21	00	854	1.50
					113	54	76					113	54	17		
	10	954	957	10.5	04	23	09	2.5	27	1022	9.3	04	23	67	1058	1.13
					113	55	67					113	57	13		