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

REPORT

LOBSTER RESOURCE STUDY IN EAST JOHOR

JOHOR, MALAYSIA
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Abstract

This study was conducted to evaluate the current resource status of spiny lobsters (*Panulirus* spp.) and slipper lobster (*Thenus orientalis*) in the East Johor waters. The objectives of this study were to obtain information pertaining to the distribution and density of spiny lobsters and slipper lobsters in the East Johor waters. The study covered the Zone B and Zone C fishing areas in East Johor. Samplings were conducted using bottom trawl nets onboard a fisherman trawler boat in August 2016 and onboard the KK Senangin II vessel in August 2017 in the same fishing area. The samples from the surveys were analyzed to gather information such as length and weight according to species and the egg maturity level of lobsters caught. The results from the surveys indicated that the average catch rate ($kg.hour^{-1}$) of slipper lobster in the year 2016 was 0.19 ± 0.09 S.E. $kg.hour^{-1}$ while in the year 2017, the average catch rate ($kg.hour^{-1}$) of both spiny lobster and slipper lobster (combined) was 0.21 ± 0.12 S.E. $kg.hour^{-1}$. There was no *Panulirus* spp. lobster sample during the year 2016 survey. The average density ($kg.km^{-2}$) for slipper lobster in the year 2016 and 2017 were 1.52 ± 0.71 S.E. $kg.km^{-2}$ and 0.32 ± 0.13 S.E. $kg.km^{-2}$ respectively. The average density ($kg.km^{-2}$) for spiny lobster in the year 2017 was 7.26 ± 3.09 $kg.km^{-2}$. The results from the surveys indicated that the distribution of *Panulirus* spp. lobsters during the August period was very sparse in the zone B and zone C areas as compared to the slipper lobsters. However, several adult size mud spiny lobsters (*Panulirus polyphagus*) were successfully caught at two deep water (>30m) locations at Zone C and were found to be bearing eggs. The establishment of a lobster refugium is proposed as a fishery management measure to protect the lobster resource in the study area.

Keywords

Spiny Lobster, *Thenus orientalis,* East Johor, Fishery Resources

Introduction

Lobsters are one of the much sought-after commercial marine species in Malaysia and elsewhere in the world. In the East Coast of Peninsular Malaysia, there are at least five main species of spiny lobsters, namely *Panulirus polyphagus*, *P. versicolor, P. homarus homarus, P. longipes longipes* and *P. ornatus* (Alias *et al.,* 2000). However, among these five species, *P. polyphagus* is the most dominant commercial species and can be found in abundance in East Johor waters. The Palinurid spiny lobsters are different from the true lobsters (such as *Homarus* spp.) usually found in the Atlantic Ocean, in that they lack the large chelae (claw) usually associated with true lobsters. However, the spiny lobsters are taxonomically more related to the slipper lobster (Scyllaridae) such as *Thenus orientalis*, and both *P. polyphagus* and *T. orientalis* can be found in abundance in East Johor waters.

For the spiny lobster *P. polyphagus*, the juvenile lobsters are usually found along the shallow coastal habitat while the adult lobsters are usually found in the deeper seabed of East Johor waters. Thus, the adult lobsters are often caught by bottom net trawlers while traditional fisherfolk such as traps and drift nets operators target the juvenile lobsters. Every year, the newly grown adult spiny lobsters will embark on a migration to deeper sea from their coastal habitat for breeding and spawning purposes (Alias *et al.,* 2000). A previous study by Alias *et al.* (2000) has indicated that the breeding and migration season begins in July and berried females were high in August. During this critical moment, the spiny lobster population is susceptible to overfishing due to the high aggregation of lobsters at any one time and the risk of capture by the fisherfolk.

Currently, the lobster's resources throughout the world are already either fully exploited or over-exploited (FAO, 2011). The Caribbean Spiny Lobster (*Panulirus argus*) fishery in Western Central Atlantic, the Cape Rock Lobster (*Jasus lalandii*) fishery in Southeast Atlantic and the palinurid spiny lobster (Palinurus spp.) fishery in Eastern Central Atlantic were all reported to be overfished (FAO, 2011). However, the state of the lobster fishery in Malaysia is still unknown but the recent trend of decreasing landings (DOFM, 2018) is of great concern to the local lobster fishery industry and management.

Thus, the aim of this study was to evaluate the current resource status of spiny lobsters (*Panulirus* spp.) and slipper lobster (*Thenus orientalis*) in the East Johor waters. The objectives of this study were to obtain information pertaining to the distribution and density of spiny lobsters and slipper lobsters in the study area.

Materials and Methods

Sampling Area and Design

The study area was located at the trawler's fishing ground in East Johor, Peninsular Malaysia. Based on the Malaysian marine fishery zoning system, the study area covered both the zone B and zone C area. Two surveys were conducted in the same area during similar periods, on the 24-27 August 2016 and 21-24 August 2017. The first survey was conducted using a chartered commercial fish trawler while the second survey was conducted onboard a Department of Fisheries Malaysia research vessel, KK Senangin II. A total of 17 locations were sampled in year 2016 survey, covering an estimated study area of 1177.16 square kilometer while in the subsequent year, 18 locations were sampled in an estimated study area of 1812.30 square kilometer (Figure 1). Initially, the sampling locations were predetermined systematically but some adjustments were made during the actual sampling to adapt to local condition and suitability.

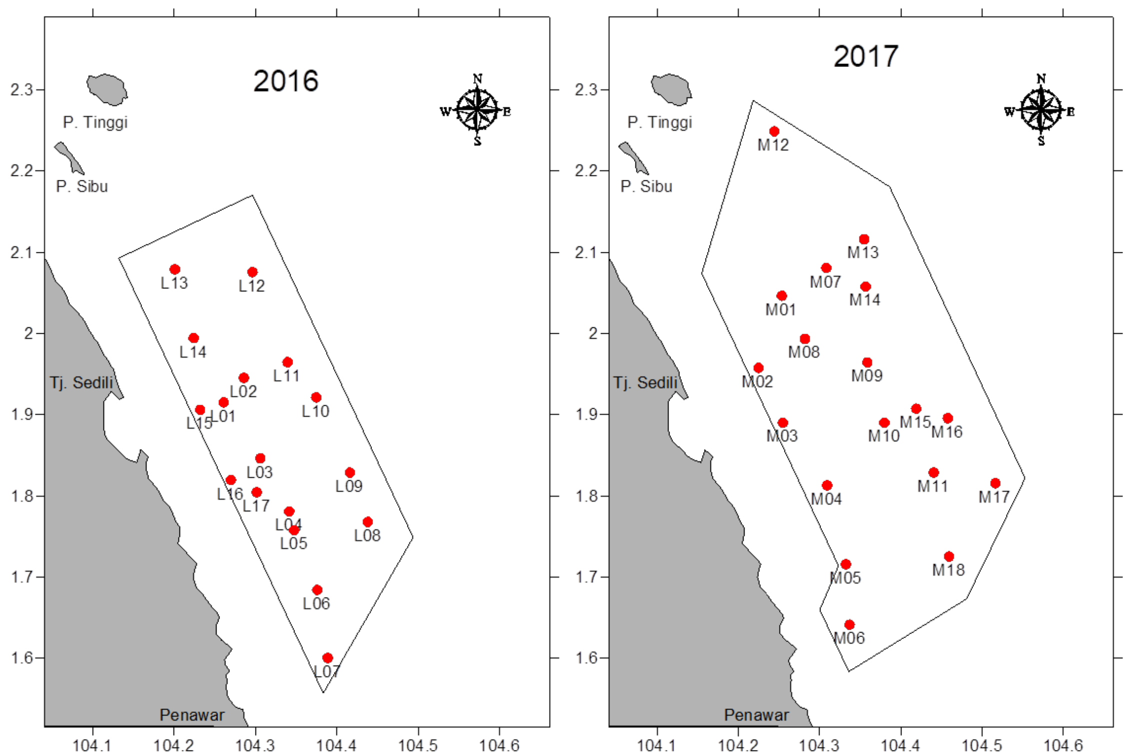

Figure 1: Maps showing the sampling locations in the survey area in East Johor in year 2016 (left) and 2017 (right). The estimated study area in year 2016 was 1177.16 square kilometer while in year 2017 was 1812.30 square kilometer

Sampling was conducted using bottom trawl nets with an average trawling operation speed of about 6.3 $km.h^{-1}$ and trawling duration of about 60 minutes. The coordinates of the starting and ending positions of each trawling operation were recorded along with other information such as water depth and trawling direction. After each haul, the catch was sorted, identified to the species level and measured onboard the study vessels.

Data analysis

The density of the fish sampled in the survey were calculated using the "swept area method" (Sparre and Venema, 1998). The swept area, a, was estimated using the following equation:

$$a = D * h * x \qquad \text{(Equation 1)}$$

$$\text{Where } D = V * t \qquad \text{(Equation 2)}$$

Where V is the average speed ($km.hr^{-1}$) of the trawling operation, t is the trawling duration (in hours), h is the length of the trawl net headrope and x is the fraction of the headrope which equal to the width of the path swept by the trawl net (FRI, 2017). In this study, the value of x used was 0.5 (Sparre and Venema, 1998).

Assuming that the weight of the catch of each haul is Cw, then the catch per hour is described as Cw/t. Also, if "a" is the area swept by the trawl net during each operation, then a/t represent the area swept per hour. Therefore, the equation for the weight of catch per unit area is as follow:

$$(Cw/t) / (a/t) = Cw/a \qquad \text{(Equation 3)}$$

The mean weight of catch per unit area (Cw/a) divided by the catchability coefficient, q will give the mean biomass per unit area. For this study, the value of q = 0.5 was used as recommended for trawlers in Southeast Asia (Sparre and Venema, 1998). The biomass, B of the study area, A was calculated with the following equation:

$$B = (Cw/a) / q * A \qquad \text{(Equation 4)}$$

The potential yield of the exploited stock (in metric ton) was calculated using the following equation:

$$\text{Potential Yield, } MSY = 0.5 * (Y + M * Bc) \qquad \text{(Equation 5)}$$

Where Y is the current yield (in metric ton),
M is the natural mortality coefficient, and
Bc is the current biomass, obtained from the swept area method

Finally, the Exploitation Rate, E was calculated using the following equation:

$$E = (Y / Bc) / ((Y / Bc) + M) \qquad \text{(Equation 6)}$$

All the calculations and equations were referred from Sparre and Venema, (1998) and FRI (2017).

Estimation of Maximum Sustainable Yield (MSY) of lobsters in the study area using surplus production model (Schaefer Model) were also carried out using data from the annual landing and effort statistic obtained from the Department of Fisheries Malaysia (DOFM, 2018). The calculations involved were referred from Sparre and Venema, (1998).

Results

Catch Rates

The average catch rate for the year 2016 survey was 65.52 ± 12.14 $kg.hr^{-1}$, comprising of significant number of low value fishes (average catch rate of 34.27 ± 9.35 $kg.hr^{-1}$), followed by commercial fishes (average catch rate of 29.44 ± 6.65 $kg.hr^{-1}$), squids (average catch rate of 5.33 ± 0.75 $kg.hr^{-1}$), crabs (average catch rate of 0.53 ± 0.12 $kg.hr^{-1}$), slipper lobsters (average catch rate of

0.19 ± 0.09 kg.hr^{-1}) and shrimps (including mantis shrimps) (average catch rate of 0.12 ± 0.05 kg.hr^{-1}) (Table 1). Slipper lobsters were only caught at 3 sampling locations (haul 11, 13 and 14) with the catch rates ranging from 0.05 to 0.35 kg.hr^{-1}. No spiny lobster was present in catch during the entire duration of the year 2016 survey.

Table 1: Catch rates (kg.hr^{-1}) of major group of fishes in the year 2016 survey

Haul	Fish	Squid	Slipper Lobster	Crab	Shrimp and Squilla	Low Value Fish	Total
	Catch rate (kg.hr^{-1})						
1	48.20	5.90		0.20		30.00	84.30
2	12.40	5.00		0.80		22.00	40.20
3	61.70	7.10				120.00	188.80
4	14.18	2.50		0.20		115.00	131.88
5	53.80	4.40				40.00	98.20
6	5.75	4.50		0.20		20.00	30.45
7	7.60	14.38		0.30		40.00	62.28
8	31.56	2.08		0.20	0.40	10.00	44.24
9	2.39	1.96		0.58	0.10	5.00	10.03
10	5.68	3.46		0.50			9.64
11	8.31	3.50	0.05	0.22		6.00	18.08
12	4.02	5.35		0.39	0.09	3.00	12.85
13	12.52	9.43	0.16	0.40	0.10	8.00	30.61
14	74.24	7.75	0.35	0.65		40.00	122.99
15	20.39	5.10		0.90	0.05	30.00	56.44
16	51.20	5.60			0.02	25.00	81.82
17	86.48	2.63		1.88	0.07		91.06
Average	**29.44**	**5.33**	**0.19**	**0.53**	**0.12**	**34.27**	**65.52**
Std. Error	**6.65**	**0.75**	**0.09**	**0.12**	**0.05**	**9.35**	**12.14**

In the subsequent survey in the year 2017, the average catch rate for the survey was 60.12 ± 22.15 kg.hr^{-1}, comprising of even higher number of low value fishes (average catch rate of 40.93 ± 21.80 kg.hr^{-1}), followed by commercial fishes (average catch rate of 13.81 ± 1.83 kg.hr^{-1}), squids (average catch rate of 4.75 ± 0.88 kg.hr^{-1}), shrimps (average catch rate of 0.69 ± 0.58 kg.hr^{-1}), crabs (average catch rate of 0.46 ± 0.11 kg.hr^{-1}) and lobsters (spiny and slipper lobsters) (average catch rate of 0.21 ± 0.12 kg.hr^{-1}) (Table 2). Spiny lobsters were caught at 2 location (station 11 and 16) while slipper lobsters were caught at 8 other sampling locations. The catch rates of spiny lobster at station 11 and 16 were 1.24 and 0.50 kg.hr^{-1} respectively while the catch rates of slipper lobsters ranged from 0.02 to 0.14 kg.hr^{-1}.

Table 2: Catch rates (kg.hr^{-1}) of major group of fishes in the year 2017 survey

Station	Fish	Squid	Lobster	Crab	Shrimp	Others	Low Value Fish	Total
	Catch rate (kg.hr^{-1})							
1	9.91	2.00	0.04			0.54	12.10	24.59
2	29.90	3.00	0.03	0.18	0.06		5.30	38.46
3	15.78	3.18	0.03				11.70	30.69
4	22.75	1.54				0.32	398.00	422.61

5	5.73	3.13		0.15	0.15		50.00	59.16
6	11.00	3.47			1.86		110.00	126.33
7	19.53	10.00	0.06	0.40			26.00	55.99
8	23.98	2.00				0.38	17.00	43.36
9	8.18	2.64	0.05				9.84	20.71
10	20.57	3.20		0.35		0.83	15.28	40.23
11	8.17	5.24	1.24	0.78			12.70	28.13
12	18.79	17.33	0.03			0.20	16.00	52.35
13	2.79	6.10	0.02	0.22			8.00	17.13
14	3.53	5.29		1.23		0.04	5.13	15.22
15	4.54	5.02		0.60		0.05	8.40	18.60
16	15.57	4.60	0.50	0.50			11.94	33.10
17	12.86	5.70	0.14	0.15			13.00	31.85
18	15.09	2.10					6.40	23.59
Average	**13.81**	**4.75**	**0.21**	**0.46**	**0.69**	**0.34**	**40.93**	**60.12**
Std. Error	**1.83**	**0.88**	**0.12**	**0.11**	**0.58**	**0.11**	**21.80**	**22.15**

Density

The average catch density for the year 2016 survey was 558 ± 105 kg.km^{-2} and catch density ranged from 84 kg.km^{-2} (haul 10) to 1644 kg.km^{-2} (haul 3) (Figure 2). For commercial fishes, the average density for the year 2016 survey was 301 ± 56 kg.km^{-2} and ranged from 44 kg.km^{-2} (haul 9) to 768 kg.km^{-2} (haul 17). The average density for low value fishes in the year 2016 survey was 292 ± 81 kg.km^{-2} and ranged from 27 kg.km^{-2} (haul 12) to 1045 kg.km^{-2} (haul 3). Fish density was generally higher in area closer to the shoreline (haul 1-7, 13-17) compared to further sea locations (haul 8 – 12).

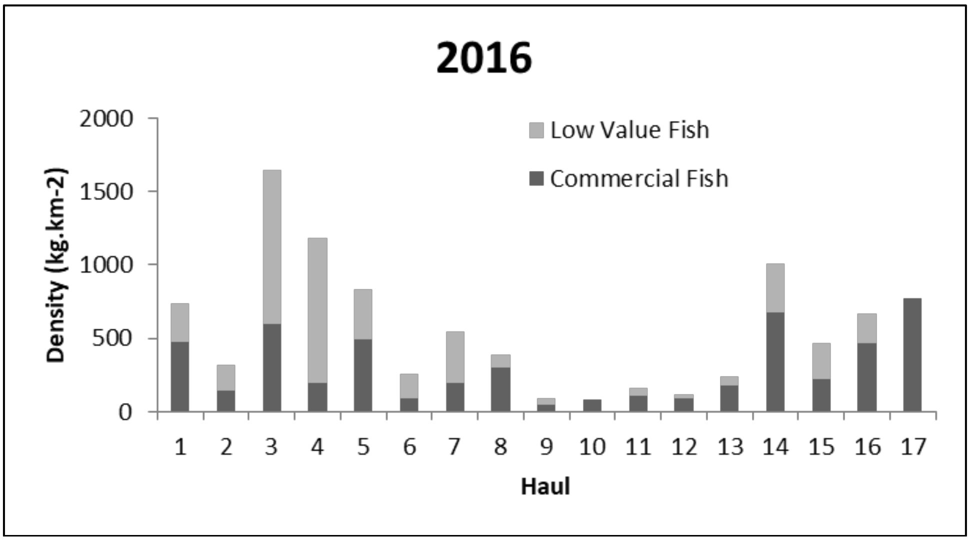

Figure 2: Fish density (kg.km^{-2}) according to haul from the 2016 survey

In the year 2017, the average catch density from the survey was 465 ± 207 kg.km^{-2} and catch density ranged from 76 kg.km^{-2} (station 13) to 3855 kg.km^{-2} (station 4) (Figure 3). For commercial fishes, the average density for the year 2017 survey was 123 ± 12 kg.km^{-2} and ranged from 41 kg.km^{-2} (station 9) to 224 kg.km^{-2} (station 4). The average density for low value fishes in the year 2017 survey was 342 ± 200 $kg.km^{-2}$ and ranged from 24 $kg.km^{-2}$ (station 2) to 3630 $kg.km^{-2}$ (station 4).

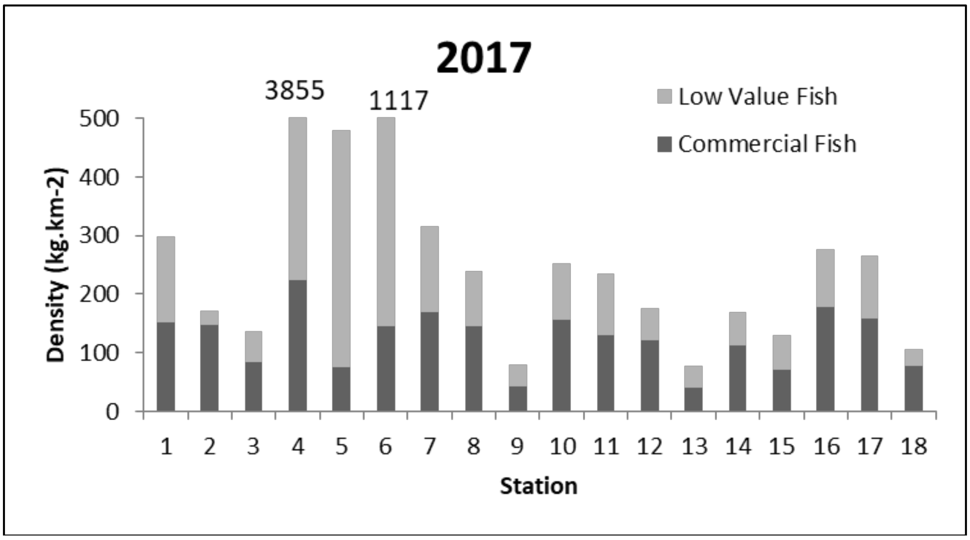

Figure 3: Fish density ($kg.km^{-2}$) according to haul from the 2017 survey

In the year 2016, only slipper lobsters were successfully caught during the survey and were found in haul 11 (0.45 $kg.km^{-2}$), haul 13 (1.23 $kg.km^{-2}$) and haul 14 (2.86 $kg.km^{-2}$) (Table 3, Figure 4). However, no spiny lobster was caught during that survey. In the following year, more samples of slipper lobsters were successfully sampled, and the density ranged from 0.09 to 1.17 $kg.km^{-2}$ (Table 4). The 2017 survey also was able to obtain 3 spiny lobster samples from two locations and the density was estimated to be 10.34 $kg.km^{-2}$ at station 11 and 1.17 $kg.km^{-2}$ at station 17. There was no occurrence of slipper lobster at station 11 and 17 during the year 2017 survey.

Table 3: Density ($kg.km^{-2}$) of slipper lobster (*T. orientalis*) from the 2016 survey

Haul	**Species**	**Density ($kg.km^{-2}$)**
11	*T. orientalis*	0.45
13	*T. orientalis*	1.23
14	*T. orientalis*	2.86

Table 4: Density ($kg.km^{-2}$) of slipper lobster (*T. orientalis*) and spiny lobster (*P. polyphagus*) from the 2017 survey

Station	**Species**	**Density ($kg.km^{-2}$)**
1	*T. orientalis*	0.43
2	*T. orientalis*	0.11
3	*T. orientalis*	0.13
7	*T. orientalis*	0.34
9	*T. orientalis*	0.18
11	*P. polyphagus*	10.34
12	*T. orientalis*	0.09
13	*T. orientalis*	0.09
16	*P. polyphagus*	4.17
17	*T. orientalis*	1.17

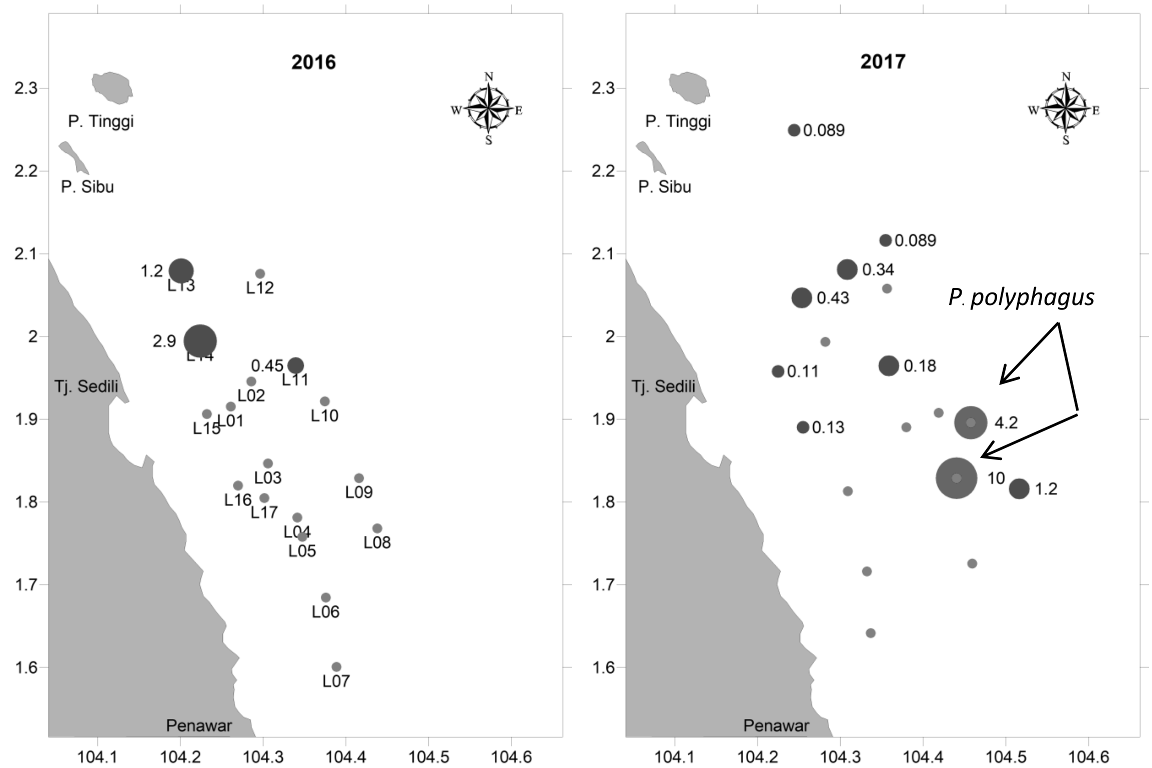

Figure 4: Maps showing the distribution and density (kg.km^{-2}) of slipper lobster (*T. orientalis*) and spiny lobster (*P. polyphagus*) in the survey area in year 2016 (left) and 2017 (right)

MSY and Exploitation Rate

From the year 2016 survey, the potential yield (MSY) of fish resources in East Johor waters was estimated to be in the range of 10,810 to 12,125 metric ton (Table 5). These values were calculated based on the natural mortality coefficient, M value of 1.6 derived from previous demersal surveys of the area (FRI, 2017). Similarly, the potential yield estimates from the year 2017 ranged from 11,696 to 12,997 metric ton. The exploitation rate, E (year^{1}) for both years were estimated to be at 0.9 and considered very high.

Table 5: The potential yield (metric ton) and exploitation rate (year ^{1}) (M = 1.6) of fish resources in the East Johor waters from the year 2016 and 2017 surveys

Year	**2016**	**2017**
Area, a (km^{2})	1,177	1,812
Density, D (kg.km^{-2})	558	465
Biomass, Bc (metric ton)	1,314	1,686
Landing, Y (metri ton)	19,517 – 22,147	20,695 - 23,297
Mortality, M	1.6	1.6
Potential Yield, MSY (metric ton)	10,810 - 12,125	11,696 - 12,997
Exploitation Rate, E (year ^{1})	0.9	0.9

* Mortality, M value derived from 2014-2016 Demersal Survey data (DOF Malaysia)

** Landing data derived 2 datasets: 0-70 GRT Trawler and Total Landing of Traps, Drift Nets and Trawlers

As for the spiny lobster resources, the potential yield (MSY) of spiny lobster in East Johor waters from the year 2017 survey was estimated to be in the range of 8 to 62 metric ton (Table 6). These values were calculated based on the natural mortality coefficient, M value of 0.45 derived from other previous studies (Kagwade, 1994; Radhakrishnan *et al.*, 2005). The exploitation rate, E (year^{-1}) for was estimated to be at the range of 0.2 to 0.9 (based on the range of landing, Y values).

Table 6: The potential yield (metric ton) and exploitation rate (year^{-1}) (M = 0.45) of spiny lobster in the East Johor waters from the year 2017 survey

Year	**2016**	**2017**
Area, a (km^2)		1,812
Density, D (kg.km^{-2})	Not Available	7.26
Biomass, Bc (metric ton)		26.3
Landing, Y (metri ton)		4 – 113
Mortality, M		0.45
Potential Yield, MSY (metric ton)		8 – 62
Exploitation Rate, E (year^{-1})		0.2 – 0.9

* Mortality, M value derived from Kagwade, 1994 and Radhakrishnan *et al.*, 2005
**Landing data derived 2 datasets: 0-70 GRT Trawler and Total Landing of Traps, Drift Nets and Trawlers

Likewise, for the slipper lobster resources, the potential yield (MSY) of slipper lobster in East Johor waters from the year 2016 and 2017 surveys were estimated to be in the 17 and 19 metric ton respectively (Table 7). These values were calculated based on the natural mortality coefficient, M value of 0.918 derived from other previous studies (Courtney, 1997; 2002). The exploitation rate, E (year^{-1}) were estimated to be at 0.90 in year 2016 and 0.97 in year 2017 and were considered very high for both years.

Table 7: The potential yield (metric ton) and exploitation rate (year^{-1}) (M = 0.918) of slipper lobster in the East Johor waters from the year 2016 and 2017 surveys

Year	**2016**	**2017**
Area, a (km^2)	1,177	1,812
Density, D (kg.km^{-2})	1.52	0.32
Biomass, Bc (metric ton)	3.57	1.15
Landing, Y (metric ton)	30	37
Mortality, M	0.918	0.918
Potential Yield, MSY (metric ton)	17	19
Exploitation Rate, E (year^{-1})	0.90	0.97

* Mortality, M value derived from Courtney, 1997; 2002
**Landing data derived from 25 - >70 GRT Trawlers landings

Catch and effort of lobster fisheries

As a comparison, the analysis of Maximum Sustainable Yield (MSY) of spiny lobsters in the East Johor waters using the statistical catch and effort data (Schaefer Model) produce a higher MSY value of 124 metric ton, with the fMSY of 49,599 boat trips per year (standardized effort based on the effort of drift nets) (Figure 5). This value is double of the estimated value of 62 metric ton using the survey data and calculation using the Cadima's equation.

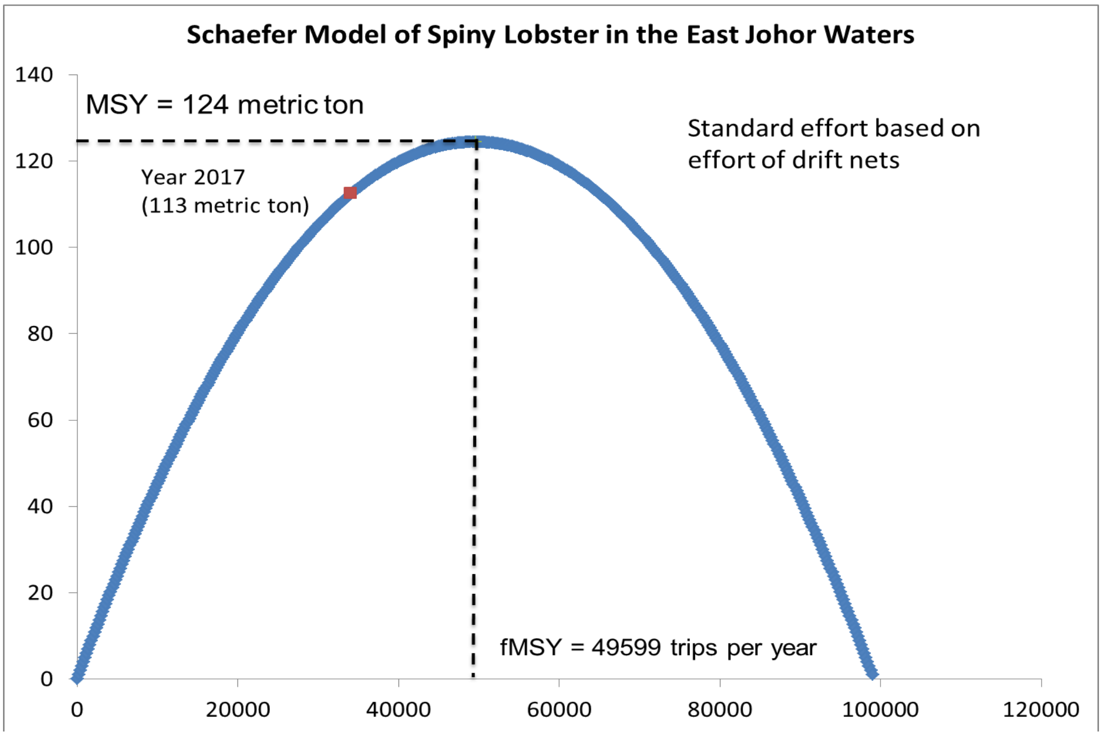

Figure 5: Schaefer Model of the spiny lobster resource in the East Johor waters. MYS was estimated to be about 124 metric ton with fMSY = 49,599 trips per year (drift nets)

A further analysis of the statistical catch and effort data covering the East Coast of Peninsular Malaysia produce a spiny lobster MSY value of 199 metric ton, with the fMSY of 427,211 boat trips per year (standardized effort based on the effort of drift nets) (Figure 6). This MSY value is 160% higher than the MSY value of spiny lobster in the East Johor waters alone.

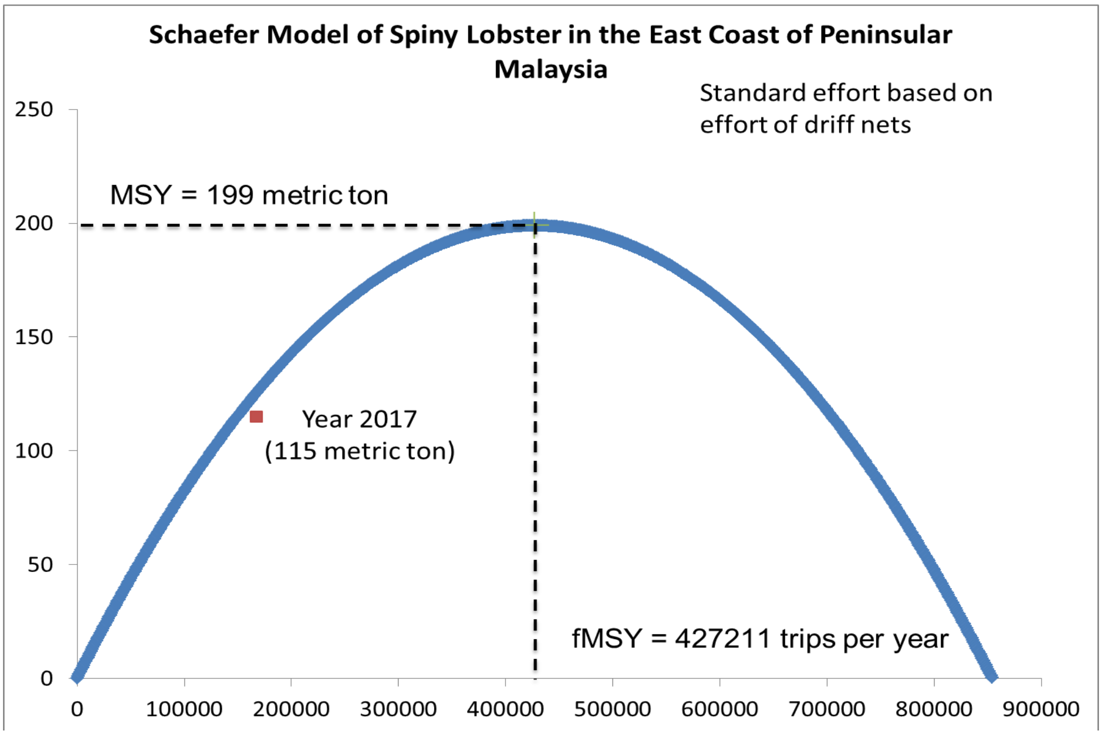

Figure 6: Schaefer Model of the spiny lobster resource in the East Coast of Peninsular Malaysia. MYS was estimated to be about 199 metric ton with fMSY = 427,211 trips per year (drift nets)

Likewise for the slipper lobster fishery in the East Johor waters, the analysis of Maximum Sustainable Yield (MSY) using the statistical catch and effort data (Schaefer Model) produce a MSY value of 172 metric ton, with the fMSY of 115,736 boat trips per year (standardized effort based on the effort of 10-24.9 GRT trawlers) (Figure 7). This value is 905% higher than the estimated value of 19 metric ton using the survey data and calculation using the Cadima's equation.

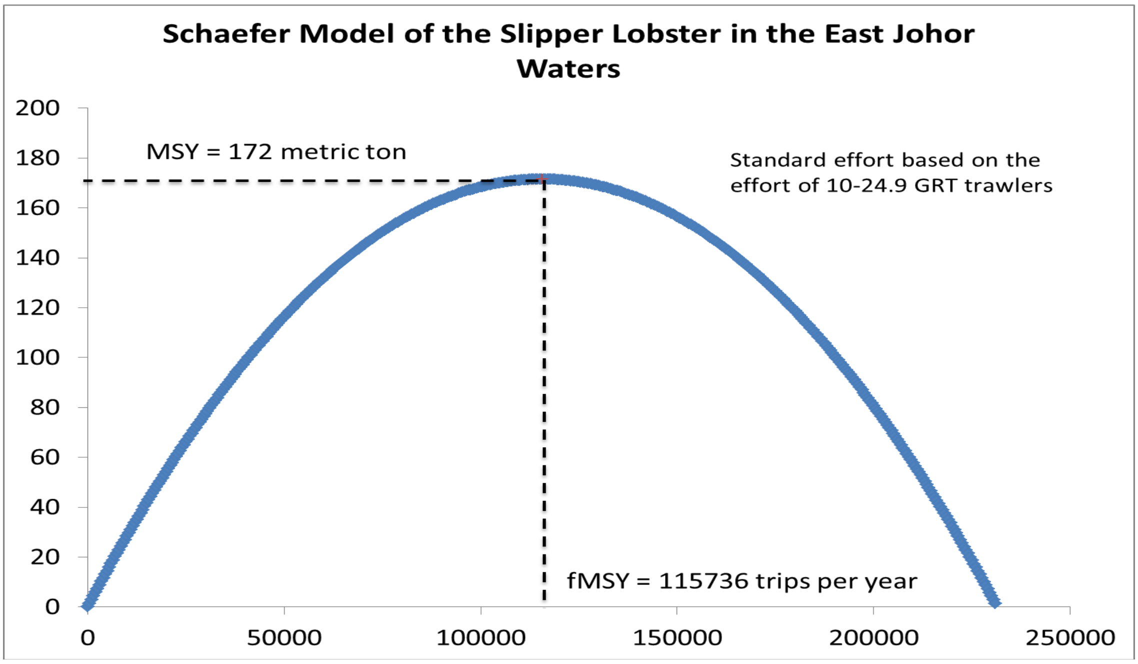

Figure 7: Schaefer Model of the slipper lobster resource in the East Johor waters. MYS was estimated to be about 172 metric ton with fMSY = 115,736 trips per year (10-24.9 GRT trawlers)

A further analysis of the statistical catch and effort data covering the East Coast of Peninsular Malaysia produce a slipper lobster MSY value of 348 metric ton, with the fMSY of 30,036 boat trips per year (standardized effort based on the effort of 25-39.9 GRT trawlers) (Figure 8). This MSY value is 202% higher than the MSY value of slipper lobster in the East Johor waters alone.

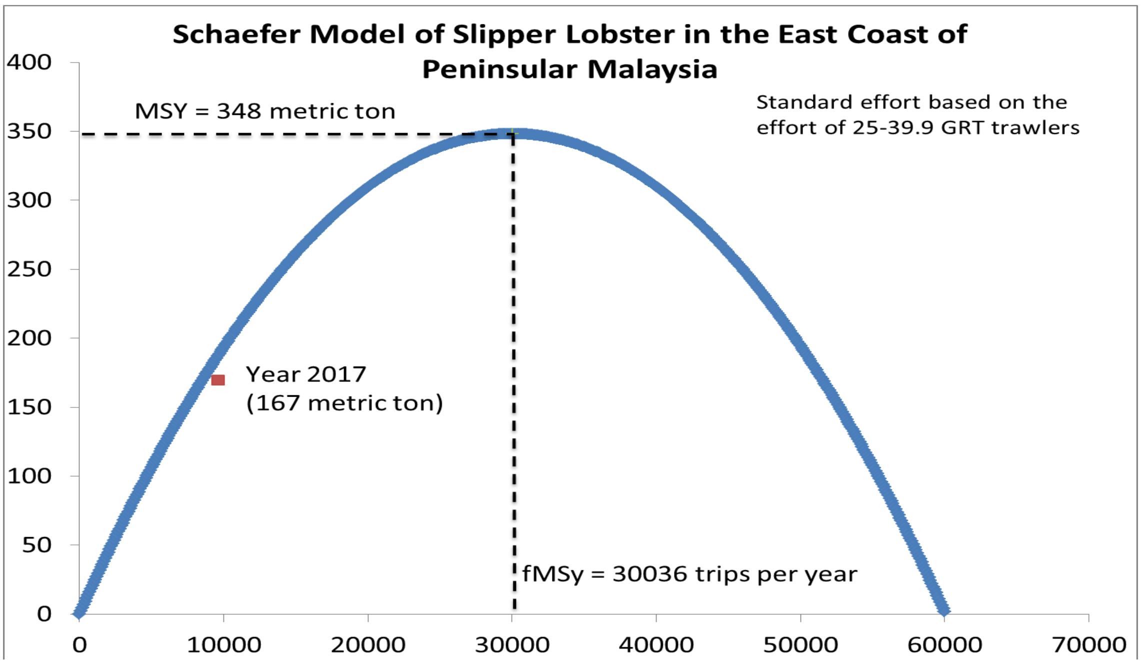

Figure 8: Schaefer Model of the slipper lobster resource in the East Coast of Peninsular Malaysia. MYS was estimated to be about 348 metric ton with fMSY = 30036 trips per year (25-39.9 GRT trawlers)

Discussion

Lobsters resource in East Johor

In this study, two scientific surveys were conducted annually at about the same period (end of August 2016 and 2017) but using two type of vessels, namely a fisherman trawler in year 2016 and a research vessel KK Senangin II in year 2017. During the course of these two surveys, the catch rate of spiny and slipper lobsters was low and in sparse locations. Slipper lobsters were only caught at 3 sampling locations (haul 11, 13 and 14) in year 2016 with the catch rates ranging from 0.05 to 0.35 $kg.hr^{-1}$ but occurred in 8 sampling locations in year 2017 with the catch rates ranging from 0.02 to 0.14 $kg.hr^{-1}$. Likewise, the density of slipper lobsters ranges from 0.45 to 2.86 $kg.km^{-2}$ in year 2016 and 0.09 to 1.17 $kg.km^{-2}$ in year 2017. The occurrence of *Panulirus* lobsters were even rarer in the surveys as they were only found at two locations in the 2017 survey, at station 11 and 16 with catch rates of 1.24 and 0.50 $kg.hr^{-1}$ respectively and density of 10.34 and 4.17 $kg.km^{-2}$ respectively.

According to a previous study conducted by Alias *et al.* (2000) in the same area, the breeding and migration season of spiny lobster begins in July and the numbers of berried females should be high by August. However, the surveys conducted in this study were not able to collect higher number of spiny lobsters and only 3 adult sized lobsters were caught in two locations. This may indicate a severe drop in spiny lobster resource in the study area since the last study by Alias *et al.* (2000). The spiny lobsters caught in the 2017 survey were also carrying eggs thus the breeding season was still in effect in August.

As such, the potential yield (MSY) of spiny lobster in East Johor waters derived from the year 2017 survey was estimated to be in the range of 8 to 62 metric ton. This high disparity in range was due to the selection of spiny lobster landing dataset. The lower potential yield value was calculated using trawlers landing dataset while the higher potential yield value (62 metric ton) took into account landings from all related gears, namely trawlers, drift nets and traps. Similarly, the high disparity in landing values also affected the exploitation rate, E ($year^{1}$) which were estimated to be in the range of 0.2 to 0.9. Based on the precautionary principle (FAO, 1996; Cadima, 2003), this study suggest to use the higher value of potential yield (62 metric ton) and the exploitation rate, E of 0.9 per year as it represent a broader scope of the spiny lobster fishery in East Johor. Subsequently, the spiny lobster fishery in East Johor can be considered as over-exploited as the year 2017 landing already exceeded the potential yield (MSY) value and the current stock biomass is less than 40% of the estimated unfished stock size (Ye, 2011).

For the slipper lobster resource in East Johor waters, the potential yield (MSY) calculated from the data of the year 2016 and 2017 surveys were quite similar (17 and 19 metric ton respectively). However, the estimated exploitation rate, E ($year^{1}$) were for this species were very high (0.90 in year 2016 and 0.97 in year 2017). Thus, the slipper lobster fishery in East Johor is also considered to be over-exploited with similar reasoning as the spiny lobster fishery. Slipper lobsters are mainly caught by trawler boats plying the East Johor waters (DOFM, 2018). Any management measures concerning slipper lobsters will need to focus on the fishing effort of the trawlers there.

Statistical catch and effort data

The analysis of Maximum Sustainable Yield (MSY) of spiny and slipper lobsters in the East Johor waters using the statistical catch and effort data (Schaefer Model) produce significantly higher MSY values than the estimates from the surveys and calculation based on the Cadima's equation. For the spiny lobster resource, the MSY value was double the estimated value from the surveys while for the slipper lobster resource, the MSY value was nine-fold (905%) higher than the value derived from the surveys and calculation using Cadima's equation. The disparity between the values from the statistical catch and effort data with the results from the surveys were influenced by several factors, such as the success rate of lobster capture during the surveys, seasonality during the surveys, frequency of surveys and the accuracy of statistical data collections. However, scientific surveys are costly to undertake and both methods have their own advantages and weaknesses (Garcia *et al*., 1989).

A comparison of the MSY values of spiny lobster resources between East Johor and the entire East Coast of Peninsular Malaysia waters indicated that the East Johor has about 62% of the total East Coast of Peninsular Malaysia spiny lobsters' resources. Likewise, for the slipper lobster resources, East Johor has about 49% of the total East Coast of Peninsular Malaysia slipper lobsters' resources. These high representation of lobster resources in East Johor warrant special management attention to conserve and protect the two lobster resources from further over-exploitations.

Role of Fishery Refugia

The spiny and slipper lobster fisheries in East Johor are high value and important fisheries and involved the livelihood of more than 550 fisherfolks (DOFM, 2018). However, the lobster resources are getting lesser and being over-exploited as indicated from the surveys of this study. As a step to promote better fishery management and to help recover the lobster resources, a fishery refugia is proposed to be established for the lobster fisheries in East Johor waters. The fishery refugia concept is unlike a fully closed marine protected area (MPA), but differ in that it only closes a certain part of the habitat area critical to the life cycle of the intended species (such as during breeding, spawning or migration season) and at a certain period of the year (UNEP, 2007).

Such move can help the recovery of lobster stocks, especially during critical stages of their life cycle such as during migration and spawning periods. The breeding season for spiny lobster begins in July and peaks in late August and the adult lobsters will migrate to deeper offshore water to spawn (Alias *et al*., 2000). However, not much information is available about the details of the location of the spawning area and migration route and further studies and surveys are needed to obtain this information. Also, the practice of releasing berried female lobsters caught by the fisherfolk back to the sea should also be encouraged and promoted by the fishery management as the current practice of taking nearly all sizes of lobster (>100g per individual) as catch is unsustainable (personal observation). Unless some evident management actions are implemented, the spiny and slipper lobsters' resources will continue to be depleted by over-exploitation.

Conclusion

This study indicated that the catch rate of spiny and slipper lobsters was low and in sparse locations. Both the spiny lobster and slipper lobster fisheries in East Johor can be considered as over-exploited as the current stock biomass is less than 40% of the estimated unfished stock size. This situation is worrying since East Johor has about 62% of the total spiny lobsters' resources and about 49% of the total slipper lobsters' resources in the East Coast of Peninsular Malaysia water. Unless some evident management actions are implemented, the spiny and slipper lobsters' resources will continue to be depleted by over-exploitation. A fishery refugium is proposed as a management measure to protect the current lobster populations in East Johor water.

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