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Short communications

Growth of *Nannochloropsis* sp. under Different Light Paths using Light Emitting Diodes (Led) as Source of Light

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Abstract: A study was carried out on flat panel photobioreactors of different light path. The aim of this study is to determine the suitable light path for culture of *Nannochloropsis* at maximum density under illumination of light emitting diodes LED light source. Photobioreactors of different width employed in this study are as follows, 200 mm, 200 mm compartmentalised, 125 mm and 100 mm. The study was carried out in a temperature-controlled environment with photoperiod of 24:0. The experiment was terminated once growth starts to decline. The result showed that the photobioreactor with shorter light path produced higher cell density as compared to the 200 mm and 200 mm compartmentalised photobioreactor. The maximum cell density achieved were $2.33 \pm 15.87 \times 10^8$ cell/ml, $3.46 \pm 15.87 \times 10^8$ cell/ml, $5.06 \pm 14.32 \times 10^8$ cell/ml and $5.07 \pm 7.78 \times 10^8$ cell/ml for the 200 mm, compartmentalised 200 mm, 125 mm and 100 mm light path photobioreactor respectively. The cell density of photobioreactor with 125 mm light path is 117.23 % and it was 46.35 % higher than photobioreactors of 200 mm light path and 200 mm light path with compartment. As for the photobioreactor with 100 mm light path it is 117.70 % and was 46.67 % higher than photobioreactors of 200 mm light path and 200 mm light path with compartment in term of cell density. The overall result clearly shows that higher cell density of the photobioreactor is contributed by shorter light path. The shorter light path enables light to travels further into the culture as compare to the longer light path. This study shows that LEDs is suitable and practical for culture of *Nannochloropsis* in a photobioreactor. However, it could still be further optimised with a little find tuning on mixing and removal of inhibitory factor.

Keywords: Photobioreactor, microalgae, *Nannochloropsis*, light emitting diodes.

Abstrak: Kajian dilakukan pada fotobioreaktor panel rata dengan jarak penembusan cahaya yang berbeza. Kajian ini adalah untuk menentukan jarak penembusan cahaya yang sesuai untuk ternakan *Nannochloropsis* pada kepadatan maksimum di bawah sumber pencahayaan diod pemancar cahaya (LED). Fotobioreaktor dengan ketebalan yang berbeza digunakan dalam kajian ini adalah seperti, 200 mm, reaktor 200 mm yang mempunyai ruang dalam fotobioreaktor, 125 mm dan 100 mm. Kajian ini dilakukan dalam ruangan di bawah kawalan suhu dengan tempoh masa cahaya 24:0. Eksperimen ini dihentikan setelah pertumbuhan mulai menurun. Hasil kajian menunjukkan bahawa fotobioreaktor dengan jarak penembusan cahaya yang lebih pendek menghasilkan kepadatan sel yang lebih tinggi berbanding dengan fotobioreaktor 200 mm dan 200 mm yang mempunyai ruang dalam fotobioreaktor. Kepadatan sel maksimum yang dicapai ialah $2.33 \pm 15.87 \times 10^8$ sel/ml, $3.46 \pm 15.87 \times 10^8$ cell/ml, $5.06 \pm 14.32 \times 10^8$ sel/ml dan $5.07 \pm 7.78 \times 10^8$ sel/ml untuk fotobioreaktor 200 mm, 200 mm yang mempunyai ruang dalam fotobioreaktor, 125 mm dan 100 mm masing-masing. Kepadatan

sel pada fotobioreaktor dengan jarak penembusan cahaya 125 mm adalah 117.23 % dan merupakan 46.35 % lebih tinggi daripada fotobioreaktor dengan jarak penembusan cahaya 200 mm dan jarak penembusan cahaya 200 mm yang mempunyai ruang dalam fotobioreaktor. Bagi fotobioreaktor dengan jarak penembusan cahaya 100 mm, ia adalah 117.70 % dan 46.67 % lebih tinggi daripada fotobioreaktor dengan jarak penembusan cahaya 200 mm dan jarak penembusan cahaya 200 mm yang mempunyai ruang dalam fotobioreaktor dari segi kepadatan sel. Hasil keseluruhan menunjukkan dengan jelas bahawa kepadatan sel yang lebih tinggi pada fotobioreaktor adalah disebabkan oleh jarak penembusan cahaya yang lebih pendek. Laluan cahaya yang lebih pendek membolehkan cahaya bergerak lebih jauh ke kultur berbanding laluan yang lebih panjang. Kajian ini menunjukkan bahawa LED sesuai dan praktikal untuk ternakan *Nannochloropsis* dalam fotobioreaktor. Namun ia masih dapat dioptimumkan dari segi pencampuran dan pengurangan faktor perencanan.

Introduction

Microalgae production has always been an important part of a marine hatchery. It is needed in larviculture for most species. Marine organism larvae feed on the microalgae either directly or indirectly. The most culture green algae, *Nannochloropsis*, is an important species for marine finfishes, it is a source of eicosapentaenoic fatty acid (EPA) (Shene *et al.*, 2016 and Ryckebosch, 2014) for early larvae. However, most of the production methods still rely on outdoor culture tanks with massive volume. These systems produce massive volumes of green water but at low cell density. Outdoor culture system could be affected by weather, sunny days promotes good growth, cloudy days may retard, and sudden change in the weather may cause the culture to collapse. Being outdoor, it is also prone to contaminations which would cause the culture to collapse as well. Such a system also takes up a lot of space and a large volume of seawater. To address the instability issue of algae production culture of outdoor tanks, photobioreactor seems to be a viable solution. Previous studies have demonstrated that *Nannochloropsis* could be successfully cultured in photobioreactor at high density (Quinn *et al.*, 2012; Richmond and Zhang, 2001; Zhang *et al.*, 2001; Zou and Richmond, 1999; Zittelli *et al.*, 1999).

Normally, fluorescent is used as a light source for indoor culture. However, this kind of lighting system is not energy efficient as it produces heat and the light intensity is lower than that of LED. LEDs have been available for some time but mainly in the electronic industry. Recently many companies have produced efficient LEDs which is energy-saving and durable. For example, lighting company such as Philips has produced LEDs suited for horticulture. An earlier study (Lee and Palsson, 1995) has reported the suitability of LED for the culture of *Chlorella vulgaris* (*C. vulgaris*), producing a cell density of more than 2×10^9 cell/ml. A preliminary study by Teoh and Wong (2011) showed that LED was suitable for *Nannochloropsis*. Fu *et al.*, (2012) showed that LED could improve the productivity of *C. vulgaris* up to 20 g dry cell weight per litre of culture media. A few recent studies also confirmed the superiority of LED in microalgae culture that LED could improve the quality and quantity of microalgae biomass (Schulze *et al.*, 2014; Li *et al.*, 2016).

A rectangular flat panel type of photobioreactor is being used in this study. The flat panel photobioreactor has been studied on *Nannochloropsis* for some time and it showed very promising result (Richmond and Zhang, 2001); Zhang *et al.*, 2001). The other kind of design would be that of tubular type (Sandnes *et al.*, 2005). In the current study, the rectangular flat panel is chosen simply because it is cheap to manufacture and easy to clean after each culture cycle, these are among factors of consideration in designing a photobioreactor as outline by Huang *et al.*, (2017). One question that remains unanswered is what is the light path or the width of the photobioreactor that is suitable for

Nannochloropsis under artificial illumination in a temperature control environment, which will be discussed in this article.

Materials and Methods

The Source of Microalgae

Pure stocks of *Nannochloropsis sp.* were from the algae lab in FRI Pulau Sayak. The culture of algae is being maintained in a 250 ml conical flask enriched with Walne-Conway media (Lavens and Sorgeloos, 1996). The 250 ml pure stock was inoculated to a 2-litre conical flask for scale-up, these 2-litre culture will be the inoculant for the photobioreactor. The culture of the 2-litre flask was put under 24 hours photoperiod with aeration enriched with CO₂ gas. Culture of microalgae in photobioreactor was done in a triplicate with warm white LED as the sole light source.

Constituents of The Culture Medium

The stock solution of Walne's medium were as follows: 100 g NaNO₃, 1.3 g FeCl₃·6H₂O; 0.36 g MnCl₂·4H₂O; 33.6 g H₃BO₃; 45 g Na₂·EDTA; 20 g NaH₂PO₄·2H₂O per litre. Trace element: 2.1 g ZnCl₂; 2 g CoCl₂·6H₂O; 0.9 g (NH₄)₆Mo₇O₂₄·4H₂O; 2 g CuSO₄·5H₂O per 100 ml. The vitamins added were 0.001 g Vitamin B12; 0.001 g Vitamin B1 and 0.2 µg Biotin per litre.

Photobioreactors set up, water treatment, illumination and carbon dioxide delivery

The study involved 4 sets of photobioreactors, the first set with a 200 mm light path. The second set of photobioreactor was compartmentalised with a light path of 200 mm, the culture in the reactor was separated by 2 empty spaces in between culture to enable light to pass through and into the culture (Fig.1). The 3rd and last set have a light path of 125 mm and 100 mm. Seawater was filtered with a 10 µm filter bag and treated with sodium hypochlorite at 10 ppm for 24 hours. Illumination was provided by LEDs from both sides of the reactor. Carbon dioxide is provided via the aeration pipeline, photoperiod at 24:0.

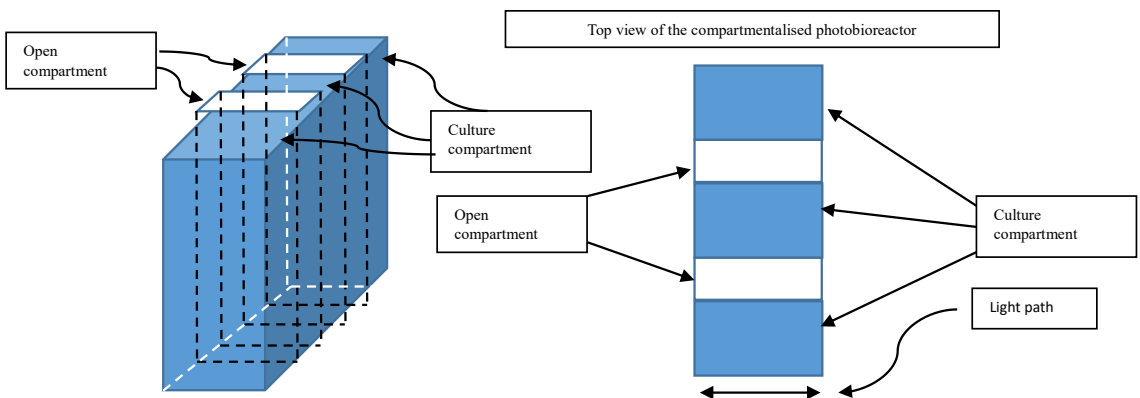


Figure 1: Schematic drawing of a 200mm light path photobioreactor with compartments.

Cell Count Estimation

Cell density was recorded daily by using a Marienfield Improved Neubaur hemacytometer under Olympus microscope (BX41) at 40x magnification. Growth, division per day and generation time were calculated as per the formulas below:

Growth of Microalgae

$$K = \ln(N_2/N_1) / (t_2 - t_1)$$

N₁, N₂ are the cell concentration at given time t₁ and t₂

Division Per Day of Microalgae:

$$\text{Number of division per day} = K/\ln(2)$$

An additional nutrient at quarter strength was introduced once a sharp drop detected in growth. The microalgae culture will be terminated once the culture reaches stationary phase.

Results

The result of the cell density of the 200 mm light path photobioreactor showed that the cell density increased steadily from day of culture (DOC) 1 until it peaked at $2.33 \pm 15.87 \times 10^8$ cell/ml on DOC 13, and density started to decline after (Fig. 2). The number of division per day remained positive between 0.8 to 0.3 from DOC 1 to DOC 13 (Fig. 3). On DOC 14, the increment of cell density as compared to DOC 13 were lower, therefore the value of number of division becomes negative. This means that the culture is in the stationary stage, a rather short one on DOC 13. This culture entered the death stage on DOC 14 which the density of cell started to reduce, with the drop in cell density, number of division per day and growth became negative, the culture is dying, as in Fig. 3 and Fig. 4.

By creating some space in between the culture, it should give some increment in term of cell density as compared to the 200 mm light path photobioreactor without space in between. Just like the first set of photobioreactor, cell density increased steadily and peaked at $3.46 \pm 15.87 \times 10^8$ cell/ml on DOC 13, as in Fig. 2. The number of division per day and the growth value remains on the positive side until DOC 13, as in Fig. 3 and Fig. 4. On DOC 14, cell density in the culture dropped, hence, the growth value and the number of division per day became negative as in Fig. 3 and Fig. 4.

By reducing the light path of the reactor from 200 mm to 125 mm, it would allow better light penetration into the culture, as a result, a higher cell count is anticipated. The result showed that the cell density increased steadily just like the other two photobioreactors but at a bigger magnitude. The cell density peaked at $5.06 \pm 14.32 \times 10^8$ cell/ml on DOC 12 as in Fig. 2.

The cell density of photobioreactor with 125 mm light path was 117.23 % and 46.35 % higher than photobioreactors that of 200 mm light path and 200 mm light path with compartment. As for the photobioreactor with 100 mm light path, it was 117.70 % and 46.67 % higher than photobioreactors that of 200 mm light path and 200mm light path with compartment in term of cell density. The cell density between photobioreactor with a light path of 125 mm and 100 mm were comparable, however photobioreactor with 125 mm light path reached maximum density 2 days earlier as showed in Fig. 2.

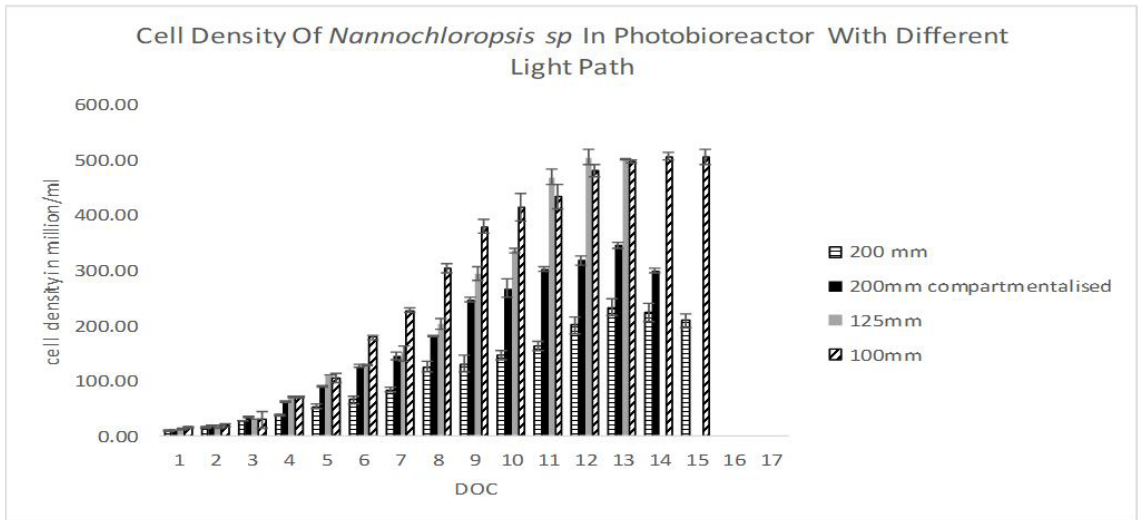


Figure 2: Comparison of cell density of *Nannochloropsis* in photobioreactors at 200 mm, 200 mm compartmentalised, 125 mm and 100 mm light path.

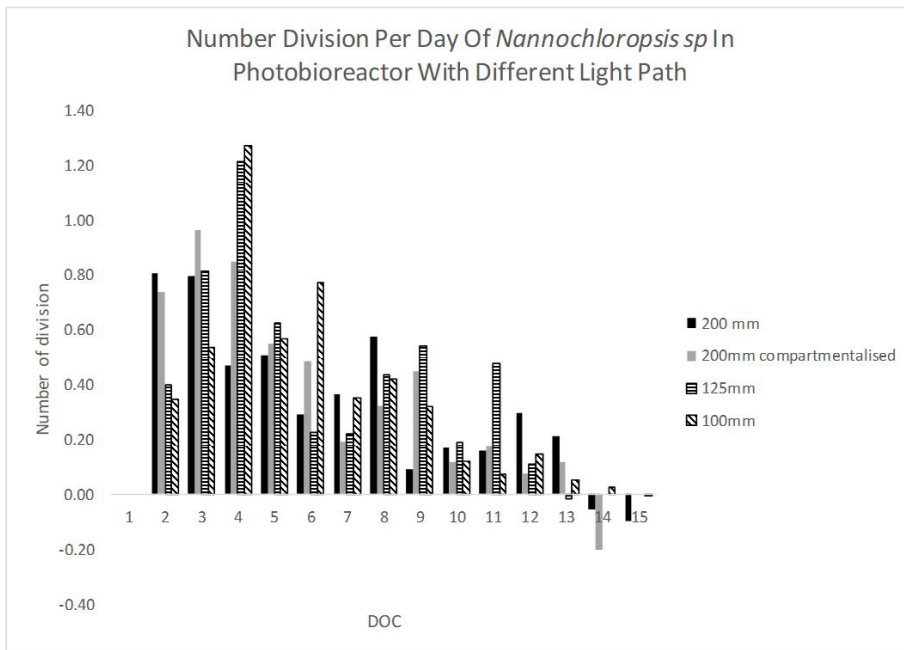


Figure 3: Comparison of the number of division per day of *Nannochloropsis* in photobioreactors 200 mm, 200 mm compartmentalised, 125 mm and 100 mm light path.

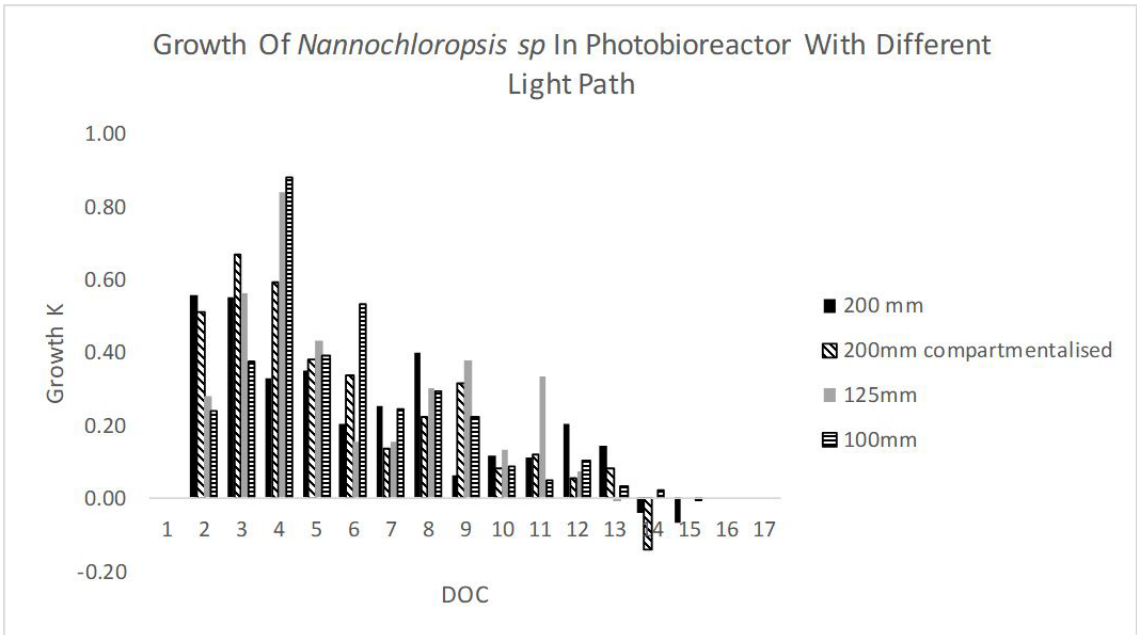


Figure 4: Comparison of growth of *Nannochloropsis* in the photobioreactors at 200 mm, 200 mm compartmentalised, 125 mm and 100 mm light path.

Discussions

The current study is aimed at determining the suitable light path for the photobioreactor with artificial illumination from that of the LEDs. In this study, the maximum cell density achieved was around 5.00×10^8 cell/ml in the 125 mm and 100 mm light path reactors, it is similar to the kind of cell density reported by Zhang *et al.*, (2001) in a 100 mm light path photobioreactor. Other finding showed that the thinner the reactor, the higher the volumetric productivity but a lower overall productivity (Hulatt *et al.*, 2017; Zou, 2000 and Zou and Richmond, 1999) due to reduce in the overall volume of the reactor. On the other hand, the thicker the reactor, the lower the cell density as reported by Taisir *et al.*, (2016) in a column type photobioreactor with a light path of 240 mm, recorded maximum cell density at 7.1×10^6 cell/ml at DOC 14. In the current study, the reactor with a 200 mm light path also faced the same issue of dark volumes in the culture, which impedes growth, resulting in low cell density. This is confirmed by Richmond *et al.*, (2003) that the shorter time for the cell to travel between the dark and light volumes along the optical path, the better the photosynthetic unit turnover time.

Illumination has always been an important factor in productivity of a photobioreactor. In this study, LEDs are used, light is provided to both side of the reactor, it is to reduce any dark zones and to reduce the travel time of the cell from the dark volume to the light volumes. Early studies of LEDs on photobioreactor shown that it is efficient and could support high density growth of *Chlorella* more than 2×10^9 cell/ml (Lee and Palsson, 1994, Lee and Palsson, 1995). Illumination of light from both side of the current 125 mm and 100 mm light path reactor proved to be better than that of 200 mm light path and internally illuminated photobioreactor (Taisir *et al.*, 2016). However, it could be improved by better mixing in the reactor, some report showed that proper mixing could enhance the light utilization (Gupta *et al.*, 2015; Charles *et al.*, 2012, Luo and Al-Dahhan, 2004).

In other studies where the photobioreactors rely on sunlight for high light intensity and abundance, productivity is affected by seasonal (Kim *et al.*, 2016; Olofsson *et al.*, 2012; Zou and Richmond, 1999) and diurnal changes (Silva Benavides *et al.*, 2013; Hu *et al.*, 1998). The use of artificial illumination by LEDs could eliminate these effects.

In the current study, the algae were harvested once at the end of the experiment, no new growth media was introduced. Enrichment was added to enhance growth once the growth slowed down. This may have accumulated some inhibitory compound secreted from the algae and cell wall as documented (Rodolfi *et al.*, 2003; Zou *et al.*, 2000; Richmond and Zou, 1999; Javanmardian and Palsson, 1999) that may retard the growth. It was also reported that frequent removal of an inhibitory compound and cell wall could counteract the inhibitory effect on algae growth. Besides that, hydrodynamics is also an important factor, better mixing improves productivity in a flat panel photobioreactor (Loomba *et al.*, 2018; Ugwu and Hideki, 2012). This is something to be investigated in future studies, so the productivity of the system could be enhanced.

Conclusion

As a conclusion, it has shown that *Nannochloropsis sp.* had adapted well to the flat panel photobioreactor at a thinner light path with the illumination of artificial light from LEDs. The current study has demonstrated that the density achieved is at par with the finding of other authors however some other factors needed to be investigated such as mixing and removal of inhibitory compounds by periodical harvesting and replenish with fresh culture medium.

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Technical communications

Preliminary Study for The Deep-Sea Trap Innovation to Improve the Landings of Commercial Demersal Species in The Northern Region of Sarawak

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Abstract: Conscious of the importance of the latest fishing technology, the innovation of fishing gears is a continuous effort in the fisheries study. As well as the deep-sea trap, a study was conducted in the waters of Miri to determine the construction cost between the conventional and improve deep-sea trap. The study was also done to examine the efficiency of 1-funnel (1F) and innovative (2F) deep-sea trap. The 1F trap is characterised by a 1-funnel entrance, while 2F trap is a 2-funnel entrance trap. A total of 40-unit traps were deployed in this study. Each station was positioned with 2 types of traps and were soaked for 7 days before harvested. The findings suggested that the 2F trap had caught 199 individuals, while 1F trap only caught 140 individuals. Overall, 23 species from 11 families were caught in the 2F trap, however the 1F trap only managed to caught 16 species from 7 families. Moreover, the 2F traps significantly have higher catch effort (CPUE) of 2.61 kg/unit than the 1F trap with CPUE 2.49 kg/unit. The results had revealed that the 2F trap is more efficient than the 1F trap for the development of reef and rock areas fishing and better fishing experience for the local fishermen in the future.

Keywords: Deep-sea trap, one funnel (1F), two funnel (2F), commercial species, CPUE.

Abstrak: Menyedari akan kepentingan teknologi penangkapan ikan terkini, inovasi terhadap alat penangkapan ikan merupakan usaha berterusan dalam kajian perikanan. Begitu juga dengan bubu laut dalam, satu kajian telah dilakukan di perairan Miri untuk menentukan perbezaan kos pembuatan bubu laut dalam konvensional dan yang telah ditambahbaik. Kajian ini juga dijalankan untuk menilai kecekapan bubu 1-injap (1F), konvensional, dan bubu 2-injap (2F), inovatif. Bubu 1-injap mempunyai 1 bukaan manakala bubu 2-injap mempunyai 2 bukaan bagi laluan kemasukan ikan. Sebanyak 40 unit bubu laut dalam dilabuhkan dalam kajian ini. Setiap stesen diletakkan dengan 2 jenis bubu laut dalam dan dibiarkan selama 7 hari sebelum dituai. Hasil kajian menunjukkan bahawa bubu 2F telah menangkap 199 individu, sementara bubu 1F hanya menangkap 140 individu. Secara keseluruhan, 23 spesies dari 11 keluarga terperangkap dalam bubu 2F, namun bubu 1F hanya berjaya menangkap 16 spesies dari 7 keluarga. Tambahan pula, bubu 2F mempunyai keupayaan tangkapan (CPUE) yang lebih tinggi sebanyak 2.61 kg/unit daripada 1F dengan CPUE 2.49 kg/unit. Hasil kajian mendapati perangkap 2F lebih cekap berbanding perangkap 1F bagi pembangunan kawasan tukun dan batu serta pengalaman menangkap ikan yang lebih baik untuk nelayan tempatan pada masa akan datang.

Introduction

The innovation of fishing gear is continuously performed to provide a better fishing experience by taking into account the quality and quantity of landings. A new technology will change the way of fishermen's fishing routine. According to Mazuki and Man (2014), fishermen required two types of technology, which are capture technology and information and communication technology. Having these technologies, will gives rise to the fishing activities and fishermen themselves.

As well as the deep-sea trap, improvement is required to enhance the fishermen's opportunity to explore deep-sea trap fishing in Sarawak waters. Trap has been one of the major fishing gears among the fisherman in Sarawak, namely Kuching, Mukah and Miri, and in Labuan waters to catch fish and crustaceans such as lobster, shrimps, crabs and squid. As stated by Chande *et al.*, (2019), traps have higher species counts per day. Sarawak in 2019 has licensed 18 vessels operating the deep-sea trap fishing (DOF, 2020) and is expected more in the near future. However, based on the communication with the fishermen previously, the conventional deep-sea trap is expensive and difficult to construct. In addition, no regulation regarding the design of trap have been gazette by the management recently to facilitate deep-sea fishing.

The traditional trap normally has one funnel. Literally, the primary function of trap is to encourage a volunteer entry in such a manner that the entrance act as an escape-prohibitor device. Therefore, this research was focused on the design improvement for the ease of construction and fishing experience development. The innovative plan to is to install the deep-sea trap with two funnels (2F) to promotes double entrance of fish, besides constructs at a low cost and less laborious for the convenience of local fishermen in Sarawak. This study is also an advantage to enhance fishermen contribution and encourage fishing effort towards expanding demersal fishing in the reef and rock areas.

Materials and Methods

Boat and Gear Design

The traps were initially constructed. The trap frame was made of iron (BRC 4 mm), which was used to shape the upper and lower part. The body was wrapped with wire netting with 1 1/2 inches mesh size. The traps shape design was nearly a quadrangular, fixed and unfolded with 1.8 m length, 1.2 m width and 0.6 m height. The trap top was covered with branches to attract fishes and to prevent the growth of barnacles. During operation, the traps were loaded and transported using a small boat (3-4 GRT). The number of traps carried onboard was depends on the boat size. The innovative traps were made of the same materials and size, but constructed with two funnels (Fig. 1).

Operation

The research was conducted during broad daylight in Miri, Sarawak for five months. The research locations were marked in Fig. 2, conducted within one quadrat with the same environmental condition. The coastal area distance is estimated at 3 to 8 nautical miles, with the survey area of 50 km² and depth between 15 and 30 meters. A total of 40 units deep-sea traps comprising of 20 units 1F and 20 units 2F were deployed in this study. Every station was placed with these two units of traps. Both trap types were left to soak for seven days at each point before harvest. The catch information was recorded in the fishing log sheet. The catch composition and CPUE were analysed using Microsoft Excel 2019. The results were further evaluated using a software IBM SPSS Statistics via Independent Sample T-Test.



Figure 1: Left: Trap one funnel (1F); Right: Trap two funnels (2F).

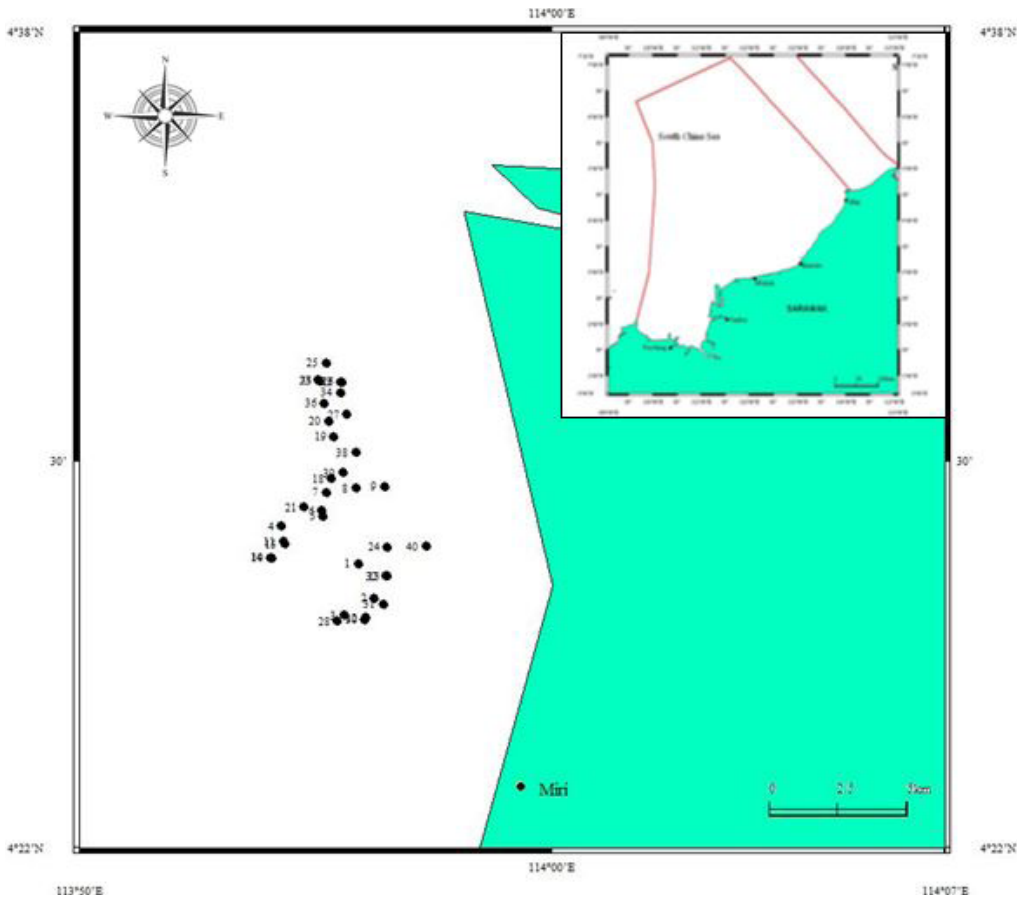


Figure 2: The positioning location of the deep-sea traps in Miri.

Results

Table 1: Species caught by 1F and 2F traps.

Family	Species	1F	2F
Lutjanidae	<i>Lutjanus Vitta</i>	24	36
	<i>Lutjanus Argentimaculatus</i>	18	22
	<i>Lutjanus Johnii</i>	18	21
	<i>Lutjanus Madras</i>	9	13
	<i>Lutjanus Malabaricus</i>	8	12
	<i>Lutjanus Gibbus</i>	11	1
	<i>Lutjanus Coioides</i>		1
Palinuridae	<i>Panulirus Polyphagus</i>	19	40
Serranidae	<i>Epinephelus Coioides</i>	11	15
	<i>Epinephelus Malabaricus</i>	4	9
	<i>Epinephelus Amblycephalus</i>	2	
	<i>Epinephelus Sexfasciatus</i>	2	
Portunidae	<i>Charybdis Cruciata</i>	4	3
	<i>Portunus Pelagicus</i>	2	2
Carangidae	<i>Elagatis Bipinnulata</i>	3	1
	<i>Caranx Sexfasciatus</i>		7
Caesionidae	<i>Caesio Caerulaurea</i>	2	1
	<i>Caesio Cuning</i>		4
Nemipteridae	<i>Nemipterus Hexodon</i>	3	2
	<i>Nemipterus Tambuloides</i>		1
Tetraodontidae	<i>Arothron Hispidus</i>		2
	<i>Arothron Manilensis</i>		1
Dasyatidae	<i>Taeniura Lymma</i>		2
Ephippidae	<i>Platax Tiera</i>		2
Haemulidae	<i>Diagramma Pictum</i>		1
Total		140	199

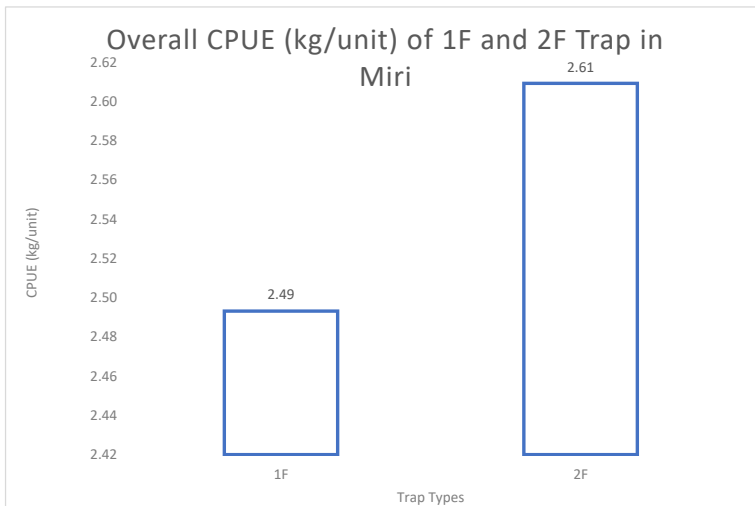


Figure 3: The CPUE difference between 1F and 2F trap. The 2F trap portrayed higher effort than the 1F trap.

Analysis of the catch composition based on the two trap types indicated that the 2F trap dominated the catch. A total of 339 individuals which contained 26 species were caught. Among that, 140 individuals comprised of 16 species were from 1F trap and 199 individuals comprised of 23 species were from 2F trap (Table 1). It was also found that the 1F and 2F trap attracted an amount of 7 and 11 families respectively.

Both trap types caught three dominant families which were Lutjanidae, Palinuridae and Serranidae, and showed that the 2F trap caught more fishes in each of the families recorded. For Lutjanidae, the individuals caught in the 1F and 2F trap were 88 and 106 respectively, Palinuridae caught 19 and 40 correspondingly, while Serranidae caught 19 and 24 accordingly. Other families mention in Table 1 such as Portunidae, Carangidae, Caesionidae, Nemipteridae, Tetraodontidae, Dasyatidae, Ephippidae and Haemulidae were also mostly caught by the 2F trap. The catch rate for 1F trap was 2.49 kg/unit lower than the 2F trap with 2.61 kg/unit (Fig. 3) and was differed significantly between trap types ($p < 0.05$).

The conventional deep-sea trap (Appendix 1) affected the income of fishers in Sarawak. This is due to the expensive construction material that involved moulding, which cost approximately RM 400-500. Alternatively, the improved deep-sea trap is a new approach to reduce the construction cost at about RM 100-150. A socioeconomic explanation was tabulated to distinguish the fishermen income based on the landing's differences between the 1F and 2F trap (Table 2).

Table 2: Average cost of operation and fishes sold for 1F and 2F deep-sea trap.

Aspect	1F	2F
Average CPUE (kg/unit)	2.49	2.61
Operation Cost/Trip/Day (RM)	120	120
Average Income* (RM)	1,700	1,800
Net Profit/Day (RM)	1,580	1,680

*Total deep-sea trap harvested per day is around 20 units.

Discussions

The current study showed that the 2F trap effectively increased the fish encounter rates by installation of two funnels. It was significantly possessed better performance than the 1F trap, indicated by the higher CPUE at 2.61 kg/unit. The possible explanation was the double entrance of fish from the two funnels rather than a single entrance from one funnel.

Species belonging to the families Lutjanidae, Palinuridae and Serranidae were the mostly caught for both trap types, reflecting that they represent the commercially most important species for Malaysian artisanal fisheries (DOF, 2019). The appearance of *Lutjanus spp.* and *Epinephelus spp.* were also observed in various studies of trap fishing previously done by Tuda *et al.*, (2016), Moran and Jenke (1990) and Williams *et al.*, (1997). Instead of 1F, the 2F trap was dominated by these commercial species. Verbally, according to the fisherman, the 2F trap has brought a positive impact to the landings, where high quality species could be captured. Besides, with the use of 2F trap, the fishermen income could be enhanced by the increase of commercial fish caught rather than the 1F trap.

Following research on this aspect, a pilot project for the 2F trap could be considered to determine its viability in fisheries, including depths, locations and fishing grounds before future comprehensive research on the fishing ground more than 200 metres SEAFDEC (2010).

This study did not consider the environmental condition and monthly sampling, which would have depicted a better 2F trap fishery in Sarawak. Thus, the results were interpreted with these limitations. Hence, we recommend that future studies should contemplate those parameters that were not in this study to portray fishery description using the 2F trap.

Conclusion

This study has successfully designed an innovative fishing gear that is more efficient in operation by increasing the landings of the demersal commercial species, which would increase the income among the local fishermen of Sarawak.

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Appendix 1



Conventional deep-sea trap of Sarawak

Spatial Distribution of Ornamental Fish Farming and Off-Farm Employment in Kluang Johor Using Geographic Information System (GIS)

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Abstract: Ornamental fish farming is the culture of attractive, colourful fish which are reared in a constrained aquatic system. Fishkeeping is a popular hobby, practised by aquarists, concerned with keeping fish in a home aquarium or garden pond. The possibility for further expansion of the industry in Malaysia is broad, especially in the export and import sector. Nevertheless, exporting activities of certain ornamental fish species are banned due to export restrictions made by the European Union (EU) since 2015, scopes covering on-farm management of aquatic animal health. The Fisheries Bio-security Division (FBD) has developed a system known as BioDOF-Map (Fisheries Biosecurity Control Management System) containing a spatial database of the compartmentalized farm to help the FBD respond to the DG SANTE- CAR being driven by EU. The objective of this study was to map on-farm and off-farm employment carried out by the farmers based on several factors; the location of farm, houses and nearby towns. Interviewed was designed and involved 25 ornamental aquaculture farms in Kluang. The mapping was supported by the designed compartmentalisation and zoning system using Geographic Information Systems (GIS). The unification of both raster and vector data was used to discover the spatial characteristics of farming activities spatially. Respondent's socio-economic profiles were described by descriptive analysis. The relationship between fish farming and independent variables were cross-tabulated and chi-square analysis was used to test the null hypothesis of the study. The majority of the farmers were male and married, 40.8% aged 41-50 years old and 51.6 % had secondary education level (Malaysian Higher Certificate or SPM). About 10 (42.5 %) of the respondents had an aquaculture farm-scale of more than 10 hectare. The average total of farm production is about 2 million a year. High demand on goldfish (29 %) tiger barb (8 %) and other fish variety (2 %) has caused the breeders to raise these fish. The study shows that there is a relationship between farming activity and age, education level, total of production and income. The spatial analysis shows that most of the farmers live less than fifteen (15) kilometres from town to house and farm. To increase the participation of farmers in off-farm employment, policy should be formulated by the government to increase the availability of off-farm jobs in the vicinity of the farmer's community.

Keywords: GIS, Fisheries Bio-security, Ornamental Fish, BioDOF-Map system, off Farm employment.

Abstrak: Penternakan ikan hiasan adalah ternakan ikan cantik dan berwarna-warni yang ditenak dalam sistem akuatik yang terhad. Memelihara ikan adalah hobi yang popular, yang diamalkan oleh peminat ternakan akuatik, samaada di akuarium atau kolam taman di rumah. Kemungkinan pengembangan industri di Malaysia lebih luas terutamanya eksport ikan hiasan. Walaupun begitu, aktiviti pengeksportan beberapa jenis spesies ikan hiasan terhenti kerana sekatan eksport yang dibuat oleh Kesatuan Eropah (EU) sejak 2015, yang merangkumi pengurusan ladang kesihatan haiwan akuatik. Bahagian Biosekuriti Perikanan (FBD) telah membangunkan sistem yang dikenali sebagai

BioDOF-Map (Sistem Pengurusan Kawalan Biosekuriti Perikanan) yang terdiri daripada pangkalan data ruang (spatial) ladang untuk membantu FBD memberi maklumbalas kepada DG SANTE-CAR yang digerakkan oleh EU. Objektif kajian ini adalah untuk memetakan lokasi kerja (ladang ternakan ikan) dan kerja selain bidang ladang ternakan ikan oleh penternak berdasarkan beberapa faktor; lokasi ladang, rumah dan bandar berdekatan. Survei telah dijalankan ke atas 25 petani ladang akuakultur di Kluang, Johor. Pemetaan ini disokong oleh sistem kompartmen dan pengezonan yang dibangunkan dengan menggunakan Sistem Maklumat Geografi (GIS). Penggabungan kedua-dua data raster dan vektor digunakan untuk mengetahui ciri-ciri spasial pada aktiviti penternakan. Profil sosio-ekonomi responden dianalisis dengan analisis deskriptif. Hubungan antara penternakan ikan dan pemboleh ubah bebas adalah taburan silang dan analisis chi-square digunakan untuk menguji hipotesis null kajian. Sebilangan besar penternak adalah lelaki dan berkahwin, 40.8 % berumur 41-50 tahun dan 51.6 % mempunyai peringkat pendidikan menengah (Sijil Pelajaran Malaysia atau SPM). Kira-kira 10 (42.5 %) responden mempunyai skala ladang akuakultur melebihi 10 hektar. Rata-rata jumlah pengeluaran ladang adalah sekitar 2 juta setahun. Permintaan tinggi terhadap ikan emas (29 %), ikan tiger barb (8%) dan jenis ikan lain (2 %) telah menyebabkan penternak menternak ikan-ikan ini. Kajian menunjukkan bahawa terdapat hubungkait antara aktiviti pertanian dengan usia, tahap pendidikan, jumlah pengeluaran dan pendapatan. Analisis spasial menunjukkan bahawa kebanyakan penternak menginap kurang daripada lima belas (15) kilometer dari bandar ke rumah dan ladang. Untuk meningkatkan penyertaan penternak dalam pekerjaan di luar ladang, kerajaan harus meningkatkan peluang pekerjaan di luar ladang di sekitar masyarakat penternak.

Introduction

The Malaysia fisheries industry plays a critical role in economic development and also a source of employment, foreign exchange and protein supply for the country. Principally, the Malaysian fisheries industry is detached into three main sub-sectors aquaculture, marine capture fisheries and inland capture fisheries. The fisheries industry in Malaysia is governed by the Department of Fisheries (DOF) under the Ministry of Agriculture and Food Industry (MAFI). DOF is known as the national Competent Authority (CA) responsible for all matters involving live fish, which DOF has jurisdictions over all matters related to living fish. In the year 2016, the fishery industry (aquaculture, marine capture fisheries and inland fisheries) produced 2.06 million tonnes of fish; an increase of 3.7 per cent compared to 2015 (1.99 million tonnes). It contributed RM10.1 billion to the national economy, compared to RM 9.3 billion in 2015, an increase of 9.24 %. Hence, in 2016 alone, the catchment and aquaculture sector accounted for 1.57 million tonnes and 490,027 tonnes of fish production. The total value contributed by the fisheries industry in 2016 was RM13 billion (Annual Fisheries Statistics, 2017).

The ornamental fish culture sector contributed to the global economy with an excessive turnover of billions of dollars yearly as ornamental fish keeping is one of the most popular hobbies in the world. The ornamental fish industry involves more than 120 countries in term of the collection, breeding, import and export of ornamental fish. The industry has big potential in creating job opportunities besides develop extremely large profit for the national treasury. Otherwise, the current global market for ornamental fish in the world for public aquaria is less than 1 % at present and over 99 % for the ornamental fish market is limited to hobbyist group. There is progressive interest in the ornamental fish industry especially from African and Asian countries. The top exporting country was Singapore followed by Hong Kong, Malaysia, Thailand, Philippines, Sri Lanka, Taiwan, Indonesia and India (Shabir *et.al.*, 2018).

The European Union (EU), accordingly, is the largest market for ornamental fish. The ornamental industry in Malaysia is doing well until the issuance of non-compliance with a requirement, standard or procedure needed by the EU. Corrective Action Request (CAR) was received based on the DG (SANTE) / 2015-7562 audit on 09th March to 17th March 2015 specifically, in monitoring the assessment of health control on aquaculture animals in aquaculture farms for export purposes. Therefore, this restriction has negatively affected the breeders and the export value. Fisheries Biosecurity Division (FBD) was established to control and manage fish health and food safety, particularly for fish and fishery products. To escape from EU sanctions, FBD carries out the role of fishery biosecurity in responding to an EU-issued audit using the Geographic Information System (GIS). Plumb (1992) stated that Bio-security or “hazard reduction through environmental manipulation”, is often defined as practices that reduce the number of pathogens that enter a facility.

Bio-security is the concept of protecting cultural animals from contamination by diseases and of preventing the spread of diseases across boundaries, which has become increasingly important with the intensification of aquaculture production systems (Sachin *et al.*, 2018). The year 2018, has witnessed the development of BioDOF-Map (Fisheries Biosecurity Control Management System) which is a system contains the non-spatial dan spatial data of the registered farm with DOF. The development of the system itself has helped the FBD to control the farm in terms that cover on-farm management of aquatic animal health. To identify the farmers, farm and spatial variables of farming activities, it needs a lot of precision, well managed and updated data gathered from various sources. This can be done with a simple database (Ruslan *et al.*,1998). The integration of spatial and non-spatial data has been a great issue (Walid and Samet H.,1995). With the development of GIS, users will be able to insert, manage, manipulate, analyse and present data related to geography or spatiality completely. Hence, Ruslan *et al.* (1998) found that both spatial and non-spatial data are important in the GIS and must be updated precisely to make it valuable to the user.

Particularly, the objective of this study was to examine the spatial characteristic variables in terms of management of aquatic animal health of 25 ornamental aquaculture farmers in Kluang using GIS spatial analysis, based on the BioDOF-Map system. The overall target at the end of this project, Malaysian ornamental industry will be free from the export restrictions and this paper will focus on on-farm employment, spatial characteristics and off-farm employment of the ornamental fish farmers in Kluang.

Materials and Methods

The research on the distribution of on and off-farm activities of ornamental fish farmers at Kluang was done through the survey. Johor is presently having the highest number of ornamental fish exporter in Malaysia. BioDOF-Map system was used as a source of collected data to propose a simplified statistics as an indicator of an area or a country. Ornamental fish farmers at Kluang were assumed to have different preferences of which off-farm activities they would choose. Therefore, this study was conducted to determine the decision making of ornamental fish farmers in Kluang towards a wide range of off-farm activities they like most to increase their income. However, their decision making whether to participate in off-farm employment or not are affected by non-spatial structural characteristics including personal characteristics, fish farm characteristics and spatial characteristics.

On the other hand, the relationship between off-farm work and a fish farm’s economic performance indicates that a farm household’s dependence on off-farm income affects the distributional consequences of agricultural policies in a country. In the terms of spatial analysis, spatial referencing

data allows the data gathering on different geographical stages such as election area, infrastructure services area, posting area or area that has postcode. Timing in research is very important, as the GIS project timing may take some period with a high cost, about 80 % from the project sources (Ruslan, 1996). Hence, GIS analysis and the usage need to be done earlier to make the data useable.

In this study, the spatial data obtained were analysed and the distribution of data was designed with creating a complicated database. The database model for spatial data needs a specific data model where it can only be found in GIS, vector model and raster model.

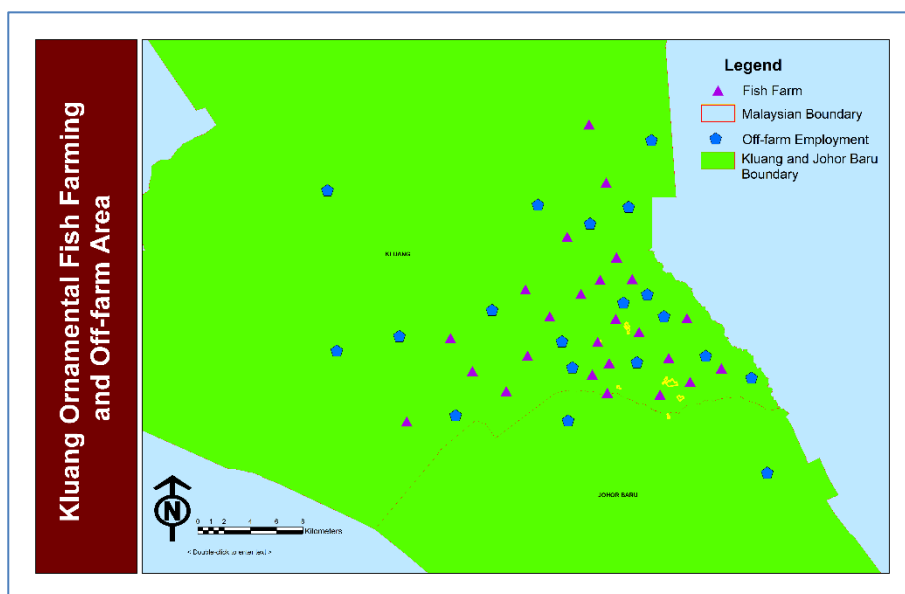


Figure 1: Kluang ornamental fish farming and off-farm area.

Sampling Design and Data Collection

In this research, the sample were the ornamental fish farmers households of an ornamental fish farm of Kluang and the sampling characteristics of the population of interest are the ornamental fish farmers who engaged or not engaged in off-farm employment. The study was targeted at ornamental fish farmers who participated or not participated in off-farm employment, the respondents were confined to the Department of Fisheries, Malaysia. The Census sampling method was used for selecting the representatives of farmers in Kluang. A structured questionnaire was used to interview 25 respondents, aimed to determine the recent status of off-farm employment among the fish farmers. The questionnaire consists of structured questions and was divided into two forms, dichotomous choice and multiple categories questions. The dichotomous choice questions offer just two answer choices, yes or no. And the multiple categories questions have more than two answers choices.

Descriptive Analysis

SPSS 25.0 were used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. This technique is used to describe the characteristics of the variables in terms of the frequencies and the percentage of distribution of the surveyed data. It also aids to make comparison among the variables. This analysis will include a summary derived from samples that will be used to illustrate the data graphically, which gives clear descriptions concerning the unvaried questions and the hypothesis of the variables. The descriptive analysis was used to

describe the respondents' perception of off-farm employment and the factors that determine engaging in off-farm activities.

Spatial Analysis

Spatial analysis is a process of looking at geographical patterns in the data and the relationships between the features. It is a research paradigm that provides a unique set of techniques and methods for analysing events in a very general sense that are located in geographical space. In a more restricted sense, spatial analysis is the technique applied to structure the human scale, most notably in the analysis of geographic data. The demographic data in the study were collected in spatial context and methods of analyses of spatial data include data description, map interpolation, exploratory data analyses (including descriptive statistics), explanatory analyses, and confirmatory data analyses (statistical inference, development and testing of models). The results of spatial analysis are depending on the locations of the objects being analysed. ArcGIS 13.0 software was used to implement spatial analysis techniques that require access to both the locations of objects and their attributes. Spatial analysis in the study was done based on a data set in which each observation is referenced to Kluang on respondents' house location, farm and off-farm activity's location.

Multivariate Analysis

Multivariate analysis is a set of statistical techniques used for the analysis of data that contain more than one variable. Multivariate analysis is used to study more complex sets of data than univariate analysis methods can handle. This type of analysis is almost always performed with software (i.e. SPSS or SAS), as working with even the smallest of data sets can be overwhelming by hand. Plus, multivariate analysis can reduce the likelihood of Type I errors. Thus, univariate analysis is preferred as multivariate techniques can result in difficulty interpreting the results of the test.

Results and Discussions

The descriptive analysis was used to discuss the involvement of respondents in off-farm employment, distance to the nearest town and the relationship between them. Spatial analyses were done to get the geographic location between paddy farmer's house, on and off-farm location including distance to the nearest town.

Descriptive Analysis Results

The majority of the farmers were male and married, 40.8 % aged 41-50 years old and 51.6 % had secondary education level at Malaysian Higher Certificate (SPM). About 10 (42.5 %) of the respondents had an aquaculture farm-scale of more than 10 ha. The average total of farm production is about 2 million a year. High demand on goldfish (29 %), tiger barb (8 %) and other fish variety (2 %) had caused the breeders to raise these fish.

Off-farm Employment Participation of The Respondents

In Kluang, 64.0 % of the respondents participated in off-farm employment, while 36 % of the respondents did not participate in any kind of off-farm employment. From the result below, we can see that farmers in Kluang preferred to participate in off-farm employment.

Type of off-farm Employment

In Kluang, 36.0 % of the respondents participated in oil palm plantation; 12.0 % work independently, 12.0 % involved in other types of agriculture and private company job and 36.0 % of the respondents did not participate in any kind of off-farm employment. From the analysis, we can

see that total of 16 out of 25 respondent farmers in Kluang participated more in off-farm employment, especially related to agricultural activities including livestock rearing and other farming activities.

Spatial Analysis

Distance from Home to Off-farm Type

In Kluang, it showed that 44.0 % of off-farm activities participants involved in agriculture, and 20.0 % involved in non-agriculture (Table 1 and Figure 2). The majority of respondents, who involved with off-farm employment lives less than 10 kilometres from their home.

Table 1: Distance of home and the type of off-farm activity.

Type of Off-farm Job	n (25)	Percentage	Off-farm Activity
Aquaculture Only	9	36.0 %	No off-farm Activity
Less than 10 km	10	40.0 %	Oil Palm
11 to 20 km	4	16.0 %	Non-Agriculture and Private Company Job
21 to 30 km	1	4.0 %	Agriculture
More than 31 km	1	4.0 %	Own Job

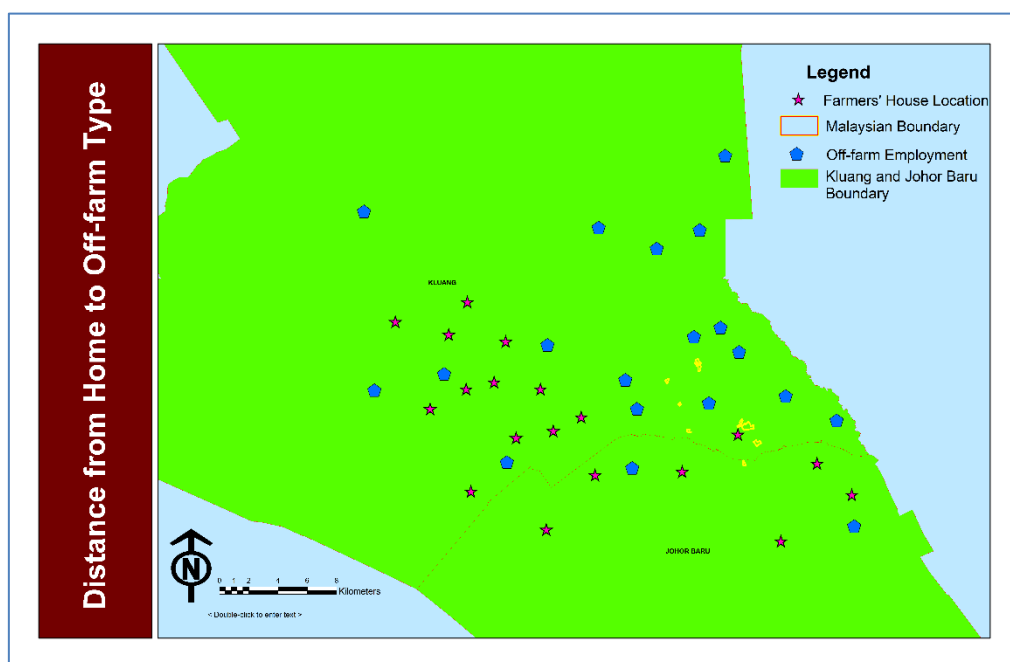


Figure 2: Distance from home to off-farm type.

Distance from Home to The Ornamental Fish Farm and Off-farm Type

Table 2 and Figure 3 below show the relationship between distance from home to the ornamental fish farm and their types of off-farm activity. 36.0 % of ornamental fish farmers who participated in agriculture as their off-farm activities were located less than 10 kilometres distance to their fish farm. 16.0 % of ornamental fish farmers who participated in non-agriculture and private company job as off-farm activities were located within 11 to 20 kilometres distance to their fish farms. 8.0 % of ornamental fish farmers who participated in Agriculture job as their off-farm activities were located more than 21 kilometres to 30 kilometres distance to their fish farms and home and 4.0 % of

ornamental fish farmers who participated in their job were located less more than 31 km from their fish farms and home. From this result, it can be concluded that house location has a positive effect on the participation in aquaculture and off-farm employment, especially in agriculture activities. Fish farmers who live near the ornamental fish farm will probably choose to do other agriculture activities because of their interests and the distance between locations do affect travelling time nor increase income.

Table 2: Distance from home to ornamental fish farm and off-farm type.

Type of Off-farm Job	n (25)	Percentage	Off-farm Activity
Aquaculture Only	9	36.0 %	No off-farm Activity
Less than 10 km	9	36.0 %	Oil Palm
11 to 20 km	4	16.0 %	Non Agriculture and Private Company Job
21 to 30 km	2	8.0 %	Agriculture
More than 31 km	1	4.0 %	Own Job

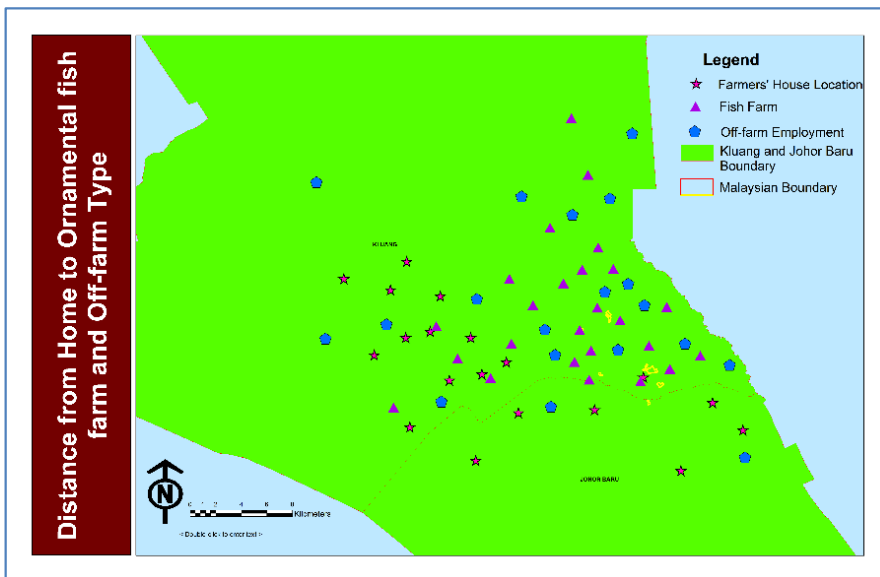


Figure 3: Distance from home to ornamental fish farm and off-farm job.

Distance from Home to The Nearest Town and Off-farm Type

Figure 4 below shows the relationship between distance from home to the nearest town and their type of off-farm job. The study showed that 52.0 % of ornamental fish farmers who participated in agriculture, non-agriculture, and private company job as their off-farm activities live less than 5 km from the nearest town and off-farm jobs. About 40.0 % who involved in aquaculture lives 6 to 10 km from home and off-farm job and 8.0 % who involved in aquaculture lived more than 11 km distance to the nearest town and off-farm job.

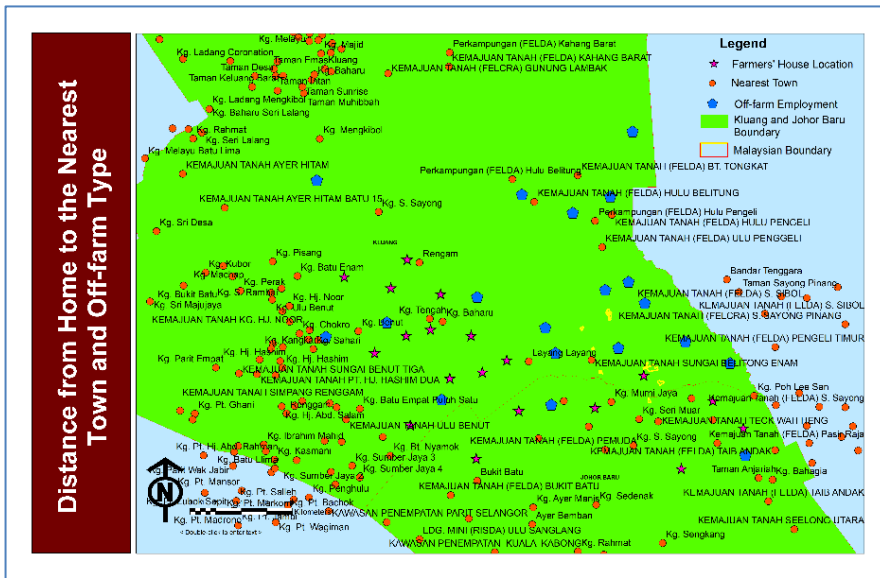


Figure 4: Distance from home to the nearest town and off-farm type.

Multivariate Tests

The result from the table shows that a “Sig.” value of .000, which means $p < .0005$. Therefore, we can conclude that this farmer’s involvement in off-farm employment was significantly dependent on which location of their farm located ($p < .0005$).

Multivariate Testsd

Effect	Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
Intercept	.989	2435.089a	2.000	56.000	.000	.989
	.011	2435.089a	2.000	56.000	.000	.989
	86.967	2435.089a	2.000	56.000	.000	.989
	86.967	2435.089a	2.000	56.000	.000	.989
Location	.616	12.681	4.000	114.000	.000	.308
	.450	13.7365a	4.000	112.000	.000	.329
	1.075	14.782	4.000	110.000	.000	.350
	.915	26.072o	2.000	57.000	.000	.478

a. Exact statistic.

b. Computed using alpha = .05.

c. The statistic is an upper bound of F that yields a lower bound on the significance level.

d. Design: Intercept + Location.

There was a statistically significant difference in farmers involvement in off-farm employment based on which location of their farm located, $F(4, 112) = 13.74, p < .0005; \Lambda = 0.450, \text{partial } \eta^2 = .33$.

Conclusion

This study showed that off-farm employment is an alternative strategy and has a good potential to improve the income and wellbeing of the ornamental fish farmers in Malaysia. So, the process of identification of on-farm and off-farm employment locations and other spatial characteristics becomes easier. The embargo of goldfish and koi carp fish by the European Union (EU) in 2015 does affect

the overall industry. To overcome the matter, the FBD developed the BioDOF-Map system which comprises the spatial and non-spatial data on the ornamental fish farmers. It is well-proven, with the help of BioDOF-Map system, there is so much more information that can be obtained and manipulated by the Malaysian government to help improve the current policy and use as an important input in strategic plans especially in terms of aquaculture and agriculture.

Acknowledgement

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Biological Aspect and Population Parameters of Kawakawa (*Euthynnus affinis*) in Tok Bali Fish Landing Ports, Kelantan, Malaysia

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Abstract: Kawakawa or scientifically known as *Euthynnus affinis* is one of the commercially important neritic tuna captured in Malaysia. This species is mainly captured by purse seine particularly in the east coast of Peninsular Malaysia. The objectives of this study were to investigate some biological aspects especially on maturity stages in estimating the spawning season and to identify the population (growth and mortality) parameters as well as exploitation level of this species in Tok Bali, Kelantan. A total of 2,295 *E. affinis* from LKIM Tok Bali were collected from February 2017 to November 2018 and comprised of 55 % male, 39 % female and 6 % juveniles, with sex ratio male to female is 1.4: 1.0. Only 45 % of samples had reached the mature stage (Stage III, IV and V). The gonadosomatic index (GSI) for all stages of *E. affinis* was in a range of 0.01 to 7.2, while GSI for mature *E. affinis* ranged from 0.59 to 12.48. The spawning season may occur between April to June as the highest GSI values were recorded within these months. The overall samples were in a length range of 234 to 525 mm, with 3 dominant modes at 265 mm, 330 mm and 435 mm which indicated at least 3 cohorts of *E. affinis* at the study area. The length-weight relationship for this species is $W = 0.0000056 FL^{3.192}$, demonstrated the positive allometric growth when b value larger than 3. UDUPA analysis showed the length at first maturity (L_m) for male and female *E. affinis* was 426.3 mm and 393.3 mm, respectively. The ELEFAN 1 and Length Converted Catch Curve (LCCC) incorporated in the FAO-ICLARM Stock Assessment Tools (FiSAT) software was used to obtain population parameters, i.e. asymptotic length (L_∞) = 549.15 mm, growth coefficient (k) = 0.16 year⁻¹, theoretical age at length zero (t_0) = 1.14, growth performance index (α') = 4.6835, total mortality coefficient (Z) = 0.62 year⁻¹, natural mortality (M) = 0.25 year⁻¹, fishing mortality (F) = 0.37 year⁻¹, current exploitation rate (E) = 0.60 and length at first capture (L_c) = 402.78 mm. *E. affinis* demonstrated a continuous recruitment pattern throughout the year with two major peaks in recruitment were observed in both female and male kawakawa. The relative yield per recruitment (YPR) analysis predicted the maximum allowable limit of exploitation (E_{max}) was 0.629 and the optimum limit of exploitation $E_{0.1}$ was 0.504. While the current E (0.6) is less than predicted E_{max} but exceed the value of $E_{0.1}$. Thus, it can be concluded the exploitation level of kawakawa in Tok Bali, Kelantan is optimum to fully exploited level.

Keywords: Kawakawa (*Euthynnus affinis*), Gonadosomatic Index (GSI), spawning season, population parameters, exploitation level, Tok Bali.

Abstrak: Kawakawa atau dikenali dengan nama saintifik sebagai *Euthynnus affinis* adalah salah satu dari spesies ikan tuna neritik yang penting yang ditangkap secara komersial di Malaysia. Kebanyakan spesies ini ditangkap oleh peralatan pukat jerut terutamanya di Pantai Timur Semenanjung Malaysia. Kajian ini bertujuan untuk menyelidiki beberapa aspek biologi terutamanya tahap kematangan gonad dalam menganggarkan musim bertelur, dan untuk mengenal pasti parameter

populasi (pertumbuhan dan kematian) yang mana status eksploitasi semasa spesies ini di Tok Bali, Kelantan juga dapat diketahui. Sebanyak 2,295 ekor *E. affinis* diperolehi dari jeti Lembaga Kemajuan Ikan Malaysia (LKIM) Tok Bali bermula Februari 2017 hingga November 2018 yang terdiri daripada 55 % jantan, 39 % betina dan 6 % juvenil dengan nisbah jantina antara jantan dan betina adalah 1.4:1.0. Hanya 47 % sampel yang mencapai kematangan (Tahap III, IV dan V). Indeks gonadosomatik (GSI) untuk semua peringkat kematangan *E. affinis* berada pada julat 0.01 hingga 7.2, sementara GSI untuk *E. affinis* yang matang berada dalam julat 0.59 hingga 12.48. Musim bertelur dianggarkan pada bulan April hingga Jun kerana nilai GSI tertinggi dicatatkan pada bulan-bulan ini. Sampel keseluruhan berada pada julat panjang 234-525 mm, dengan tiga mod yang dominan iaitu pada 265 mm, 330 mm dan 435 mm yang menunjukkan sekurang-kurangnya terdapatnya tiga kohort *E. affinis* di kawasan kajian. Hubungan panjang berat untuk spesies ini ialah $W = 0.0000056 FL^{3.192}$, yang bermaksud pertumbuhan allometrik positif berlaku apabila nilai b lebih besar daripada 3. Analisis UDUPA menunjukkan saiz panjang pada kematangan pertama (L_m) ikan jantan dan betina *E. affinis* masing-masing adalah pada 426.3 mm dan 393.3 mm. Kaedah analisis ELEFAN 1 dan Length Converted Catch Curve (LCCC) yang terdapat di dalam Perisian FAO-ICLARM Stock Assessment Tools (FiSAT) digunakan untuk menentukan parameter populasi, seperti panjang asimptotik (L_∞) = 549.15 mm, koefisien tumbesaran (k) = 0.16 per tahun, umur pada panjang sifar (t_0) = 1.14, indeks prestasi tumbesaran (ϕ') = 4.6835, koefisien kematian total (Z) = 0.62 per tahun, kematian semula jadi (M) = 0.25 per tahun, kematian aktiviti perikanan (F) = 0.37 per tahun, kadar eksploitasi semasa (E) = 0.60 dan panjang pada tangkapan pertama ($L_c 50$) = 402.78 mm. Corak rekrutmen *E. affinis* adalah berterusan sepanjang tahun dengan dua puncak rekrutmen diperhatikan pada *E. affinis* jantan dan betina. Analisis hasil relatif per rekrutmen (YPR) meramalkan had eksploitasi maksimum yang dibenarkan (E_{max}) adalah 0.629 dan had eksploitasi optimum $E_{0.1}$ ialah 0.504. Manakala nilai E semasa (0.6) adalah kurang dari nilai anggaran E_{max} tetapi melebihi nilai $E_{0.1}$. Oleh demikian, dapat disimpulkan bahawa tahap eksploitasi *E. affinis* di Tok Bali, Kelantan adalah pada tahap optimum hingga ke tahap eksploitasi sepenuhnya.

Introduction

Kawakawa or scientifically known as *Euthynnus affinis* is among the commercially important pelagic species found in the Malaysian waters (Ahmed *et al.*, 2014). This species is widely consumed by the Malaysian locals and has high commercial value in the market as an economic importance species. Besides, as a species of tuna, they also play a key ecological role as high-level predators in oceanic pelagic ecosystems. They occupy higher levels and consume more prey to satisfy their high energy needs (Griffiths *et al.*, 2009; Korsmeyer and Dewar, 2001; Brill, 1987). This neritic tuna species grows rapidly with a maximum weight of 14 kg and a total length of 100 cm fork length, although they are more usually caught at less than half this size almost everywhere (Griffiths *et al.*, 2009; Froese and Paul, 2007).

According to the Annual Fisheries Statistics of Malaysia in 2016, about 32 % of the total landing of neritic tunas (73,903 MT) was contributed by kawakawa, which amounted to 24,284 MT. Particularly, the east coast of Peninsular Malaysia (ECPM) recorded the highest landing of Kawakawa at approximately 63 % (Department of Fisheries Malaysia, 2017). In 2017, kawakawa landings increased by 4 0% compared to 2016 which amounted to 31,216 MT by which 18,000 MT of the total catches landed in the ECPM. As such, Tok Bali which located in Pasir Putih, Kelantan is one of the major landing sites for kawakawa in the ECPM. Annual fish landing statistics in 2008 to 2017 as in Table 1 showed that kawakawa was landed at 9 out of twelve states in Malaysia, where Perak has significantly dominated the landings at about 26 % from the total landings (61,991 MT) throughout the duration, followed by east Johor (51,935 MT; 21 %), Terengganu (39,746 MT; 16%), and Kelantan (33,615 MT; 14 %).

Table 1: The landings of *E. affinis* in Malaysia's states, in 2008-2017 (Metric tonne).

Year	Perlis	Kedah	Pulau Pinang	Perak	Selangor	Kelantan	Terengganu	Pahang	East Johor	Sarawak	Sabah	W.P.Labuan
2008	0	1	3	2575	0	3671	4350	1075	1625	1414	4734	401
2009	22	1	8	4984	145	2047	4827	1112	3269	647	1932	130
2010	37	1	17	5544	0	1291	4583	1449	4784	890	854	152
2011	297	0	12	8098	1	752	3176	1182	5268	1096	918	126
2012	569	0	8	9901	0	388	5534	1293	6321	1568	1251	99
2013	1117	0	2	6140	0	876	5507	540	7907	2235	794	88
2014	431	0	2	6212	0	1185	3290	566	15016	2156	613	64
2015	596	70	6	7516	0	3288	3349	788	5414	1805	1094	67
2016	572	0	3	6022	0	10287	2519	2514	55	1539	773	0
2017	5535	0	1	4999	5	9830	2611	3284	2276	1887	787	0
TOTAL	9176	73	62	61991	151	33615	39746	13803	51935	15237	13750	1127

Figure 1 shows the trend of the kawakawa landings by five water bodies in Malaysia over ten years. In overall, the ECPM contributed the highest landing compared to west coast of Peninsular Malaysia (WCPM), Sarawak, and Sabah. It is observed that both ECPM and WCPM recorded the highest landing in 2014 (20,057 MT) and 2012 (10,470 MT) over ten years, respectively.

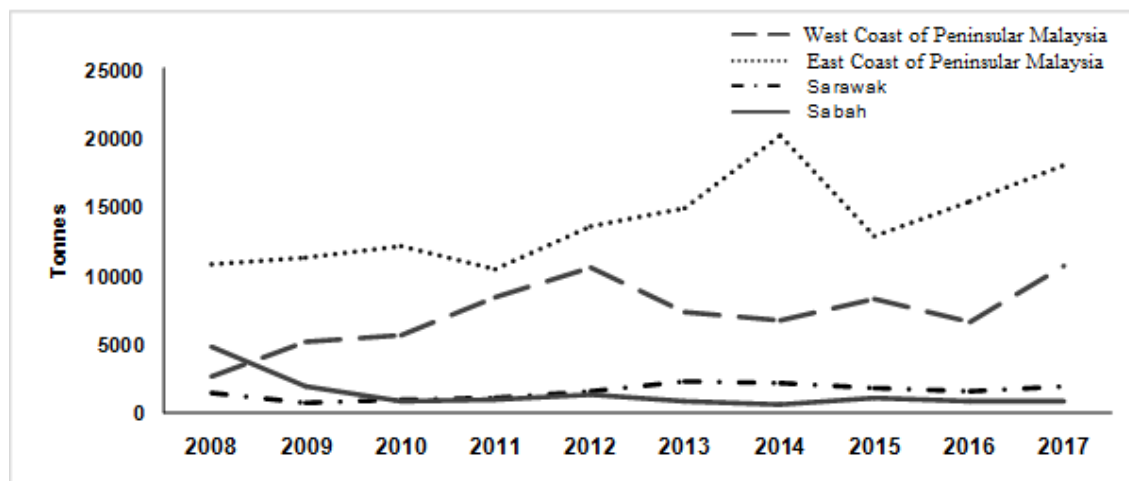


Figure 1: Trend of *E. affinis* landings by main water bodies in Malaysia, 2008-2017.

Table 2: Landings of *E. affinis* by three (3) main fishing gears in main water bodies in Malaysia, 2008-2017.

Year	WCPM			ECPM			Sarawak			Sabah			Labuan		
	Purse Seines	Drift Nets	Hooks and Lines	Purse Seines	Drift Nets	Hooks and Lines	Purse Seines	Drift Nets	Hooks and Lines	Purse Seines	Drift Nets	Hooks and Lines	Purse Seines	Drift Nets	Hooks and Lines
2008	2557	6	0	9957	50	708	717	680	5	3487	583	568	274	81	46
2009	5122	5	0	9547	476	1130	350	207	36	1519	232	180	0	128	0
2010	5543	20	0	9652	877	1421	449	410	25	543	258	46	0	151	0
2011	8371	23	0	8845	499	974	386	589	119	524	258	85	2	124	0
2012	10431	36	0	9445	534	3469	983	448	137	898	243	109	10	89	0
2013	7223	20	0	11185	156	3412	1121	973	111	570	135	89	7	80	0
2014	6624	13	0	18519	156	1371	1549	524	71	357	183	72	2	62	0
2015	8091	80	0	12039	31	751	1243	527	35	621	338	136	0	8	59
2016	6576	12	0	13990	5	1355	938	466	133	296	306	160	0	0	0
2017	10518	2	0	16899	1	1075	759	1073	55	368	285	72	0	0	0
TOTAL	71056	217	0	120078	2785	15666	8495	5897	727	9183	2821	1517	295	723	105

In Malaysia, kawakawa was commonly captured by purse seines, hook and line, trawls, drift nets and trap (Table 2). A purse seine is noticeably dominated the total landings in the ECPM, WCPM, Sarawak and Sabah. In contrast, drift nets were used more by fishers in Labuan to capture this species, as well as it was popular in Sarawak and Sabah. Aside, a huge amount of kawakawa captured using hook and line was recorded in the ECPM.

Kawakawa is exploited worldwide as it was abundant in neritic and open ocean ecosystems throughout their distribution (Griffiths *et al.*, 2009). Hence, understanding the population dynamics of these fish in particular their stock condition, growth, spawning season, recruitment pattern, mortality, etc. are crucial before identifying proper management techniques on any wild fish stock (Rahman and Hafzath, 2012). For example, the gonad maturity study is vital in estimating the spawning season of kawakawa. Proper understanding of these parameters is expected to be useful in providing scientific information to manage the stock status sustainably and holistically. There are numerous studies of this species as reported by Rohit *et al.*, (2012), Chodrijah *et al.*, (2013), Sallehudin *et al.*, (2016) and Effarina *et al.*, (2019). All these studies had investigated mainly on population parameters of kawakawa throughout the Indian Ocean including the Malacca Straits. However less is known about the kawakawa populations in Tok Bali waters, Kelantan specifically. The objectives of this study were (1) to investigate some biological aspects especially on maturity stages which may indicate spawning season, and (2) to identify population (growth and mortality) parameters that indirectly determine the exploitation level of kawakawa in Tok Bali, Kelantan.

Materials and Methods

Study Area

Kawakawa was sampled in a fish landing port in Tok Bali, Kelantan which is located at the northern part of the east coast of Peninsular Malaysia (Figure 2). The location was chosen as the sampling site due to its strategic location which is important fisheries areas in the southern part of the Gulf of Thailand and the east coast of Peninsular Malaysia. Therefore, the results of the study could be beneficial in delivering efficient management of transboundary fishery resources for both Malaysia and Thailand.

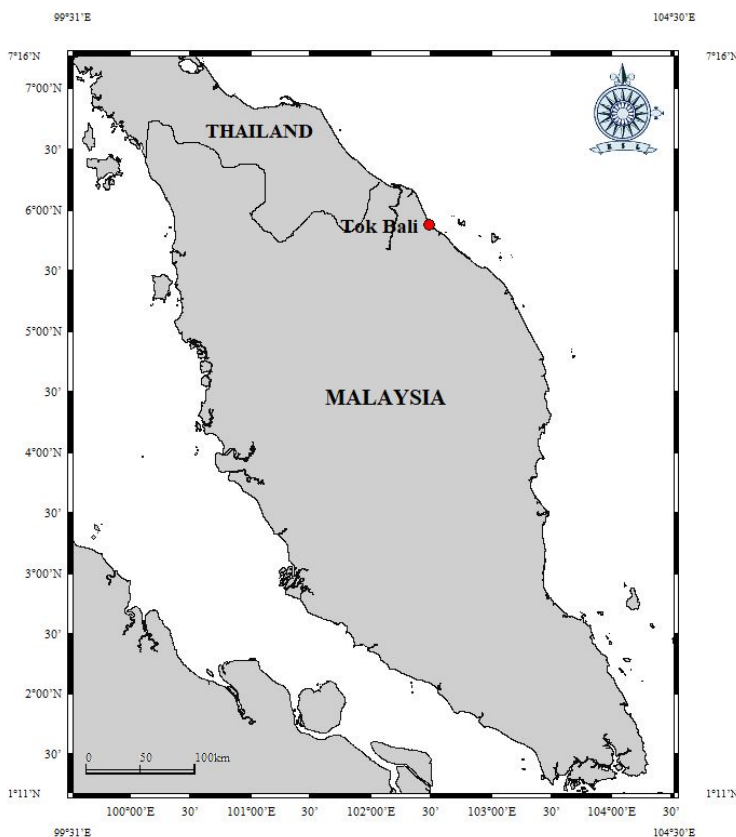


Figure 2: The location of sampling site where the red dot represents the fish landing port in Tok Bali, Kelantan.

Sample Collection

Kawakawa was collected between February 2017 and November 2018 at the Fisheries Development Authorities of Malaysia (LKIM Complex) Tok Bali, Kelantan. However, no samples were collected during the monsoon season which occurred from December 2017 until February 2018. On average, there are 120 fishes were sampled for each month during this study period.

A total of 2,295 kawakawa were sampled and examined from catches by purse seines with 2.5 cm mesh size of cod-end during the study duration. Fish were put on ice upon collected to keep fresh and transported to a wet laboratory in Institut Sumber Marin Asia Tenggara (ISMAT), where they were frozen and later examined.

Sample Measurement and Gonad Maturity

All the measurements were taken in the wet laboratory by following the Standard Operating Procedure (SOP). Each specimen was sorted, labelled in numbers first before its fork length (FL) were measured using a measurement board. Fork length was measured in millimetre (mm) from the tip of the snout to the end of the middle caudal-fin rays as shown in Figure 3.

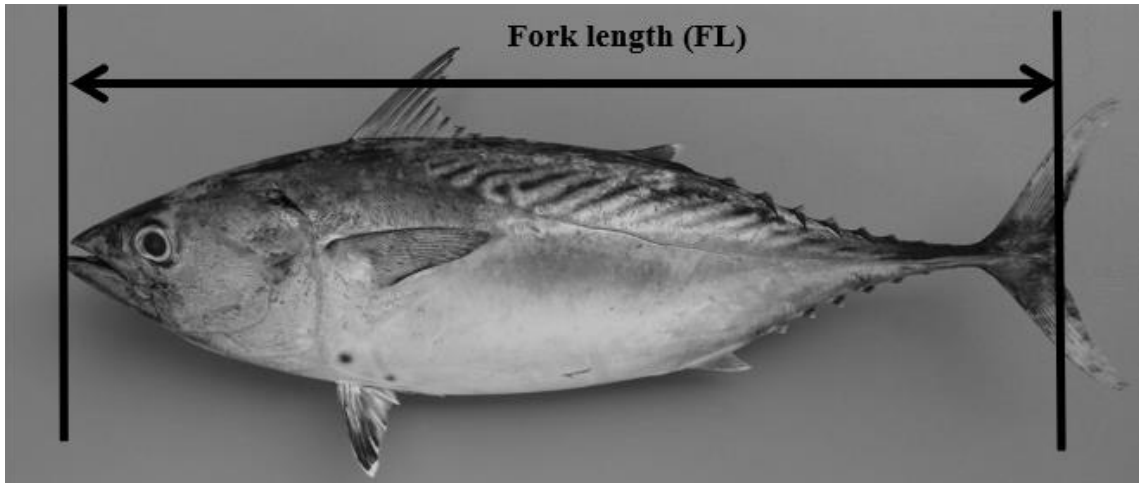


Figure 3: The measurement of *Euthynnus affinis* or kawakawa.

Bodyweight (BW) of each specimen was taken in gram (g) with a calibrated digital balance. The specimen was dissected from the lower abdominal (pelvic) using a knife. The stomach and gonads were removed carefully and weight was taken to the nearest 0.01 g.

Then the removed gonads were weighed and recorded. The sex and gonad maturity of the specimen was determined by macroscopic examination of gonads (Nasir and Zarrien, 2011).

According to the Standard Operating Procedure (SOP) for Data Collection and Analysis of Neritic Tunas (MFRDMD, 2015; Holden and Raitt, 1974; Orange, 1961), there are five stages of gonad maturity: Stage I (*immature*), Stage II (*maturing*), Stage III (*ripening*), Stage VI (*ripe*) and Stage V (*spent*). Meanwhile, the smaller and younger fish in which its sex is unidentified were classified as a juvenile. In some cases, the sex of the specimens was unidentified due to undeveloped gonad (Rahman and Hafzath, 2012).

Gonadosomatic Index (GSI)

The spawning season was determined by the value of gonadosomatic index (GSI). GSI was estimated using the equation:

$$\frac{(GW, g)}{(BW, g)} \times 100$$

Where GW = gonad weight and BW = body weight. The data of assessed GSI for all samples were recorded and analysed using Microsoft Excel.

Length-weight Relationship

The length-weight relationship was estimated using the equation:

$$W = aL^b$$

Where W is the derived weight, L is fork length, a is a coefficient related to the body form and b an exponent indicating fish growth (Sallehudin *et al.*, 2020; Ricker, 1979). In the length-weight

relationship, the value of exponent b provides information on fish growth. When $b = 3$, the increase in weight is isometric. The increase of weight is positive allometric if $b > 3$, while the increase of weight is negative allometric if $b < 3$. The null hypothesis of the isometric growth ($H_0: b = 3$) was tested using a T-test (Morey *et al.*, 2003).

Length at First Maturity (L_m)

Length at first maturity (L_m) was analysed using the Spearman-Kärber formula as given by Udupe (1986).

$$m = xk + \frac{x}{2} - (X \sum pi)$$

Where m is the log size at first maturity, xk is the last log size at which 100 % of the fish are fully mature, X is the log size increment and pi is the proportion of the mature fish for each size group.

Data Analysis by FAO-ICLARM Stock Assessment Tools (FiSAT) Software

Monthly length-frequency distributions from the kawakawa length measurements were analyzed using the FiSAT computer programme (Gayanilo *et al.*, 1996). ELEFAN 1 Module which incorporated into the FiSAT was used to estimate the growth parameters i.e. von Bertalanffy growth function (VBGF), asymptotic length (L_∞) and growth coefficient (k). K scan routine was conducted to assess a reliable estimate of the k value. The theoretical age at length zero (t_0) was obtained from Pauly's (1979) equation:

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{Log} L_\infty - 1.038 \text{Log} K$$

Potential longevity (t_{\max}) of the species was calculated from the Pauly (1984) formula:

$$T_{\max} = 3/K$$

The estimated L_∞ and K were used to calculate the growth performance index (ϕ') (Pauly and Munro, 1984) of *E. affinis* from the equation:

$$\phi' = 2 \log_{10} L_\infty + \log_{10} K$$

The Length-converted catch curves (LCCC) were developed from the length frequencies, L_∞ and k to estimate the total mortality (Z) (Gayanilo *et al.*, 2005). Natural mortality (M) was determined using Pauly's equation by taking the mean annual habitat water temperature as 30°C (Pauly, 1983):

$$\text{Log} M = -0.0066 - 0.279 \text{Log} L_\infty + 0.6543 \text{Log} K + 0.4634T$$

where T is the mean annual habitat temperature.

The fishing mortality (F) was estimated using the following formula once Z and M were obtained:

$$F = Z - M$$

where Z is the total mortality, F fishing mortality and M , the natural mortality.

Gulland, 1971 presented the formula to calculate the current exploitation level (E) as follows:

$$E = F/Z = F / (F + M)$$

According to the method of Pauly (1987), the probability of capture of each length class is analyzed by using the ascending left arm of the LCCC. By plotting the cumulative probability of capture against mid-length, a resultant curve was obtained from which the length at first capture (Lc) was taken as corresponding to the cumulative probability at 50 %.

The recruitment pattern of the stock was analysed by available time-series of length-frequency data which determines the number of pulses per year and the relative strength of each pulse as described in FiSAT. The input parameters required for this procedure were L_{∞} , K and t_0 ($t_0 = 0$). Pauly and Caddy (1985) stated that the normal distribution of the recruitment pattern was determined by NORMSEP in FiSAT (Nurul *et al.*, 2008).

The modified model of Beverton and Holt (1966) by Pauly and Soriano (1986) was used in the estimation of the relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) and then integrated into the FiSAT software package.

Results and Discussions

Biological Parameters

Sex Ratio

The male of kawakawa was dominant in some samples during the study period. The highest percentage of male kawakawa was recorded in August and September 2017 (more than 95 %) while the lowest was in July 2018 (only 14 %). Meanwhile, the highest percentage of female was recorded in March 2018 (57 %) and the lowest in July 2018 (less than 10%). The sex ratio of male to female is 1.4: 1.0. A study by Yesaki (1994) in the Philippines waters shows the sex ratio of male to female is 1.2: 1.0. This shows a slightly difference between the sex ratio of kawakawa in Tok Bali waters and kawakawa in the Philippines waters. On the other hand, the number of juvenile kawakawa was seen as abundant in July 2018. Compared to a study by Chiou and Lee (2004), juvenile kawakawa in Taiwan waters seen abundant from October to December every year.

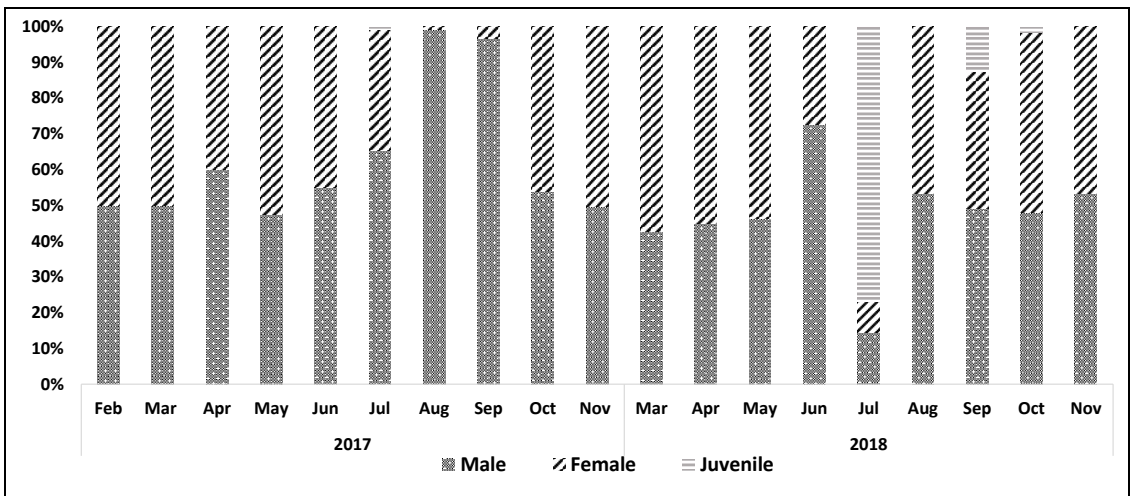


Figure 4: Percentage of sex of *E. affinis* at Tok Bali, 2017-2018.

Gonad Maturity Stage

The gonad maturity stages of kawakawa from Tok Bali fish landing port was presented in Figure 5, where it showed that fish with gonad maturity Stage I dominated the second half of each year, in which high percentage was observed from July to September 2017, and also in June and August 2018. On the other hand, a high percentage of kawakawa in stage III and IV were reported in the first half of each year, which are from February to June 2017 and from March to May 2018. Lastly, the juvenile kawakawa had a significant percentage in July and September 2018.

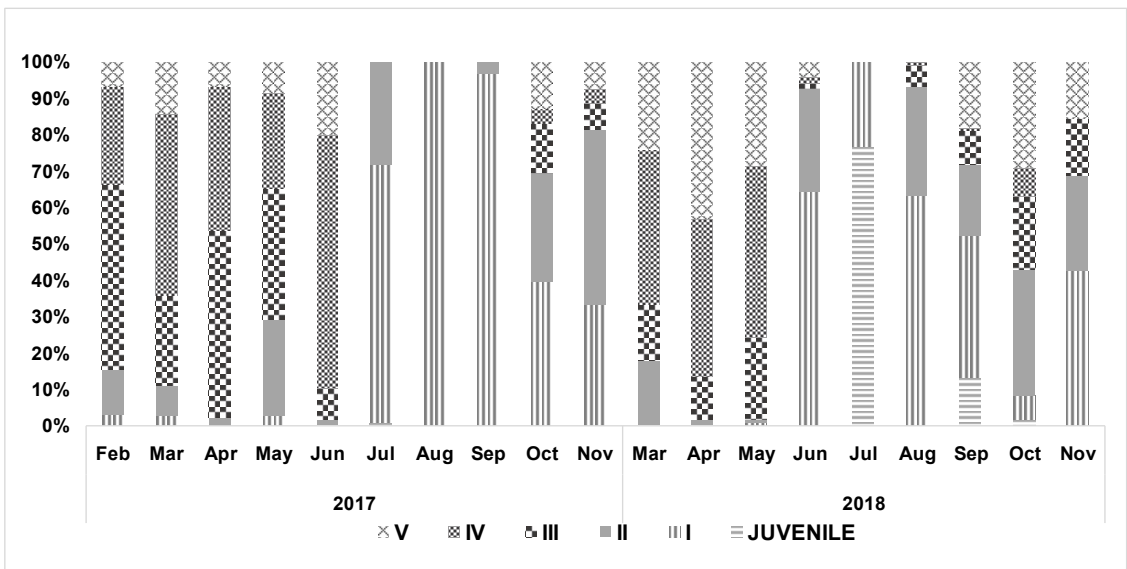


Figure 5: Monthly percentages of gonad maturity stages *E. affinis* at Tok Bali, February 2017–November 2018.

The spawning season could be estimated by calculating the mean numbers of fish with gonad maturity at stage III (*maturing*), stage IV (*matured*) and stage V (*spent*) (Arrafi *et al.*, 2016). Based on Figure 5, it is estimated that kawakawa has a long spawning period which lasts around the five months of the first half of the year at Tok Bali as shown by maturity stages. During this period, 50 % of the individuals were usually found to be in stage III, IV and V. Such a high percentage of fish in the spawning area is assumed due to a continuous migration of spawners into the area or repeated spawning by the same group of fish since the fishing area for this study might only cover a small part of the total distribution area (Sousa and Gislason, 1985). However, to estimate the specific spawning month or peak of the spawning season, the results from Gonadosomatic Index (GSI) is required.

This study found that 55 % of kawakawa landed from February 2017 to November 2018 at Tok Bali had immature gonad while only 45 % was matured fish. Another study showed that 85 % of kawakawa caught from March to August 2015 at Kuala Perlis had immature gonad, and only 15 % had matured gonad stage III (Sallehudin *et al.*, 2016).

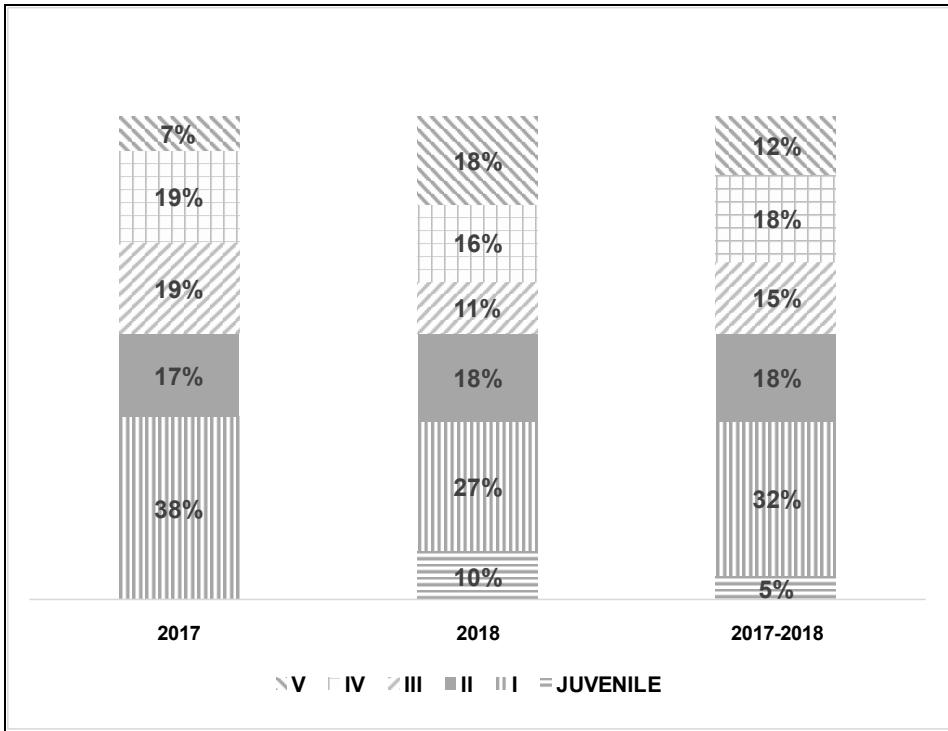


Figure 6: Annual percentages of gonad maturity stages of *E. affinis* at Tok Bali, 2017-2018.

Mean Gonadosomatic Index (GSI)

Gonadosomatic Index (GSI) is one of the parameters used in reproduction studies of fish (Hunter *et al.*, 2001). The monthly changes in the mean GSI of kawakawa are presented in Figure 7. The monthly mean GSI of all gonad maturity stages for kawakawa ranged from 0.01 to 7.20. In 2017, the highest GSI was observed in February and followed by June. Furthermore, in 2018, the GSI value rapidly increased after March and reached a peak in May. The GSI was declining drastically afterwards.

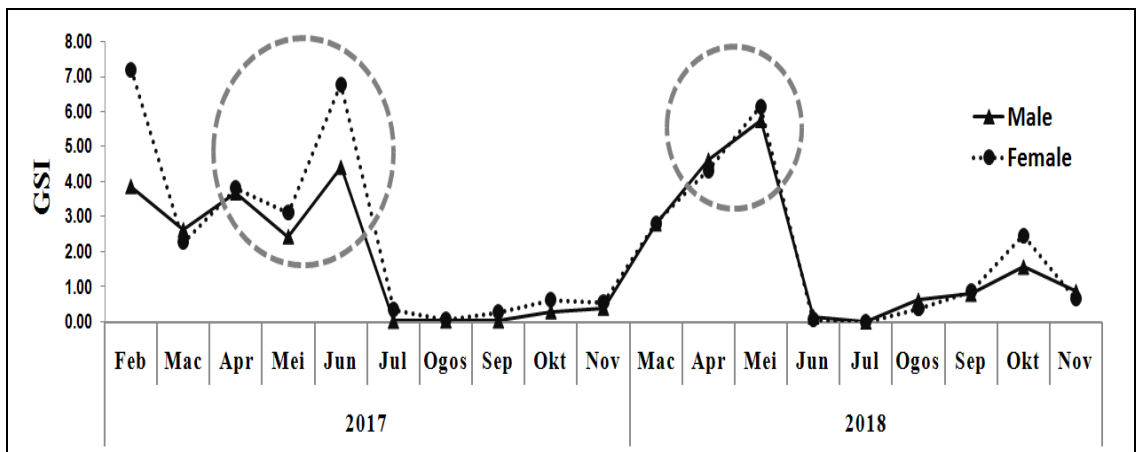


Figure 7: Mean GSI for all gonad maturity stages of *E. affinis* at Tok Bali, February 2017-November 2018.

In addition, GSI for matured kawakawa as shown in Figure 8 used to strengthen and emphasize the finding of spawning season. GSI for matured Kawakawa is more accurate and reliable in determining spawning season. The monthly mean GSI for matured kawakawa ranged from 0.59 to 12.48. The highest GSI was observed in April and June 2017, and from April to May 2018. The distribution of matured stage (Stage III and IV) along with high values of GSI over some time is used to estimate the spawning season. Therefore, using the findings in Figure 5, 7 and 8, it was estimated that the spawning period for kawakawa at Tok Bali was observed all around the year with peaks during April to June specifically. This result is in line with the result of gonad maturity stages, which shows that the spawning period of kawakawa occurs within five months of the first half of the year. A past study by Ronquillo (1963) also noted that the highest GSI for kawakawa were found from March to May in the Philippines waters.

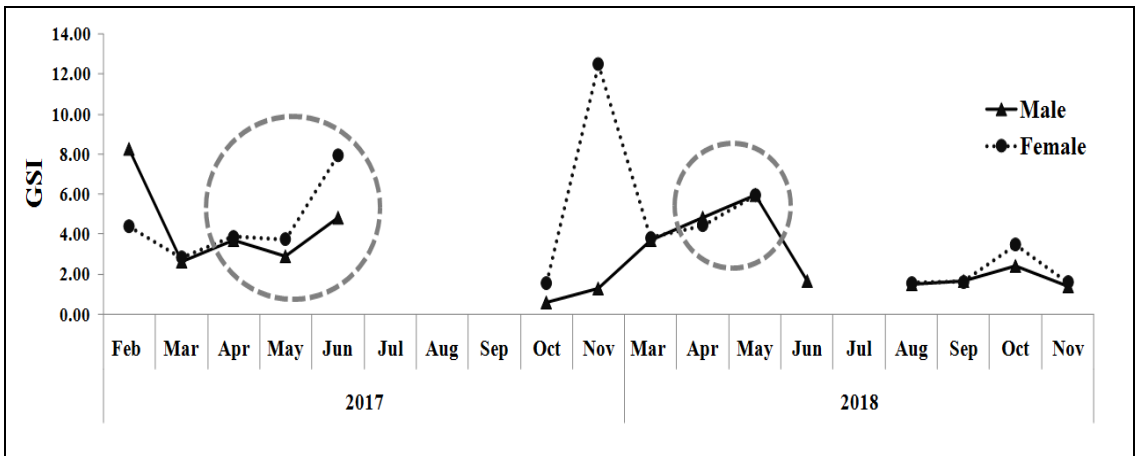


Figure 8: Mean GSI for mature (Stage III and IV) *E. affinis* at Tok Bali, 2017-2018.

Different findings of the spawning season for kawakawa were found from numerous studies. The spawning season for *E. affinis* in the western Indian Ocean near Seychelles is during the period of the northwest monsoon, from October-November to April-May including a peak from January to March (Wheeler and Ommanney, 1953). In 1963, According to William (1963), the spawning season extends from January to July in waters off the coast of East Africa. In Madagascar waters, fish in spawning condition were observed in November and December (Fourmanoir, 1957) and around December in Mauritius (Baisaac, 1960).

Length-frequency Distribution

The overall length ranged from a minimum of 234 mm to a maximum of 525 mm. In 2017, three dominant modes of size were found at 265 mm, 330 mm and 415 mm. While in 2018, the dominant modes of size were at 380 mm and 440 mm (Figure 9). Overall, there are 3 dominant modes observed at 265 mm, 330 mm and 435 mm during the study period (Figure 10). Therefore, it can also indicate that there are at least three cohorts of this species in the study area since the size of each mode is significant. Sallehudin *et al.*, (2016) was also recorded a dominant mode at 330 mm for this species in Kuala Perlis.

Ahmed *et al.*, (2014) reported that the kawakawa fishery along the Karachi coast (Arabian Sea) is supported by fishes with two modes, 34-58 cm and 40-60 cm. However, a longer modal length of kawakawa with 54-56 cm was recorded in the east coast of India (Bay of Bengal) as reported by Kasim and Abdussamad (2003).

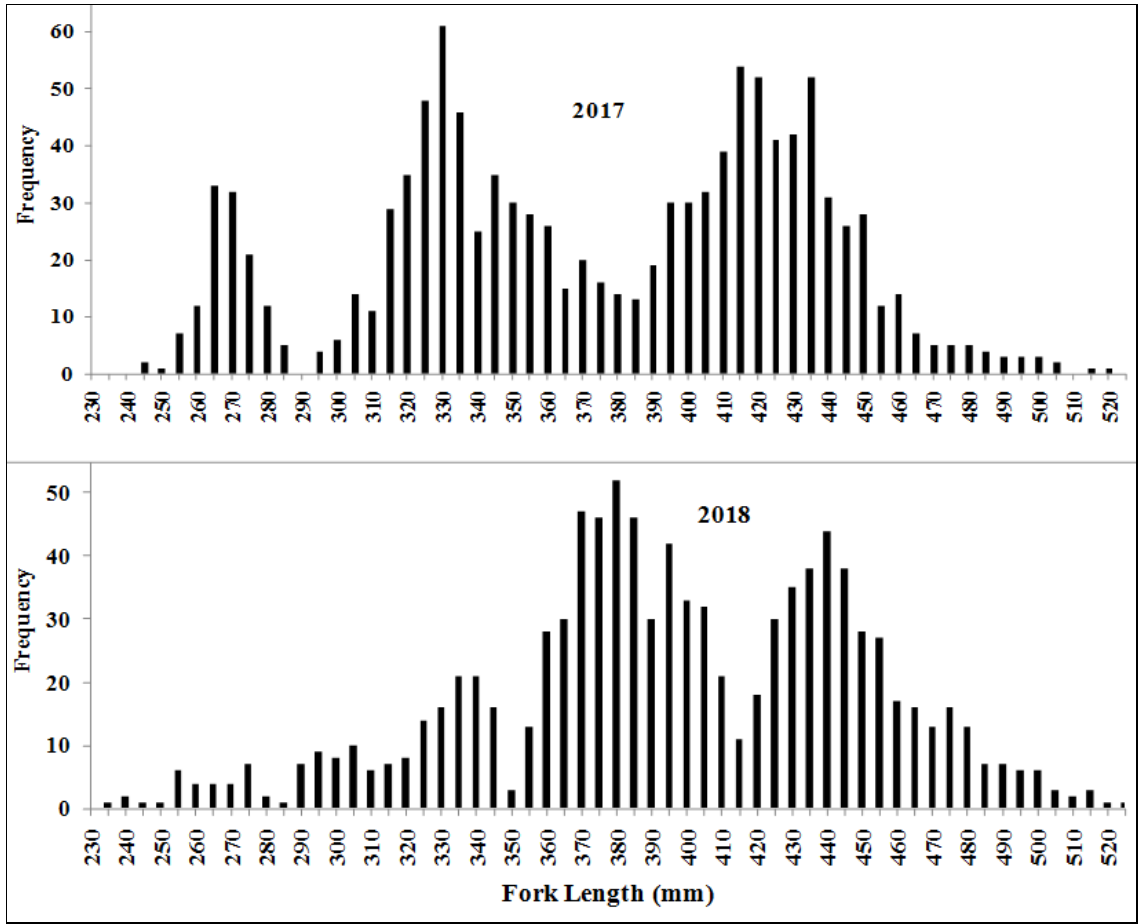


Figure 9: The length-frequency distribution of *E. affinis* at Tok Bali, 2017 and 2018.

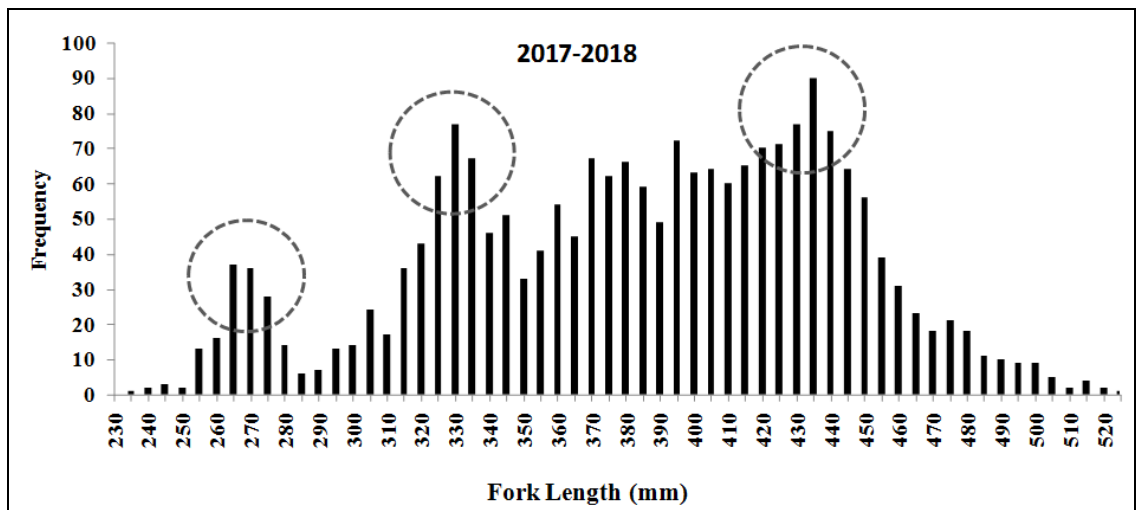


Figure 10: Length frequency distribution of *E. affinis* at Tok Bali, 2017-2018.

Length-weight (LW) Relationship

Length-weight (LW) relationships are frequently used in fisheries biology to convert length measures into weight and to ascertain the growth characteristics related to those variables (Griffiths *et al.*, 2009). The observed length-weight relationship (LWRs) in this study with R² values were 0.9887 and 0.9891 in 2017 and 2018 respectively. Since the R² value is higher than 0.5, the length-weight relationship is positively correlated (Biswas, 1993; Arrafi *et al.*, 2016).

The LW relationship for 2017 was $W = 0.0000056 FL^{3.193}$, while 2018 was $W = 0.0000089 FL^{3.115}$ (Table 3). Collectively, the length-weight analysis for 2,235 kawakawa was $W = 0.0000056 FL^{3.192}$ with coefficient determination (R²) of 0.9887 (Figure 11). Tesch (1968) reported values of *b* parameter to vary usually between 2 and 4. The value of *b* was bigger than 3 in this study, indicating the growth of kawakawa was positive allometric. Thus, it means the fish grows in terms of weight rather than length. Jin *et al.*, (2015) stated that positive allometric indicates the largest specimen has a thicker body than the smallest specimen.

In contrast, a recent study of kawakawa at Kuala Perlis reported negative allometry for LW relationship, whereby $W = 0.000062 L^{2.7759}$ (Sallehudin *et al.*, 2016). The length-weight relationship of a species could be influenced by few factors like season, habitat, gonad maturity, sex, stomach fullness, health and preservation techniques (Tesch, 1971; Moutopoulos and Stergiou, 2002).

Table 3: The value of *a*, *b* and R² from analysis of length-weight relationships between fork length (FL) and whole weight (WW) of *E. affinis* at Tok Bali, 2017-2018.

	2017	2018	2017-2018
<i>a</i>	5.6 x 10-06	8.9 x 10-06	5.6 x 10-06
<i>b</i>	3.193	3.115	3.192
R ²	0.9887	0.9891	0.9887

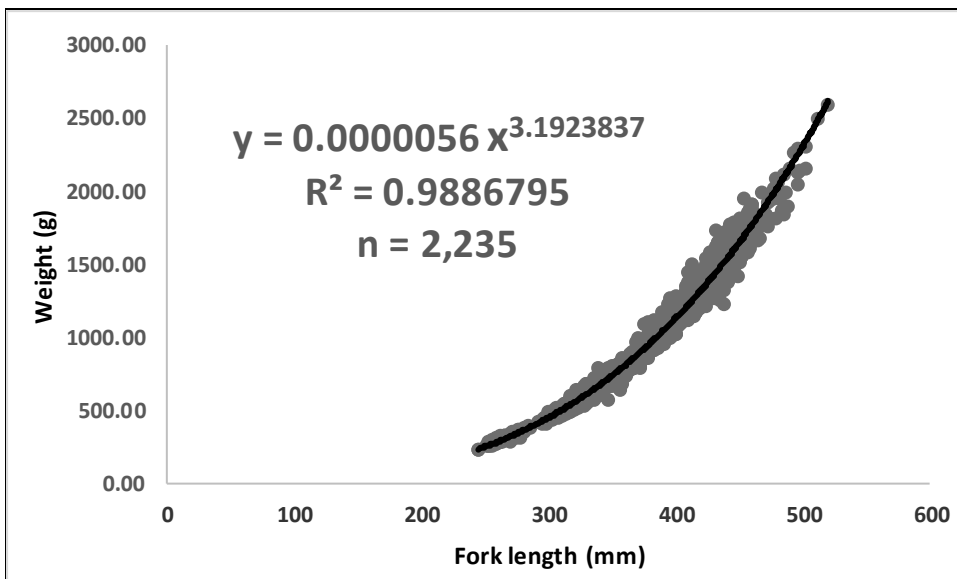


Figure 11: The graph of the length-weight relationship of *E. affinis* at Tok Bali, 2017-2018.

Length at First Maturity (L_m) using UDUPA Method

The length at first maturity using UDUPA method was used to estimate the L_m value for male kawakawa as 426.3 mm and 393.3 mm for female kawakawa. This showed that female reaches their first maturity at a smaller size than the males. It also indicated when the fish reach their maturity length (426.3 mm and 393.3 mm). Kawakawa samples from Tok Bali landing port from 2017 to 2018 shows 33 % (757 fishes) of the samples already reach the maturity stage (Stage III and IV). Full maturity (stage IV) only can be achieved when stage III had been fully completed (Udupe, 1986).

Table 4: The length at first maturity for *E. affinis* at Tok Bali, 2017-2018 using UDUPA method.

L_m	2017	2018	2017-2018
Male	448.19	419.36	426.29
Female	420.20	417.20	393.31
Male and Female	439.02	419.86	421.32

Population (Growth and Mortality) Parameters

FAO-ICLARM Stock Assessment Tools (FiSAT) Software Results

In this analysis, results were obtained by using fork length-frequency data of kawakawa samples, ranging from 235.5 to 530.5 mm. According to VBGF parameters, the asymptotic length (L_∞) was estimated as 549.15 mm, with k value 0.16 per year. Results from other studies show the asymptotic lengths obtained are around 600 mm in Kuala Perlis (Sallehudin *et al.*, 2016), around 590 mm in the Java Sea (Chodriyah *et al.*, 2013) and around 810 mm in the Indian Sea (Rohit *et al.*, 2012). The differences in size might be attributed to the depth of the waters (at which the fishing gears catch the samples) as well as the size of fishing gears or equipment.

The von Bertalanffy (optimized) growth curve was superimposed on the restructured length-frequency histograms (Figure 12). Using the estimated value of asymptotic length ($L_\infty = 549.15$ mm) and growth coefficient ($k = 0.16 \text{ year}^{-1}$), the theoretical age at length zero (t_0) by Pauly's (1979) equation was calculated as 1.14, while the growth performance index (ϕ') equal to 4.6835 (Figure 13) and potential longevity of kawakawa ($t_{\max} = 3/K$) was calculated as 18.75 years.

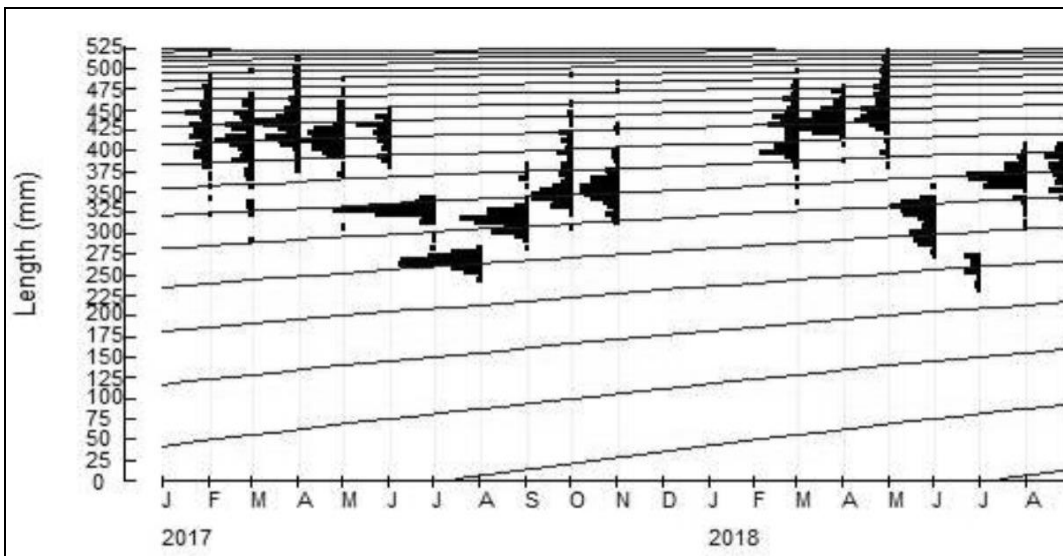


Figure 12: Von Bertalanffy growth curve ($L_\infty = 549.15$ mm and $K = 0.16 \text{ year}^{-1}$) for *E. affinis* superimposed on the restructured length-frequency histograms.

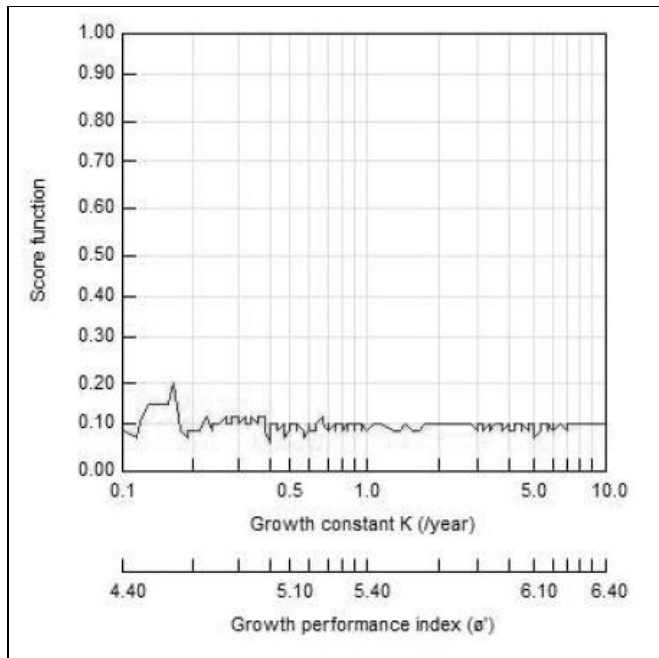


Figure 13: Estimation of k for *E. affinis* by employing ELEFAN-1.

The mortality and exploitation rate were estimated by using a Length-converted catch curve (Figure 14). The result from the kawakawa sampling at Tok Bali from February 2017 to November 2018 altogether reported natural mortality (M) of 0.25 per year. Meanwhile, the fishing mortality (F) is 0.37 per year. Thus, the total mortality (Z) is 0.62 per year. The current exploitation level (E) is 0.60 per year, showed that the fishery has exceeded the 0.50 optimum level of exploitation (Gulland, 1971) and thus, had been fully exploited by fishing activities. The E values of 0.5 to 0.6 are still considered as optimum to fully exploit level.

The M/K value in this study was 1.56. The M/K value for most tropical species is between 1.12 to 2.50 (Beverton and Holt, 1957; Zhu *et al.*, 2011). In term of analysis, more precise population parameters can be obtained if the length frequencies had a wider range of size (i.e., < 235 mm). However, the samples from fish purse seine catch are limited to only a certain size range. Samples of smaller sizes could be obtained from other gears such as trawlers.

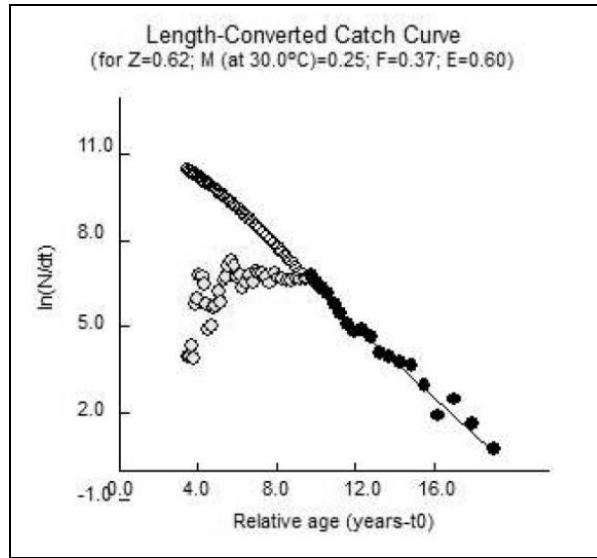


Figure 14: The linearized length-converted catch curve analysis to estimate total mortality, Z , from the length frequency distribution of *E. affinis* in Tok Bali water.
($Z = 0.62 \text{ year}^{-1}$, $M = 0.25 \text{ year}^{-1}$, $F = 0.37 \text{ year}^{-1}$ at 30°C)

Results from FISAT software for kawakawa by other studies are summarized in Table 5. It appears that the finding from the study done by Sallehudin *et al.*, (2016) is most similar to the finding from this present study done in Tok Bali. The different growth pattern might be due to the differences in genetic structure and environmental conditions like mean environmental temperature, density and food availability (Pauly, 1980).

Table 5: Population parameters of *E. affinis* from other sampling locations.

Study Area	L_∞	K	Z	M	F	M/K	$E = F/Z$	Source
Tok Bali	54.92	0.16	0.62	0.25	0.37	1.56	0.60	Present study, 2017-2018
Kuala Perlis	60.43	0.26	0.80	0.33	0.47	1.26	0.59	(Sallehudin <i>et al.</i> , 2016)
Java Sea	59.63	0.91	2.64	1.13	1.50	1.24	0.57	(Chodrijah <i>et al.</i> , 2013)
Indian water	81.92	0.56	1.68	0.93	0.75	1.66	0.45	(Rohit <i>et al.</i> , 2012)

Length at First Capture (L_{c50})

The length at first capture (the length at which 50 % of the kawakawa becomes vulnerable to the gear) was calculated as a component of the length converted catch curve analysis (Figure 15). The value obtained was $L_{50} \% = 402.78 \text{ mm}$ from the analysis of the probability of capture. The length at which 25 % and 75 % of the fish are retained in the gear was estimated at $L_{25} \% = 371.16 \text{ mm}$ and $L_{75} \% = 434.39 \text{ mm}$. In general, by using LCCC analysis, there are 50 % of the samples were estimated to be captured at a length less than a length at first maturity (421.32 mm) as shown in Table 4.

The sustainability of purse seine is still being questioned because it catches non-selective species and non-selected sizes (Chumchuen *et al.*, 2016) but it still an eco-friendly fishing gear because of less impact on the seabed due to near-surface operation (Suuronen *et al.*, 2012). According to Nishida (2017), the stock status of kawakawa in 2013 at the Pacific Ocean side (South China Sea) is still at the safe zone or green zone (underexploited). The purse seine in Malaysian waters still can maintain the sustainability of fisheries through law enforcements by the government of Malaysia such as input control, output control and technical control (Harlyan, 2019).

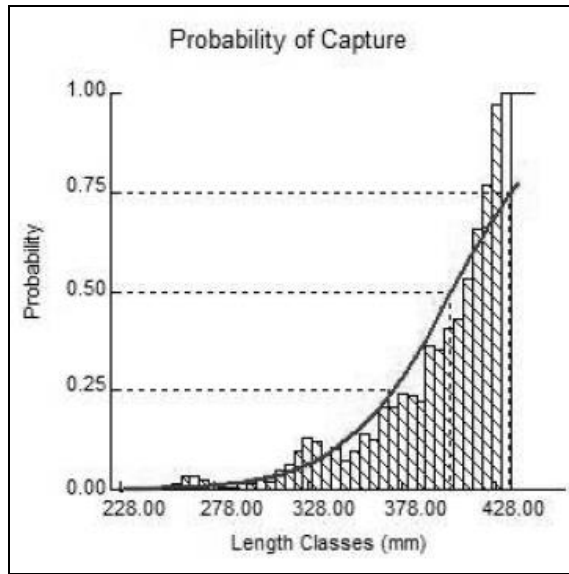


Figure 15: Probability of capture of each length class of *E. affinis* at Tok Bali, 2017-2018.

Recruitment Pattern

The recruitment pattern of kawakawa was continuous throughout the duration with two peaks in recruitment were observed (Figure 16). The recruitment percentage varied from 0.97 % to 17.11 % for kawakawa during the study period. The major recruitment period was during July-August meanwhile the minor recruitment period was observed during September-October (Figure 16). The highest and lowest recruitment percentage was observed in August and November respectively for kawakawa in Tok Bali waters. A study by Sulistyaningsih *et al.*, (2014) found the highest recruitment percentage of kawakawa in the Indian Ocean was in May while the lowest recruitment percentage was in November.

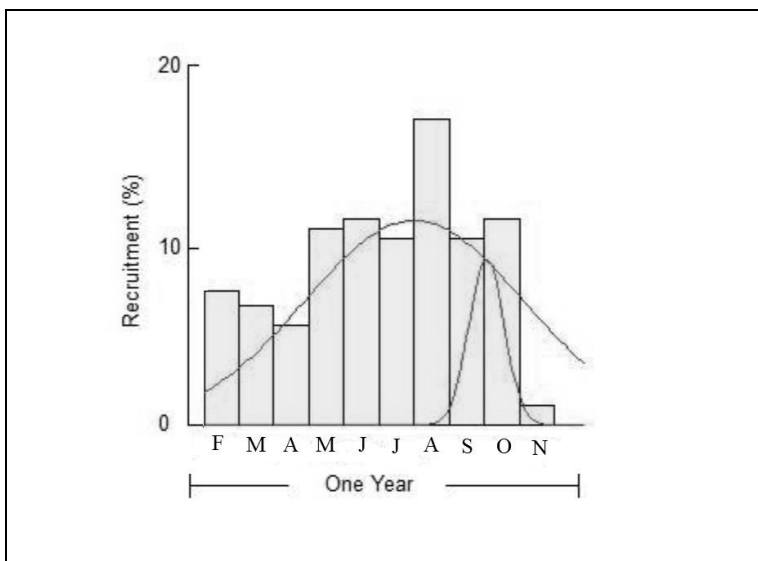


Figure 16: Recruitment pattern of *E. affinis* in Tok Bali, indicating two peak pulse per year.

Prediction of Relative Yield Per Unit (Y/R) and Biomass of Per Recruit (B/Y) Analysis

The input requirements needed in the computation of relative yield per unit (Y/R) and biomass of per recruit (B/Y) analysis were the values of $L/L\infty = 0.73$ and $M/K = 1.56$. The relative yield per recruit analysis showed estimation values of E_{max} , $E_{0.1}$ and $E_{0.5}$ were 0.629, 0.504 and 0.339, respectively (Figure 17). The maximum allowable limit of exploitation rate (E_{max}) giving maximum relative yield-per-recruit (Y/R), was estimated as 0.629, compares well with the current exploitation rate (E) of 0.60 established for *E. affinis* in this study. This indicates that the fishery is slightly below the level of overexploitation. Results from the analysis of the exploitation rate (E) based on the mortality estimates, and from the relative yield-per-recruit (Y/R), indicated that the fishery has exceeded the level of optimum based on the $E_{0.1}$ principle of 0.504. According to Pauly (1979), $E_{0.1}$ is the value of E at which the slope of the Y/R is 1/10 of its value at the origin. On the other hand, $E_{0.1}$ also refer to the level of exploitation at which the marginal increase in relative yield per recruit is 10 % of its value at $E = 0$. This reveals that the fishery is probably being fully exploited in terms of relative yield-per-recruit and fishing pressure on the stock is moderately high. The exploitation level which corresponds to 50 % of relative biomass per recruit of the unexploited stock was estimated at 0.339.

Overall, the current level of kawakawa exploitation can be considered fully exploited. This is supported by the results of a stock assessment using the Kobe Plot by Nishida *et al.*, (2017). The study found that the stock of kawakawa in 2013 in the Southeast Asian Waters (Pacific Ocean side) was in a safe zone (green) and not approaching the situations of overfishing or overfished. The study area has wider coverage encompassing several countries in the South China Sea as compared to this study area which is limited in Tok Bali waters only. The risk assessment study of kawakawa conducted by Nishida (2017) in the same study area as aforementioned, projected that total biomass from the year 2014 to 2023 will outlast only if the current catch in 2013 is maintained over the years. However, it is much preferable to obtain sustainable yields by a reasonable decrease in the fishing efforts for stock recovery purposes.

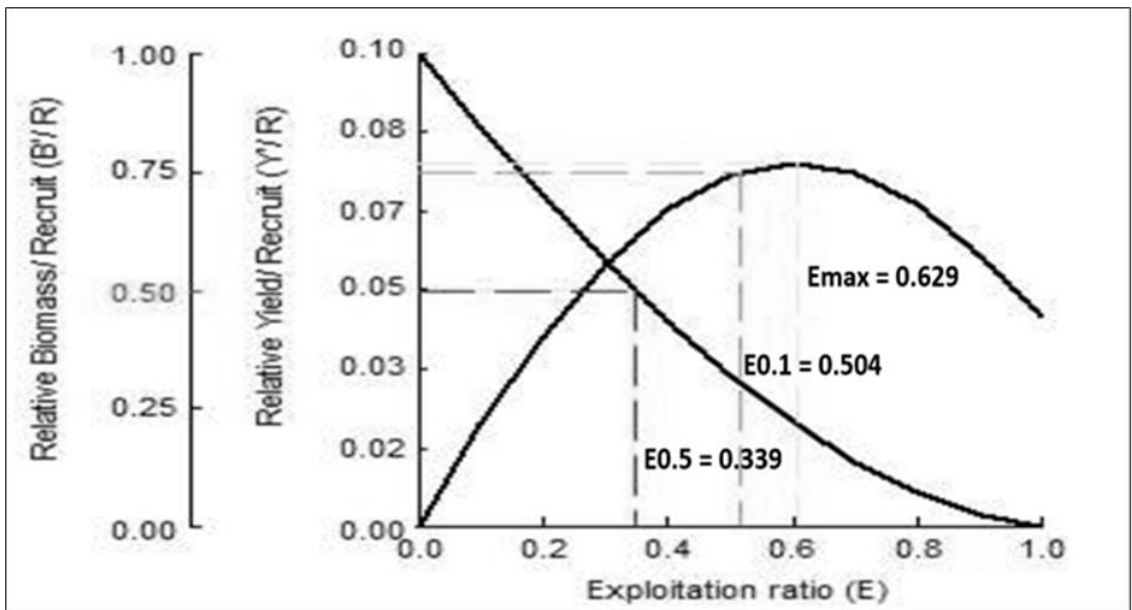


Figure 17: Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) analyses of *E. affinis* in Tok Bali, 2017-2018 ($L\infty = 549.15$ cm TL, $M/K = 2.75$).

Conclusion

A total of 2,295 kawakawa from LKIM Tok Bali were sampled during the study period comprising 55% male, 40% female and 5% juvenile, with a sex ratio of 1.4:1.0. Out of the total samples, 55% of kawakawa was in immature stages and the spawning season was estimated between April to June annually. Length frequency distribution showed three dominant modes for kawakawa which were 265 mm, 330 mm and 435 mm. The significant size of modes also means at least three main cohorts of kawakawa were found in the study area. The mode of 265 mm and 330 mm were caught below the length at first capture (L_{c50}) 402.78 mm by using a 2.5 cm mesh size of purse seine cod end. The length at first maturity by using UDUPA method showed that female fish reached their first maturity length in a smaller size (393.3 mm) as compared to male fish (426.3 mm). Based on these two maturity values, it was also found that the mode (cohort) of kawakawa at a size of 330 mm was comprised of immature males and females while the mode at 435 mm was vice versa. On the other hand, for the mode of Kawakawa at size 265 mm, the majority of fish were in the juvenile stage. The length-weight analysis ($W = 0.0000056 FL^{3.192}$) indicated that the growth of kawakawa was positive allometric ($b > 3$ or $3.192 > 3$) with coefficient determination (R^2) of 0.9887, which means the fish growth was in terms of weight than the length.

The population parameters analysis shows the estimated asymptotic length (L_{∞}) was 549.15 mm, with VBGF growth co-efficient (k) value of 0.16 per year. The total mortality (Z) was 0.25 per year with exploitation rate (E) was 0.60, slightly lower than the maximum exploitation rate (E_{max}) of 0.629 but exceed the value of $E_{0.1}$, 0.504. Based on the current exploitation rates (E) 0.60, it could be concluded the exploitation level of kawakawa in Tok Bali is optimum to the fully exploited level.

In general, purse seine is non-selective gear but quite sustainable and environmentally friendly gear. However, the finding from this study shows the L_{c50} of kawakawa caught in Tok Bali waters are smaller (402.78 mm) than the size at length at first maturity (421.32 mm). This might be due to different fishing equipment specification and different horsepower of the engine in the fishing vessels used by the fishers. Further study for some aspects of fishing efforts (trips, days, hauls etc.) should be done to get even precise results.

The results of the spawning period can be used if management measures such as closed season or closed area are introduced. This is to avoid catching the juveniles and immature fish, thus safeguarding kawakawa growth. Department of Fishery is advised to implement this method instead of controlling fishing efforts which are more difficult to supervise. Despite the difficulties, certain actions such as an increase of the mesh size of cod-end (technical aspects) can be employed to ensure that only matured fish or the fish had spawn at least once is caught. This measure could be effective to prevent the stock of the kawakawa from reaching the over-exploited status. Therefore, it is hoped that the Department with the assistance of other enforcement agencies such as the Malaysian Maritime Enforcement Agency (MMEA) Royal Malaysian Navy and Royal Malaysia Police will cooperate as the proposal progresses.

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Species Composition of Sharks and Rays Caught in the East Coast of Peninsular Malaysia

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Abstract: During the monsoon season in the East Coast of Peninsular Malaysia, a small size trawl net namely ‘Monsoon Season Trawl Net’ or locally known as Pukat Tunda Musim Tengkujuh (PTMT) was licensed for fishing in Zone A. The objectives of this study were to determine the catch composition of sharks and rays at the species level and their nursery ground for some species as a consequence of the trawling activity during monsoon season. The study was conducted in November and December 2018, and February and March 2019 during monsoon season in Kuala Pahang waters. Six trips were conducted and a total of 36 trawl stations were studied. Sharks and rays were sorted by species, sex and individual length-weight were measured. Almost all shark and ray specimens were released *in situ* after all information recorded. Three species of sharks and eight species of rays were confirmed inhabiting at the study area. A total of 449 individuals of shark from order Orectolobiformes and family Hemiscylliidae were caught comprising of *Chiloscyllium hasseltii*, *Chiloscyllium indicum* and *Chiloscyllium punctatum*. Out of 449 individuals, 445 individuals were still at juvenile stage. As for rays, 406 individuals were caught from order Myliobatiformes and family Dasyatidae comprising of *Brevitrygon imbricata*, *Brevitrygon heterura*, *Maculabatis gerrardi*, *Telatrygon biasa*, *Hemitrygon akajei*, *Maculabatis pastinacoides*, *Pateobatis uarnacoides* and *Telatrygon zugei*. As for rays out of 406 individuals, 232 individuals were at the juvenile stage. In general, almost all sharks and more than 50 % of rays caught during PTMT were at the juvenile stage. These findings confirmed that the study area in Kuala Pahang waters is an important nursery ground for at least three species of sharks and eight species of rays. The recruitment cycle of these species will be affected and their population could be threatened in future. Special management measures should be applied for sustainable exploitation of these resources. The findings from this study are important as a guide for management in developing special measures to ensure the sustainability of these resources.

Keywords: Species composition, Sharks, Rays, Nursery ground, Kuala Pahang, Trawl net.

Abstrak: Pada musim tengkujuh di Pantai Timur Semenanjung Malaysia, pukat tunda saiz kecil yang dipanggil Pukat Tunda Musim Tengkujuh (PTMT) akan dilesenkan untuk beroperasi di Zon A. Objektif kajian ini ialah untuk mengenalpasti komposisi tangkapan ikan yu dan pari mengikut spesies dan menentukan kawasan nuseri bagi beberapa spesies sebagai hasil aktiviti pukat tunda pada musim tengkujuh. Kajian ini telah dijalankan pada bulan November dan Disember 2018, serta bulan Februari dan Mac 2019. Enam trip kajian dijalankan dan sebanyak 36 stesen tundaan telah dikaji. Ikan yu dan pari diasingkan mengikut spesies, seks dan diukur panjang dan berat. Hampir semua spesimen ikan yu dan pari dilepaskan secara *in situ* selepas semua maklumat direkodkan. Tiga spesies yu dan lapan spesies pari telah dikenalpasti menghuni kawasan kajian. Sebanyak 449 ekor ikan yu daripada order Orectolobiformes dan famili Hemiscylliidae telah ditangkap yang terdiri daripada *Chiloscyllium hasseltii*, *Chiloscyllium indicum* dan *Chiloscyllium punctatum*. Daripada 449 ekor, 445 ekor masih di peringkat juvenil. Bagi ikan pari pula, sebanyak 406 ekor telah ditangkap yang terdiri daripada order Myliobatiformes dan famili Dasyatidae daripada spesies *Brevitrygon imbricata*, *Brevitrygon*

heterura, *Maculabatis gerrardi*, *Telatrygon biasa*, *Hemitrygon akajei*, *Maculabatis pastinacoides*, *Pateobatis uarnacoides* dan *Telatrygon zugei*. Untuk ikan pari pula daripada 406 ekor, 232 ekor masih di peringkat juvenil. Secara umumnya, hampir semua ikan yu dan lebih dari 50 % ikan pari masih di peringkat juvenil. Kajian ini telah mengesahkan bahawa kawasan yang dikaji di perairan Kuala Pahang ialah kawasan nurseri yang penting untuk sekurang-kurangnya tiga spesies ikan yu dan lapan spesies ikan pari. Kitaran rekrutmen spesies-spesies ini akan terjejas dan populasi mereka akan terancam pada masa depan. Maklumat yang diperolehi daripada kajian ini dapat dijadikan panduan oleh pihak pengurusan untuk melaksanakan langkah-langkah yang khusus bagi memastikan sumber ini dieksploitasi secara lestari.

Introduction

Malaysia is rich in diversity of sharks and rays. Until year 2016, Malaysia had recorded 85 species of rays, 70 species of sharks, six species of skates and one species of chimaera. A total of 18 families of sharks, 12 families of rays, two families of skates and one family of chimaera were recorded. The numbers are expected to be more in future as new species were continuously discovered and many deep-water species are still unknown due to limited research activities (Abd Haris Hilmi *et al.*, 2017). The life cycle of most of these fishes were distinguished by late maturity, long life spans, long gestation periods, and few well-developed progenies (Dulvy *et al.*, 2008). The landings of shark and ray in Malaysia contributed about 1 % and 2 % of total marine landings respectively from 2015-2016 (Abd Haris Hilmi *et al.*, 2017). However, shark and ray are not intentionally fished but are mostly caught as by-catch in many fishing gears such as trawlers and drift nets. By-catch is the unintentionally capture of non-targeted species or juvenile size ranges of the target species by non-selective fishing gear (Hall, 1996; Crowder and Murawski, 1998).

Fishing vessels in Malaysian waters operate in different zone according to their type of gear and gross registered tonnage (GRT). Vessels in Zone A (less than 10 GRT) operate in the radius of less than five nautical miles from the coastline, vessels in Zone B (10-40 GRT) operate between 5-15 nautical miles from the coastline and vessels in Zone C (more than 40 GRT) operate in the radius more than 15 nautical miles from the coastline. However, during monsoon season in the East Coast of Peninsular Malaysia, a special permit to operate bottom trawl net in a radius of less than five nautical miles was a license to fishers in Zone A namely 'Monsoon Season Trawl Net' or locally known as Pukat Tunda Musim Tengkujuh (PTMT). Monsoon season trawl net was targeted to catch the high quality of shrimps and fishes on the seafloor of shallow coastal area less than 10 m depth. The operation of PTMT only allowed to be operated in four months' period, starting from November until February the next year. In 2017, the operation period was starting in December 2017 until March 2018. The area for trawling activity must exceed two nautical miles (nm) radius from the coastline to conserve the natural habitat and nursery ground of marine fishes. However, special permission from the Department of Fisheries Malaysia (DoF) was given to Southeast Asia Marine Resources Institute (ISMAT) researchers to conduct this study within two nautical miles from the coastline.

This study conducted in Kuala Pahang due to the frequent highest catch of sharks and rays recorded in Pahang compared to other states in the East Coast of Peninsular Malaysia. In the year 2018, the total landing of sharks and rays were 1,845 tonnes and 2,565 tonnes respectively. The landing of sharks and rays recorded in Pahang were 774 tonnes (42 %) and 1,194 tonnes (46 %) respectively, (DoFM, 2020). The objectives of this study were to determine the catch composition of sharks and rays at the species level and their nursery ground for some species as a consequence of the trawling activity during monsoon season. This is the first study conducted in Malaysia and Southeast Asia.

The results are intended to provide scientific information to the DoF policymakers in taking actions to conserve and manage shark and ray resources for sustainable exploitation.

Materials and Methods

Six sampling activities comprising of 36 trawl stations were conducted in November and December 2018; February and March in 2019 at Kuala Pahang waters using a Zone A fishing wooden vessel. The GRT of the vessel is 22.03 tones with 13.9 m length, 4 m width and powered with 190 HP engine. The vessel was equipped with Garmin GPSMAP 585 Plus GPS chart plotter with chirp fish finder and Sonar with GT20 transducer. The sampling gear used was shrimp bottom trawl net with 25.6 m net length, 9.14 m net opening width, 36.6 m warp wire, 4.6 m sweep line, 10 m headline and 25 mm cod-end mesh size. The duration of trawl operation at each station was about one hour at a trawling speed of about 2.5 knots. The study was conducted in waters between 2.3-8.3 m depth located between 0.4-1.8 nm from the coastline. The distance of the trawl at each station was about 1.7 nm with a swept area of about 0.29 km² (0.091 km X 3.15 km). Figure 1 shows the study area, trawl stations and direction of towing activity. Coordinate at the start and at end of trawled at each station and other details information is shown in Appendix III. Sharks and rays were sorted by species, sex and individual length-weight were measured. All shark and ray specimens were released *in situ* after all information recorded. Some specimens were preserved for DNA bar-coding analysis for confirmation of look-alike species. Sub-samples of commercial fish and shrimp as well as trash fish were sorted according to species and their weight was recorded. The total catch for each trawl was weighed.

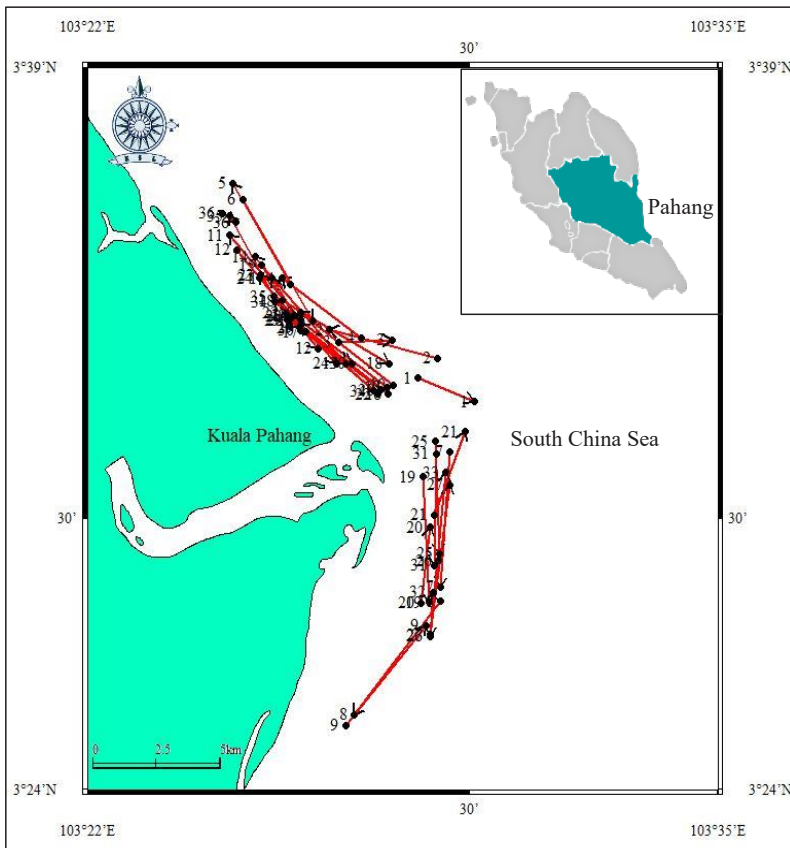


Figure 1: Study area showing trawl stations and trawling direction.

Materials and Methods

Catch Composition of Shark and Ray by Month

A total of 2,234.5 kg of catches comprising 32.7 kg of sharks, 83.3 kg of rays and 2,118.5 kg of other fishes and shrimps were recorded. In general, the landing of sharks and rays contributed only 1.5 % and 3.7 % respectively.

The composition of sharks by weight percentage by month ranged from 0.18-2.3 % with an average of 1.42 %. The highest weight of sharks caught by month was 15.75 kg in February 2019. All catches were from six stations. The lowest weight of sharks caught by month was 0.92 kg in November 2018. All catches were from 12 stations. In terms of Catch Per Unit Effort (CPUE), sharks contributed between 0.61-2.62 kg/hour.

However, the composition of rays by weight percentage by month ranged from 1.2-5.82 % with an average of 3.48 %. The highest weight of rays caught by month was 29.49 kg in November 2018. All catches were from 12 stations. The lowest weight of rays caught by month was 2.65 kg in December 2018. All catches were from six stations. In terms of Catch Per Unit Effort (CPUE), rays contributed between 0.44-4.30 kg/hour. Other catches were including commercial fish, low-value fish, lobster, prawn, crab and one green turtle (*Chelonia mydas*). The average weight of other catches during this study was 529.62 kg with a percentage of 95.10 % of the total catch. Figure 2 shows weight in kilogram and composition percentage of shark, ray and other catches, and CPUE of sharks and rays recorded during the study.

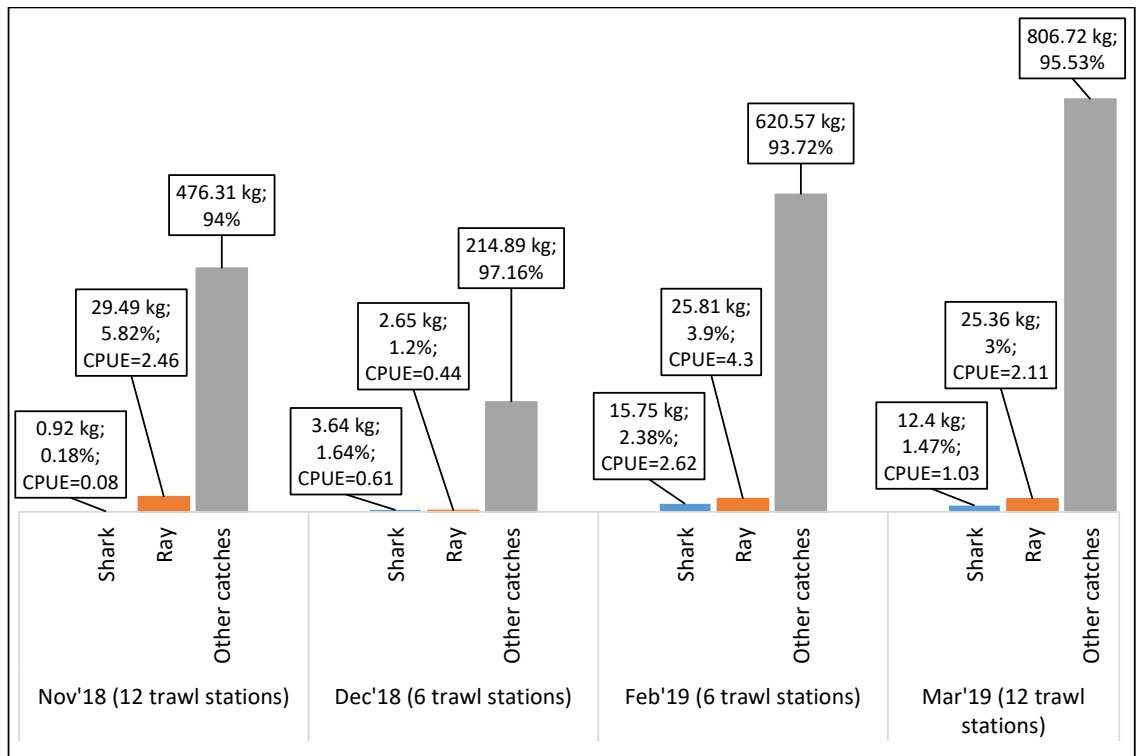


Figure 2: Weight (kg) and composition percentage of shark, ray and other catches and CPUE of sharks and rays.

Total Catch of Sharks and Rays by Station

The top five highest landings of sharks were recorded at Station 24 weighed 5.03 kg followed by Station 23 (4.14 kg), Station 20 (2.64 kg), Station 29 (2.25 kg) and Station 27 with 2.21 kg. As for rays, the top five highest landings were recorded at Station 1 weighed 19.59 kg followed by Station 21 (12.4 kg), Station 26 (8.48 kg), Station 27 (6.39 kg) and Station 24 with 5.64 kg. Station 1, Station 23, Station 24 and Station 29 were located in the Northern part of the Pahang River mouth. Whilst Station 20, Station 21, Station 26 and Station 27 were located in the Southern part of the Pahang River mouth. Station 24 and Station 27 showed the highest catch of sharks and rays.

The top five highest individuals of sharks were recorded at Station 24 (62 individuals) followed by Station 23 (49 individuals), Station 20 (31 individuals), Station 27 (29 individuals) and Station 29 with 26 individuals. As for rays, the top five highest individuals were recorded at Station 21 (62 individuals) followed by Station 26 (53 individuals), Station 27 (47 individuals), Station 20 (28 individuals) and Station 30 with 26 individuals. Station 23, Station 24, Station 29 and Station 30 were located in the Northern part of the Pahang River mouth. Whilst Station 20, Station 21, Station 26 and Station 27 were located in the Southern part of the Pahang River mouth. Station 20 and Station 27 showed the highest catch of sharks and rays. The highest individual of sharks and rays was 62. Details are shown in Appendix I.

Biodiversity, Sample Size (Number of Specimens) and Actual Weight of Shark and Ray

A total of 449 individual sharks (3 species) and 406 individuals of rays (8 species) were collected and identified. Three species of sharks were identified as *Chiloscyllium hasseltii*, *Chiloscyllium indicum* and *Chiloscyllium punctatum* and eight species of rays were *Brevitrygon heterura*, *Brevitrygon imbricata*, *Hemistrygon akajei*, *Maculabatis gerrardi*, *Maculabatis pastinacoides*, *Pateobatis uarnacoides*, *Telatrygon biasa* and *Telatrygon zugei*. All sharks were from order Orectolobiformes and family Hemiscylliidae and all rays were from order Myliobatiformes and family Dasyatidae.

The highest specimen of sharks recorded was 181 in February 2019 followed by 155 specimens in March 2019. The most common and abundant shark species were dominated by *Chiloscyllium hasseltii* with 435 individuals. For *Chiloscyllium indicum* and *Chiloscyllium punctatum* only 13 individuals and one individual respectively. All species were landed every month throughout this study except *Chiloscyllium punctatum* only recorded in February 2019.

The highest specimen of rays recorded was 176 in March 2019 followed by 139 specimens in February 2019. The most common and abundant ray species were dominated by *B. imbricata* with 268 individuals followed by *B. heterura* and *M. gerrardi* 68 and 62 individuals respectively. *B. imbricata* and *M. gerrardi* were landed every month throughout this study. Other species such as *B. heterura*, *H. akajei*, *M. pastinacoides*, *P. uarnacoides*, *T. biasa* and *T. zugei* only recorded between 1-3 months. Details are shown in Table 4.

Table 4: Number of individuals of shark and ray by species recorded by month.

No	Order	Family	Group / Species / Common Name	Year / Month				Total
				2018		2019		
				Nov	Dec	Feb	Mar	
1	Orectolobiformes	Hemiscylliidae	<i>C. Hasseltii</i> (Indonesian Bambooshark)	40	71	171	153	435
2			<i>C. Indicum</i> (Slender Bambooshark)	1	1	9	2	13
3			<i>C. Punctatum</i> (Brownbanded Bambooshark)	-	-	1	-	1
			Total Shark	41	72	181	155	449
1	Myliobatiformes	Dasyatidae	<i>B. Heterura</i> (Scaly Whipray)	31	-	2	35	68
2			<i>B. Imbricata</i> (Bengal Whipray)	36	3	103	126	268
3			<i>H. Akajei</i> (Red Stingray)	1	-	-	-	1
4			<i>M. Gerrardi</i> (Whitespotted Whipray)	7	8	34	13	62
5			<i>M. Pastinacoides</i> (Round Whipray)	-	-	-	1	1
6			<i>P. Uarnacoides</i> (Whitenose Whipray)	1	-	-	-	1
7			<i>T. Biosa</i> (Indonesian Sharpnose Ray)	-	3	-	1	4
8			<i>T. Zugei</i> (Pale-edge Sharpnose Ray)	1	-	-	-	1
			Total Ray	77	14	139	176	406

Figure 3 shows number of juvenile, adult, male and female of sharks and rays recorded during the study. The highest catch of sharks and rays was recorded in March 2019 with 331 individuals, followed by 320 individuals in February 2019, 118 individuals in November 2018 and 86 individuals in December 2018. Out of total 449 individuals of shark, 200 individuals were male and 249 individuals were female. As for rays, out of total 406 individuals, 215 individuals were male and 191 individuals were female. Almost all sharks caught in this study were at a juvenile stage with a percentage of 98.7 % except in February 2019, only six individuals (1.3 %) of sharks were matured. Whilst, a total of 266 individuals (65.5 %) of rays were at the juvenile stage and 140 individuals (34.5 %) were matured.

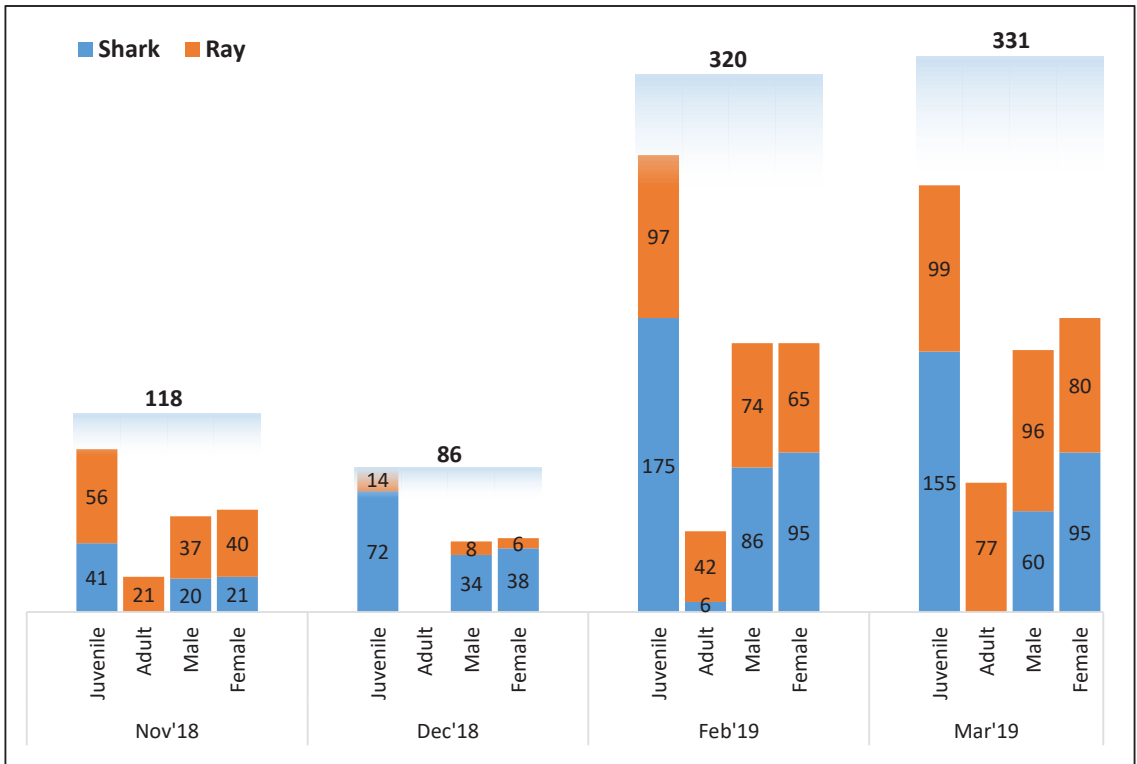


Figure 3: Number of juveniles, adults, males and females of sharks and rays.

In term of weight, *C. hasseltii* recorded the highest at 30.88 kg followed by *C. indicum* at 1.41 kg. Weight of *C. punctatum* only 0.38 kg. The highest weight of shark recorded was 15.75 kg in February 2019 followed by 12.4 kg in March 2019 and 3.64 kg in December 2018.

As for rays, *M. gerrardi* recorded the highest at 38.12 kg followed by *B. imbricata* (31.49 kg) and *B. heterura* with 9.96 kg. The weight of other species ranged between 0.19-2.2 kg. The highest weight of ray recorded was 29.49 kg in November 2018 followed by 25.81 kg in February 2019 and 25.36 kg in March 2019. The lowest catch of rays was 2.65 kg recorded in December 2018. Details are shown in Table 5.

Table 5: Weight of shark and ray (in kilograms, kg) by species.

Group / Species	Year / Month				Total
	2018		2019		
	Nov	Dec	Feb	Mar	
<i>C. Hasseltii</i> (Indonesian Bambooshark)	0.84	3.62	14.17	12.29	30.92
<i>C. Indicum</i> (Slender Bambooshark)	0.08	0.02	1.19	0.11	1.41
<i>C. Punctatum</i> (Brownbanded Bambooshark)	-	-	0.38	-	0.38
Total Shark	0.92	3.64	15.75	12.40	32.71
<i>B. Heterura</i> (Scaly Whipray)	2.59	-	0.71	6.66	9.96
<i>B. Imbricata</i> (Bengal Whipray)	3.87	0.24	13.26	14.12	31.49
<i>H. Akajei</i> (Red Stingray)	0.24	-	-	-	0.24
<i>M. Gerrardi</i> (Whitespotted Whipray)	20.40	2.25	11.83	3.63	38.12
<i>M. Pastinacoides</i> (Round whipray)	-	-	-	0.85	0.85
<i>P. Uarnacoides</i> (Whitenose Whipray)	2.20	-	-	-	2.20
<i>T. Biasa</i> (Indonesian Sharpnose Ray)	-	0.16	-	0.09	0.26
<i>T. Zugei</i> (Pale-edge Sharpnose Ray)	0.19	-	-	-	0.19
Total Ray	29.49	2.65	25.81	25.36	83.30

Size Range of Shark and Ray by Species

The range size of all shark was 12.5-56.5 cm with an average of 25.7 cm. The range size of *C. hasseltii* was 12.5-56.5 cm with an average of 25.5 cm. The range size of *C. indicum* was 19.8-50.3 cm with an average of 33.8 cm. Almost all specimens were at the juvenile stage.

Whilst for rays the ranged of disc length was 6.5-75 cm with an average of 15.6 cm. The ranged size of *M. gerrardi* 15.5-75 cm with an average of 20.7 cm, *B. heterura* (6.5-21.8 cm with an average 15.2 cm) and *B. imbricata* (6.8-25 cm with an average of 14.5 cm). Other species ranged between 8.5-38 cm. Details are shown in Table 6.

Table 6: Size range of sharks (total length) and rays (disc length) by species. All measurements are in cm.

Group / Species	Year / Month												Summary Size Range		
	2018						2019								
	Nov			Dec			Feb			Mar					
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
<i>C. Hasseltii</i>	12.5	34.9	17.7	14.4	35.4	22.4	13.0	56.5	26.5	14.1	40.2	27.5	12.5	56.5	25.5
<i>C. Indicum</i>	32.7	32.7	32.7	19.8	19.8	19.8	20.9	50.3	36.2	29.8	30.8	30.3	19.8	50.3	33.8
<i>C. Punctatum</i>	-	-	-	-	-	-	48.4	48.4	48.4	-	-	-	48.4	48.4	48.4
<i>B. Heterura</i>	6.5	20.0	12.2	-	-	-	20.7	21.4	21.1	11.0	21.8	17.5	6.5	21.8	15.2
<i>B. Imbricata</i>	6.8	22.0	13.9	12.5	13.5	13.0	7.5	25.0	14.7	7.1	20.5	14.5	6.8	25.0	14.5
<i>H. Akajei</i>	18.7	18.7	18.7	-	-	-	-	-	-	-	-	-	18.7	18.7	18.7
<i>M. Gerrardi</i>	18.1	75.0	28.0	18.3	20.5	19.2	15.5	23.5	20.3	17.2	21.3	18.7	15.5	75.0	20.7
<i>M. Pastinacoides</i>	-	-	-	-	-	-	-	-	-	30.5	30.5	30.5	30.5	30.5	30.5
<i>P. Uarnacoides</i>	38.0	38.0	38.0	-	-	-	-	-	-	-	-	-	38.0	38.0	38.0
<i>T. Biasa</i>	-	-	-	8.5	13.0	11.3	-	-	-	14.9	14.9	14.9	8.5	14.9	12.2
<i>T. Zugei</i>	20.0	20.0	20.0	-	-	-	-	-	-	-	-	-	20.0	20.0	20.0

Discussions

Based on previous research conducted by DoF researchers, during the monsoon season, shrimps, crabs and other juveniles of fishes are widespread and abundant in the coastal area of the East Coast of Peninsular Malaysia. Traditional fishers operated PTMT targeted for shrimps due to its high commercial value. Most catches comprising juvenile of shrimps, crabs and other commercial value fishes. In term of percentage, this study found that shrimp only contributed between 9.07-13.9 % from the total catch, commercial value fishes between 18.31-34.03 % and low-value species (including juvenile of highly commercial species) 48.43-63.32%. Details are shown in Appendix II. Normally, juvenile sharks and rays were categorized as low-value fish and sold at very low prices (about RM0.50 /kg).

The range size of sharks was between 12.5-56.5 cm in total length. The maximum total length for *C. hasseltii* recorded in this study was 56.5 cm, *C. indicum* (50.3 cm) and *C. punctatum* about 48.4 cm. According to Ahmad and Annie Lim (2012), only *C. hasseltii* and *C. indicum* were matured. Out of 449 individuals of sharks caught, only four individuals were matured. *C. hasseltii* matured at total length ranged between 44-59 cm and total length at hatching are between 9-12 cm. *C. indicum* matured at total length ranged between 39-43 cm. *C. punctatum* matured at total length ranged between 68-76 cm.

The range size of rays was between 6.5-75 cm disc length. Only one individual of *M. gerrardi*, one individual of *T. zugei*, 43 individuals of *B. heterura* and 129 individuals of *B. imbricata* were matured. *M. gerrardi* matured at ranged between 48-63 cm, *T. zugei* (16-19 cm), *B. heterura* (16-17 cm) and *B. imbricata* at 15 cm disc width. This showed that almost all sharks and most of the rays caught during PTMT were still at juvenile stage with the percentage of 98.7 % and 65.5 % respectively. The abundance of juvenile sharks and rays have proved that the study area is an important nursery

ground for at least three species of sharks and eight species of rays. The continuous and uncontrollable PTMT activities would affect the recruitment cycle of shark and ray and their population could be threatened in future.

Researchers from Universiti Malaysia Terengganu (Abdullah *et al.*, 2020) had conducted research using stable isotope analysis of carbon and nitrogen ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) to study the food web and determine the dietary carbon sources of juvenile sharks and rays in Kuala Pahang waters. The findings have proved that juvenile sharks and rays strongly depended on estuarine nursery areas for food and protection, before venturing further out to sea.

The study sites in Kuala Pahang waters is an inshore coastal area with the sandy bottom surface and sometimes muddy during monsoon season. The condition suits the habitat for sharks from the family Hemiscyllidae and stingrays from the family Dasyatidae. Bamboo sharks (*Chiloscyllium spp.*) are small inshore demersal sharks. They commonly inhabit on soft-bottom inshore and offshore in open and enclosed bays, inshore coral reefs and sometimes in shallow water sufficient enough to cover them (Compagno, 2001; Cavanagh *et al.*, 2013; Nur-Farhana *et al.*, 2013). Stingrays from the family Dasyatidae inhabit sandy bottom and commonly found in the coastal area (Furumitsu *et al.*, 2019).

Conclusion

This study found that all 449 specimens of shark were from order Orectolobiformes and family Hemiscylliidae and 406 specimens of ray were from order Myliobatiformes and family Dasyatidae. The most common and abundant species of sharks recorded were *C. hasseltii*, *C. indicum* and followed by *C. punctatum*. Whilst, the most common and abundant species of rays were dominated by *B. imbricata*, *B. heterura* and *M. gerrardi*. Other species of ray were *H. akajei*, *M. pastinacoides*, *P. uarnacoides*, *T. biasa* and *T. zugei*. The range of shark sampled was between 12.5-56.5 cm and the ranged of rays was between 6.5-75 cm disc length. Out of 449 individuals of sharks, 445 individuals (99.1 %) were still at the juvenile stage. As for rays out of 406 individuals, 232 individuals (57.1 %) were at the juvenile stage.

In term of the number of individuals per haul for sharks and rays, it was ranged between 1-62 individuals and 0-62 individuals respectively. The study found that shark and ray landings contributed to 5.19 % of the total catch. This value is higher as compared to about 1.3-2.2 % for Malaysia from 1982-2018. Based on this finding, we found that the study area in Kuala Pahang waters is a natural nursery ground for at least three species of sharks and eight species of rays. Further research and study should be conducted to investigate other nursery ground of sharks and rays in the East Coast of Peninsular Malaysia. The results could be used to assist fisheries management in taking actions to preserve and conserve the population of sharks and rays in future.

Acknowledgement

The greatest gratitude to the Department of Fisheries Malaysia for providing financial supports to conduct this study. A special thanks to Mr Raja Bidin bin Raja Hassan, the Director of Southeast Asia Marine Resources Institute and Dr Ahmad bin Ali, the Head of Fishery Oceanography and Resource Enhancement Section, for his guidance in the data analysis and preparation of this manuscript.

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Appendix I

Weight and number of individuals of shark and ray by trawl station at Kuala Pahang during the study in November, December 2018, and February and March 2019.

Month	Station	Weight (kg)		No of Individuals	
		Shark	Ray	Shark	Ray
November 2018	1	0.031	19.59	3	13
	2	0.154	1.335	14	8
	3	0.009	0	1	0
	4	0.125	0.24	2	1
	5	0.094	0.42	2	3
	6	0.009	0.1	1	1
	7	0.086	2.825	3	5
	8	0.106	0.9174	3	12
	9	0.132	0.688	4	8
	10	0.059	1.147	2	4
	11	0.029	1.4142	1	15
	12	0.089	0.812	5	7
December 2018	13	0.422	1.053	11	6
	14	0.452	0.248	11	1
	15	1.385	0.3	16	1
	16	0.482	0.18	11	2
	17	0.624	0.57	15	2
	18	0.273	0.298	8	2
February 2019	19	0.472	0.225	8	4
	20	2.633	1.812	31	28
	21	1.537	12.396	15	62
	22	1.928	0.358	16	3
	23	4.144	5.374	49	23
	24	5.034	5.64	62	19
March 2019	25	0.503	1.121	5	5
	26	1.494	8.483	23	53
	27	2.207	6.389	29	47
	28	1.168	0.705	11	4
	29	2.246	2.325	26	15
	30	0.702	2.871	7	26
	31	0.176	0.05	4	1
	32	1.314	2.533	13	13
	33	0.769	0.041	8	3
	34	0.601	0.334	9	2
	35	0.622	0	11	0
	36	0.598	0.507	9	7

Appendix II

Weight in kilogram and percentage of catch by group at Kuala Pahang during the study in November, December 2018, and February and March 2019.

Group	Year / Month				Grand Total
	2018		2019		
	Nov	Dec	Feb	Mar	
All Sharks (kg)	0.92	3.64	15.75	12.4	32.71
Percentage of Sharks (%)	0.18	1.64	2.38	1.47	1.46
All Rays (kg)	29.49	2.65	25.81	25.36	83.3
Percentage of Rays (%)	5.82	1.2	3.9	3	3.73
Commercial Fishes (kg)	126.33	75.27	182.28	154.66	538.54
Percentage of Commercial Fishes (%)	24.93	34.03	27.53	18.31	24.1
Shrimp (kg)	56.24	30.49	60.05	117.36	264.15
Percentage of Shrimp (%)	11.1	13.79	9.07	13.9	11.82
Crab (kg)	3.77	1.71	0.66	0	6.14
Percentage of Crab (%)	0.74	0.78	0.1	0	0.27
Lobster (kg)	0	0.29	0	0	0.29
Percentage of Lobster (%)	0	0.13	0	0	0.01
Green Turtle (kg)	11	0	0	0	11
Percentage of Green Turtle (%)	2.17	0	0	0	0.49
Low-value Fishes (kg)	278.97	107.11	377.58	534.7	1,298.36
Percentage of Low-value Fishes (%)	55.05	48.43	57.03	63.32	58.11
Sum of Total Catch (kg)	506.72	221.17	662.12	844.48	2,234.5

Appendix III

Trip	Date	Trawl Station	Distance from Coastline (Nautical)	Coordinate at Start		Coordinate at End	
				Latitude	Longitude	Latitude	Longitude
1	06/11/2018	1	1	3°32.863'	103°28.875'	3°32.404'	103°30.072'
		2	1.3	3°33.272'	103°29.301'	3°33.845'	103°27.014'
		3	0.5	3°33.600'	103°27.215'	3°33.644'	103°28.334'
	07/11/2018	4	0.9	3°33.677'	103°27.691'	3°34.886'	103°26.019'
		5	0.7	3°34.769'	103°26.181'	3°36.809'	103°24.962'
		6	1.8	3°36.477'	103°25.181'	3°34.026'	103°26.671'
2	28/11/2018	7	1.6	3°31.378'	103°29.554'	3°28.642'	103°29.357'
		8	1.2	3°28.357'	103°29.364'	3°26.038'	103°27.525'
		9	1.1	3°25.824'	103°27.358'	3°27.858'	103°29.068'
	29/11/2018	10	0.8	3°32.726'	103°28.353'	3°34.194'	103°26.401'
		11	0.8	3°34.056'	103°26.394'	3°35.770'	103°24.894'
		12	0.9	3°35.451'	103°25.042'	3°33.467'	103°26.781'
3	29/12/2018	13	1.2	3°32.669'	103°28.240'	3°34.138'	103°26.246'
		14	0.9	3°34.141'	103°26.262'	3°35.331'	103°25.449'
		15	1	3°35.152'	103°25.567'	3°33.151'	103°27.361'
	30/12/2018	16	0.8	3°32.551'	103°28.261'	3°33.930'	103°26.396'
		17	0.9	3°33.803'	103°26.507'	3°34.885'	103°25.795'
		18	0.7	3°34.438'	103°26.007'	3°33.150'	103°28.275'
4	19/02/2019	19	0.4	3°30.880'	103°28.988'	3°28.320'	103°29.124'
		20	0.5	3°28.298'	103°28.955'	3°29.851'	103°29.146'
		21	0.9	3°30.092'	103°29.232'	3°31.776'	103°29.884'
	20/02/2019	22	1.2	3°32.557'	103°28.035'	3°34.110'	103°26.147'
		23	0.6	3°34.180'	103°26.098'	3°34.951'	103°25.544'
		24	0.4	3°34.889'	103°25.542'	3°33.161'	103°27.155'
5	04/03/2019	25	0.7	3°31.587'	103°29.250'	3°29.307'	103°29.339'
		26	0.6	3°29.185'	103°29.314'	3°27.639'	103°29.136'
		27	0.7	3°27.679'	103°29.152'	3°30.691'	103°29.567'
	05/03/2019	28	1.3	3°32.636'	103°28.098'	3°34.040'	103°26.171'
		29	0.7	3°34.050'	103°26.110'	3°33.904'	103°26.373'
		30	1.1	3°33.838'	103°26.395'	3°33.163'	103°27.492'
6	17/03/2019	31	0.7	3°31.322'	103°29.274'	3°29.062'	103°29.225'
		32	0.5	3°28.934'	103°29.208'	3°28.522'	103°29.221'
		33	0.5	3°28.587'	103°29.181'	3°30.957'	103°29.475'
	18/03/2019	34	1.3	3°32.612'	103°27.958'	3°34.415'	103°25.860'
		35	1	3°34.527'	103°25.840'	3°36.144'	103°24.896'
		36	1.4	3°36.208'	103°24.757'	3°36.023'	103°25.024'

Sea Cucumber Population in Pulau Mabul, Sabah

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Abstract: Pulau Mabul, located on the eastern side of Sabah, has a large number of full-time artisanal fishermen (2000 people), thus overexploitation of certain commercial marine species such as sea cucumber might occurred. This study was carried out on between 6th-10th of January 2020. Data collection was done using roving diver search method at eight sampling sites. Sea cucumber was recorded at shallow reef flat areas and Site 4. *Stichopus pseudohorrens*, *Pearsonothuria graeffei*, *Colochirus robustus* and *Bohadschia marmorata* been recorded at sampling sites with depths between 3-18 m. The total average density of sea cucumbers was 0.14 ± 0.13 individuals /m². The highest number of sea cucumber found was at the S3 and the lowest was at S6. The diversity indexes calculated were Shannon Weiner at 1.04, population density and diversity observed was low compared to the past studies. Therefore, an immediate action such as restoration activities as well as the introduction of conservation and protection measures are needed urgently. Conservation via public awareness with local villagers is also needed.

Keywords: Sea cucumber, Pulau Mabul, Species diversity, Diversity index, Richness index.

Abstrak: Pulau Mabul, yang terletak di sebelah timur Sabah, mempunyai sejumlah besar nelayan artisanal (2000 orang), sehingga eksploitasi berlebihan spesies laut komersial seperti timun laut mungkin berlaku. Kajian ini dilakukan antara 6-10 Januari 2020. Pengumpulan data dilakukan dengan menggunakan kaedah pencarian penyelam roving di lapan lokasi persampelan. Tidak ada timun laut yang direkodkan di kawasan rata dan terumbu karang cetek. *Stichopus pseudohorrens*, *Pearsonothuria graeffei*, *Colochirus robustus* dan *Bohadschia marmorata* direkodkan di lokasi pengambilan sampel dengan kedalaman antara 3-18 m. Kepadatan purata timun laut adalah 0.14 ± 0.13 individu /m². Jumlah timun laut tertinggi dijumpai di S3 dan terendah di S6. Indeks kepelbagaian yang dikira adalah Shannon Weiner pada 1.04, Evenness Index pada 0.75 dan Margalef richness index pada 0.92. Kepadatan dan kepelbagaian populasi timun laut yang diamati adalah rendah berbanding kajian yang lalu. Oleh itu, tindakan segera seperti aktiviti pemulihan serta pengenalan langkah-langkah pemuliharaan dan perlindungan sangat diperlukan. Pemuliharaan melalui kesedaran masyarakat dengan penduduk kampung juga diperlukan.

Introduction

Sea cucumbers in many countries have experienced cases of excessive exploitation and depletion of resources (Purcel, 2010). The absence of a species in a particular place is often referred to as local extinction. It can occur if a particular species is not found in the habitat where the species can normally be found (Purcel, 2010). The major cause of resource extinction is over exploitation and habitat destruction (Baine and Choo, 1999)

The common species of sea cucumber that can normally be found in the shallow reef of Pulau Mabul are *Holothuria atra*, *H. leucospilota* and *Stichopus chloronotus* (Woo *et al.*, 2010).

Seven species of sea cucumbers were recorded in the previous study at Pulau Mabul (Woo *et al.*, 2010; Zulfigar *et al.*, 2008). These species included a valuable species such as *Thelenota anax* and *Bohadschia argus* followed by low-value and non-commercial species such as *Holothuria edulis*, *Pearsonothuria graeffei*, *Synaptula lamperti* and *Colochirus robustus* (Clarke and Rowe, 1971; Choo, 2004). Daily and continuous collection activity carried out by most of the local people during low tide threatened the sea cucumber population (Ho *et al.*, 2011). This was done by fishers from a wide range of ages, from children to adults and targeting the shallow-water species (Choo, 2004). More than 10 sea cucumber species were recorded in Sabah where 12 sea cucumber species can usually be seen in the Semporna market from the fishermen collection (Kamarudin *et al.*, 2009; Choo, 2012).

Pulau Mabul is located on the east Sabah, 27 km to the south of Semporna Town and 16 km north of Pulau Sipadan. The island is a popular tourist destination especially for diving activities. The population density of Pulau Mabul was 3318 inhabitants with 60 percent of the total population was Suluk and fishing was the main source of their income (Norhaya and Amran, 2015). This caused the resources around the island to deplete fast (Ho *et al.*, 2011). It primarily affects prized sedentary animals such as snails, clams and sea cucumbers which are the easiest target.

In this area, the number of people who are depending on marine life are high. Some involved in excessive catch and illegal fishing methods which destroy the coral reefs and reduced the resources (Arai, 2015). Lee *et al.*, (2018) stated that the sea cucumber can serve as indicators of the reef health. A survey was carried out to determine the sea cucumber population which later can be used to relate to the overall reef condition. The objectives of this study were to estimate the diversity and density of sea cucumbers around Pulau Mabul. The results could be used as baseline data for future management of reef community of Pulau Mabul and its neighbouring islands.

Materials and Methods

Surveys were carried out at six SCUBA dive sites and two reef flat sites around the island (Fig. 1 and Tab. 1). The dive sites were Panglima Reef (S1), Eel Garden (S2), Lobster Wall (S3), Borneo Divers House Reef (S4), Scuba Junkie House Reef (S5) and Ray Point (S6). While the shallow reef flats were Uncle Chang Chalet beach front (S7) and Borneo Divers beach front (S8).

One dive was done at each site counting the number and species of sea cucumber encountered. Photo of each species especially the unidentified ones were taken. All diving activities were carried out during the day except in S5, which was also done at night.

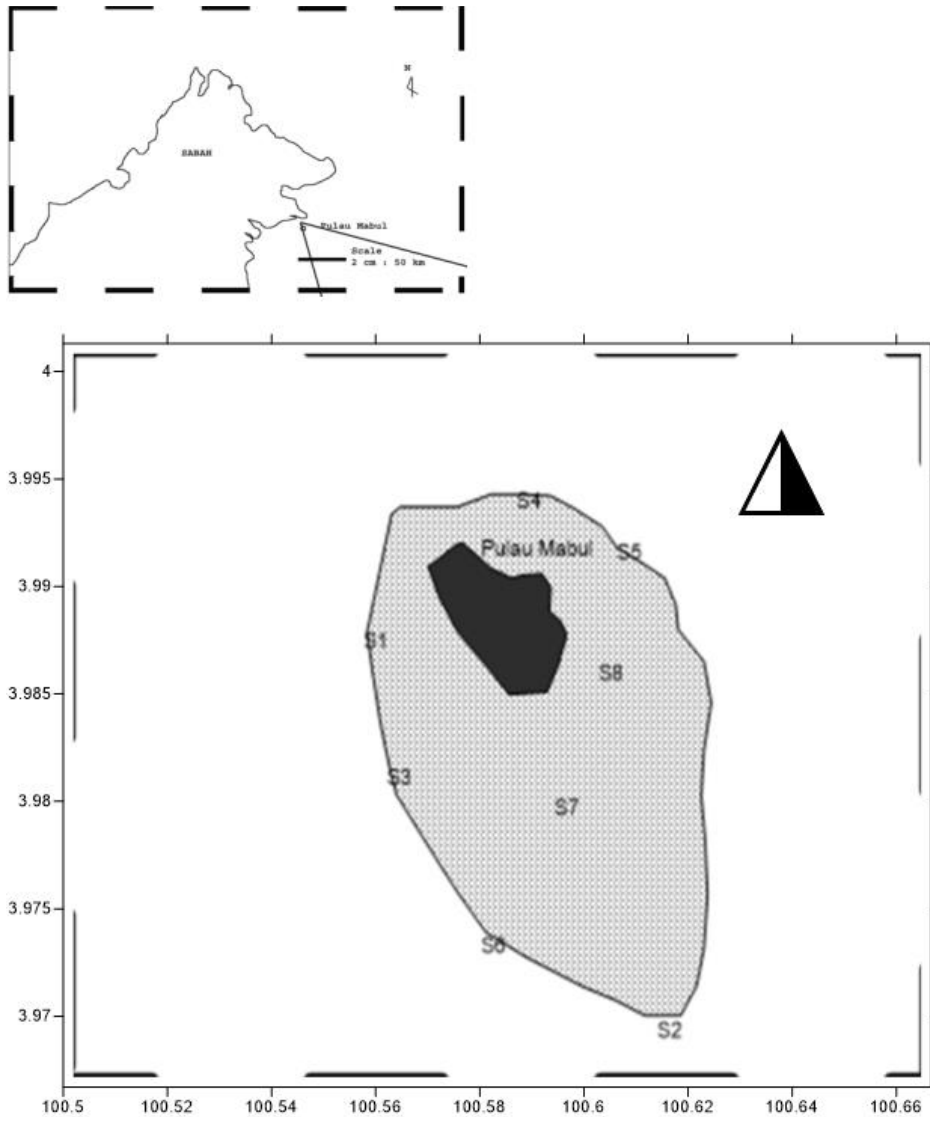


Figure 1: The location of eight sampling sites in Pulau Mabul.

Table 1: Sampling Sites.

Site	Location	Profile	Substrate	The Maximum Depth Reached (m)
S1	Panglima Reef	Wall Type	A mixture of rocks, soft coral and patches of hard coral	15
S2	Eel Garden	Wall and Sloping Bottom	A mixture of rocks, soft coral and patches of hard coral. Sandy reef bottom	15
S3	Lobster wall	Wall	A mixture of rocks, soft coral and patches of hard coral	15
S4	Borneo Diver House Reef	Shallow Sloping Bottom	Soft coral on the slope and sandy bottom	15
S5	Scuba Junkie House Reef	Shallow Sloping Bottom	Soft coral on the slope and sandy bottom	15
S6	Ray Point	Wall	A mixture of rocks, soft coral and patches of hard coral	15
S7	Uncle Chang Resort	Sandy Flat	Sandy and seagrass	0.5
S8	Borneo Diver Beach Front	Sandy Flat	Sandy and seagrass	0.5

Water quality such as salinity was determined using a refractometer, while water temperature was recorded using diving watch (Suunto D4i). Six sampling sites were explored by roaming scuba diver method, following the method of English *et al.*, (1994), and reef walking was done on two shallow reef flats. The reef walking was conducted during low tide by walking parallel to the beach along a belt transect covering 2.5 m on each side for a distance of 90 m (total area 450 m²).

The sea cucumber species were identified using sea cucumber guides (Forbes *et al.*, (1999); Forbes and Zainuddin, (1999); Desurmont (2003). Substrates were described following English *et al.*, (1994). Sea cucumbers found were recorded of species, number and size (length). Species diversity indices were calculated using Shannon Weiners index H' values, evenness index and Margalef richness index (Zar, 2010). The total number and standard deviation were calculated using a statistical program in excel (WPS Spreadsheets (10.2.0.7636).

Results and Discussions

Seawater salinity of Pulau Mabul was high at 35 ± 0.5 ppt compared to the west coast of the peninsular Malaysia at a range of around 29-31 ppt (Siti Akmar and Raymie, 2016). Underwater visibility was also well above 10 m with high underwater temperatures of $29 \pm 1^\circ\text{C}$.

The reef profile on which the study was conducted can be divided into three types: steep wall, shallow gentle sloping reef bottom and reef flat. The sites S1 and the S3 were of vertical wall type while S2, S4, S5 and S6 were gentle sloping and have a shallow reef bottom. Depth profile of the dive area was as shown in Tab. 1.

The steep reef walls below 10 m depth were covered with a variety of soft coral species. White sandy patches were also observed on the reef during the dives and were not determined of origin (Fig. 2). Destructive fishing methods were reported to be the main problem on Pulau Mabul and one is explosive fishing (Soo Ling, 2013). Sea cucumber was not found in the shallow areas of the reef, this may indicate that they have been fished out. Due to the increasing demand from international market, the Indo-West Pacific area has been heavily overfished (Lane and Limbong, 2013).



Figure 2: The condition of the coral reef during the survey.

Four species of sea cucumber were recorded *Pearsonothuria graeffei*, *Colochirus robustus*, *Bohadschia marmorata* and *Stichopus pseudohorrens* during the present study (Fig. 3). *P. graeffei* was the most abundant species represent 50 % of the total specimens recorded followed by *C. robustus* (38.5 %), *B. marmorata* (7.7 %) and last *S. pseudohorrens* (3.8 %). The number of sea cucumber by species and sampling sites is shown in Table 2. Sites S3 recorded the highest species number with three species followed by S5 (two species) and one species each at S1, S2 and S6. Sea cucumber was not recorded at S4, S7 and S8. The sizes of the sea cucumber species observed were *Pearsonothuria graeffei* (15-30 cm), *Colochirus robustus* (1-3 cm), *Bohadschia marmorata* (20 cm) and *Stichopus pseudohorrens* (30 cm).



Figure 3: The species of sea cucumber found, *Pearsonothuria graeffei* (left) and *Bohadschia marmorata* (right).

The sea cucumber diversity index, Shannon Weiner Index H' , calculated was 1.04, Evenness index 0.75 and Margalef richness index 0.92. The H' index of sea cucumber of Pulau Mabul (1.04) was lower compared to the H' index of sea cucumber from Pulau Payar Marine Park in Kedah (1.17) (Woo, 2013). The H' from Pulau Payar was only calculated for the Stichopodidae sea cucumber (Woo, 2013).

Table 2: The number of sea cucumber by species and sampling sites.

	S1	S2	S3	S4	S5	S6	S7	S8
<i>Bohadschia Marmorata</i>	0	0	0	0	2	0	0	0
<i>Peorsonothuria Graeffei</i>	4	4	2	0	1	2	0	0
<i>Stichopus Pseudohorrens</i>	0	0	1	0	0	0	0	0
<i>Colochirus Robustus</i>	0	0	10	0	0	0	0	0
Total Specimen	4	4	13	0	3	2	0	0
Total Species	1	1	3	0	2	1	0	0

Table 3: Number of sea cucumbers recorded in previous studies compared to the present study around Pulau Mabul.

	Zulfigar <i>et al.</i> , 2008	Woo <i>et al.</i> , 2010	Current study
Family Cucumariidae			
<i>Colochirus Robustus</i>		+	+
Family Synaptidae			
<i>Synaptula Lamperti</i>		+	
Family Holothuriidae			
<i>Bohadschia Argus</i>	+	+	
<i>Bohadschia Marmorata</i>			+
<i>Holothuria Edulis</i>	+	+	
<i>Holothuria Leucospilota</i>	+	+	
<i>Pearsonothuria Graeffei</i>	+	+	+
Family Stichopodidae			
<i>Thelenota Anax</i>		+	
<i>Stichopus Pseudohorrens</i>			+
<i>Stichopus Chloronotus</i>	+		
<i>Stichopus Hermannii</i>	+		
Number of Species	6	7	4

We recorded a lower number of species compared to the two previous studies (Woo *et al.*, (2010); Zulfigar *et al.*, (2008) (Table 3), but on the other hand, Woo *et al.*, (2010) recorded a lesser number of sea cucumber (19) compared to this study (26). The differences in the number of species observed might be due to the difference in the number of sites studied. From the list of the sea cucumber observed, *P. graeffei* was the only similar sea cucumber species. We managed to record *B. marmorata* from the only one night dive during the trip. We surveyed eight sites compared to four by Woo *et al.*, (2010) and only two sites were similar. The sites were Ray Point and Lobster wall. These eight sites were distributed around the reef of Pulau Mabul. Although a similar observation method was used, water conditions, low visibility, strong current and the observer's expertise might affect the outcome.

Ho *et al.*, (2011) pointed out that the collection of marine life frequently resulted in species failed to recover. High human population density on the island can increase the pressure on fisheries resources and affect the marine population (Ho *et al.*, 2011). New income sources which do not endanger natural resources should be generated. Besides that, conservation measures such as the general release of target species, developing fishing restrictions and new fishing methods should be introduced. The pressure on fisheries resources especially on the sea cucumber, sea urchins, snails, clams and others must be alleviated immediately before the population is depleted. It will also affect the tourism industry due to the reduction in attractive marine life which is the speciality of Pulau Mabul.

Conclusion

The sea cucumber population around Pulau Mabul Island was small and endangered. Only four species were recorded during this survey, it was lower compared to the previous studies but the number individuals (26) were higher. This finding is alarming and needs urgent restoration measures to be taken before the situation becomes worse.

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Stock Assessment of Threadfin Bream (*Nemipterus spp.*) in the East and West Coast of Peninsular Malaysia Waters using a Stock-production Model Incorporating Covariates (ASPIC)

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Abstract: Threadfin bream (*Nemipterus spp.*) is a demersal fish species of commercial importance to Malaysia. According to Malaysian fisheries statistical data, the landing of threadfin bream on the East coast was more than the West coast, between 12,000-21000 and 7,000-20,000 tons respectively. Trawlers are the main fishing gears that catch threadfin bream. Stock assessment on threadfin bream was conducted using a stock-production model incorporating covariates (ASPIC) software version 5.05 based on standardized catch per unit effort, STD-CPUE, and subsequent risk assessments were conducted using Kobe plot and Risk assessment software. The maximum sustainable yield, MSY derived for East and West coast Peninsular was 17,680 and 17,510 tons respectively. The result of the analysis showed the status of the current threadfin bream stock in East coast waters was in the safe zone (green area). The value of current total biomass (TB) over total biomass at MSY (TB_{MSY}), TB / TB_{MSY} is 1.14, and the value of current fishing mortality overfishing mortality at MSY (F_{MSY}), F / F_{MSY} is 0.83. While, in West Coast waters, the stock was in the overfished zone (red area) with $TB / TB_{MSY} = 0.95$ and $F / F_{MSY} = 1.12$. However, the current catch of threadfin bream in East and West coast was higher than the MSY level and both fisheries were leaning towards a medium high-risk situation. It was recommended the current catch for both East and West coast be reduced up to 16 % and 20 % giving total allowable catch, TAC figures of 16,340 and 14,904 tons respectively.

Keywords: Threadfin bream, stock assessment, ASPIC, MSY, risk assessment.

Abstrak: Ikan kerisi (*Nemipterus spp.*) merupakan spesies ikan demersal yang mempunyai kepentingan komersial di Malaysia. Menurut data statistik perikanan Malaysia, pendaratan ikan kerisi di pantai timur lebih banyak berbanding pantai barat, masing-masing antara 12,000-21000 dan 7,000-20,000 tan. Pukat tunda adalah alat penangkap utama bagi ikan kerisi. Penilaian stok pada ikan kerisi dilakukan dengan menggunakan perisian model produksi stok yang menggabungkan kovariat (ASPIC) versi 5.05 berdasarkan tangkapan se-unit usaha yang piawai, STD-CPUE dan penilaian risiko berikutnya dilakukan dengan menggunakan perisian Kobe plot dan Risk assessment. Pendaratan maksimum yang mapan, MSY yang diperolehi bagi Semenanjung pantai Timur dan Barat masing-masing ialah 17,680 dan 17,510 tan. Hasil analisis menunjukkan status stok ikan kerisi semasa di perairan pantai Timur berada di zon selamat (kawasan hijau). Nilai semasa keseluruhan biomas (TB) berbanding jumlah biomas pada tahap MSY (TB_{MSY}), TB / TB_{MSY} adalah 1.14 dan nilai kadar kematian tangkapan berbanding kadar kematian tangkapan pada tahap MSY (F_{MSY}), F / F_{MSY} adalah 0.83. Sementara itu, di perairan pantai Barat, stok berada di zon penangkapan ikan berlebihan (kawasan merah) dengan $TB / TB_{MSY} = 0.95$ dan $F / F_{MSY} = 1.12$. Walau bagaimanapun, tangkapan ikan kerisi pada ketika ini di pantai Timur dan Barat lebih tinggi daripada tahap MSY dan kedua-dua perikanan ini cenderung ke arah situasi berisiko tinggi sederhana. Adalah disyorkan tangkapan semasa untuk

kedua pantai Timur dan Barat dikurangkan sebanyak 16 % dan 20 % dengan membenarkan jumlah tangkapan, TAC masing-masing sebanyak 16,340 dan 14,904 tan.

Introduction

Malaysia is surrounded by four seas: the Strait of Malacca, South China Sea, Sulu Sea, and the Celebes Sea. With a vast marine area, Malaysia has the potential to be one of the leading fishing nations in the Southeast Asian region and is poised to step into a new era of development in the marine fishing industry.

One type of marine food fish that is very popular with Malaysian consumers is the *Nemipterus spp.*, a threadfin bream or locally known as ikan kerisi (Kholilah *et al.*, 2017; Russell, 1993). *Nemipterus spp.* belongs to the family Nemipteridae that is native to the Indian and the Pacific Oceans (FishBase, 2020). Nemipterids are an important component of the demersal fish with Family Nemipteridae having five genera comprising 67 species. Within genus *Nemipterus*, worldwide there are 25 species of which 19 species are documented in Malaysia (Edward, 1992; Russell, 1990). Threadfin breams are abundant in the coastal waters and can be found on muddy and sandy bottoms. One of the threadfin bream species, *Nemipterus japonicus*, is widely distributed in Indo West Pacific region, where it constitutes one of the most abundant demersal resources, especially in waters between the depths of about 70 to 180 meters (Devaraj and Guiati, 1988).

Most of the threadfin bream species form schools to protect themselves from the predator. Threadfin breams are carnivorous, feeding mainly on crustaceans (small prawns, stomatopods, and crabs) and other teleosts (FishBase, 2020; Murty, 1982). The special characteristics of this genus are their pinkish body coloration with variable yellow streaks on the whole abdominal length and fins (Imtiaz *et al.*, 2016) with a maximum length of about 32 cm and a maximum weight of 596 g (FishBase, 2020). Members of this genus are well known for their delicious taste and commercial importance: marketed as fresh, frozen, steamed, dried salted, drily smoked, fermented, or made into fish balls and fish meal (Russell, 1990). The trawl net, drift net, hooks, and lines, and fish trap are the fishing gears that were used to catch threadfin breams in Malaysia. and the catch (landings) of this fish has increased every year since 2008 (Anon.,2003 until 2018).

Recent fisheries resource surveys (2013-2016) conducted by the Department of Fishery Malaysia showed that the demersal fish resources within Peninsular Malaysia waters were over-exploited (FRI, 2017). During the surveys, threadfin breams were caught at a relatively higher catch rate than any other demersal fish species. At 50-100 meters water depth, the catch rate of threadfin breams fish in the East and West coast of Peninsular Malaysia can reach up to 15.27 kg hr⁻¹ and 15.85 kg hr⁻¹ respectively (FRI, 2018). However, stock assessment analysis specifically on threadfin breams has never been performed in Malaysia.

ASPIC (A stock-production model incorporating covariates) software (Prager 2004) is based on a non-equilibrium surplus production model, ignores biological factors (e.g. the age and size structure, sexual ratio) when assessing stock status. The minimum data needed to estimate stock status with such models are time series of relative abundance index and catch. In this regard, this method can be used to determine the stock status of fish resources such as threadfin bream based on available information or data in the annual Malaysian fisheries statistics system. Considering the fisheries importance, it is essential to assess the stock of this species for proper management and sustainable exploitation of the resource. Thus, the current research aims are to determine the stock status of genus *Nemipterus* in East and West coast Peninsular Malaysia using ASPIC.

Materials and Methods

Data collected from annual Malaysian Fisheries Statistics from 1966 to 2018 (Anon. 1966 until 2018) was in the form of catch and effort for genus *Nemipterus* in the West coast, while from 2003 to 2018 for the East coast. The catch is measured in tons and the effort is measured in a number of powered fishing vessels. These catch data were later converted to nominal catch per unit effort (CPUE) based on a number of fishing vessels. Subsequently, the nominal CPUEs were then transformed to Standard Catch-Per-Unit- of Effort (STD-CPUE) using the method of Generalized linear method (GLM) of a menu-driven software (Nishida, and Iwasaki, 2020). The STD-CPUEs obtained will be used in the analysis of the stock assessment by ASPIC version 5.05 software (Prager 2004) and ASPIC grid (parameter) search menu-driven software (Nishida, and Iwasaki, 2020). Finally, Kobe plot and risk assessments were generated using menu-driven software (Nishida 2018).

ASPIC software version 5.05 (Prager 2004) estimates MSY of the fishery stock by using two surplus production models viz. Fox (1970) and Schaefer (1954). The main output parameters computed through this software are maximum sustainable yield, MSY; carrying capacity, K; catchability coefficient, q; the ratio of initial biomass over carrying capacity (B_1/K), the coefficient of determination (R^2), stock biomass giving MSY (B_{MSY}) and fishing mortality rate at MSY (F_{MSY}).

Results and Discussions

Figure 1 shows the catch trend of threadfin bream on the East coast of Peninsular Malaysia (ECPM) from 2003 to 2018. Catch has been increasing steadily from 2003 until 2013 (17,000 tons) but dropped to about 14,000 tons in 2014. In recent years (2014-2017), there was a sharp increase in catches with the highest at 21,000 tons (2016) but decreased to 15,000 tons in 2018. Meanwhile, in West coast Peninsular Malaysia (WCPM), the catch has been increasing steadily from 2003 until 2012 (>19,000 tons). In 2013, the catch decreased to 15,000 tons but increased back to the highest catch at 20,700 tons in 2014. In East and West coast Peninsular Malaysia, threadfin bream was mostly landed by trawl net followed by drift net and purse-seine. The trend in percentage contribution by these 3 gears was almost constant from 2008 until 2018.

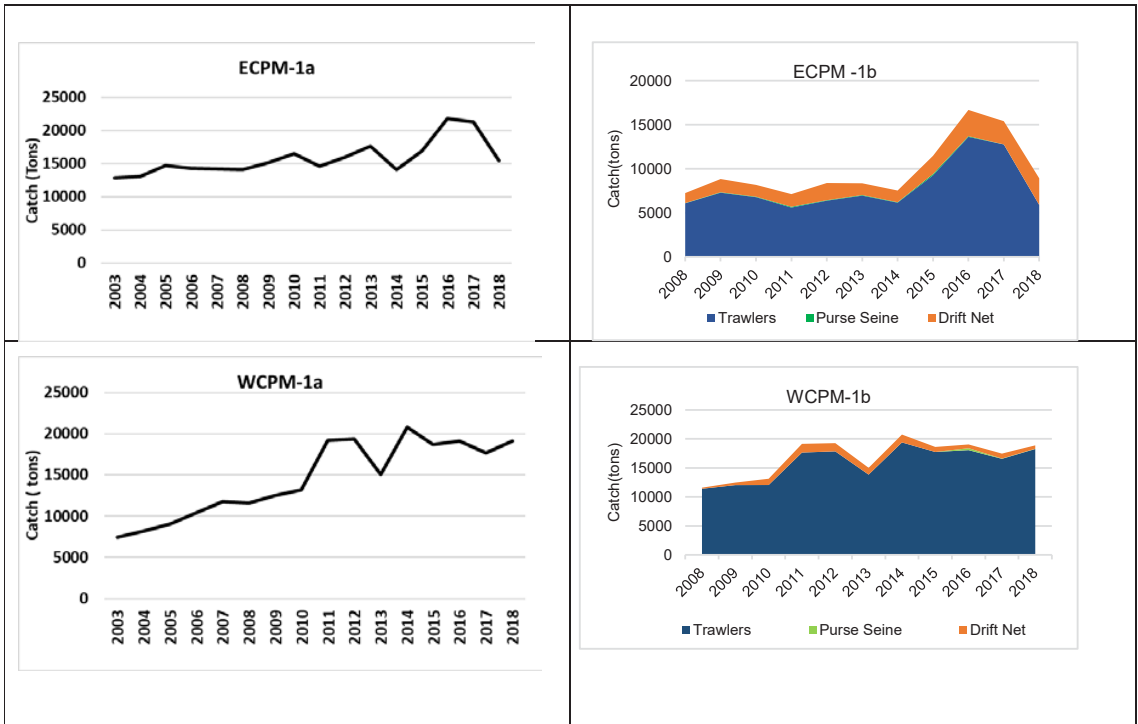


Figure 1: Threadfin Bream annual catch trend in East coast Peninsular Malaysia (ECPM) and West coast Peninsular Malaysia (WCPM). (Note: 1a refer to annual landing and 1b landing by gears).

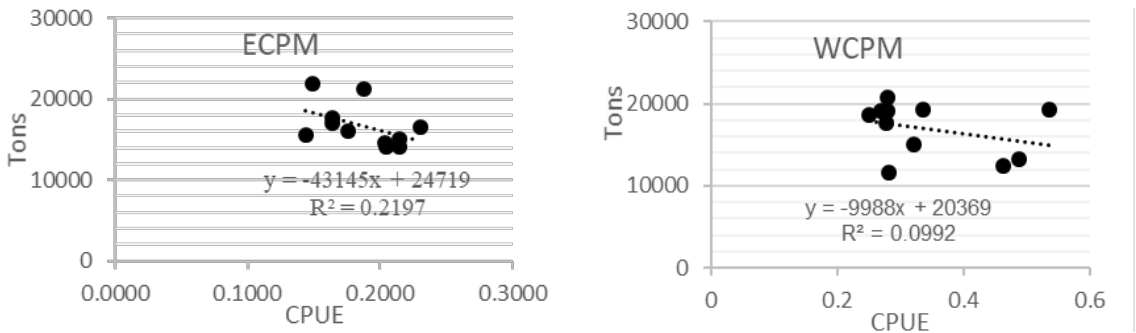


Figure 2: Relationship between catch and standardized CPUE of threadfin bream from East coast Peninsular Malaysia (ECPM) and West coast Peninsular Malaysia (WCPM).

Figure 2 shows the negative correlation between catch and standardized CPUE of threadfin bream in East and West coast Peninsular Malaysia for the last 11 years (2008-2018), and that the regression coefficients, R^2 derived at 22 % and 9.9 % for East and West coast of Peninsular Malaysia respectively.

Table 1: Results of ASPIC batch job (version 2) run by scenarios using parameters 1101 and 1111 in the East and West coast Peninsular Malaysia.

East Coast Peninsular Malaysia-using Parameter 1101										
Model	K (fixed) (1000t)	B1/K= 1	r	MSY (1,000t)	F/F _{MSY}	TB _{MSY}	F _{MSY}	TB	R ²	RMS
Schaefer	130.00	0.50	0.50	16.34	0.83	65.00	0.25	73.60	0.47	0.13
Fox	130.00	0.50	0.39	16.34	0.57	47.82	0.39	69.28	0.47	0.13
West Coast Peninsular Malaysia-using Parameter 1111										
Schaefer	109.00	0.03	0.56	15.19	1.64	54.51	0.28	44.41	0.49	0.22
Schaefer	109.40	0.03	0.56	15.21	1.63	54.68	0.28	44.71	0.49	0.22
Schaefer	109.30	0.03	0.56	15.36	1.59	54.64	0.28	45.11	0.48	0.22
Fox	63.00	0.09	0.79	18.30	0.85	23.18	0.78	29.18	0.44	0.23
Fox	62.19	0.04	0.80	18.32	0.85	22.88	0.80	28.82	0.44	0.23
Fox	62.19	0.04	0.80	18.32	0.85	22.88	0.80	28.83	0.44	0.23

ASPIC was conducted using catch in the East and West coast peninsular Malaysia and standardized CPUE by Terengganu and Perlis trawlers respectively, and the results of the analysis are shown in Table 1.

Four parameters (B1/K, MSY, K, and q) were estimated of East and West coast using the best grid search combinations, 1101 (unchanged K while B1/K, MSY, and q can be changed) and 1111 (all parameters can be changed accordingly) respectively. Computed parameters by using ASPIC batch Job (version 2) are given in Table 1. Schaefer model was chosen for the best output based on the large range differences between TB and MSY in both areas of study. For the Schaefer model, the obtained MSY, TB, and R2 values on the East coast were 16,340 tons, 73,600, and 0.47, respectively. The same parameters were calculated for the West coast and the obtained values were 15,190 tons, 44,410, and 0.49, respectively. The fishing mortality rate at MSY (FMSY) and stock total biomass giving MSY (TBMSY) of the East coast were 250 and 65,000 tons, while on the West coast their values were 280 and 54,510 tons, respectively. The estimated values of K (carrying capacity) of the East coast in the Schaefer model, 130,000 tons, were the same in the Fox, while on the East coast Schaefer model, 109,000 tons higher than in the Fox model, 63,000 tons respectively.

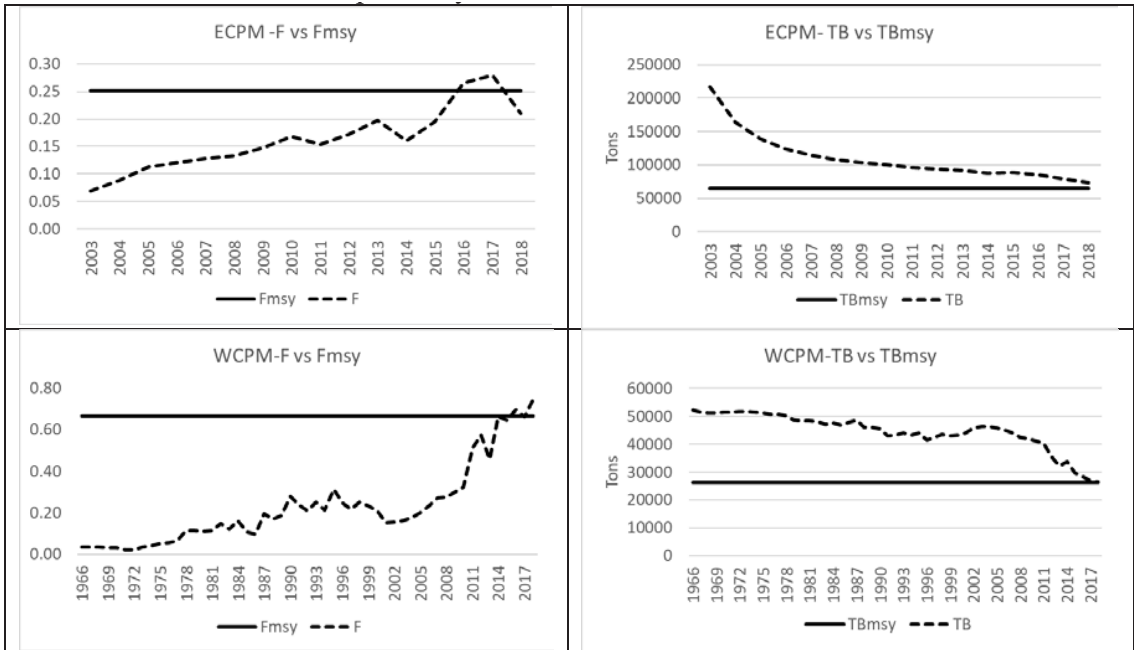


Figure 3: Trajectories of TB-ratio (TB / TB_{MSY}) and F-ratio (F / F_{MSY}) of Threadfin bream fish in the East and West coast Peninsular Malaysia.

Figure 3 shows the result of ASPIC from 2003 to 2018 on the East coast where the level of fishing mortality (F) is higher than F_{MSY} in 2017. If the fishing mortality is higher than F_{MSY} , the fish are being removed at higher rates than would keep the stock at TB_{MSY} and overfishing is occurring. Towards 2018, the fishing mortality (F) starts to decline and was below the F_{MSY} level causing the total biomass (TB) to drop below TB_{MSY} . Meanwhile, on the West coast, the result of ASPIC from 1966 to 2018 showed that the level of fishing mortality (F) was higher than F_{MSY} in 2016. Similar to the trend on the East coast, overfishing occurred from 2016 onwards. In 2017, the fishing mortality (F) starts to decline and was below the F_{MSY} level with total biomass (TB) above TB_{MSY} until 2017 and on the MSY level in 2018.

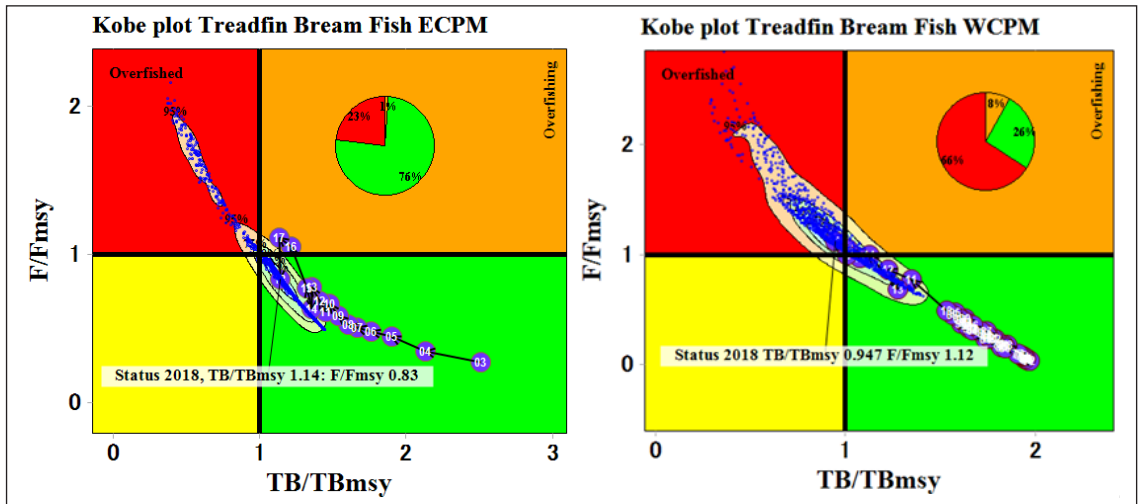


Figure 4: Kobe Plot: Stock status of Threadfin Bream in East and West Coast Peninsular Malaysia.

Further analysis using ASPIC results, the Kobe plot was created as in figure 4 and the results of risk assessment are shown in Table 2 below. The Kobe Plot stock status of the East coast threadfin bream in 2018 is in the green (safe) zone with a 76 % probability with TB / TB_{MSY} higher at 1.14 and a lower F / F_{MSY} at 0.83. While in West coast Peninsular Malaysia, the current Kobe plot stock status (2018) is in the overfished (red) zone with a 66 % probability with TB / TB_{MSY} lower at 0.947 and a higher F / F_{MSY} at 1.12.

Table 2: Risk Assessments on Threadfin Bream stock in East and West coast of Peninsular Malaysia.

		Color legend				
Risk levels		Low risk	Medium low risk	Medium high risk	High risk	
Probably		0 - 25%	25 - 50%	50 - 75%	75 - 100	
	60% (-40%)	70% (-30%)	80% (-20%)	84% (-16%)	90% (-10%)	100%
						110%
						120%
						130%
						140%
			MSY level	Current catch (*)		
10 catch scenarios (tons)	11,719	13,672	15,625	16,340	17,578	19,531
						21,484
						23,437
						25,390
						27,343
TB2021 < TBmsy	24	27	30	33	36	41
						46
						52
						58
						63
F2021 > Fmsy	15	18	26	36	52	79
						97
						100
						100
						100
TB2028 < TBmsy	14	18	32	42	55	75
						88
						97
						100
						100
F2028 > Fmsy	10	16	28	42	64	90
						100
						100
						100
						100

East Coast Peninsular Malaysia

		Color legend				
Risk levels		Low risk	Medium low risk	Medium high risk	High risk	
Probably		0 - 25%	25 - 50%	50 - 75%	75 - 100	
	60%	70%	80%	90%	94%	100%
						110%
						120%
						130%
						140%
			MSY level	Current catch (*)		
10 catch scenarios (tons)	11,178	13,041	14,904	16,767	17,510	18,630
						20,493
						22,356
						24,219
						26,082
TB2021 < TBmsy	46	51	54	58	59	62
						66
						69
						72
						75
F2021 > Fmsy	13	25	43	56	61	68
						76
						82
						85
						89
TB2028 < TBmsy	24	32	45	64	71	82
						90
						95
						98
						99
F2028 > Fmsy	12	18	36	63	72	84
						92
						96
						98
						99

West Coast Peninsular Malaysia

Risk assessment on the threadfin bream stock for both East and West coast showed that the current catch was leaning towards medium-high risk (Table 2), and to avoid TB and F violating their MSY levels, the current catch needs to be reduced. $TB_{2028} < TB_{MSY}$ and $F_{2028} > F_{MSY}$ should be chosen to apply and manage the fishery to reduce the stress that fishermen will face compared to 3 years period ($TB_{2021} < TB_{MSY}$ and $F_{2021} > F_{MSY}$) in reduction catch schema to return Total Biomass (TB) to the safe zone.

Table 3 is the summary of the current stock status (2018) of threadfin bream in East and West coast Peninsular Malaysia and the Total Allowable Catch (TAC) based on the stock and risk assessments by ASPIC.

Table 3: Summary on the stock status (2018) of threadfin bream in East and West coast Peninsular Malaysia.

Threadfin Bream	East Coast Peninsular Malaysia	West Coast Peninsular Malaysia
Stock Status 2018	76 %	66 %
TB / TB_{MSY}	1.14	0.947
F / F_{MSY}	0.83	1.12
Current Catch Level (tons) (average 2016-2018)	19,531	18,630
MSY (tons)	16,340	17,510
Total Allowable Catch, TAC (tons)	16,340	14,904
Catch Reduction	-3,191	-3,726
Percentage Catch Reduction	-16 %	-20 %

In the current scenario, the most practical harvest control rule is having a management target at Total Allowable Catch, TAC. The stock status in East coast Peninsular Malaysia is in the green zone but the current catch (2016-2018) is still higher than the MSY level. It is appropriate that the catch level be reduced by 16 % to the level of Total Allowable Catch of 16,340 tons with a 42 % chance of TB and F violating the MSY. The current threadfin bream stock in West coast Peninsular Malaysia is in the overfished zone, hence, it is safe to reduce 20 % to the level of Total Available Catch of 14,904 tons (Probabilities 45 % and 36 % of TB and F violating MSY respectively).

A fishery management policy based on the TAC principle aims at keeping the biomass of threadfin bream fish stocks above BMSY. For the stock on the West coast that is overfished, a timeframe needs to be introduced to allow stocks to reach MSY. Catch levels should be adjusted during a transitional period in such a way as to allow for the biomass of the stock to increase to be above the B_{MSY} level by the given deadline. Accordingly, stock status and risk assessments should be conducted periodically to ensure that management measures were successful.

The unrestrained fishing may create stock collapse and in turn causing the cease of fishing activities especially in the west coast. Effort should be made towards the conservation of marine resources by monitoring the number of vessels and total landing catch. Since *Nemipterus spp.* can be catch by three most common gears (trawl, purse seine and drift net) there is a need to regulate the usage of those gears through technical measures in order to sustain the fishing capacity.

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76

77 **Table 1.** Use Times New Roman 12 font

Component	Content (% w/w)
Protein	44.9 ± 0.37
Carbohydrate	22.3 ± 0.94
Water content	13.7 ± 0.02
Ash	6.1 ± 0.19

78

79 Number tables consecutively in accordance with their appearance in the text and place
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