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FISHERIES AND BIOLOGICAL INFORMATION OF BOTTLENOSE WEDGEFISH (*Rhynchobatus australiae*) IN THE PULAU KAMBING FISH LANDING PORT, TERENGGANU

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Abstract: *Rhynchobatus australiae* is a species of wedgefish that is vulnerable to overfishing due to their life history characteristics. This study aims to assess the fisheries and biological information of *R. australiae* in Terengganu waters. Over a span of 3 months, a total of 26 fish were collected from the Pulau Kambing fish landing port in Terengganu. They were analysed to determine the species' abundance, length frequency distribution, length-weight relationships (LWRs), and growth parameters. The results indicated that the abundance of *R. australiae* in Terengganu was higher compared with other locations, with a catch per unit effort of 49.05 kg/haul and 9.15 kg/day. The LWRs for males, females, and pooled sexes were a = 0.0057, b = 2.9404; a = 0.0018, b = 3.2078; and a = 0.0029, b = 3.0979, respectively. The von Bertalanffy growth function parameters for males, females, and pooled sexes of *R. australiae* were determined as k = 0.035, $L\infty$ = 332.825, t_0 = -4.495; k = 1.005, $L\infty$ = 43.161, t_0 = -2.99; and k = 0.089, $L\infty$=222.412, t_0=-2.565, respectively. Male *R. australiae* exhibited a higher average length than females. This study was limited in terms of the time span the sample size, which may have introduced variability in the results and may not fully represent of the larger fish population. However, the results of this study may serve as preliminary data for understanding the fish population dynamics of *R. australiae* in Terengganu waters and can guide future research efforts. Future studies should consider a longer period and a larger, more diverse sample size to obtain more accurate estimates of the abundance and size of *R. australiae* in this region.

Keywords: Fish population dynamics, growth analysis, overfishing, von Bertalanffy growth function, wedgefish.

Introduction

Elasmobranchs, which encompasses sharks, rays, and skates play a significant role in regulating marine ecosystems (Boldrocchi *et al*., 2021). They are vital components of marine and estuarine nektons communities, contributing to energy exchange at the highest trophic level, and hold significant commercial value worldwide (Arai & Azri, 2019). In recent years, concerns have been raised regarding the sustainability of shark populationss. Elasmobranchs, including sharks are known for their life history patterns characterised by slow growth, long lifespan, large adult size, delayed sexual maturity, and reproduction, lengthy gestation, low fecundity, iteroparity, and precocial offspring. This conservative strategy has rendered many species vulnerable to overfishing (Cortés, 2000; Conrath, 2005; Clark-Shen *et al*., 2021).

Elasmobranchs face a significant threat from overfishing, both as targeted species and bycatch. They are captured through the use of active and passive fishing gears, with longlines and gillnets being the most common methods (Broadhurst & Cullis, 2020). They are captured worldwide for their fins, meat, skin, liver oils, and gills (Booth *et al*., 2021). Rhinidae (wedgefishes) is among the most threatened taxa (Booth *et al*., 2021).

The International Union for the Conservation of Nature (IUCN) has classified 10 species from the family as "Critically Endangered". The 10 known species that belong to this family are targeted globally for their valuable meat and fins and are at risk of overexploitation due to their life history characteristics (Daly *et al*., 2021). The bottlenose wedgefish, *R. australiae* is one of the elasmobranchs in this family. *R. australiae* is considered "Critically Endangered" by the IUCN Redlist (Kyne *et al*., 2019). The species have a distribution range that includes Thailand, Malaysia, Indonesia, the Philippines, and Australia. In Malaysia, the species is generally found in Sabah and Sarawak, and their distribution in Peninsular Malaysia has not been scientifically documented (Md-Zain *et al*., 2018). *Rhynchobatus* spp. are under immense fishing pressure collectively, and taxonomic confusion among the species within the group has created challenges in obtaining the species' fisheries data, which is crucial for developing effective management strategies (Giles *et al*., 2016; Groeneveld *et al*., 2023).

Due to concerns regarding the population of bottlenose wedgefish, this study aims to gather fisheries and biological information on *R. australiae* at the Pulau Kambing fish landing port in Terengganu, Malaysia. To date, no fisheries population dynamic study has been conducted for this species in Malaysia. Local management actions based on an understanding of fisheries population dynamics are crucial to address the growing concerns and prevent further decline and potential extinction of the bottlenose wedgefish species. The information provided from this study will serve as a foundation for the development and implementation of effective management and conservation strategies for the species, in line with the National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks). This study will also contribute to the baseline information for monitoring the population status of the species.

Materials and Methods

Sampling Location and Time

R. australiae samples were collected at the Pulau Kambing fish landing port (5°19'20.4"N 103°07'42.0"E), shown in Figure 1, between July 2022 and September 2022. The sampling for this study was conducted during the final week of each month to ensure standardization of the sampling period. A total of 26 samples were collected.

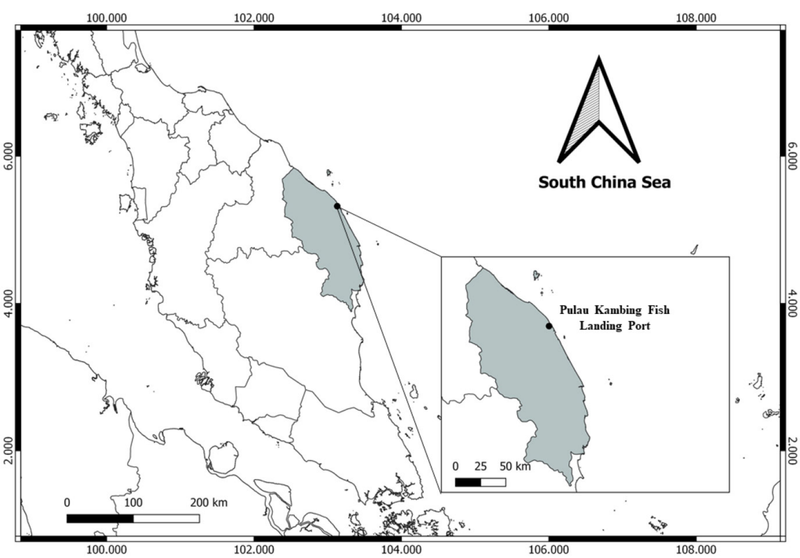

Figure 1: The location of the Pulau Kambing fish landing port, Terengganu

Sampling and Fisheries Information Gathering and Inquiry

The samples were collected randomly from local Trawls B and C fishing vessels operating in local waters at the fish landing port. The fisheries information data collected during the sampling session were landing weight, fishing gear, and vessel information. Sex determination of the samples was done by observing the presence of the clasper, as shown in Figure 2 (Rigby *et al*., 2019). The total length and weight of each fish were measured to their nearest 0.01 cm and 0.01 g using a measuring tape and a digital weight scale, respectively.

Figure 2: The clasper of *Rhynchobatus* sp.

R. australiae was identified by observing the white and black spots on the fish, where the diagonal row of white spots right above the middle of the pectoral fin is above the black pectoral spot (Ali *et al*., 2019). The samples were taken to the Fisheries Science Lab, Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu for further processing.

Vertebral Age Count

Vertebral age count was carried out based on the methods described by White *et al.* (2014) and Rigby *et al.* (2019). From the vertebral column, vertebrae beyond 1 cm from the posterior of the column and of suitable size were selected. The vertebrae were then submerged in 5% sodium hypochlorite for 30 minutes and then submerged in 6% hydrogen peroxide for 5 minutes to remove excess tissue and rinsed with tap water before air-drying them for 24 hours. After drying, the vertebrae were embedded in epoxy resin and cured for 1 week. After the epoxy has cured, the sample was then cut into 0.3 mm longitudinal cross-sections, focusing on the vertebrae using IsoMet 1000 Precision Saw before mounting them on microscope slides. Using a dissecting microscope, the age of the samples was determined by observing and counting the opaque and translucent bands on the cross-section of the vertebrae, which were found on the hard part of the spine called corpus calcareum. To elaborate, the birthmark was determined by counting the bands after the birthmark. Figure 3 shows the processed samples after each steps described.

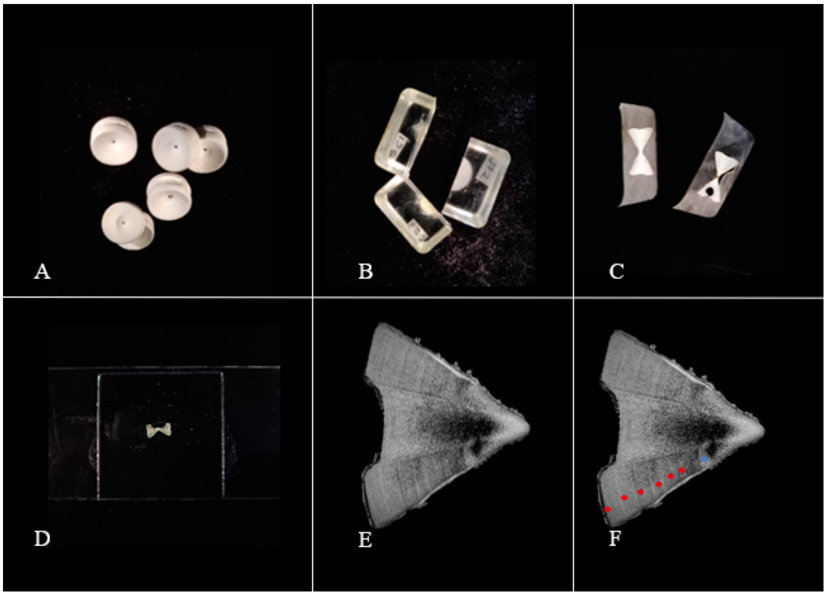

Figure 3: The vertebrae columns after each laboratory process. A: Samples after cleaning and tissue removal; B: Embedded samples that have been cut; C: Cross-sectioned embedded samples; D: Sample cross-section mounted onto a microscope slide; E: A mounted sample under microscope and F: Band determination and count for age

Data Analysis

The calculations for fisheries information included catch per unit effort, CPUE=∑Weight/∑Effort. The size range assessment was carried out by calculating the ratio between immature and mature specimens. Analysis of growth parameters involved the examination of the age-length key, length-frequency distribution, and the von Bertalanffy growth function (VBGF). The age length key was created based on the data from the vertebral determination of age and length. The Ford-Walford Plot was created and used to gather preliminary data for L∞ and k using the formula $L_t + 1 = L\infty * (1 - e^{(-k) + Lt} * e^{(-k)})$, where L_t is the length at a specified age (years), L∞ is the asymptote length, and k is the growth rate. Then, using the values derived for L∞ and k, the growth curve for the species was plotted and the von Bertalanffy growth formula was used to estimate the t_0, age at length 0 (Faizah & Chodrijah, 2020). The formula is $Lt = L\infty * (1 - e^{(-k * (t - t0))})$, where t is the present age (years), and t_0 is the age at length age 0.

Results and Discussion

Exploitation and Catch Per Unit Effort of Rhynchobatus Australiae

From observation at the Pulau Kambing fish landing port, the landings for *R. australiae* were from Class C trawl fishing vessels. Class C fishing vessels are vessels between 40 to 70 GRT that operate 12 to 30 nautical miles from the shore. Table 1 shows that the CPUE for *R. australiae* at the Pulau Kambing fish landing port is 49.05 kg/haul and 9.15 kg/day. The highest capture composition was recorded in June.

Table 1: CPUE of *R. australiae* by class C trawling vessel at the Pulau Kambing fish landing port from January to November 2022 calculated from the data collected

CPUE	CPUE/Haul (kg/haul)	CPUE/Day (kg/day)
Value	49.06	9.15

These estimates indicate a higher abundance of the species in Terengganu waters compared with estimates made by Arshad *et al*. (2021) in Perak, which was 0.21 kg/haul and 0.09 kg/day. It is important to note that CPUE is generally used to estimate relative abundance and biases related to fisheries-dependent data should be considered (Ducharme-Barth *et al*., 2022). The higher abundance in June could be due to seasonal factors that affect the abundance of bycatch (*Mohidin et al*., 2022). These factors could include changes in rainfall patterns and temperature, which may cause variations in environmental conditions.

Size Composition

Table 2 shows the fish composition of *R. australiae* at the Pulau Kambing fish landing port. The length for males, female, and pooled sexes ranged from 44.32 cm to 106.50 cm, with an average size of 64.58±18.52 cm; 45.30 cm to 111.40 cm, with an average size of 58.86±18.29 cm; and 44.32 cm to 111.40 cm with the average size of 61.50±18.26 cm, respectively. In terms of weight, the samples ranged from 250.00 g to 6592.00 g, with an average of 1349.77±1605.29 g.

Table 2: The length and weight of *R. australiae* at the Pulau Kambing fish landing port, Terengganu, in terms of sex

Sex	n	Total Length (cm)			Mass (g)		
		Min.	Max.	Mean	Min.	Max.	Mean
Male	12	44.32	106.50	64.58±18.52	469.00	5600.00	1515.33±1613.64
Female	14	45.30	111.40	58.86±18.29	350.00	6592.00	1207.86±1644.83
Pooled sexes	26	44.32	111.40	61.50±18.26	350.00	6592.00	1349.77±1605.29

Min. = minimum; Max. = maximum = sample size; SD = standard deviation

In comparison, Arshad *et al*. (2021) found that the average size of *R. australiae* in Perak was 78.20 cm. The difference in average length between the two studies could be due to a smaller sample size in the current study, which may result from fisheries bias. However, this difference could also indicate a lack of older fish in the population (Hale & Baremore, 2013) and in the sample.

Figure 4 shows the length frequency distribution histogram of *R. australiae.* The males are dominated by 62 cm fish, females are dominated by fish ranging from 47 cm to 50 cm, and 69 cm, while the pooled sexes are dominated by 50 cm and 70 cm fish. The length-frequency histograms are all right-skewed.

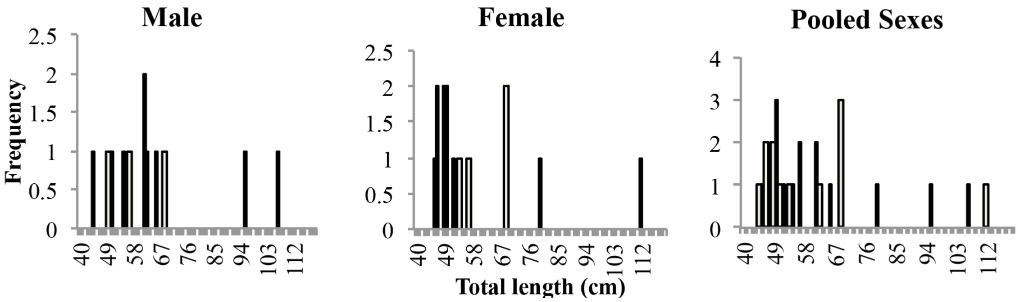

Figure 4: Length frequency distribution of *R. australiae* at Pulau Kambing fish landing port, Terengganu

In a study conducted by Kurniawan *et al*. (2021) in Indonesian waters, similar findings were observed, including a right-skew in the length frequency distribution. The study proposed that the use of non-selective fishing gear might contribute to the vulnerability of both young and adult fish to fishing activities.

Length-weight Relationships

Table 3 shows the LWRs of *R. australiae*. The LWRs for males, females, and pooled sexes were a = 0.0057, b = 2.9404; a = 0.0018, b = 3.2078; and a = 0.0029, b = 3.0979, respectively.

Table 3: The length and weight of *R. australiae* at the Pulau Kambing fish landing port, Terengganu, in terms of sex

Sexes	n	Length-weight Parameters		
		a	b	R^2
Male	12	0.0057	2.9404	0.9957
Female	14	0.0018	3.2078	0.9996
Pooled sexes	26	0.0029	3.0979	0.9981

n = sample size; a = intercept; b = slope of the regression; R^2 *= Regression coefficient*

In LWRs, the parameter b is used as an index for allometry, where a value of b=3 signifying isometry (i.e., fish grow equally in length and weight), b>3 signifying positive allometry (i.e., fish grow faster in weight), and b<3 signifying negative allometry (i.e., fish grow faster in length) (Purushottama *et al*., 2020a; 2020b). The estimated values of b in the current study align with those found in previous studies on *Rhina annandalei* and *Rhynchibatus laevis* (Purushottama *et al*., 2020a; 2020b). However, there is a disparity in the allometry between sexes in *R. australiae*, which could be attributed to availability, seasonal variations, and sexual characteristics (e.g., male and female reproductive development) (Jisr *et al*., 2018).

The von Bertalanffy Growth Function Parameters

The VBGF parameters for males, females, and pooled sexes of *R. australiae* were found to be k=0.035, L∞=332.825, t_0=-4.495; k=1.005, L∞=43.161, t_0=-2.99; and k=0.089, L∞=222.412, t_0=-2.565, respectively, as shown in Table 4.

Table 4: The von Bertallanfy growth parameters of *R. australiae* at the Pulau Kambing fish landing port, Terengganu

	n	K	L∞ (cm)	t_0 (year)
Male	12	0.035	332.825	-4.496
Female	14	1.005	43.161	-2.99
Pooled sexes	26	0.089	222.412	-2.565

n = number of samples; K = growth coefficient; L∞ (cm) = assymptotic length in cm; t_0 (year) = age at 0 length

The estimated k for females is significantly higher than for males and pooled sexes, while the estimated L∞ is relatively lower. This difference may be due to the insufficient sample variation, which can interfere with estimating the VBGF using the Ford-Walford plot. Previous studies on *R. australiae* have found different VBGF parameters, including k=0.460, L∞=330.00, t_0=-1.18, n=407 (Faizah & Chodrijah, 2020); k=0.095, L∞=307.90, n=2064 (Kurniawan *et al*., 2021); and k=0.41, L∞=204.50 cm, n=47 (White *et al*., 2014). The disparity in VBGF parameters between the current study and previous studies could be due to several factors, including the age and size of the fish population, the types of fishing gear used, and the location of the study. Most importantly, the previous studies all used different approaches to calculate the VBGF, especially when it comes to age. For instance, White *et al*. (2014), in their study, utilised several growth models, including two-parameter von Bertalanffy, three-parameter von Bertalanffy, two-parameter Gompertz, three-parameter Gompertz, and logistic models.

Sex Ratio

The sex ratio, as shown in Table 5, of male to female of the samples collected in July, August, and September were 1:1.33, 1:2.00, and 1:0.67, respectively. The overall sex ratio is 1:1.17 for the whole sampling period. The X^2 test indicated no significant difference in the sex ratio (p>0.05).

Table 5: Sex ratio of *R. australiae* at Pulau Kambing fish landing port, Terengganu

Month	Total	Males	Females	Males	Females	Sex Ratio	X^2
	n	n	n	%	%		
July	7	3	4	42.86	57.14	1:1.33	0.143
August	9	3	6	33.33	66.67	1:2.00	1.000
September	10	6	4	60.00	40.00	1:0.67	0.400
Grand Total	**26**	**12**	**14**	**46.15**	**53.85%**	**1:1.17**	**0.154**

The critical value for the Chi-squared test is 5.991 at p<0.05

The results of the current study show that there is no significant difference in the sex ratio of males to females throughout the sampling period, with an overall ratio of 1:1.17. This finding is in contrast with Faizah and Chodrijah (2020), who reported a sex ratio of male to female of 1:5.44. Various factors could contribute to this discrepancy, including sexual segregation, sex-specific migration, and others (Purushottama *et al*., 2020b). IT is possible that females may segregate due to spawning in shallower waters. However, it should be noted that the current study has certain limitations that may have influenced the findings such as a lack of data on the spawning season and a limited sampling area.

Conclusion

In summary, this study examined the abundance and size of *R. australiae* in Terengganu waters by analysing variables such as CPUE, length frequency distribution, LWRs, VBGF parameters, and the sex ratio. The findings indicated a higher abundance of *R. australiae* in Terengganu compared with other locations and revealed differences in the size between male and female specimens. The current study also found no significant difference in the sex ratio of males to females throughout the sampling period, with an overall ratio of 1:1.17.

However, due to the limited time span and sample size of the study, the results should be interpreted with caution as they may not fully represent the larger fish population. Additionally, the samples collected in this study may have varied in terms of age, size, and other characteristics, which could also have affected the findings. Despite these limitations, the results of this study may serve as preliminary data for the fish population dynamics in Terengganu waters and could be used to guide future research.

Based on these findings, it is recommended that future research focus on collecting a larger sample from various locations over a longer period to further investigate the reproductive biology of *R. australiae* in Terengganu waters. In addition, it is suggested that additional fisheries-independent methods such as prolonged or seasonal acoustic studies be carried out to gain a more comprehensive understanding of the population from a spatial-temporal perspective. A year-long study on fisheries-dependent data along with acoustic surveys, for example, could provide more comprehensive data on the reproductive patterns and trends of this species in the region. Such research could inform management and conservation efforts for *R. australiae* in Terengganu and Malaysian waters. Finally, the findings suggest that conservation efforts such as implementing catch and release measures are urgently needed to address the high number of immature samples being caught from the ocean.

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