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Management parameters and gillnet selectivity of blacktip sea catfish *Plicofollis dussumieri* (Valenciennes, 1840) to support sustainable fishery management in the Oman Sea

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Abstract

Plicofollis dussumieri (Valenciennes, 1840) is a commercially important fish species that is caught using gillnets in the Oman Sea. However, the lack of standard gillnets with a suitable mesh size has resulted in damage to the stocks of this species and a high number of undersized fish being caught each year. In this regard, the selectivity of gillnets for *P. dussumieri* was studied from December to March 2021. Four commercial gillnets with mesh sizes of 4.8, 6.3, 10.0, and 15.3 cm were used in this study to find the best mesh size. A total of 818 specimens were caught during the experiment. The SELECT method was applied to fit four different gillnet selectivity models. The bi-normal curve yielded the lowest model deviance and was judged to provide the best fit to the data. The mean length ±SE was estimated as 34.13±0.41, 36.93±0.44, 38.74±0.33 and 42.7±0.44 cm for 4.8, 6.3, 10.0 and 15.3 cm mesh sizes, respectively. The size of *P. dussumieri* at first maturity was determined to be 32.3 cm. The results of the Kolmogorov-Smirnov (K-S) test of the length frequency of *P. dussumieri* species caught with different mesh sizes showed that there is a significant difference between the 4.8 and 15.3 cm mesh sizes (p<0.05). The findings of the study showed that there would be no threat of recruitment overfishing of *P. dussumieri* in the event of the introduction of gillnets with a mesh size of 10.0 cm for commercial fishing.

Introduction

The Oman Sea connects to the Persian Gulf through the Strait of Hormuz, which separates Iran from the Arabian Peninsula and serves as the link between the Persian Gulf and the Arabian Sea. It extends about 560 km in length, and 320 km in width (Azari *et al*., 2021). Owing to its direct connection with the open ocean, the Oman Sea supports high marine biodiversity. The region's fisheries are organised into three main sectors; the artisanal (traditional), coastal, and commercial (industrial). In 2021, the combined fish production from these three sectors was estimated at 34,000 t (IFO, 2021). In recent years, rising population levels and growing number of fishermen, particularly from various Asian, countries have driven an increased demand for marine food resources. Among these, marine catfishes have emerged as an important resource for food and income, with bulk of the catch processed and exported, especially to Asian markets. This trend has underscored the urgent need for effective management and regulation to ensure the sustainable exploitation of this promising resource.

Ariidae is a large family of catfishes, distributed worldwide in tropical and subtropical marine, brackish and freshwaters, and currently contains 31 genera with more than 150 species (Marceniuk and Menezes, 2007; Marceniuk *et al.,* 2012). *Plicofollis dussumieri* is known as the most widespread species of the genus and has been reported from the east coast of Africa (Mozambique and Kenya) and Madagascar, the Oman Sea, Pakistan and India, east to western Indonesia (Kailola, 1999; Ng and Sparks, 2003; Taghavi Motlagh, 2018). *P. dussumieri* is a highly mobile species that undertakes long migrations and inhabits a variety of dynamic environments that fluctuates with monsoonal changes (Menon *et al.,* 1990; Dutta and Hazra, 2013). The species is purely marine and forms large shoals that move vertically in the water column and horizontally along surface waters (Menon and Bande, 1987). It is found at depths of 20-50 m (*Mehanna et al.,* 2012). *P. dussumieri* supports livelihoods in coastal communities creating employment opportunities in processing and distribution, thereby providing a stable source of income and generating added value through post-harvest processing. Socially it holds significant importance as a dietary staple and cultural resource for people across the Indian and Pacific oceans and their adjoining regions. The catch and sale of this fish contribute to the subsistence of thousands of fisher families. This dependency helps prevent the social disintegration of fishing communities by sustaining employment opportunities and economic stability.

Vietnam is one of the largest producers of catfish globally, with an annual catch of about 1 million t. The country primarily focuses on exporting this fish. In the U.S., particularly in southern states like Mississippi and Arkansas, catfish are caught extensively, with annual catches around 300,000 t. India is also recognised as a significant producer of catfish, with an estimated annual catch of about 250,000 t. In Thailand, catfish fishing is an important source of food and economic activity, with an estimated annual catch of around 100,000 t. Blacktip sea catfish are a key component of demersal fisheries in the Persian Gulf and the Sea of Oman, with an average annual yield of about 3,500 t. From 2011 to 2019, the catfish catches in gillnet fisheries increased steadily (IFO, 2021). This sharp rise was largely attributed to the absence of regulations governing gillnets use particularly mesh size in *P. dussumieri* fisheries in the Oman Sea. Consequently, many fish species in southern Iranian waters have become vulnerable to overfishing, with a significant proportion of immature individuals being harvested (Hosseini, 2016; Sadough Niri *et al.,* 2020).

Gillnets are the most common fishing gear used in Iran, accounting for more than 93% of the total catch (Eighani *et al.,* 2021). Compared with other fishing gears, gillnets are highly size-selective; as a particular mesh size captures individuals of a specific size range most efficiently, with catch rates dropping sharply for fish either smaller or larger than the optimal size class. Gillnet selectivity relies on both the probability that a fish encounters the net and the probability that the fish is caught and retained by the net (Hamley, 1975; Santos *et al.,* 2002). Therefore, fish stocks can be effectively managed by varying the size of the net mesh to control the size of the fish harvested. Effective management measures can improve the sustainability of gillnet fisheries in the Oman Sea by balancing community livelihoods with marine conservation. Key actions include regulating mesh size and net dimensions to prevent the capture of juveniles and non-target species, enforcing seasonal or area closures to protect spawning grounds, promoting bycatch reduction devices such as turtle excluders, requiring gear marking for better monitoring, mandating comprehensive catch reporting to guide adaptive management, involving local communities and stakeholders in decision-making to ensure transparency and shared responsibility, and strengthening enforcement through regular patrols and electronic surveillance. Understanding key management parameters such as asymptotic length, length at maturity (Lm_{50}) and optimal catch length in gillnets is vital for gillnet fisheries management, as it helps maximise yield while ensuring that smaller fish can spawn at least once before entering the fishery (Cortes, 2000; Prince, 2005). By using the size selectivity of gillnets to regulate the size and maturity of fish caught, managers can promote stable harvests and long-term stock sustainability (Faroogh *et al*., 2017).

Several studies have examined gillnet selectivity and management parameters in Iran (Haghighatjou *et al.*, 2017; Hosseini *et al*., 2017; Mohseni *et al*., 2020; Sadough Niri *et al*., 2020; Barmooz *et al*., 2021). However, most of these studies were conducted using Sechin methods and did not account for fish caught by tangling and no study has specifically addressed gillnet selectivity in *P. dussumieri*. Since *P. dussumieri* is one of the economically important commercial fish species in Iranian waters, and in recent years, its stocks appear to have been severely impacted by overfishing and unmanaged fishing (IFO, 2021), understanding how gillnet selectivity affects *P. dussumieri* catches is important for developing stable harvest strategies and improving economic efficiency to support stock recovery. Hence, for the sustainable exploitation of resources, the use of an optimum mesh size of gillnets is needed, aimed at protecting immature fish and thus allowing them to spawn at least once. Therefore, this study was undertaken to estimate key management parameters such as asymptotic length, length at maturity (Lm_{50}) and optimal catch length, along with gillnet selectivity to guide improved management of this valuable species.

Materials and methods

Study area and fishing experiment

Fishing operations of *P. dussumieri* were carried out in the Konarak Fishing Harbor (25°20´N; 60°30´E) in south-eastern Iran (Oman Sea) from December to March 2021 (Fig. 1). The sampling stations were characterised by shallow coastal bathymetry (10 to 30 m deep) with a soft-bottom substrate that was predominantly sand and mud, which is the typical benthic habitat of the species.

For the surveys, four commercial gillnets with a stretch mesh of 4.8, 6.3, 10.0 and 15.3 cm were used. The gillnets consist of 6 to 20 panels with a total length of 91.44-182.88 m, a net depth of 4-6 m and hanging ratios of 0.5. Two 10 mm diameter polyethylene (PE) ropes are connected as headlines and bottom lines and the ropes used in the gillnet consist of twines No. 210D/30. In each experiment, four mesh sizes were simultaneously placed in water. The experimental gillnets were placed in water for a soaking time of 10-12 h. *P. dussumieri* specimens caught in the gillnet selectivity trials, were sorted according to mesh size and recorded. A total of 818 fish samples were obtained (209 from the gillnet with a mesh size of 4.8; 205 from 6.3 mesh size and 203 from 10 and 201 from 15.3 mesh size). All specimens were measured for fork length using a steel ruler with an accuracy of 0.1 cm.

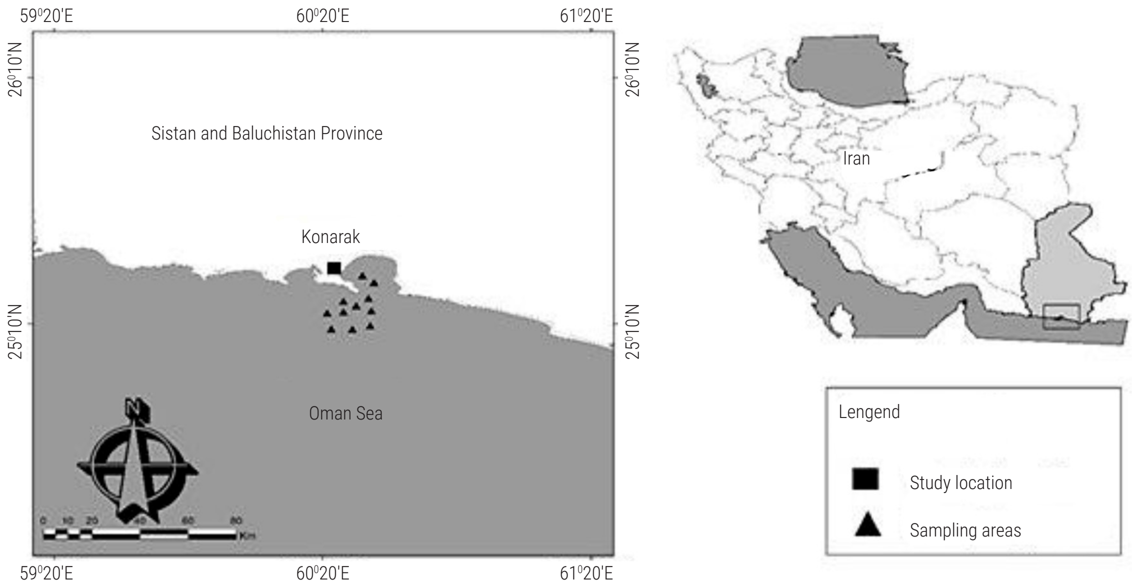

Fig. 1. Sampling locations in Oman Sea, Iran

Catch-per-unit-effort (CPUE)

CPUE, or catch rate is frequently the single most useful index for long-term monitoring of the fishery, which expresses the quantity of fish caught (in numbers or weight) by a given amount of fishing effort. It is often used as an index of stock abundance, where some relationship is assumed between the index and the stock size.

Catch-per-unit-effort (CPUE) estimates were calculated as follows:

$$CPUE = \left(\left(\frac{CN}{U.NL}\right)/ST\right) \times 10 \text{ (hour)} \quad (1)$$

Where CN is the catch number in each mesh size, U.NL is the unit net length (m) and ST is soaking time (hour).

Capture modes in gillnet

Information related to gillnet selectivity is obtained by using nets of varying mesh sizes to assess how catchability changes with fish size (Hovgard and Lassen, 2000). Understanding selectivity also requires examining how fish are captured when they encounter the net. Fish may be snagged at the front gill cover, gilled when caught behind the gill cover, wedged around the first dorsal fin behind the gill cover, or entangled when wrapped in the netting and held by the teeth, fins, or spines (Baranov, 1948).

Estimation of fisheries management indicators

In fisheries management, sustainable catches are taken with the minimum impact on stocks. This can be done by catching fish at an optimum size or length at maturity (Lm_{50}) (Froese and Binohlan, 2000; Froese, 2004). Therefore, the following equations were used to calculate the asymptotic length, the length at maturity (Lm_{50}) and the optimum catchable length (Froese and Binohlan, 2000).

$$\log L_\infty = 0.044 + 0.9841 * \log(L_{max}) \text{ Asymptotic length} \quad (2)$$

Where L_∞ in this equation is the asymptotic length and L_{max} maximum length

$$\log L_{opt} = 1.0421 * \log(L_\infty) - 0.2742 \text{ Optimum catchable length} \quad (3)$$

Also, the length at maturity (Lm_{50}) was estimated with the following regression relationship:

$$\log Lm_{50} = 0.8979 * \log L_\infty - 0.0782 \text{ Length at maturity} \quad (4)$$

After calculating the length at maturity, the percentage of immature fish (fish with a length smaller than the length at maturity) was calculated in the catch.

Large fish in the catch, *i.e.* fish of a size larger than the optimum length plus 10% are considered mega-spawners (Froese, 2004).

Estimation of selection curve

In this study, mesh selectivity was estimated using the indirect SELECT method (Share Each Length's Class Catch Total), which was applied to the catch data to evaluate gillnet performance (Millar, 1992; Millar and Fryer, 1999; Millar and Holst, 1997). In this method, the number of fish of length l_j caught in a gillnet with mesh size m_i is shown as:

$$Cij = pi\lambda jS(Rij) \quad (5)$$

where. p_i is the relative fishing intensity ($\sum^{k}_{i=1} pi = 1$), λ_j is the expected number of fish of length l_j that are in contact with the net and $s(R_{ij})$ is the selectivity function of the ratio of fish length to mesh size, the relative length $R_{ij} = (l_j/m_i)$. Fujimori and Tokai (2001) defined the relative fishing intensity (*pi*) as being expressed by the gear efficiency (q_i) and catch effort (x_i).

In this study, four types of selection curve models (normal, log-normal, skew-normal and bi-normal models) were applied to describe gillnet selectivity (Fujimori and Tokai, 2001) as detailed in Table 1.

R_0 in each model is the relative length at the peak of the selection curve and the parameter σ denotes the curve width.

R_a and R_b in bi-normal are the relative length with the maximum value (=1.0) of each constituent normal curve and σ_a and σ_b denote the width of each curve. The weighting factor ω decides the height of the second curve and the parameter δ in the skew-normal model is the scaling constant to make the maximum value of the selectivity 1.0. The parameter η in the skew-normal model is the skewness constant (Table 1).

Additionally, two model types were compared, one with a fixed constant relative fishing intensity and another, with the relative fishing intensity estimated from the data.

The following equation was used to calculate the Maximum log-likelihood by the Solver add-on program in MS-Excel.

$$\log_e L = \sum_{j=1}^{n} \sum_{i=1}^{k} (c_{ij} \log_e (p_i s(R_{ij}) / \sum_{i=1}^{k} (p_i s(R_{ij})) \quad (10)$$

The degree of freedom was calculated from *n.(k-1)-r* when p_i was fixed and also from $n.(k-1) - (r + k - 1)$ when p_i is estimated and where *r* is the number of model parameters, and *n* is the number of length classes and *k* is the number of various mesh sizes (Fujimori and Tokai, 2001).

To identify the optimal model and assess its goodness of fit, model deviance was calculated from the residual differences between both observed and expected proportions, using the following equation described by Millar and Frye (1999):

dij = ±[2Cj (ϕij loge (ϕij/ϕ(Rij) + (1 - ϕij)loge (1- ϕij)/(1- ϕ (Rij))))]^ 1/2 ....(11)

Estimation of standard mesh size

In the present study, assessing gillnet mesh size selectivity was essential and the calculation followed the formula proposed by Fridman (1986) as given below:

$$M_{OG} = \frac{L}{K_m} \quad (12)$$

L: is the length of the fish body from the tip of the snout to the base of the caudal fin

K_m: is an empirical coefficient depending on the morphology of the fish (value of coefficient)

K_m = 5 for a narrow fish, K_m = 3.5 for medium girth fish and K_m = 2.5 for thick or deep-bodied fish).

Data analysis

The distribution of data (mean length and standard error) was calculated for each mesh size using general descriptive statistics. Microsoft Excel 2016 software and the Solver program were used for statistics and data analysis. The Kolmogorov-Smirnov (K-S) test in SPSS 26 software was used to analyse the length frequency distribution between different mesh sizes. R 4.3.3 software was used to draw graphs.

Results

Length distribution and catch pattern

The catch number of *P. dussumieri* for the different specifications of the net is shown in Table 2. Altogether, 818 *P. dussumieri* were caught, and ranged from 24.5 to 56.5 cm in fork length. The mean lengths were estimated as 34.13±0.41, 36.93±0.44, 38.74±0.33 and 42.7±0.44 cm for 4.8, 6.3, 10.0 and 15.3 cm mesh sizes, respectively. The fork length at the peak of the plots was calculated as 28.5, 36.5, 40.5 and 44.5 for the mesh sizes 4.8, 6.3, 10 and 15.3 cm, respectively. There was an increase in the length distribution of fish captured as mesh size increased. The results of the Kolmogorov-Smirnov (K-S) test of the length frequency of *P. dussumieri* species caught with different mesh sizes showed that there is a significant difference between the 4.8 cm and 15.3 cm mesh sizes ($p<0.05$). Table 2 indicates the length frequency by the different mesh sizes and the catch and relative catch effort.

Fig. 2 illustrates the catch pattern for *P. dussumieri* across different mesh sizes. For 4.8 cm net, over 60%, of the catch was gilled, increasing to more than 90% in 6.3 cm nets and over 74% in 10.0 cm nets. In contrast, with a 15.3 cm mesh, entanglement dominated, accounting for over 54% of the catch, while only 17% was gilled.

Estimation of selectivity model parameters

Data from nine length classes (24.5–56.5 cm) were used for the estimation of selectivity curve. Table 3 summarises the estimated parameters, the model deviance, and related results

Table 1. Models for normal, log-normal, skew-normal and bi-normal selection curves

Model	Selection curve	Parameters	NO.
Normal	$s(R_{ij}) = \exp - \left[\frac{(R_{ij} - R_o)^2}{2\sigma^2}\right]$	R_0, σ	(6)
Log-normal	$s(R_{ij}) = \exp - \left[\frac{(\ln R_{ij} - \ln R_o)^2}{2\sigma^2}\right]$	R_0, σ	(7)
Skew-normal	$s(R_{ij}) = \exp - \left[\frac{(R_{ij} - R_o)^2}{2\sigma^2}\right] 1 - 1/2\eta\sigma^{3/2} \left[\frac{(R_{ij} - R_o)}{\sigma} - \frac{(R_{ij} - R_o)^3}{3\sigma^3}\right]$	R_0, σ, η	(8)
Bi-normal	$s(R_{ij}) = \frac{1}{\delta} \left[\exp\left(-\frac{(R_{ij} - R_a)^2}{2\sigma_a^2}\right) w\exp\left(\frac{(R_{ij} - R_b)^2}{2\sigma_b^2}\right)\right]$	$\sigma_a, \sigma_b, \omega, \delta$	(9)

Table 2. Frequency distribution of fork lengths of *P. dussumieri* captured across all gillnet mesh sizes

Length, l_j (cm)	Mesh size, m_i (cm)				
	4.8	6.3	10.0	15.3	Total
24.5	14	5	1	2	22
28.5	56	30	6	5	97
32.5	46	41	32	9	128
36.5	39	50	57	36	182
40.5	38	39	77	30	184
44.5	10	24	21	74	129
48.5	6	13	4	29	52
52.5	0	3	5	8	16
56.5	0	0	0	8	8
N	209	205	203	201	818
P-value (K-S)	0.000	0.075	0.200	0.000	
Mean length±SE	34.13±0.41	36.93±0.44	38.74±0.33	42.7±0.44	
(CPUE) xi	135	42	18	11	206
Relative catch effort (xi/∑ixi)	0.6553	0.2038	0.08737	0.05339	1

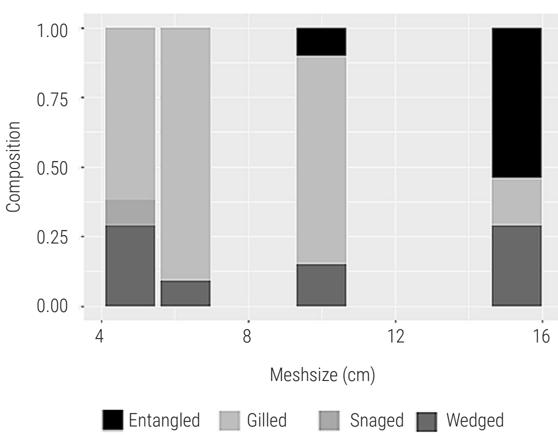

Fig. 2. Catch pattern of *P. dussumieri* in different gillnet mesh sizes

of each model. A high deviance indicates either a poor model or unsuitable underlying assumptions. Across all curve functions, model deviance differed only slightly between the *pi*-fixed and the *pi*-estimated approaches. Among the models tested, the bi-normal model showed the lowest deviance, outperforming the normal, log-normal and skew-normal models. The higher model deviance was seen in the normal, log-normal and skew-normal models, which all exhibited higher deviance values. Thus the bi-normal model provided the best fit to the data by giving the smallest deviance value.

Selection curve and fitting model

Fig. 3 shows the master selectivity curves for each model with pi is estimated. The optimum relative lengths at the peak of the curves (*i.e.,* the optimum relative length) were similar across models. While the bi-normal model shared a comparable modal relative length with the normal, log-normal and skew-normal models; its overall curve shape was distinctly different.

Table 3. SELECT model parameter estimates and deviance values for each model. (*MLL*, maximum log-likelihood The values of *pi* are fixed by *1/k* (the reciprocal of mesh size number)

Model	Parameters								*MLL*	*df*	*Model deviance*
	$R_0(R_a, R_b)$	η.ω	s	δ	p_1	p_2	p_3	p_4			
Normal											
P_i estimated	3.4512		0.3688		0.6272	0.1950	0.09250	0.08521	-1257.0452	24	118.24
P_i fixed	3.9570		0.4725		0.6553	0.2038	0.08737	0.05339	-1694.0388	24	159.40
Log normal											
P_i estimated	3.3980		0.3798		0.6100	0.2086	0.0831	0.0982	-1062.9558	24	86.49
P_i fixed	3.3996		0.3997		0.6553	0.2038	0.08737	0.05339	-1083.9862	24	144.17
Skew normal											
P_i estimated	3.6526	1.0285	0.5528		0.6386	0.1716	0.1026	0.0872	-2410.2326	24	128.57
P_i fixed	3.5626	1.0228	0.5540		0.6553	0.2038	0.08737	0.05339	-2574.6690	24	131.12
Binormal											
P_i estimated	3.5396 5.1477	0.6734	0.5606 2.2035	1.5160	0.4071	0.2182	0.1129	0.2208	-1057.1590	24	76.07
P_i fixed	3.0561 3.7703	0.6030	0.6852 2.2936	1.5689	0.6553	0.2038	0.08737	0.05339	-1066.3257	24	94.98

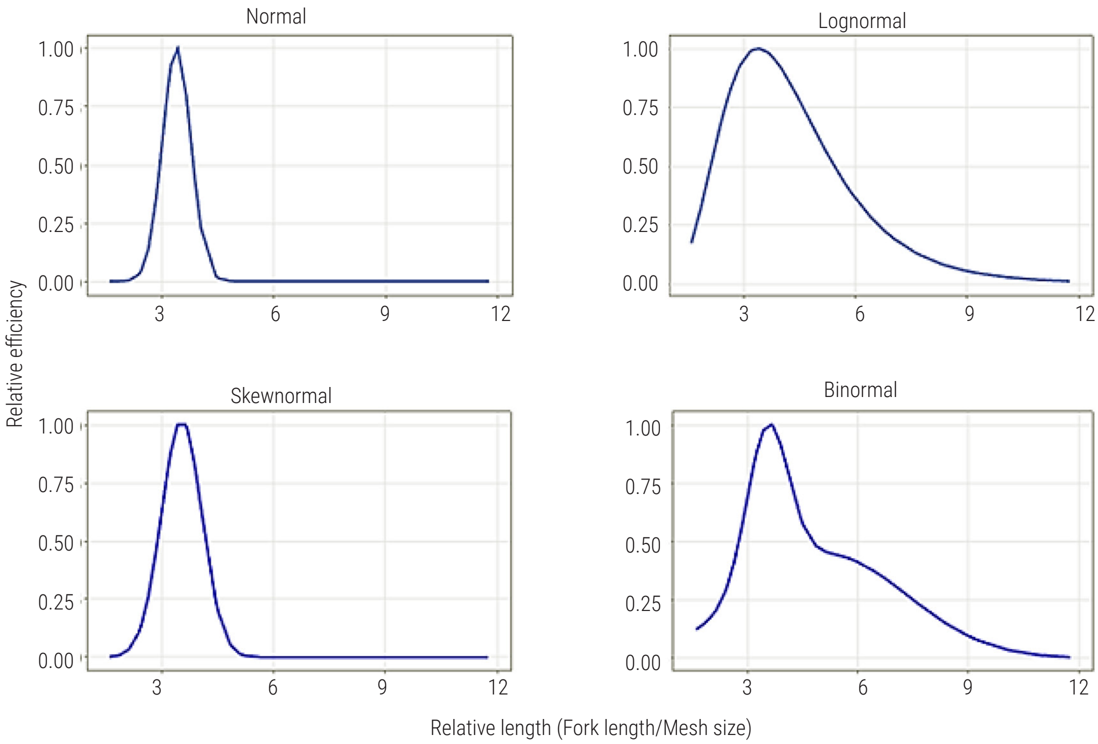

Fig. 3. Estimated master curves of mesh selectivity for *P. dussumieri*

Fitting results of the SELECT method for each mesh size are depicted in Fig. 4. The selection curve in each model showed a shift to the right with an increase in mesh size, with a corresponding increase in the body length of the fish caught. The width of the selection curve was remarkably wider in the 15.3 cm mesh size across all models. The upper limits of selection for the 10.0 and 15.3 cm mesh sizes exceeded the maximum fork lengths observed in the catch.

Fisheries management indicators

Table 4 presents the fisheries management indicators from this study. The asymptotic length, length at maturity (Lm_{50}), optimum catchable length, and mega-spawner length were estimated as 58.6, 32.3, 37 and >40.7 cm, respectively. Table 5 summarises fisheries management indicators for different mesh sizes. The proportion of non-standard size fish declined with increasing mesh size, measuring 33.50, 17.10, 3.50 and 3.48% for 4.8, 6.3, 10.0 and 15.3 cm meshes, respectively. Conversely, the proportion of mega-spawner length fish rose with mesh size, reaching 25.84, 38.54, 52.22 and 59.20% for the same mesh sizes.

Selection curve and length at maturity

Fig. 5. shows the relationship between the length at maturity and the binomial modal selection curve relative to body length across different mesh sizes. In this study, the size of *P. dussumieri* at first maturity was determined to be 32.3 cm, closely matching previous findings of 32.0 cm (Paighambari *et al.*, 2020); and 30.55 cm (Mohseni *et al.*, 2020).

Discussion

Estimation of optimum mesh size requires sufficient information about length frequency, selectivity and fish-length-based indicators (Gerami and Abdollahi, 2014).In this study, *P. dussumieri* specimens ranged from 24.5 to 56.5 cm in fork length. Previous reports show similar variability; Cheraghi Shevi *et al.* (2015) reported a range of 24.5-76.7 cm, while Abdi and Ghazizade (2019) recorded 36-48 cm for gillnet catches in the Oman Sea. Factors such as fish behaviour around the net, species size, stock status, and fishing depth strongly influence the length distribution of fish caught in the gillnets (Genc, 2002; Kalaycı and Yesilcicek, 2014). Many fisheries target fish within a certain size range due to the size-selective characteristics of the fishing gear used. Understanding the size range vulnerable to capture is therefore of critical importance for effective management

Table 4. Fisheries management indicators for *P. dussumieri*

Parameter	Fork length (cm)
Asymptotic length (cm)	58.6
Length at maturity lm_{50} (cm)	32.3
Optimum catchable length L_{Opt} (cm)	37
Mega-spawner length	>40.7

Table 5. Fisheries management indicators of *P. dussumieri* across different mesh sizes

Parameter	Mesh size (cm)			
	4.8	6.3	10.0	15.3
% Non-standard size fish	33.50	17.10	3.50	3.48
% Mega-spawner length	25.84	38.54	52.22	59.20

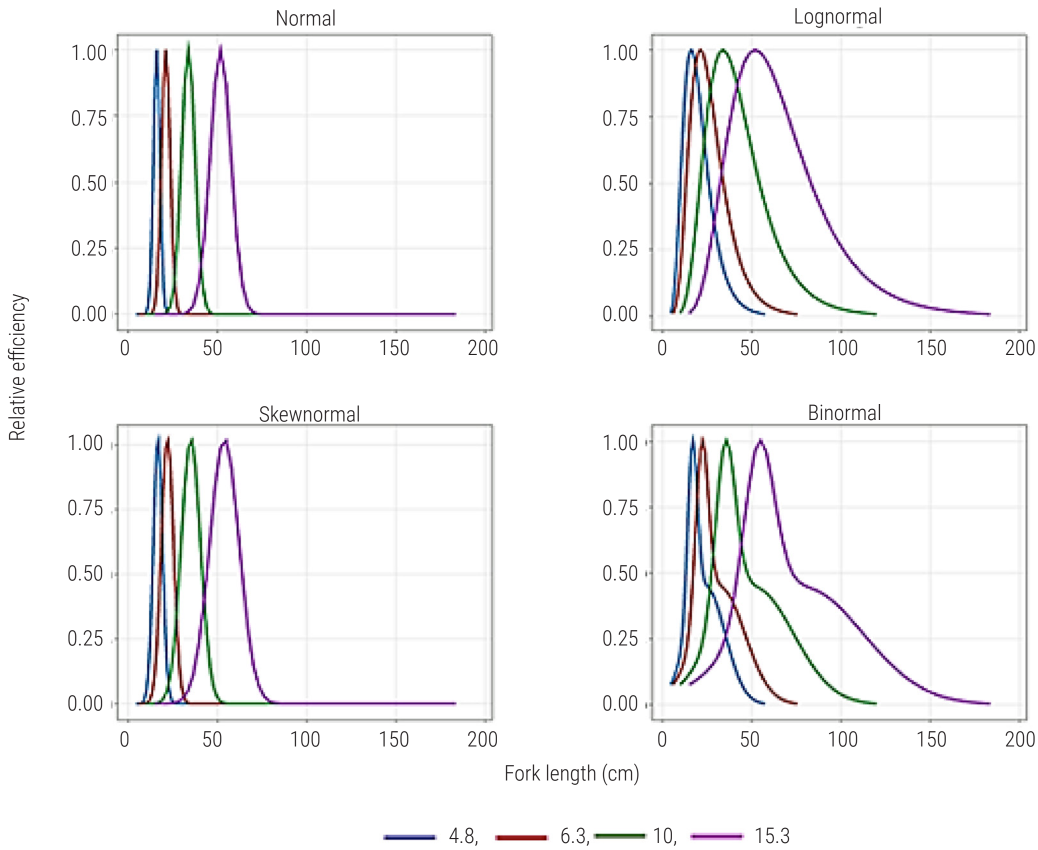

Fig. 4. Selection curves for each experimental gillnet across all models

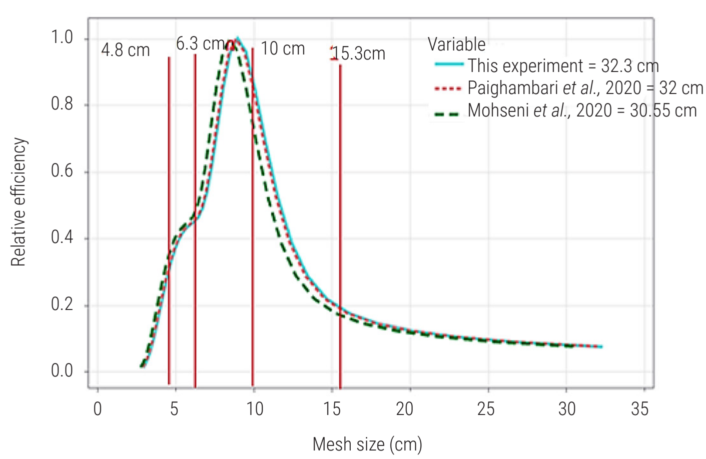

Fig. 5. Relation between length at maturity from this study and previous studies and the bi-normal model selection curve relative to body length across different mesh sizes

(Gerami and Abdollahi, 2014). Variability in fish size has significant implications for diverse aspects of fisheries science and population dynamics (Erzini, 1994). Also, the length frequency distribution of any fish is significant for understanding the size structure of that fish population, serving as a fundamental step in evaluating gear selectivity and for selecting the most appropriate analytical model.

Based on the model deviance and the residual plot, the bi-normal model was identified as the most suitable selection curve for *P. dussumieri* (Table 3). This pattern reflects the frequent entanglement of fish, where retention in the net occurs at multiple body parts, such as fins or the operculum, creating more than one mode of capture. Pope *et al.* (1975) noted that when multiple capture mechanisms operate, the selection curve can exhibit two or more peaks. Similarly, Fujimori and Tokai (2001) emphasised that discontinuous enmeshment caused by fins or the operculum, leads to multi-part selection resulting in bi-normal selectivity.

Studies in several fish species have shown that bimodal curves (bi-normal) often yield superior fit for gillnet selectivity. Fujimori and Tokai (2001) obtained good results using the bi-normal model for pink salmon, while Park *et al*. (2004) found it appropriate for *Konosirus punctatus* in coastal waters of Korea and Kalaycı and Yesilcicek (2014) confirmed its suitability for whiting (*Merlangius merlangus euxinus*). However, examining the actual capture pattern is necessary for confirmation of selectivity. In this study, four capture modes were observed in the gillnets. In 4.8 cm mesh nets, over 60% of the catch was gilled, rising to more than 90% in 6.3 cm and over 74% in 10.0 cm meshes.. In contrast, the 15.3 cm showed more than 54% entanglement and only 17% gilling. Bayse and Grant (2020) reported that entanglement is less size-dependent and can capture both large and small fish, leading to multiple capture patterns and resulting in bi-normal selectivity.

Analysis of the *P. dussumieri* data revealed that more than 43% of the catch comprised mega-spawners, indicating a desirable age structure. This high proportion of large, mature individuals suggests strong resilience to natural disturbances, such as recruitment failures caused by unfavourable environmental conditions. Therefore, the percentage of mega-spawners in a stock can serve as a practical indicator of resilience to random environmental events. Several studies in Iran have investigated key biological characteristics of blacktip sea catfish including optimal catchable length, management parameters (L_{∞}, L_{opt}) and length at maturity (Cheraghi Shevi *et al*., 2015; Mohseni *et al*., 2020; Barmooz, *et al*., 2021). As fisheries development programs in the Oman Sea continue to increase harvesting pressure, assessing parameters such as length at maturity (Lm_{50}), optimal catchable length, and asymptotic length seems necessary (Vinothkumar *et al*., 2022). Because fish populations are dynamic and their vital parameters can change over time, regular evaluation of these ndicators is critical. Understanding these biological characteristics enhances the accuracy of stock assessments and supports effective fisheries management (Gerami and Abdollahi, 2014).

The length first at maturity (Lm_{50}) is widely used as a key indicator for setting minimum catch sizes (Sadough Niri *et al.,* 2023). Estimating L_{m50} from length structure data is very important for stock assessment and developing fisheries management strategies, as it reflects the reproductive status of a population and guides catch regulations based on size. For *P. dussumieri* in coastal waters of Iran, Mohseni *et al.* (2020) reported an L_{m50} of 30.55 cm, while Paighambari *et al.* (2020) estimated it at 32 cm, highlighting consistency across studies. Fig. 5, shows that the length at first maturity of *P. dussumieri* was estimated to be 32.3 cm, which is consistent with previous studies. Based on this, fish larger than 32.3 cm was considered suitable for harvest. The Kolmogorov-Smirnov (K-S) test of the length frequencies across different mesh sizes revealed a significant difference between 4.8 and 15.3 mesh sizes ($p<0.05$). Therefore, mesh sizes of 6.3 and 10 cm were identified asappropriate for harvesting this species, but according to the Fridman method (38.125/3.5=10.89), a mesh size of 10.0 cm is the most suitable size for commercial fishing. Adoption of this mesh size would help prevent recruitment overfishing of *P. dussumieri*.

The gradual reduction in mesh size over the years may reflect fishers' attempts to increase catches as the number of large individuals in the stock has declined, indicating rising fishing pressure over time. Implementing optimal mesh sizes can help curb overfishing and promote the recovery of depleted stocks. Effective catch management also requires ongoing assessments of fish populations and habitats through systematic data collection and scientific research. Promoting sustainable practices and raising awareness among local fishing communities about the ecological impacts of fishing can further enhance compliance with regulations. Strong collaboration among governmental bodies, non-governmental organisations and local stakeholders is crucial for establishing and enforcing effective management strategies that safeguard aquatic ecosystems and ensure the long-term viability of commercial fisheries. While this study provides valuable insights, several limitations should be acknowledged. Sampling was limited to a specific location and time period, which may not capture the full spatial and temporal variability of *P. dussumieri* population dynamics and size structure across the entire Oman Sea. Future studies should incorporate a broader geographic range and multi-year sampling to account for environmental and annual variations. Although the selectivity analysis is robust, it relies on indirect methods; direct observations of capture patterns such as underwater camera footage or enhanced onboard monitoring, would provide stronger confirmation of the bi-normal selectivity and more precise identification of enmeshment points.

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