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Original Article

Size at sexual maturity estimation for 36 species captured by bottom and mid-water trawls from the marine habitat of Balochistan and Sindh in the Arabian Sea, Pakistan, using maximum length (Lmax) and logistic (L50) models

Estimativa do tamanho na maturidade sexual de 36 espécies capturadas por redes de arrasto de fundo no hábitat marinho do Baluchistão e Sindh, no Mar Arábico, Paquistão, usando modelos de comprimento máximo (Lmax) e logístico (L50)

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Abstract

The aim of this study was to estimate the size at first sexual maturity (L_m) for 36 species belonging to 24 families from the marine habitat of Balochistan and Sindh in Arabian Sea, Pakistan through maximum length based an empirical and logistic model using commercial catch during June 2020 to May 2021. Individual total length (TL) was noted up to 0.1 cm using measuring broad. The Lm was calculated using two formulae; (i) log (Lm) = - 0.1246 + 0.9924 * log (L_{max}) for Elasmobranchs and (ii) log (L_m) = -0.1189 + 0.9157* log (L_{max}) for ray-finned fishes. The minimum Lm was recorded as 10.27 cm TL for *Caranx malabaricus* and 108.38 cm TL for *Isurus oxyrinchus*, respectively. Around L_m with 58.33% species were ranges from 19.00 cm to 25.00 cm TL. This study was estimated 16 newly L_m which is globally absent and rest 20 L_m are absent in the Arabian Sea (Pakistan coastal habitats). Therefore, the results will be helpful for the sustainable management and conservation of these marine fishes through the establishment of mesh size of trawl nets based on the size at sexual maturity (L_m).

Keywords: size at first sexual maturity, selected habitat, coastline, Pakistan.

Resumo

O objetivo deste estudo foi estimar o tamanho na primeira maturidade sexual (Lm) para 36 espécies pertencentes a 24 famílias do hábitat marinho do Baluchistão e Sindh, no Mar Arábico, Paquistão, por meio de modelo empírico e logístico com base no comprimento máximo usando captura comercial, durante junho de 2020 e maio de 2021. O comprimento total individual (TL) foi anotado até 0,1 cm usando medição ampla. O Lm foi calculado por duas fórmulas; (i) log (Lm) = - 0,1246 + 0,9924 * log (Lmax) para elasmobrânquios; e (ii) log (Lm) = - 0,1189 + 0,9157* log (Lmax) para peixes com nadadeiras raiadas. O Lm mínimo foi de 10,27 cm de TL para *Caranx malabaricus*, e o máximo, de 108,38 cm de TL para *Isurus oxyrinchus*. Em 58,33% das espécies com Lm foram encontradas faixas de 19,00 cm a 25,00 cm de TL. Este estudo estimou que 16 espécies com Lm estão globalmente ausentes e as 20 espécies restantes com Lm estão ausentes no Mar Arábico (hábitats costeiros do Paquistão). Portanto, os resultados serão úteis para o manejo sustentável e a conservação desses peixes marinhos por meio do estabelecimento da malhagem das redes de arrasto com base no tamanho na primeira maturidade sexual (Lm).

Palavras-chave: tamanho na primeira maturidade sexual, hábitat selecionado, litoral, Paquistão.

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1. Introduction

Fishes are the most affluent creatures and the most abundant group on the earth which secure livelihood and consist of 50% species the chief sources of high-quality protein to provides sustenance to billions of people worldwide and are used to develop the national economy (Costello et al., 2012; FAO, 2012; Hassan et al., 2021; Hussain et al., 2021; Abidin et al., 2022).About 39 million people are engaged in capture fisheries globally, and more than 90% work in the small-scale fisheries sector (Islam et al., 2020). Marine fisheries play an important role in Pakistan national economy by adding value to the agricultural sector (Mohsin et al., 2015; Hassan et al., 2021). A large variety of aquatic organisms are found in inland, coastal and marine waters of Pakistan (Pernetta, 1993). The Arabian Sea of Pakistan is one of the most identical seas around the world. The coastline of Pakistan extends 1050 km, 250 km falling in Sindh state and 800 km in Balochistan. The continental shelf of the Sindh coast extends to a distance of 150 km. whereas that of Balochistan only measures 15-40 km (Siddiqui et al., 2008; Kazmi, 2013). The coast of Pakistan shows extensive diversity of marine fauna and flora, with many commercially vital species dwelling the intertidal, near-shore and off-shore areas (Siddiqui et al., 2008). Environmental conditions influence the sex ratio of many gonochoristic fish species. They have the ability to determine or impact sex distinction. Although temperature is the most prevalent environmental factor influencing fish sexual maturity (Baroiller et al., 2009). Effective fisheries management depends on having an exact assessment of biological parameters, including growth parameters, reproduction (e.g., spawning season), size at sexual maturity (L_m) and stock assessment (Tracey et al., 2007). The development of the aquaculture industry and its success necessitate knowledge of each species sexual maturity 'seed production under different environmental condition for successful breeding performance needs mature brood stock for excellent seed production (Hassan et al., 2023; Hussain et al., 2021). The size at sexual development in fish species is fundamental to discover the reasons on behalf of modifications of the length of maturity (Templeman, 1987). Subsequently, it is habitually castoff as a sign of least-acceptable capture dimensions (Lucifora et al., 1999). A list of 36 species from the coast of Sindh and Balochistan in Pakistan is documented in Table 1. To the

Table 1. A list of total 36 fish species in collected from various habitat of study area.

Sl.no	Family	Scientific name	Common name
01	Ariidae	*Netuma thalassina*	Khagga
02		*Arius arius*	Threadfin sea catfish
03		*Arius maculatus*	Spotted catfish
04	Haemulidae	*Pomadasys kaakan*	Javelin grunter
05	Lutjanidae	*Lutjanus argentimaculatus*	Red snapper
06		*Lutjanus malabaricus*	Malabar snapper
07		*Lutjanus rivulatus*	Maori Snapper
08		*Lutjanus fulvus*	Blackmail snapper
09	Nemipteridae	*Nemipterus japonicus*	Threadfin bream
10	Serranidae	*Epinephelus coioides*	Greasy grouper
11		*Epinephelus tauvina*	Greasy rockcod
12		*Epinephelus diacanthus*	Gobra, Grouper
13	Sparidae	*Acanthopagrus berda*	Black bream
14		*Acanthopagrus latus*	Yellow fin sea bream
15		*Acanthopagrus bifasciatus*	Twobar bream
16	Sciaenidae	*Argyrosomus heinii*	Arabian sea meagre
17		*Otolithes ruber*	Croaker
18	Carangidae	*Carangoides malabaricus*	Kat-bangada
19		*Parastromateus niger*	Black pomfret
20		*Caranx malabaricus*	Bagada, onion kingfish
21	Terapontidae	*Terapon jarbua*	Borguni
22	Scombridae	*Rastrelliger kanagurta*	Rake gillat mackerel
23	Monacanthidae	*Aluterus monoceros*	Unicorn filefish
24	Sillaginidae	*Sillago sihama*	Shorangi
25	Sphyraenidae	*Sphyraena putnamae*	Sawtooth barracuda
26	Cynoglossidae	*Cynoglossus arel*	Kukur jeeb
27	Muraenesocidae	*Muraenesox cinereus*	Darkfin Pike -eel
28	Psettodidae	*Psettodes erumei*	Indian halibut
29	Stromateidae	*Pampus argenteus*	Silver pomfret
30	Trichiuridae	*Lepturacanthus savala*	Ribbon fish
31	Mullidae	*Mullus barbatus*	Blunt snouted mullet
32	Platycephalidae	*Platycephalus indicus*	Gobi flathead
33	Centropomidae	*Lates calcarifer*	Barramundi
34	chanidae	*Chanos chanos*	Milk-fish
35	Exocoetidae	*Parexocoetus brachypterus*	Sailfin flying fish
36	Lamnidae	*Isurus oxyrinchus*	Shortfin Mako shark

best of our knowledge, there is no available literature on size at sexual maturity (L_m) of these 36 species from the Arabian Sea covering the coast of Sindh and Balochistan, Pakistan. The objective of this research is to estimate the L_m for 36 species from the coast of Sindh and Balochistan in Pakistan that will be helpful for the management strategies of these species in the Arabian Sea, Pakistan and adjacent ecosystems.

2. Materials and Methods

The research was conducted in the coastal areas of Sindh and Balochistan, Pakistan link to Arabian Sea (Figure 1). Pakistan is brilliant with rich fishing potentials. Study area located in the northern part of the Arabian Sea, the geographical location is 61°30′ E. 68°10′ E. Pakistan has a coastline of about 1050 km. The Arabian Sea at the coast of Sindh and Balochistan has rich fish deposits of commercial importance. Sampling was done from June 2020 to May 2021. The recent study comprises one year data including four different seasons in each year. Sample collected by wooden boat from the different sites (Wooden boat registration number 18511-B).

Fishing was done during late-night with the help of local fishers. Fishes were caught with several different type of fishing gears, namely trawls, gill nets, trammels nets, pond nets, long- line, traps and hooks (Whitehead et al., 1986; Saldanha, 1995; Hassan et al., 2020) and then preserved in 10% formalin for the further process. Each individual was measured (TL, to nearest 0.1 cm) by measuring board. The length on 50% maturity (50% L_m) of the 36 fish species was estimated by the equations (Binohlan and Froese, 2009): (i) Log (L_m) = -0.1246 + 0.9924 * Log (L_{max}) for Elasmobranchs and (ii) Log (L_m)= -0.1189 + 0.9157* Log (L_{max}) for ray-finned fishes.

L50 denoted the minimum length break wherein 50% of the individual specimens were matured. In order to analysis of *TL50*, a logistic curve following King (2007) was applied for the data by plotting the\ percentage of mature individuals (PMI) against TL class as PMI = 100/ [1+ exp{-*f* (TL_m -TL_{50})}] where, *f* is the growth coefficient and TL_m is the median value of each TL class. However, all mature individuals in a population do not continue in a reproductive cycle at the same time. Consequently, PMI was not more than 100% even in the largest TL class. Therefore, following the established method of King (2007), the data were adjusted to overcome an unreasonably high estimate of TL_{50}.

3. Results and Discussion

A total 1273 specimens of 36 fish species belonging to 24 families were evaluated in the current study. The minimum length was 5.00 cm in TL for *Otolithes ruber* and *Pampus argenteus* and maximum length was 150.00 cm in TL for *Sphyraena putnamae* and *Isurus oxyrinchus*. The estimated minimum L_m was 10.27 cm (TL) for *Caranx malabaricus,* maximum was 108.38 cm (TL) for *Isurus oxyrinchus* and mean value was 30.21 cm (TL) for the 36 species of from selected habitat of Arabian Sea, Pakistan. The estimated minimum L_m was 16.08 cm (TL) and maximum was 32.31 cm (TL) for the family Ariidae. Size at sexual maturity varied from 21.45 to 45.82 cm (TL) for the family Lutjanidae. The estimated minimum L_m was 19.47 cm (TL) and maximum was 31.10 cm (TL) for the family Serranidae. The L_m varied from 15.44 to 20.46 cm (TL) for the family Sparidae, 10.27 to 20.44 cm (TL) for Carangidae. However, the maximum length, L_m with 95% confidence limit, and L_{50} are given in Table 2.

Nevertheless, the size at sexual maturity was estimated by several models including brooding of eggs over time, appearance of ovary and maturation stages over time (King, 2007), relative weight of gonads (TL *vs.* gonadosomatic index, modified gonadosomatic index and Dobriyal index)

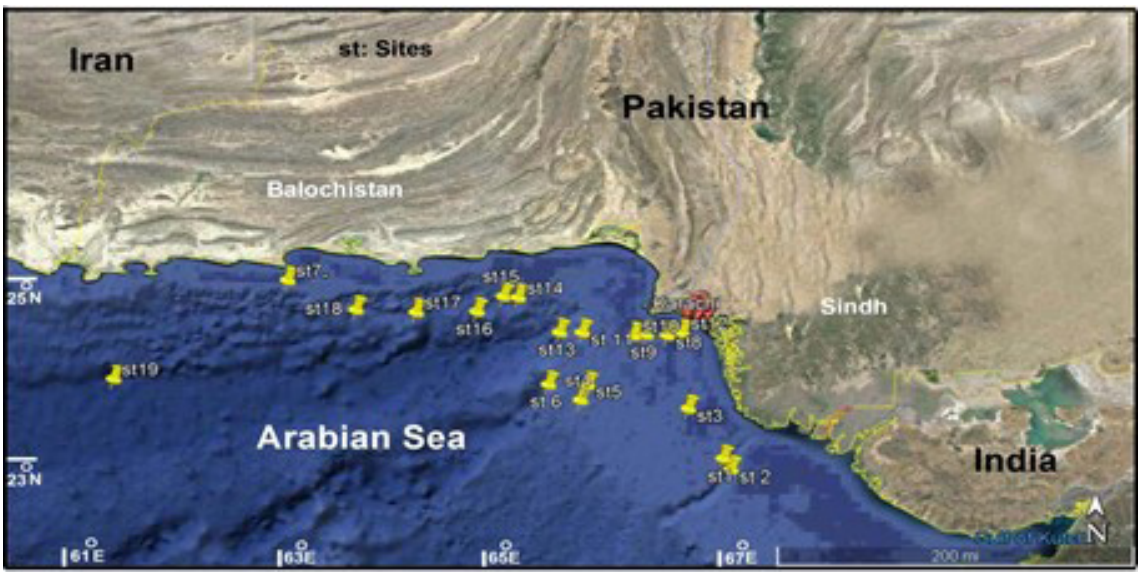

Figure 1. Map showing the collection localities of 36 fish species the Sindh and Balochistan coasts in the Arabian Sea, Pakistan.

Table 2. Size at first sexual maturity (L_m) of 36 fish species in Arabian sea of Pakistan.

Family	Scientific name	*n*	Minimum length (cm)	Maximum length (cm)	L_m (95% of CL)
Ariidae	*Netuma thalassina*	80	20.00	40.00	22.29 (17.12-28.81)
	Arius arius	66	10.00	28.00	16.08 (12.53-20.56)
	Arius maculatus	70	9.00	60.00	32.31 (24.42-42.30)
Haemulidae	*Pomadasys kaakan*	10	24.00	45.00	23.92 (16.35-16.01)
Lutjanidae	*Lutjanus argentimaculatus*	40	21.00	45.00	23.92 (16.35-16.01)
	Lutjanus malabaricus	80	32.00	91.00	45.82 (30.22-69.49)
	Lutjanus rivulatus	70	10.00	53.00	27.82 (18.86-41.05)
	Lutjanus fulvus	40	25.00	40.00	21.45 (14.75-31.21)
Nemipteridae	*Nemipterus japonicus*	40	7.00	37.00	19.96 (13.78-28.93)
Serranidae	*Epinephelus coioides*	15	30.00	47.00	24.90 (16.98-36.52)
	Epinephelus tauvina	16	16.00	60.00	31.10 (21.01-46.32)
	Epinephelus diacanthus	20	15.00	36.00	19.47 (13.46-28.17)
Sparidae	*Acanthopagrus berda*	48	15.00	38.00	20.46 (14.11-29.69)
	Acanthopagrus latus	24	16.00	30.00	16.45 (11.48-23.59)
	Acanthopagrus bifasciatus	38	18.00	28.00	15.44 (10.81-22.05)
Sciaenidae	*Argyrosomus heinii*	10	50.00	90.00	45.36 (29.93-68.75)
	Otolithes ruber	100	5.00	45.00	23.92 (16.35-35.01)
Carangidae	*Carangoides malabaricus*	40	22.00	37.00	19.96 (13.78-28.93)
	Parastromateus niger	16	15.00	42.00	22.44 (15.39-32.73)
	Caranx malabaricus	12	12.00	18.00	10.27 (7.35-14.34)
Terapontidae	*Terapon jarbua*	22	6.00	35.00	18.97 (13.13-27.41)
Scombridae	*Rastrelliger kanagurta*	18	20.00	75.00	38.33 (25.53-57.56)
Monacanthidae	*Aluterus monoceros*	20	40.00	70.00	37.21 (27.95-48.94)
Sillaginidae	*Sillago sihama*	22	15.00	44.00	23.43 (16.03-34.25)
Sphyraenidae	*Sphyraena putnamae*	28	55.00	150.00	72.69 (46.75-113.05)
Cynoglossidae	*Cynoglossus arel*	80	27.00	75 .00	39.64 (29.70-52.24)
Muraenesocidae	*Muraenesox cinereus*	76	59.00	110.00	56.29 (41.53-75.07)
Psettodidae	*Psettodes erumei*	40	18.00	30.00	17.13 (13.31-21.95)
Stromateidae	*Pampus argenteus*	8	5.00	36.00	19.47 (13.46-28.17)
Trichiuridae	*Lepturacanthus* savala	6	38.00	99.00	49.53 (32.53-75.43)
Mullidae	*Mullus barbatus*	8	10.00	30.00	16.45 (11.48-23.59)
Platycephalidae	*Platycephalus indicus*	80	14.00	30.00	17.13 (13.31-21.95)
Centropomidae	*Lates calcarifer*	8	13.00	120.00	59.16 (38.48-90.97)
chanidae	*Chanos chanos*	10	24.00	28.00	16.08 (12.53-20.56)
Exocoetidae	*Parexocoetus brachypterus*	4	10.00	25.00	14.49 (11.35-18.47)
Lamnidae	*Isurus oxyrinchus*	8	38.00	150.00	108.38 (59.32-197.88)

over time (Hossain et al., 2017; Ahamed et al., 2018; Khatun et al., 2019) and histological studies (Chelemal et al., 2009; Jan and Ahmed, 2019; Lucano-Ramirez et al., 2019). However, in the current study, we estimated the L_m of 36 species by length-based empirical models which can be executed in many water-bodies without the sacrifice of lives Information on length at first sexual maturity (L_m) was available for 20 species in the Fish base among 36 studied fishes (Froese and Pauly, 2020) which are shown in Table 3 and 16 species' L_m are totally absent in the literature. In the estimation of L_m of fishes using this logistic equation, some studies have reported low accuracy, but its accuracy for short life cycle species is under investigated. However, it was highly prejudiced to use the proportion of

Table 3. Available information on size at first sexual maturity (L_m) of 20 species in different water bodies worldwide.

Species	Water bodies/countries	Size at first sexual maturity (L_m) cm	Reference
Arius thalassinus	North-west coast of India	36.00 TL	Parab (1998)
Lutjanus argentimaculatus	Philippines	57.00 TL	Emata et al. (1999)
Lutjanus malabaricus	Great Barrier Reef	57.60 FL	Mc-Pherson et al. (1992)
	Papua New Guinea	36.00 TL	Lokani et al. (1990)
Lutjanus fulvus	Yaeyama Islands	22.50 FL	Shimose and Nanami (2014)
Nemipterus japonicus	Kuwait	14.00 TL	Samuel (1986)
Epinephelus coioides	Southern Arabian Gulf	43.50 TL	Grandcourt et al. (2005)
Epinephelus tauvina	Arabian Gulf	61.10 TL	Lee and Al-Baz (1989)
Acanthopagrus latus	Persian Gulf	24.40 FL	Vahabnezhad et al. (2017)
	Arabian Gulf	23.70 TL	Lee and Al-Baz (1989)
Acanthopagrus bifasciatus	Southern Arabian Gulf	26.40 FL	Grandcourt et al. (2004)
Otolithes ruber	Southern African estuaries	23.00 SL	Whitfield (1998)
	Arabian Gulf	22.10 TL	Lee and Al-Baz (1989)
Terapon jarbua	Southern African estuaries	13.00 SL	Whitfield (1998)
Rastrelliger kanagurta	New Zealand	22.00 TL	Menon and Radhakrishnan (1974)
	Tuticorn coast (India)	18.80 TL	Samad et al. (2010)
	Rembang (Indonesia)	20.40 FL	Pralampita and Chodriyah (2010)
Sillago sihama	Pulicat Lake	22.50 TL	Krishnamurthy and Kaliyamurthy (1978)
Pampus argenteus	Cochin (India)	26.50 NG	CMFRI (2013)
Lepturacanthus savala	Ratnagiri coast	38.00 TL	Pakhmode et al. (2013)
Mullus barbatus	Hellenic seas	12.50 TL	Stergiou et al. (1997)
Platycephalus indicus	Southern Africa	40.00 FL	Van Der Elst and Adkin (1991)
Chanos chanos	Philippines	110.00 TL	Bagarinao (1991)
Cynoglossus arel	India	21.00 TL	Rajaguru (1992)
Isurus oxyrinchus	New Zealand	280.00 FL	Ministry of Fisheries (2009)
	Western North Atlantic	298.00 TL	Mollet et al. (2000)

mature females as an indicator of population reproduction (Mawa et al., 2021).

The size at first sexual maturity of fish species might be differed due to feeding rate, sex and gonadal development, behavior, season, flow of water, populations density, water temperature and foods (Hossain et al., 2006, 2012; Tarkan et al., 2006; Muchlisin et al., 2010). As it is the first work on L_m for 36 species in coastline of Pakistan, so it can be used as a base for the future studies and essential for the selection of the permissible mesh size of nets which will be helpful for the sustainable management strategies of these fish species from the marine habitat of Sindh and Balochistan linked to Arabian Sea, Pakistan and contiguous ecosystems.

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