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Original Article

The Omani sandfish sea cucumber, *Holothuria scabra* Jaeger, 1833 (Holothuroidea: Holothuriidae): Fishery, length-Weight relationship and condition factor

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Abstract: The fishery of Omani sea cucumber, *Holothuria scabra*, is limited so far to the Mahout Bay in Al Wusta governorate. This fishery supports an uncertain number of fishermen ranging from 100 to 150. This fishery is not well-studied and has no current management program. In order to prepare a management strategy, the government has suspended this fishery for 2 years from March 2018 to March 2021. Apart from presenting a thorough review on the sea cucumber fishery in Oman, the current work presents a detailed analysis of the length–weight relationship, sex ratio, and condition factor of the *H. scabra* collected from four different areas during the period February-May 2019. Based on the results, the females were longer than males, that is 226±33.4 and 221±37.8 mm, respectively. The overall sex ratio of the entire/pooled sample was 0.49 which was not different from the anticipated theoretical sex ratio of 0.5. The mean K_n and the empirical weight–length equations for the total sample were between 0.12±0.01 and 1.0±0.16, and W=0.03L$^{1.6}$, respectively.

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Introduction

Sea cucumbers are non-migratory space-specific species that are found in shallow protected seagrass and muddy sea beds around and within protected bays, coral reefs, and mangrove areas (Hamel et al., 2001; Agudo, 2006). They are reported to spawn throughout the year with enhanced peaks at certain period of the year (Lokani, 1990; Battaglene and Bell, 2004). In addition, sea cucumbers reproduce asexually as well (Conand, 1996; Conand et al., 2002; Dolmatov, 2014) and their life span ranges between 5 and 12 years depending on the species (Conand, 1990). Sea cucumber larvae spend 70 days in a planktonic stage before they settle into the ground where they develop into a juvenile. The growth rate of sea cucumbers is assumed to be slow and may take up to 5 years to mature (Conand, 2008). It grows up to 0.5 cm per month (≈14 g) under favorable conditions and attains maturity between 23 and 26 cm (Agudo, 2006; Navarro *et al*., 2012; Omar et al., 2013; Yanti et al., 2020). Sea cucumbers are scavengers or deposit feeders (Mercier et al., 1999). There are reports suggesting existence of sea cucumbers from long ago in many places, for example Solomon Islands, India, the Philippines, and Indonesia among others (Conand, 1990; Battaglene and Bell, 1999) and are known to be harvested for decades from the Indo-Pacific region (James, 2001; Bumrasarinpai, 2006). Yet, there is not much information on sea cucumber fisheries around the world.

With the increasing demand for sea cucumbers in the international market, the different types and sizes of sea cucumbers excavated in the absence of management resulted in more pressure for sea cucumber hunting and eventually to overfishing (Conand, 2008; Hair et al., 2018). Overfishing has been documented in Australia (Skewes et al., 2006), Fiji (Preston, 1988), and New Caledonia (Conand, 1990). In several countries, it was heavily exploited, which led these countries to apply moratorium on the fishery and ban fishing like in the case of the Egyptian sea cucumber (Hasan, 2003), the Papua New Guinea

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(Hair et al., 2018), and Turkey (Aydin, 2017). Other countries have introduced zonation or sea cucumber marine-protected areas where fishing areas are closed for a period of up to 4 years before they are opened again. In addition, whenever open, closed season is always applied during reproductive season (Purcell et al., 2016).

The price and demand for sea cucumber increased 16.6% in the international markets from 2011 to 2016 (Purcell et al., 2018). The increase in demand has an effect on the international fishing activities for sea cucumbers. The sea cucumber fishery and industry in Oman is in the initial stage, and the fishery being so far limited to small areas of Mahout Bay and targeted by small number of traditional fishermen. Omani sea cucumber, *Holothuria scabra* is a valuable species and an excellent source of income for the local communities and the fishery so far is an open access and hardly studied. So far, in Oman there are no fixed records of sea cucumber landings or about the actual number of fishermen involved. Furthermore, there are no data available on the basic stock assessment or population distribution of the sea cucumbers. Basically, there are plenty of missing information that needs to be understood and managed to develop the fishery. Hence, the current study reviews the Omani sea cucumber fishery and provides information on the length–weight relation and sex ratio from four main fishing areas in Oman.

Materials and Methods

All the available publications and reports (published and unpublished) on sea cucumbers were reviewed to understand their fishery. Fishing areas were visited and officials, fishermen, traditional processors, and traders were interviewed. The review present data on the sea cucumber landings, income, export, and any other information. As per the information obtained, the sandfish sea cucumber samples were collected from four major fishing areas viz. Ashaghia, Hofnat, Al Naqil, and Ashaghia (Fig. 1) in Mahout Bay during the period February-May 2019. The samples were measured to the nearest of 1 mm for total length (from mouth to anus) using a flexible plastic tape. An

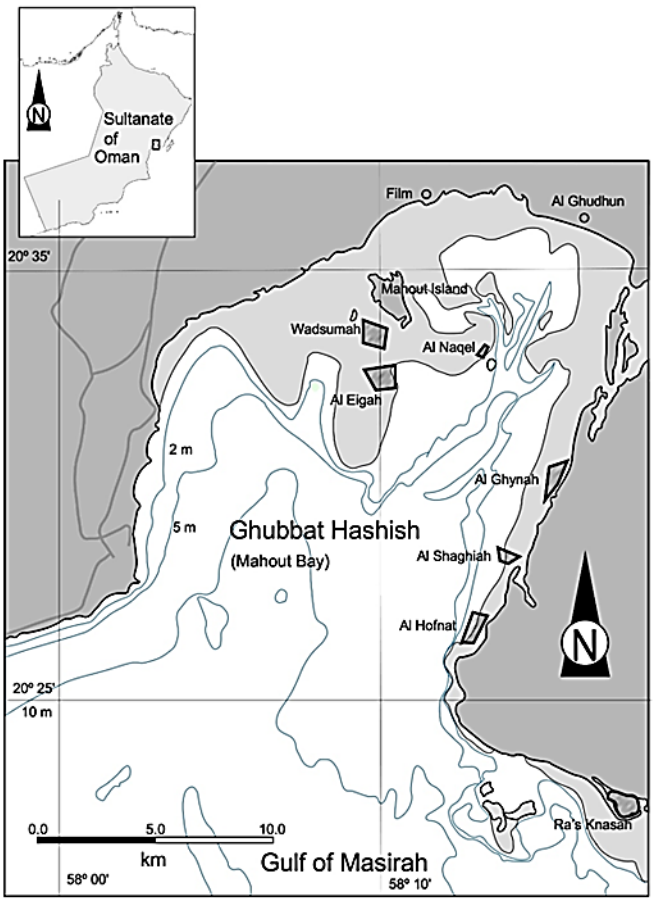

Figure 1. The Mahout Bay and the sea cucumber fishing areas.

electronic balance was used to record the wet weight to the nearest 1 g for each sea cucumber. Sea cucumbers were dissected for visual sex identification purposes.

Length-weight relationship was calculated using Pauly's (1984) equation of $W = a \times L^b$, where W is the wet weight in g, L the total length in mm, a and b the regression constants, "a" the intercept, and "b" the slope. Fulton's condition factor (K_n) was obtained by $Kn = W/(a \times L^b)$ (Le-Cren, 1951). The length–weight relation, the condition factor, and sex ratio were obtained for the whole sample, for each area, males, females, and unsexed sea cucumbers. The sex ratios were also presented by different length intervals and per sampling area.

Results

The fishery: The sandfish sea cucumber is the primary species among the other 21 different species that are identified in Oman (Claereboudt and Al-

Figure 2. Women and kids wading for sea cucumbers.

Rashdi, 2011). According to the information available, it is distributed around the Mahout Bay in the Gulf of Masira along the Al Wusta governorate in sandy protected and seagrass bays. Six main fishing areas are famous in this region, Alnaqil, Al-Eigah, Wadsumah, Al-Shaghia, Al-Hofnat, and Ras-Knasah (Fig. 1). The fishery started in the 1960s at a low scale and the catch was exchanged for food. Owing to the demand from the neighboring countries, the fishery expanded in 2003 and 2004 (Al-Rashdi et al., 2007). As it is not very difficult to catch sea cucumbers, this fishery encourages women and their kids also to help in catching practice, in many cases, they give a competition to the fishermen (Fig. 2). To catch sea cucumbers easily, one requires to walk on shallow water, spot the sea cucumber, and catch it. It is reported that women make 50% of the total fishing community and men contribute up to 30%, while kids contribute 20% (MAF, 2009). Few of these people dive in traditional ways to about 3-m depth, especially during high-tide periods. Of late, the number of divers were observed to increase due to higher market demands.

The intensity of fishing increases during low and extreme low-tide periods. The actual number of total fishermen involved in the fishery is not known, however, it is expected to be around 100–150 (unpublished data). There is no information about the number of traders involved; however, a vast percentage of sea cucumbers that are eviscerated, boiled, dried, re-boiled, and re-dried are collected in woven bags and exported to neighboring countries in car trunks. Collecting and selling sea cucumbers

Figure 3. Samples of sea cucumber catches. Sea cucumbers range from large to undersized.

became popular among fishing people in Mahout Bay area and the landings increased from 3.6 t in 2013 to 39.4 t in 2015. Targeting sea cucumber is open throughout the year and the intensity depends on the demand and request from the traders. Every year, however, the fishermen target the sea cucumbers from November to March for 3-4 h per day with an average catch of 100 different sizes of sea cucumbers (MAF, 2009). An increase in collecting and processing sea cucumber into beche-de-mer among the fishermen and even drying undersized sea cucumbers are also observed (Fig. 3). The unlicensed number of fishermen doubled in 2004-2005, that is to 100-200, respectively, keeping in mind the increase in prices per kg to five times from 2000 to 2005 (Al-Rashdi et al., 2007). It was also noticed that the fishermen started to dry undersized sea cucumber widely within

Table 1. Descriptive statistics for the sandfish sea cucumber, *Holothuria scabra* from Oman.

Sampling area		Mean	Median	Mode	Minimum	Maximum	Count
Al Naqil	Male	237	240	210	170	320	39
	Female	252	260	260	190	300	33
	Unsexed	232	235	230	130	300	70
	Combined	238	240	250	130	320	142
Aleigah	Male	221	220	220	160	310	36
	Female	224	220	230	170	290	36
	Unsexed	190	190	190	130	250	9
	Combined	219	220	230	130	310	81
Ashaghia	Male	208	210	210	160	310	20
	Female	211	210	210	160	250	23
	Unsexed	173	180	180	100	250	41
	Combined	192	195	210	100	310	84
Hofnat	Male	207	210	210	150	270	26
	Female	207	210	220	160	290	24
	Unsexed	142	140	140	70	270	374
	Combined	149	140	140	70	290	424
All data	Male	221	210	210	150	320	121
	Female	226	220	220	160	300	116
	Unsexed	158	150	140	70	300	494
	Combined	179	170	140	70	320	731

Mahout Bay area ultimately resulting in an increased number of fishermen. As a result, the government, as a precautionary approach, decided to suspend the fishery for 1 year starting from March 2018 to March 2019. The ministry later extended the suspension for another year until 27th March 2021. Although the suspension still exists, few people were found with approximately 1.2 t of illegal sea cucumbers in 2018 (unpublished data).

The price of each sea cucumber ranges from 0.5 to 2.00 Riyal Omani (OR) (1 OR = 2.6 $), while the price per kg for the dry sea cucumbers range between 35 and 55 OR. It is worth mentioning that 100 sea cucumbers make up to almost 2 kg after drying (MAF, 2009).

Length-weight relationship and sex ratio: During the present study, a total of 713 sea cucumbers were collected from four fishing areas, of which 121 were males, 116 females, and 494 unsexed. In all, 424 (59%) samples were collected from the Hofnat area, with 374 unsexed samples, 26 males, and 24 females. A total of 142 (19%) samples were collected from Al Naqil area, with 70 unsexed samples, 39 males, and 33 females. A total of 84 (12%) samples were collected from Ashaghia, with 41 unsexed samples, 23 females, and 20 males. Finally, 81 (11%) samples were collected from Aleigah with 36 males, 36 females, and 9 unsexed (Table 1, Fig. 4). The maximum length recorded was 320 mm for a male sample from Al Naqil, while the smallest sample was an unsexed sea cucumber of 70 mm length from Hofnat area (Table 1). Overall, the females were found to be longer than males, that is 226±33.4 and 221±37.8 mm, respectively. On the other hand, the heaviest sea cucumber, wet weight of 600 g, was captured from Al Naqil area, while the lowest weight recorded was 280 g from Ashaghia. Overall, males were heavier than females, that is 271±81.49 and 264.48±64.61 g, respectively (Table 2).

The overall sex ratio of the entire/pooled sample was 0.49 which was not different from the anticipated theoretical sex ratio of 0.5 (χ^2=0.11; df=1; P>0.05). The sex ratio within the sampling areas Al Naqil, Aleigah, Ashaghia, and Hofnat were 0.49, 0.53, 0.5, and 0.48, respectively, and all were not different from

Table 2. Length (mm) and wet weight (g) data collected from the four different sampling areas during the period February–May 2019.

Sampling area		Mean		Median		Mode		Minimum		Maximum		Count	
		L(mm)	W(g)	L(mm)	W(g)	L(mm)	W(g)	L(mm)	W(g)	L(mm)	W(g)	L(mm)	W(g)
Al Naqil	Male	237	295	240	270	210	240	170	170	320	600	39	39
	Female	252	309	260	300	260	300	190	180	300	500	33	33
	Unsexed	232	254	235	240	230	240	130	120	300	600	70	70
	Combined	238	278	240	255	250	300	130	120	320	600	142	142
Aleigah	Male	221	256	220	250	220	250	160	140	310	550	36	36
	Female	224	256	220	250	230	230	170	170	290	430	36	36
	Unsexed	190	198	190	230	190	230	130	100	250	280	9	9
	Combined	219	219	220	220	230	230	130	130	310	310	81	81
Ashaghia	Male	208	241	210	235	210	190	160	190	310	400	20	20
	Female	211	246	210	240	210	260	160	150	250	340	23	23
	Unsexed	173	185	180	200	180	210	100	50	250	280	41	41
	Combined	192	215	195	220	210	240	100	50	310	400	84	84
Hofnat	Male	207	-	210	-	210	-	150	-	270	-	26	-
	Female	207	-	210	-	220	-	160	-	290	-	24	-
	Unsexed	142	125	140	120	140	130	70	30	270	450	374	374
	Combined	149	-	140	-	140	-	70	-	290	-	424	-
All data	Male	221	271	210	250	210	250	150	140	320	600	121	121
	Female	226	264	220	250	220	230	160	150	300	500	116	116
	Unsexed	158	150	150	130	140	130	70	30	300	600	494	493
	Combined	179	188	170	180	140	130	70	30	320	600	731	731

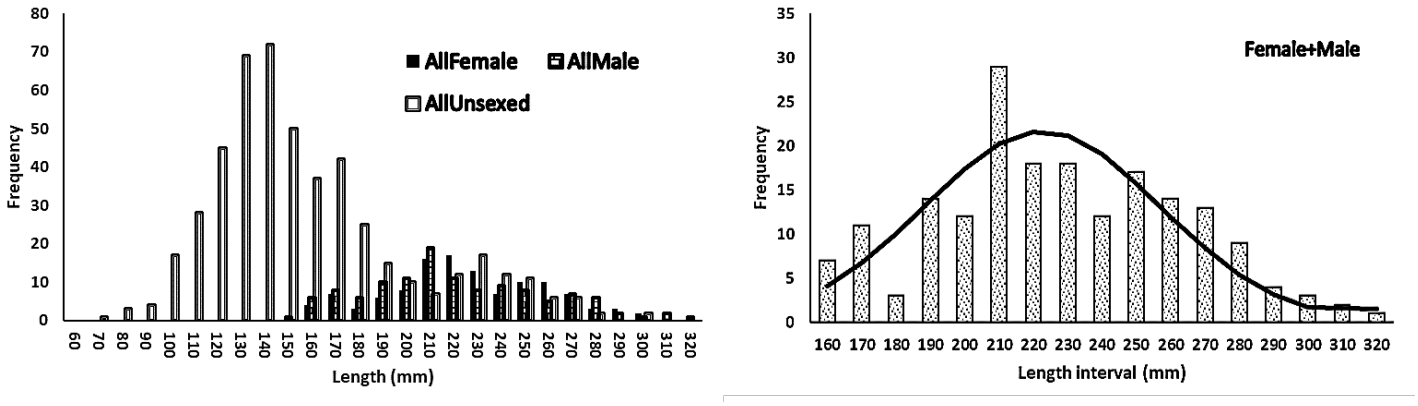

Figure 4. The length–frequency distribution of male, female, and unsexed sandfish sea cucumber samples (top graph) and for the combined males and females (bottom graph).

the theoretical sex ratio of 0.5 (P>0.05). The monthly sex ratios ranged between 0.38 (Al Naqil/May sample) and 0.75 (Ashaghia/February sample) (Table 3). The sex ratio versus total sea cucumber length within the sampling areas showed no pattern and females could be more than male in any given length group or could be less than the males (Fig. 5). However, the overall sample sex ratio did not show a pattern for sea cucumbers below 180 mm or above 240 mm. The overall sex ratio showed a pattern between lengths 180 and 230 mm and is explained by the power function (sex ratio=2.1*10-7 $L^{2.7}$, r=0.97) (Fig. 6). In addition to the mean K_n, the empirical weight-length equations for the total sample, female, male, unsexed, and combined male and female *H. scabra* per sampling area are presented in Table 4. The length-weight relationship for the total samples collected was W=0.03$L^{1.6}$ for a total of 680 male, female, and

Table 3. Monthly and overall sex ratios for sea cucumber samples collected from Anaqil, Ashaghia, Aleigah, and Hofnat sampling areas during the period February-May 2019.

	Alnaqil			Ashaghia		
Month	**Sex ratio**	**Chi-square**	***P*-value**	**Sex ratio**	**Chi-square**	***P*-value**
Feb-19	0.43	0.43	0.51	0.75	1	0.32
Mar-19	0.5	0	1	0.55	0.14	0.71
Apr-19	0.5	0	1	0.44	0.22	0.64
May-19	0.38	0.69	0.41	0.57	0.29	0.6
Overall	0.49	0.5	0.48	0.53	0.21	0.65
		Aleigah			Hofnat	
Feb-19	0.5	0	1	0.66	0.33	0.56
Mar-19	0.47	0.07	0.8	0.56	0.53	0.47
Apr-19	0.47	0.05	0.82	0.4	0.6	0.44
May-19	0.55	0.2	0.65	0.4	0.6	0.44
Overall	0.5	0	1	0.48	0.08	0.78
Feb-19	0.5	0	1			
Mar-19	0.52	0.15	0.7			
Apr-19	0.46	0.53	0.47			
May-19	0.48	0.06	0.8			
Overall	0.49	0.1	0.74			

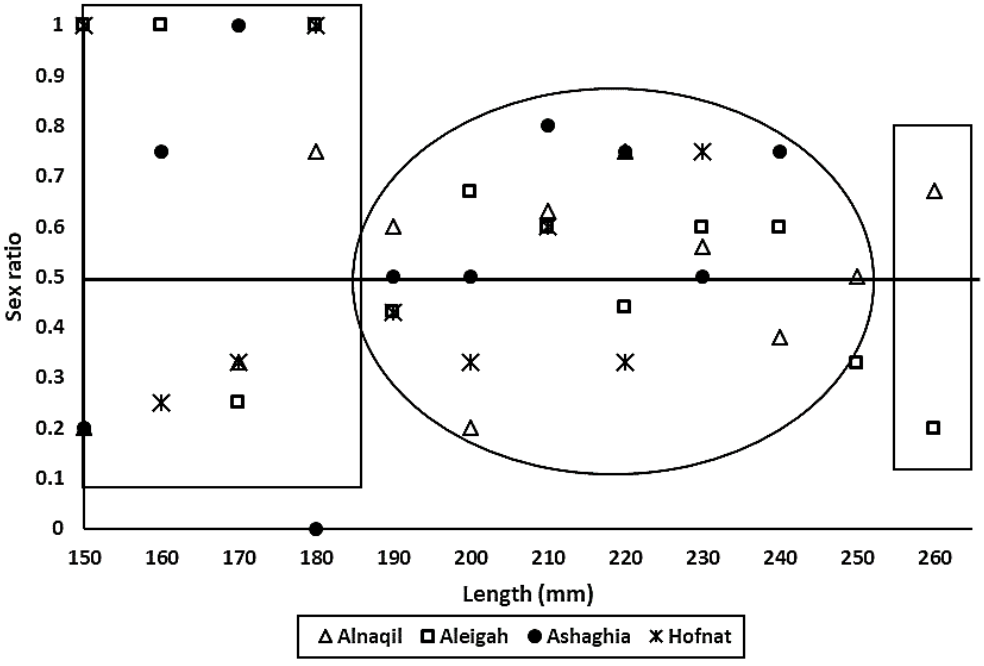

Figure 5. Sex ratio distribution based on sandfish sea cucumber length (mm).

unsexed sea cucumbers. The linear regression resulted in a high goodness of fit (R^2) which ranged from 0.61 to 0.9 (Table 4).

The mean condition factor (K_n) for *H. scabra*, ranged between 0.12±0.01 and 1.0±0.16 (Table 4). Overall, the unsexed sea cucumbers seemed to be on the lower side of the wellbeing with K_n of 0.89±0.16. Per sampling area, the males in Ashaghia had the lowest condition factor with a K_n of 0.12±0.01.

Discussions

The sandfish sea cucumber fishery in Oman is advancing fast to its developing stage. The number of fishermen involved increased fast. There is a tendency among fishermen to explore more fishing grounds as the demand increases. Enforcing regulations therefore

Table 4. Length-weight equations from different sampling areas with the mean condition factor provided.

Sampling area	Gender	Length-weight relationship	n	R^2	Mean K_n±SD
Al Naqil	Male	W=0.07L1.53	39	0.82	1.01±0.13
	Female	W=0.04L1.62	33	0.61	1.01±0.13
	Unsexed	W=0.34L1.22	70	0.67	1±0.14
	Male+female	W=0.07L1.52	72	0.73	1±0.12
	Combined	W=0.11L1.43	142	0.7	1±0.14
Aleigah	Male	W=0.17L1.36	36	0.76	1±0.13
	Female	W=0.3L1.47	36	0.78	0.4±0.04
	Unsexed	-	9	-	-
	Male+female	W= 0.21L1.31	72	0.77	1.00±0.11
	Combined	W=0.13L1.41	81	0.82	1±0.11
Ashaghia	Male	W=1.02L1.02	20	0.88	1.00±0.07
	Female	W=0.43L1.18	23	0.63	1±0.12
	Unsexed	W=0.08L1.5	41	0.84	1±0.16
	Male+female	W=0.74L1.08	43	0.75	1±0.09
	Combined	W=0.13L1.41	84	0.84	1±0.13
Hofnat	Male	-	-	-	-
	Female	-	-	-	-
	Unsexed	W=0.01L1.88	374	0.8	1±0.17
	Male+female	-	-	-	-
	Combined	W=0.01L1.82	424	0.8	1±0.21
Total sample	Male	W=0.17L1.4	95	0.8	1±0.21
	Female	W=0.19L1.3	92	0.71	1±0.12
	Unsexed	W=0.33L1.65	493	0.86	0.89±0.16
	Male+female	W=0.18L1.34	187	0.746	1±0.12
	Combined	W=0.03L1.64	680	0.9	1±0.16

The equations are given by sampling areas and by genders.

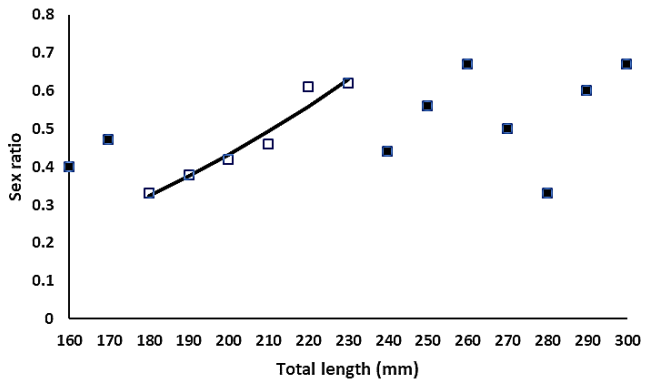

Figure 6. Relationship between the lower total length interval (cm) and the total sample sex ratio for the Omani sandfish sea cucumber, *Holothuria scabra*.

could be an issue if stricter measures are applied.

The overall sex ratio for samples collected for this study was not different from 1:1 (0.49), and this was different from the sex ratio within the sampling areas ranging 0.48-0.53. This result was supported by the *H. scabra* study from Abu Rhamada Island in the Red Sea (Hassan, 2005). The female-to-male ratio for the same species was 1.48:1 for samples collected from Kudat, Malaysia; however, the sex ratio was not significantly different (Arsad et al., 2017). The sex ratio for samples collected from Mahout Bay in Oman was reported to be 1:1 (Al-Rashdi et al., 2007). As far as the sex ratio among different length groups is considered, the sex ratio did not have a prevailing of one sex over the other. The sex ratio power function identified within this study can be used for reconstructing the sex structure from catch data and therefore can be used for sex-based management applications and assessment models.

Analysis of length-weight relationship indicated that the growth is negative allometric as all the *b*-values obtained were lower than 3. The *b*-values ranged from 1.22 to 1.88 for the different sexes and for the unsexed in different sampling areas. In addition, the overall *b*-values were 1.4, 1.3, 1.65, and

1.64 for the male, female, unsexed, and for the combined sexes, respectively. These *b*-values were significantly lower than the regression coefficient of 3 (Pauly, 1983) i.e. the length growth is greater than the weight growth, results that were supported by length–weight relationship of *H. spinifera*, *Bohadschia marmorata*, *Stichopus naso*, and *H. atra* samples collected from Point Pedro and Mullaitivu in North-east region of Sri Lanka (Veronika et al., 2018) and from Gulf of Mannar, India (Venkataraman, 2007). The length-weight equations obtained by Al-Rashdi et al. (2007) was W=0.033L$^{2.178}$ for *H. scabra* from the data collected from Mahout Bay, Oman. This was also supported by *H. scabra* from Fiji (W=0.1878L $^{2.5807}$) (Lee et al., 2018). The results showed slightly higher *b*-values than the current study. Different length-weight results can be obtained by different studies depending on the sampling methodology, time of sampling, and area.

The status of sea cucumbers cannot be concluded as underexploited or overexploited, since it is in its early stages of developing. It is recommended to form a liaison committee between the government and the sea cucumber fishermen society i.e. for a successful control over the fishery a strong co-management and cooperation between the government and the fishermen are highly recommended.

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