Western Indian Ocean JOURNAL OF Marine Science

Volume 19 | Issue 1 | Jan – Jun 2020 | ISSN: 0856-860X

Chief Editor José Paula

Western Indian Ocean
JOURNAL OF
Marine Science

Published biannually

Aims and scope: The *Western Indian Ocean Journal of Marine Science* provides an avenue for the wide dissemination of high quality research generated in the Western Indian Ocean (WIO) region, in particular on the sustainable use of coastal and marine resources. This is central to the goal of supporting and promoting sustainable coastal development in the region, as well as contributing to the global base of marine science. The journal publishes original research articles dealing with all aspects of marine science and coastal management. Topics include, but are not limited to: theoretical studies, oceanography, marine biology and ecology, fisheries, recovery and restoration processes, legal and institutional frameworks, and interactions/relationships between humans and the coastal and marine environment. In addition, *Western Indian Ocean Journal of Marine Science* features state-of-the-art review articles and short communications. The journal will, from time to time, consist of special issues on major events or important thematic issues. Submitted articles are subjected to standard peer-review prior to publication.

Manuscript submissions should be preferably made via the African Journals Online (AJOL) submission platform (http://www.ajol.info/index.php/wiojms/about/submissions). Any queries and further editorial correspondence should be sent by e-mail to the Chief Editor, wiojms@fc.ul.pt. Details concerning the preparation and submission of articles can be found in each issue and at http://www.wiomsa.org/wio-journal-of-marine-science/ and AJOL site.

Disclaimer: Statements in the Journal reflect the views of the authors, and not necessarily those of WIOMSA, the editors or publisher.

ISSN 0856-860X

Cover image: Ponta Mazondúe, Inhaca Island, Mozambique (© Jose Paula, 2014)

Size-distribution and length-weight relationship of a deep-water population of *Holothuria scabra* (Jaeger, 1833) in Zanzibar, Tanzania

Yussuf S. Yussuf[1, 2] *, Saleh A. Yahya[1]

[1] Institute of Marine Sciences, Mizingani Road, P.O Box 668, Zanzibar, Tanzania

[2] Department of Biology, Collage of Natural and Mathematical Sciences, University of Dodoma. P.O. Box 388, Dodoma, Tanzania

* Corresponding author: yussufyams@hotmail.com

Abstract
A study was carried out on the size distribution, length-weight relationship and condition factor of a deep-water population of the commercially important tropical sea cucumber *Holothuria scabra* in Zanzibar, Tanzania. Samples were collected from fishers and supplementary information gathered. The deep water (15-20 m) population of *H. scabra* is dominated by large sized individuals that have already attained maturity. There was no significant difference in size between male and female individuals (p>0.05). The sex ratio in this population significantly differed from 1:1 in favour of male individuals (p=0.01). The results showed significant correlation between length and weight for male, female, indeterminate individuals, and pooled data, with r values of 0.681, 0.794, 0.821 and 0.680, respectively. Moreover, the b-value for male, female, indeterminate individuals and pooled data was 1.288, 1.439, 1.686 and 1.407 respectively, which revealed that individuals of deep-water *H. scabra* exhibit negative allometric growth. The mean condition factor (K) value when all data were pooled together was 4.213±0.106 indicating that individuals were in good condition and came from a healthy environment. This study fills a key information gap that is relevant to the management of the *H. scabra* fishery in the country.

Keywords: *Holothuria scabra*, Size distribution, Length-weight relationship, Condition factor, Allometric growth, Zanzibar

Introduction
Sea cucumbers constitute an important part of marine fisheries in Tanzania (Semesi *et al.,* 1998) and have provided a source of income to individual collectors as well as revenue at a national level through export (Eriksson *et al.,* 2010). However, as in other producing countries across the region, the resource has already dwindled in Tanzania as evidenced by catch reduction, dominance of small size individuals (Jiddawi, 1997; Mgaya and Mmbaga, 2007; Mmbaga, 2013) and a decrease in the number of exporters (Marshall *et al.,* 2001).

Despite the crucial role played by sea cucumbers both economically and ecologically, the status of wild stocks of commercially important species is unknown and has not yet been quantified in Tanzania (Mmbaga and Mgaya, 2004), even though the resource could be at high risk. Unlike in mainland Tanzania where a total moratorium on sea cucumber fishing has been implemented for more than a decade (Eriksson *et al.*, 2010) (though its enforcement is still questionable), the situation is much worse in Zanzibar, where the fishery is still operating despite a directive aimed at prohibiting it.

As shallow water (near shore) sea cucumbers have already been depleted in Zanzibar, sea cucumber collectors are now moving further off-shore (Eriksson *et al.*, 2010); a common practice along the whole west coast of Unguja Island. This represents a significant threat to the sea cucumber population, ecosystem (Uthicke, 1999) as well as the safety of fishers (Eriksson *et al.*, 2010).

http://dx.doi.org/10.4314/wiojms.v19i1.9

Holothuria scabra, commonly known as sandfish, is one of the more commercially important tropical species and contributes a significant portion of the total sea cucumber catch in Tanzania (Mmbaga and Mgaya, 2004). It is a deposit-feeding species found in low-energy environments behind fringing reefs up to 20 metres deep or within protected bays and shores of the tropics (Hamel *et al.,* 2001). The deep-water populations (>10 m depth) (Ram *et al.,* 2016) are the last potential group of breeders that the ecosystem relies on to repopulate the dwindling shallow water population of *H. scabra*. However, they are at high risk of being overfished due to the existing fishing pressure which is influenced by high prices obtained for the species by collectors. With existing fishing pressure on the deep-water *H. scabra* population, it is most likely the species will disappear in the near future, unless appropriate and effective management measures are taken.

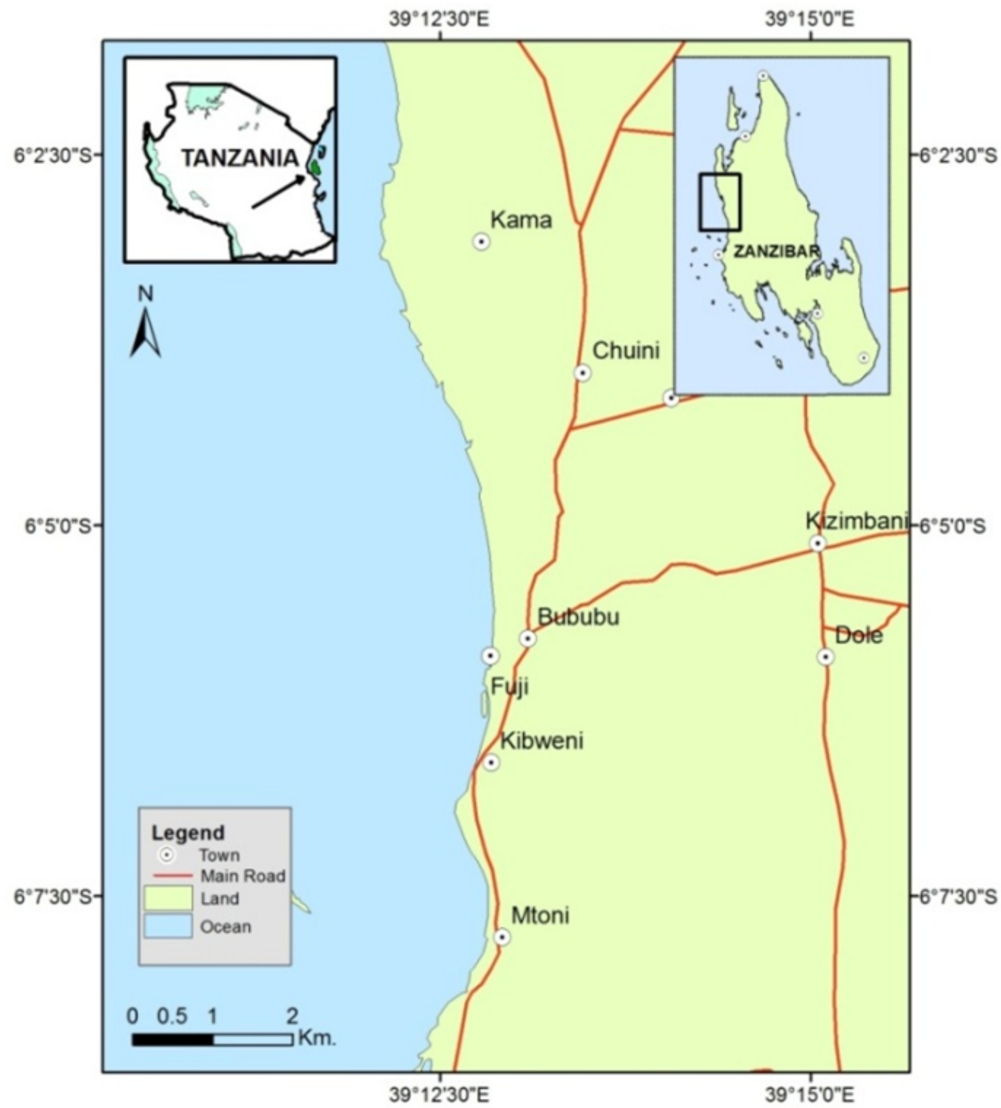

Figure 1. The study site (Fuji-Kama fishing ground) in Unguja Island, Zanzibar, Tanzania.

Knowledge on the size composition of harvested individuals and their length-weight relationships is crucial in fisheries management (King, 2007; Ahmed *et al.,* 2018) as they provide information about the impact of harvesting on the population and distribution of different-sized individuals both temporally and spatially (Montgomery, 1995; Natan *et al.,* 2015). The length-weight relationship is the standard method used in fisheries biology to estimate average weight of an animal at a given length group or class (Froese, 2006; Gerritsen and McGrath, 2007). Moreover, this can also be used to determine condition factor which in turn determines the well-being or relative fatness of an organism and the health of its environment (Natan *et al.,* 2015; Aydin, 2016; Ram *et al.,* 2016). However, this information is missing for the *H. scabra* population in Zanzibar and Tanzania as a whole, especially for those found in deeper waters, which presents a key information gap that is relevant to their management. The present study aimed to determine the size distribution, length-weight relationship and condition factor (K) of deeper water *H. scabra* along the coast of Zanzibar, Tanzania.

Methodology

Study site and sample collection

This study was conducted at the Fuji-Kama fishing ground located on the west coast of Unguja Island, Zanzibar between 6°2′30″S to 6°7′30″E, 4 km off the coastline (Fig. 1). The water depth of the fishing ground is between 15-20 m and the sea floor is characterized by muddy-sandy sediment with no seagrasses. The sea cucumber population in the fishing ground is dominated by *H. scabra*. Sea cucumber samples were collected directly from the fisherman who fish within the studied fishing ground. Prior to the study, the fishermen were requested to collect all *H. scabra* encountered, regardless of size.

Measurements

Upon the arrival of fishers at the landing site, sea cucumbers were transferred from drums to trays filled with sea water to allow them to relax for five minutes. When they were fully relaxed, total length was measured from the mouth to the anus using a ruler to the nearest 0.5 cm. The total body weight of each individual was measured, followed by dissection and removal of all internal organs (guts, respiratory trees and reproductive system), after which the body wall weight was measured to the nearest 0.1 g. Gonad samples were taken from each individual and stored in a plastic container for microscopic examination and determination of their sex (presence of eggs or sperm). Unsexed individuals which had no sperm and eggs in their gonad were recorded as indeterminate.

Length-weight relationship

Length-weight relationship was estimated using the power function (Pauly, 1984)

$$W = a L^b$$

Where W = Weight in g, L = Length in cm, a = Intercept, b = Slope

The value of b from the power function equation was tested and used to determine growth patterns of the sea cucumber (i.e. isometric growth (b=3) or allometric growth (b≠3)) by using the Students t-test (after Pauly, 1984). The coefficient of determination (R^2), that is, the degree of relation between the length and weight, was computed by linear regression analysis.

Condition factor (K)

Fulton's condition factor (K) was analysed according to Pauly (1984)

$$K = 100W/L^3$$

Where K = Condition factor, W = weight in g, L = Length in cm

Statistical analysis

All data were tested for normality and homogeneity of variances using Shapiro-Wilk and Levene's test, respectively. Chi-square was used to test whether the sex ratio significantly deviated from 1:1. The mean differences in body weight, total length and condition factor (K) between male, female and indeterminate *H. scabra* were tested using a one-way ANOVA.

Results and discussion

Sex ratio

A total of 179 individuals of *H. scabra* were collected between August and September, 2019. The number of samples collected per sampling day is presented in Table 1. There were significantly more male than female *H. scabra* in this population during the study period, with 104 (58.1%) males, 70 (39.1%) females and 5 (2.8%) sexually undifferentiated (indeterminate) individuals. The chi-square test results show that the sex ratio significantly deviated from 1:1 (x^2 = 6.644, df=1, p=0.01).

A male-biased sex ratio for *H. scabra* has been also reported by Conand (1993), Mercier *et al.* (2000), Al-Rashdi *et al.* (2007) and Muthiga *et al.* (2009) from New Caledonia, Solomon Islands, Sultanate of Oman, and Kenya, respectively. However, their sex ratio values were not significantly different from 1:1. Muthiga *et al.* (2009), from data collected in three different years, reported a shift in sex ratio from precisely 1:1 in the first year towards significantly more males than females in the last year of their study. The same result was also reported by Natan *et al.* (2015) from Indonesia which is comparable to the findings of the present study.

Table 1. Study period and the number of samples collected on each sampling date, and their sex distribution.

Date	Number of Sample	Male	Female	Indeterminate
24/08/2019	23	13	10	-
27/08/2019	10	4	6	-
29/08/2019	29	13	16	-
01/09/2019	17	9	8	-
05/09/2019	40	30	9	1
09/09/2019	34	18	12	4
15/09/2019	26	17	9	-
Total	179	104	70	5

Hasan (2005) has pointed out that a population with more male than female individuals may be an indication of increase in fishing pressure, which is also possible in the current study. As shallow water sea cucumber populations are already depleted locally, fishermen are now shifting their efforts toward deep-water populations. Other authors have interpreted this phenomenon in different ways, for example: this might be due to high mortality of larvae, juveniles and adults of female individuals (Hoareau and Conand, 2001); or limited dispersal ability of female larvae as reported for other holothurians species (Uthicke and Benzie, 1999).

Size distribution

The overall size of all collected individuals expressed as body weight (BW), body wall weight (BWW) and total length (TL) ranged from 410 to 1957.8 g (1077.63±20.75 g (SE)), 220 to 960.6 g (579.42±9.44 g (SE)), and 20 to 42 cm (29.83±0.29 cm (SE)), respectively. There was no significant difference in average size between male and female individuals (Table. 2). However, female individuals were slightly longer and heavier than males. Indeterminate individuals had significantly lower body weight, body wall weight and total length ($p<0.05$) compared to sexed individuals (Table 2). The size distributions (total length, body weight and body wall weight) of collected individuals are shown in Fig. 2A, 2B and 2C respectively. More than 85% (153) of all collected individuals from this population had a length between 25 and 35 cm, 9.5% (17) were below 25 cm, 5% were above 35 cm, with no individuals smaller than 20 cm (Fig. 2).

Size at first sexual maturity for *H. scabra* in Tanzania has been found to be 16.8 cm (Kithakeni and Ndaro, 2004) from samples collected in Dar es Salaam, mainland Tanzania. Therefore, it can be concluded that all individuals collected in the present study had already reached maturity as they were all greater than 20 cm. Even if it is assumed that the size at first maturity is 25 cm, which is the highest ever recorded for *H. scabra* (India and Northern Australia) (Lee *et al.*, 2018), the majority (>90%) of all individuals collected in the present study would have already attained maturity. The presence of indeterminate individuals in this population does not signify that these individuals had not reached maturity, but rather that their gonads were in a resting stage during their collection. Individuals

Table 2. Mean size comparison between male, female and indeterminate individuals. Values on the same row with different superscripts indicate significant differences.

	Mean Values (±SE)		
	Male	Female	Indeterminate
Total Length (cm)	29.548 ± 0.381^{a}	30.586 ± 0.451^{a}	25.00 ± 1.342^{b}
Total Body Weight (g)	1068.438 ± 27.580^{a}	1118.691 ± 30.705^{a}	694.08 ± 87.336^{b}
Body Wall Weight (g)	575.965 ± 12.691^{a}	599.965 ± 13.176^{a}	363.92 ± 27.598^{b}

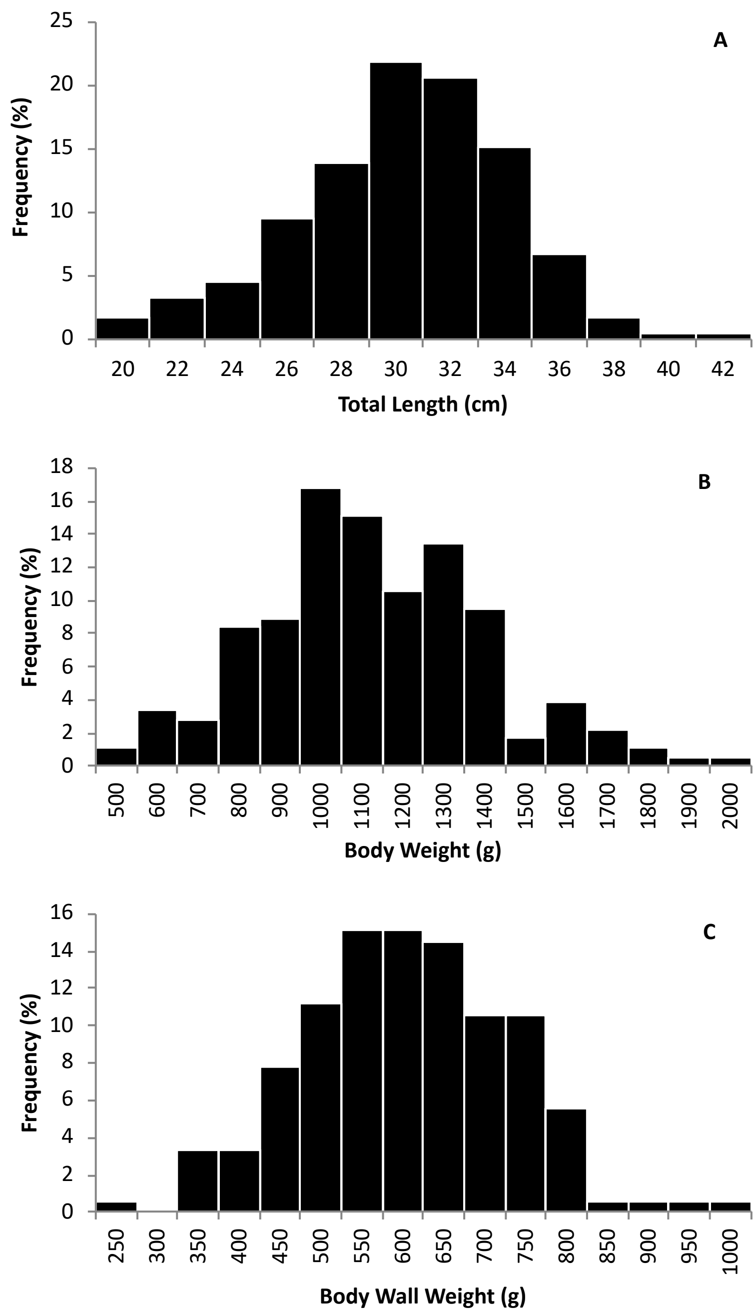

Figure 2. Size distribution of collected *Holothuria* scabra from the deep-water population. (A): Length, (B): Body weight and (C): Body wall weight.

with gonads at different maturation stages have been reported to occur throughout the year in Tanzania (Kithakeni and Ndaro, 2002).

The present findings add to the number of studies that support the fact that large sized individuals are found in deeper waters, probably migrating from the intertidal zone as they grow bigger (Mercier *et al.*, 2000). For instance, in the Solomon Islands, individuals >25 cm were mainly located in the deep water zone and small size individuals (4-15 cm) were found in shallow (intertidal) waters (Mercier *et al.*, 2000). However, James (1994) reported individuals of 30-35 cm in 5-10 m depth in India which is contrary to other studies. Murphy *et al.* (2011) suggests that it may be difficult to find small size sea cucumbers as they burrow during the day and become active at night.

The size frequency distribution of sea cucumber populations can either be unimodal, bimodal or plurimodal (Hamel *et al.*, 2001) depending on the population. In this study, the size (length) frequency distribution was unimodal with 12.3% of all individuals having a length of 32 cm (Fig. 2A). Conand (1994) and Natan *et al.* (2015) reported a plurimodal length frequency distribution with poorly defined modes in New Caledonia and Indonesia respectively. However, Basker (1994), Uthicke and Benzie (1999), and Al-Rashdi *et al.* (2007) recorded a unimodal length frequency distribution from India, Australia and the Sultanate of Oman, which is comparable to the present study. However, their modal value was smaller (23 and 26.9 cm) than the value recorded in the present study.

Based on published records, the maximum length and body weight of *H. scabra* ever recorded was 70 cm in China and 2 kg in India, respectively (Hamel *et al.*, 2001). The maximum length and body weight recorded in the present study is smaller than this, but average body weight was higher than other reported values, for example: 300 g (Papua New Guinea, Sultanate of Oman, India), 335 g (Australia), 500 g (Egypt) and 580 g (New Caledonia) (Purcell *et al.*, 2012).

Moreover, the average length recorded in the present study is quite high, exceeded only by 37 cm mean length in Egypt (Purcell *et al.*, 2012). The values from other countries such as Australia, New Caledonia, Papua New Guinea and India ranged from 19 to 25 cm (Purcell *et al.*, 2012). The difference in size of *H. scabra* from different populations or countries could be attributed to differences in environmental factors (Uthicke and Benzie, 1999) such as food availability (Morgan, 2001; Pitt, 2001), fishing pressure (Uthicke and Benzie, 1999; Hasan, 2005) and the depth where the samples were collected (Kithakeni and Ndaro, 2002) in addition to the actual biological differences of individuals between populations. Furthermore, it could be due to inconsistency of measurement methods between studies since body length and weight of sea cucumber are highly variable (Hamel *et al.*, 2001).

Length-weight relationship

The calculated correlation coefficient (r) values for male, female, indeterminate and pooled data ranged from 0.680 to 0.821 while the respective tabulated

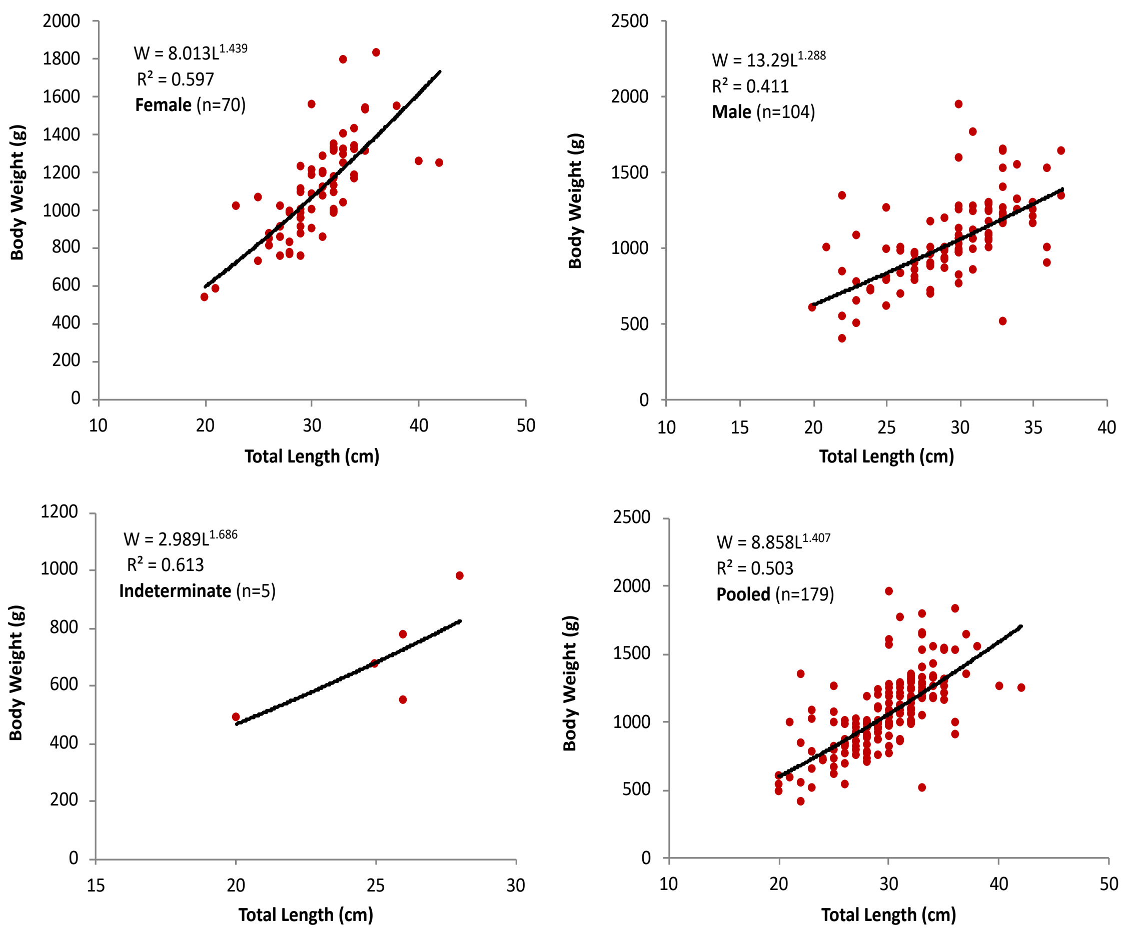

Figure 3. Length-weight relationship of *Holothuria scabra* collected from deep water.

Table 3. Length-weight relationship of *Holothuria scabra* collected from deep water.

Sex	n	W=a L^b	Log W = Log a + b x Log L	r calc	r table (p=0.01)	t calc	t table (p=0.01)	K
Female	70	$W=8.013L^{1.439}$	Log W=0.903+1.44LogL	0.794*	0.295	10.890*	2.66	4.018
Male	104	$W = 13.29L^{1.288}$	Log W=1.123+1.28LogL	0.681*	0.295	11.218*	2.62	4.331
Indeterminate	5	$W=2.989L^{1.686}$	Log W=0.475+1.69LogL	0.821*	0.805	1.700*	1.638	4.491
Pooled	179	$W=8.858L^{1.407}$	Log W=0.947+1.41LogL	0.680*	0.114	15.155*	2.626	4.213

* Denoted significant difference

r values ranged from 0.114 to 0.805 (Table 3). The calculated r was found to be larger than critical r which indicates highly significant correlation between length and weight for male, female, indeterminate and pooled data. Moreover, the coefficient of determination (R^2) value which shows the percentage contribution of the independent variable to the dependent variable ranged from 0.411 to 0.613 (Fig. 3). The R^2 value in this study is smaller than that recorded by Lee *et al.*, (2018) (R^2=0.90), Al-Rashdi *et al.* (2007) (R^2=0.80) and Natan *et al*. (2015) (R^2=0.43-0.68) from Fiji, Sultanate of Oman and Indonesia, respectively.

The length-weight relationship results (Table 3 and Fig. 3) also show that the b values for male, female, indeterminate and pooled data ranged from 1.288 to 1.686. The b value was significantly less than 3, so it can be concluded that the growth pattern of deep-water *H. scabra* is negatively allometric. Such growth patterns have also been reported elsewhere, for example in Indonesia (b=1.264 to 2.127; Natan *et al*., 2015), Sultanate of Oman (b=2.18; Al-Rashdi *et al.,* 2007), Vietnam (b=2.84; Pitt and Duy, 2004), and New Caledonia (b=2.28; Conand, 1990; b=1.26; Purcell *et al.,* 2009). This indicates that at a given length, the individuals collected from deep water in Zanzibar are leaner than in these other locations, except for those collected in the Purcell *et al.* (2009) study. The value of b in length-weight relationships is always changing depending on the animal's habitat, physiological condition, maturity stage and food availability (Froese, 1998; Natan *et al.,* 2015). Moreover, the differences could be attributed to the actual differences existing between individuals in relation to the environmental conditions around them, or the inconsistency in procedures used to estimate length and weight between studies (Al-Rashdi *et al.,* 2007).

Condition factor (K)

The mean K value for *H. scabra* from this population was 4.213±0.106 when all data were pooled together. One-way ANOVA results show no significant differences in K values between male, female and indeterminate individuals (F=0.607, df=177, p=0.799). However, male individuals have a slightly higher mean K value than female individuals. The overall mean K value reported in this study is high which indicates that *H. scabra* from this population are in good physical condition and come from a healthy environment (Pauly, 1984).

Conclusions

It can be concluded that the deep-water population of *H. scabra* on the west coast of Unguja Island, Zanzibar mainly consists of large sized mature individuals. The sex ratio in this population is significantly different from 1:1 in favour of males, indicating high fishing pressure. Like other sea cucumber species, *H. scabra* from this study shows negative allometric growth, i.e. length increment is faster than weight increment. The condition factor (K) recorded reveals that the individuals were in good condition and that they came from a healthy environment. This study provides baseline information on the overall condition of the deep-water population of *H. scabra* in the coastal waters of Zanzibar, hence contributing towards better management of the species. Since this group of individuals consist mainly of potential breeders which are expected to repopulate dwindling shallow water populations, management measures such as temporal (seasonal) closure or total prohibition should be enforced to minimize fishing pressure on deep water populations. However, more studies are needed on the reproductive biology, spawning pattern and stock status of the species across the Zanzibar Islands and Tanzania as a whole.

Acknowledgements

Many thanks go to the Swedish International Development Agency (Sida)-Bilateral Marine Science Program (BMSP) for financially supporting this study.

We also thank A. Ali and K. Mudathir for their assistance in field work and data collection. We also wish to express our thanks to the Food and Agricultural Organization of the United Nations (FAO) through the Zanzibar Marine Multispecies Hatchery Project for their technical support and for permission to use their equipment and laboratory during the course of this study.

References

Ahmed Q, Poot-Salazar A, Qadeer Mohammad Ali QM, Bat L (2018) Seasonal variation in the length-weight relationships and condition factor of four commercially important sea cucumbers species from Karachi Coast-Northern Arabian Sea. Natural and Engineering Sciences 3(3): 265-281

Al-Rashdi KM, Claereboudt MR, Al-Busaidi SS (2007) Density and size distribution of the sea cucumber, *Holothuria scabra* (Jaeger, 1935), at six exploited sites in Mahout Bay, Sultanate of Oman. Agricultural and Marine Sciences 12: 43-51

Aydin M (2016) Sea cucumber (Holothuroidea) species of Turkey. Turkish Journal of Maritime and Marine Sciences 2 (1): 49-58

Basker BK (1994) Some observation on the biology of the holothurians, *Holothuria (Metriatyla) scabra*. In:Regarajan K, Bedu JD (eds) Proceedings of the national workshop on Beche-de-mer. Bulletin of the Central Marine Fisheries Research Institute 46. India Council of Agricultural Research, Cochin, India. pp 39-43

Conand C (1990) The fishery resources of Pacific island countries. Part 2: Holothurians. FAO Fisheries Technical Paper. FAO, Geneva. 143 pp

Conand C (1993) Reproductive biology of the holothurians from the major communities of the New Caledonian lagoon. Marine Biology 116: 439-450

Conand C (1994) The fishery resources of Pacific Island countries. Part 2: Holothurians. FAO Fisheries Technical Papers. FAO, Rome. 143 pp

Eriksson BH, Torre-Castro M, Eklof J, Jiddawi NS (2010) Resource degradation of the sea cucumber fishery in Zanzibar, Tanzania: a need for management reform. Aquatic Living Resources 23: 387-398

Froese R (1998) Length-weight relationship for 18 less-studied fish species. Journal of Applied Ichthyology 14:117-118

Froese R (2006) Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. Journal of Applied Ichthyology 22: 241-253

Gerritsen HD, McGrath D (2007) Significant differences in the length–weight relationships of neighbouring stocks can result in biased biomass estimates: Examples of haddock (*Melanogrammus aeglefinus*, L.) and whiting (*Merlangius merlangus*, L.). Fisheries Research 85: 106-111

Hamel JF, Conand C, Pawson DL, Mercier A (2001) Biology of the sea cucumber *Holothuria scabra* (holothuroidea: echinodermata) and its exploitation as Beche-de-mer. Advances in Marine Biology 41:129-223

Hasan MH (2005) Destruction of a *Holothuria scabra* population by over-fishing at Abu Rhamada Island in the Red Sea. Marine Environmental Research 60: 499-511

Hoareau T, Conand C (2001) Sexual reproduction of *Stichopus chloronotus*, a fissiparous sea cucumber, on Reunion Island, Indian Ocean. SPC Beche-de-mer Information Bulletin 15: 4-12

James DB (1994) Ecology of commercially important holothurians of India. In: Rengarajan K, James BD (eds) Proceedings of the National Workshop on Beche-de-mer, pp 37-38. Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Cochin, India. 83 pp

Jiddawi N (1997) Reef dependent fisheries in Zanzibar. In: Johnston RW, Francis J, Muhando C (eds) Proceedings of the national conference on coral reefs. Coral reefs: values, threats and solutions. Zanzibar-Tanzania, December 1997. SIDA/SAREC, UNEP and University of Dar Es Salaam. pp 12-24

King M (2007) Fisheries biology, assessment and management. Second Edition. Wiley-Blackwell Publishing, Oxford. 382 pp

Kithakeni T, Ndaro SGM (2002) Some aspects of sea cucumber *Holothuria scabra* (Jaeger, 1935) along the coast of Dar es Salaam. Western Indian Ocean Journal of Marine Science 1 (2):163-168

Lee S, Amanda F, Sangeeta M, Christian W, Sebastian F (2018) Length-weight relationship, movement rates, and in situ spawning observations of *Holothuria scabra* (sandfish) in Fiji. SPC Beche-de-mer Information Bulletin 38: 11-14

Marshall N, Milledge SAH, Afonso PS (2001) Stormy seas for marine invertebrates; trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique. TRAFFIC East/Southern Africa. Harare. 70 pp

Mercier A, Battaglene SC, Hamel JF (2000) Periodic movement, recruitment and size-related distribution of the sea cucumber *Holothuria scabra* in Solomon Islands. Hydrobiologia 440: 81-100

Mgaya YD, Mmbaga TK (2007) Sea cucumbers in Tanzania. In: Conand C, Muthiga NA (eds) Commercial sea cucumbers: a review for the Western Indian Ocean, WIOMSA Book Series No. 5 iii. Kul Graphics, Nairobi, Kenya. pp 53-59

Mmbaga T, Mgaya Y (2004) Studies on sea cucumber in Tanzania and the gaps towards resource inventory and management In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper, No. 463. pp 193-203

Mmbaga TK (2013) The effect of fishing on the ecology of sea cucumber (Holothuroidea: Echinodermata) *Holothuria scabra* and *Holothuria nobilis* in Tanzanian sea water. International Journal of Development and Sustainability 2: 1099–1126

Montgomery SS (1995) Patterns in landings and size composition of *Jasus verreauxi* (H Milne Edwards, 1851) (Decapoda, Palinuridae) in waters off New South Wales, Australia. Crustaceana 68 (2): 257-266

Morgan AD (2001) The effect of food availability on early growth, development and survival of the sea cucumber, *Holothuria scabra* (Echinodermata: Holothuroidea). Marine Biology 14: 6-12

Murphy NE, Skewes TD, Filewood F, David C, Seden P, Jones A (2011) The recovery of the *Holothuria scabra* (sandfish) population on Warrior Reef, Torres Strait. CSIRO Wealth from Oceans Flagship. Final Report, CMAR, Cleveland. 44 pp

Muthiga NA, Kawaka JA, Ndurangu S (2009) The timing and reproductive output of the commercial sea cucumber *Holothuria scabra* on the Kenyan coast. Estuarine, Coastal and Self Sciences 84: 353-360

Natan Y, Uneputty PrA, Lewerissa YA, Pattikawa JA (2015) Species and size composition of sea cucumber in coastal waters of UN Bay, Southeast Maluku, Indonesia. International Journal of Fisheries and Aquatic Studies 3 (1): 251-256

Pauly D (1984) Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM, Manila. 325pp

Pitt R (2001) Review of sand fish breeding and rearing methods. SPC Beche-de-mer Information Bulletin No. 14: 14–21

Pitt R, Duy NDQ (2004) Breeding and rearing of the sea cucumber *Holothuria scabra* in Vietnam. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper, No. 463. 333–346

Purcell SW, Gossuin H, Agudo NS (2009) Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. World Fish Centre Studies and Review. The World Fish Centre, Penang, Malaysia. 136 pp

Purcell SW, Samyn Y, Conand C (2012) Commercially important sea cucumbers of the world. Food and Agricultural Organization species catalogue for fishery purposes. No. 6: 223 pp

Ram R, Chand RV, Southgate PC (2016) An overview of sea cucumber fishery management in the Fiji Islands. Journal of Fisheries and Aquatic Sciences 11: 191-205

Semesi AK, Mgaya YD, Muruke MHS, Francis J, Mtolera M, Msumi G (1998) Coastal resources utilization and conservation issues in Bagamoyo. Ambio 27 (8): 635-644

Uthicke S (1999) Sediment bioturbation and impact of feeding activity of *Holothuria (Halodeima) atra* and *Stichopus chlorontus*, two sediment feeding holothurians, at Lizard Island, Great Barrier Reef. Bulletin of Marine Science 64: 129-141

Uthicke S, Benzie JAH (1999) Population genetics of the fissiparous holothurian *Stichopus chloronotus* (Aspidochirotida) on the Great Barrier Reef, Australia. Coral Reef 18: 123-132