



- RESEARCH ARTICLE -

Seasonal Variation in the Length-Weight Relationships and Condition Factor of Four Commercially Important Sea Cucumbers Species from Karachi Coast- Northern Arabian Sea

Quratulan Ahmed^{1*}, Alicia Poot-Salazar², Qadeer Mohammad Ali¹, Levent Bat³

¹The Marine Reference Collection and Resource Centre, University of Karachi, Karachi, Pakistan.

²Centro Regional de Investigaciones Pesqueras de Yucalpeten, Instituto Nacional de Pesca y Acuacultura, Blvd. del Pescador S/N, Puerto de Abrigo, 97320 Progreso, Yucatan, Mexico.

³University of Sinop, Fisheries Faculty, Department of Hydrobiology, TR57000 Sinop, Turkey.

Abstract

Length-weight relationships and condition assessment are a common practice in fisheries analyses; however, such information is unknown for most sea cucumber species. The present study investigated length-weight relationships and relative condition indices of four commercially important sea cucumbers: *Holothuria arenicola*, *Holothuria atra*, *Holothuria pardalis* and *Holothuria verrucosa*. Additionally, the seasonal variations obtained between three climatic seasons (pre-monsoon, monsoon and post-monsoon) were analyzed. The results showed that the four species grow allometrically, with negative allometric b values ranging from 0.84 to 1.74. There were significant differences of length-weight relationships between climatic seasons for *H. arenicola* and *H. atra*. The lower b values were observed during post-monsoon and the higher b values during monsoon in three of the four species. During the post-monsoon, the condition of the bigger individuals of *H. arenicola* and *H. atra* was lower than that of the small individuals. The differences in length-weight relationships of *H. pardalis* and *H. verrucosa* were not significant between climatic events. The higher temperatures occurred during monsoon and the lower during post-monsoon, but these data only showed a significant correlation with the relative condition factor of *H. arenicola*. Best condition of the individuals of *H. arenicola* occurred at temperatures between 22 to 31°C. Studies about environmental variables and characteristics of the substratum type are necessary in order to complement the understanding of the length-weight relationships and condition of these species.

* Corresponding Author: Quratulan Ahmed, e-mail, quratulanahmed_ku@yahoo.com

Keywords:

Holothuria arenicola, *Holothuria atra*, *Holothuria pardalis*, *Holothuria verrucosa*, Northern Arabian Sea.

Article history:

Received 06 June 2018, Accepted 08 June 2018, Available online 10 October 2018

Introduction

Length-weight relationships are commonly used in fisheries biology to convert length measures into weight and to determine the growth characteristics related to those variables. Data analysis on length-weight relationships and condition indices is one of the standard methods more employed in fishery biology and widely discussed in many papers of fish (Le Cren, 1951; Froese, 2006).

Sea cucumbers fisheries are an important source of income for many otherwise resource-limited communities (Clarke, 2004), principally in Asia. Although worldwide about 66 species of sea cucumbers are harvested (Purcell, 2010), important biological parameters are unknown for most species. One of these parameters is the allometric coefficient, which is obtained from length-weight relationships and can be used to convert length distributions into weights for biomass estimates (Gerritsen & McGrath, 2007). Biomass estimates are utile to assess the status of sea cucumbers stocks (Purcell, 2010).

In the scientific literature, there are some works about allometric coefficients and condition indices of sea cucumbers (Sang, 1963; Conand, 1989; Purcell and Tekanene, 2006; Herrero-Pérezrul and Reyes-Bonilla, 2008; Purcell et al., 2009; Kazanidis et al., 2010; Hannah et al., 2012; Purcell and Agudo, 2013; Poot-Salazar et al., 2014; Prescott et al., 2015; Natan et al., 2015; Aydin, 2016; Ram et al., 2016), but in the most species, this information is unknown.

Total 19 sea cucumber species have been recorded from coastal waters of Pakistan, seven of which are important commercially (Purcell, 2010; Purcell et al., 2013; Purcell et al., 2014). Neither traditional fishery of these echinoderms is exist in Pakistan nor studies on them. Only a few studies are exists (Ahmed & Ali, 2014; Siddique et al., 2014; Haider et al., 2015; Ahmed & Ali 2016; Ahmed et al., 2018). Ahmed et al. (2017) have worked on the heavy metals concentration in *Holothurians* from the northern Arabian Sea coasts of Pakistan. Thus the biological information on the commercially important species is necessary for management of worldwide sea cucumbers current fisheries.

The goal of our study was to investigate the seasonal variability (pre-monsoon, monsoon, and post-monsoon) of length-weight relationship and the relative condition factor of four commercially important sea cucumbers species: *Holothuria arenicola* Semper, 1868, *Holothuria atra* Jaeger, 1833, *Holothuria pardalis* Selenka, 1867 and *Holothuria verrucosa* Selenka, 1867 in the coastal waters of Karachi, Pakistan.

Material and methods

Field procedures

Two rocky shores Buleji coast (24°50'20.41" N, 66°49'24.15" E) and Sunehri (24°52'33.49" N, 66°40'40.20" E) were selected (Figure 1). Specimens were collected by hand-picking through forceps at low tide from intertidal zone. Collected specimens were kept alive in water filled containers. Specimens were transported to the laboratory and shifted in well aerated aquaria.

For taxonomic studies and identification, morphological features were examined and microscopic studies were conducted. Ossicles were taken from three positions (dorsal and ventral body walls, and tentacles), wet mounts were prepared by placing a small piece of skin tissue on slide and adding few drops of 3.5% bleach, the slides were then rinsed with drops of distilled water. The slides were examined under a microscope at 10x10 magnifications (Nikon LABOPHOT-2). Microphotography was also performed through digital camera (Fujifilm 16 MP).

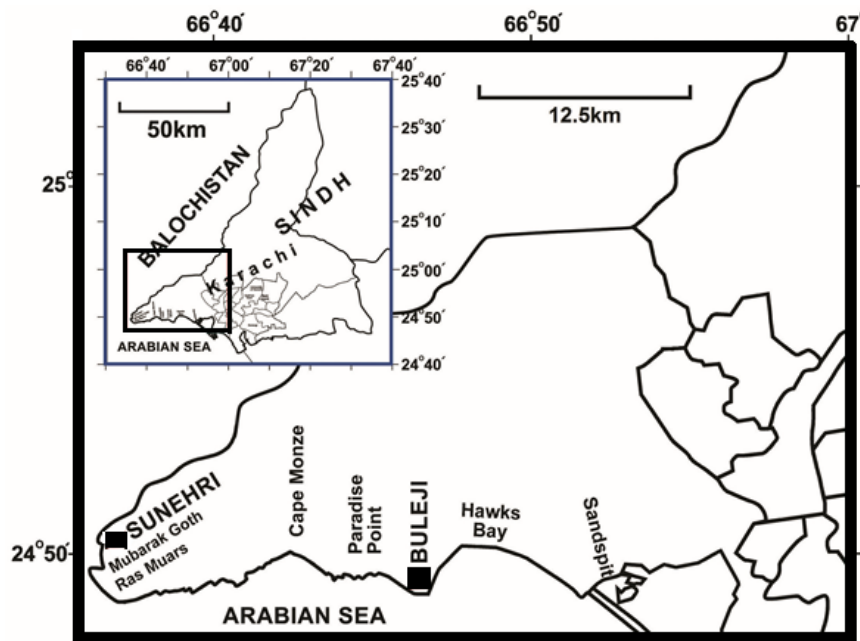


Figure 1. Study area Map. The red squares indicate the localities where the sea cucumbers *H. arenicola*, *H. atra*, *H. pardalis* and *H. verrucosa* were collected.

Length (cm) and weight (g) data were collected for each sea cucumber after allowing the sea cucumber to relax in water for 5 min. Total length from mouth to anus was measured to the flexible ruler. Wet weight was measured to the nearest 0.01 g immediately after removing the animal from the water to avoid evisceration.

Data analysis

We compared size frequency distributions between Holothurians from Sunehri and Buleji using the Kolmogorov-Smirnov non-parametric test (Sokal and Rohlf, 1997), discriminated by species.

Length-weight relationships were computed for specimens using general regression method (Ricker, 1973). Growth curves for population were also calculated by the same method used by Ricker (1975). In order to describe relative changes in sea cucumbers morphology we used the allometric equation $y = ax^b$, where a and b are parameters, x is the body length (L) and y the wet weight (W). Parameters were calculated by species with non-linear regression analysis, which is a good tool in allometric studies (Ebert and Russel, 1994). The loss function was evaluated with Marquardt's compromise algorithm (Marquardt, 1963), which minimizes the sum of squares (SSQ) of the difference between sample weights and pseudo-weights (Gayanilo and Pauly, 1997). Convergence was reached at 50 iterations in each regression. Student's t -test was conducted to test the hypothesis of isometry ($b = 3$). Allometric growth occurred when either $b > 3$ (negative) or $b < 3$ (positive).

We analyzed sea cucumbers condition by the relative condition factor K_{rel} (Le Cren, 1951) as follows:

$$K_{rel} = \frac{W}{W'}$$

Where W is the weight of an individual sea cucumber and W' is the predicted mean weight for the same sea cucumber as calculated from a composite of length-weight regression throughout the range of the species:

$$W' = aL^b$$

Seasonal variations in the length-weight relationships were evaluated through one-way analysis of covariance (ANCOVA), using season (pre-monsoon, monsoon and post-monsoon) as the main factor \log_{10} weight as the dependent variable and \log_{10} length as the co-variable. Separate analyses were done by specie. The assumptions of homogeneity of the slopes (parallelism test) and linear relationship between the dependent variable and the covariate were tested. When the parallelism assumption was not met, a separate slope model was used as an alternative. When significant differences were found, multiple comparisons were performed using Tukey tests (HSD) (Zar, 1984; Sokal and Rohlf, 1997). In order to detect seasonal variation (pre-monsoon, monsoon and post-monsoon) in the b and K_{rel} values, we focused on variation in condition with the help of a $\log K_{rel}$ vs $\log L$ plot (Froese, 2006). All statistical analyses were considered significant at $p < 0.05$ and highly significant at $p < 0.001$.

Results

A total of 302 sea cucumbers were identified, measured and weighted, 53 *H. arenicola*, 30 *H. atra*, 157 *H. pardalis* and 62 *H. verrucosa*. The total lengths ranged from 12.0 to 48.0 cm (mean 22.6 ± 6.9 cm) for *H. arenicola*, from 12.0 to 34.0 cm (mean 19.1 ± 5.6 cm) for *H. atra*, from 4.0 to 16.0 cm (mean 8.7 ± 3.1 cm) for *H. pardalis* and from 5.0 to 19.0 cm (mean 11.6 ± 3.2 cm) for *H. verrucosa*. Weights ranged from 16.0 to 136.0 g (mean 59.2 ± 29.6 g), 15.0 to 104.0 g (mean 38.6 ± 21.2 g), 5.0 to 27 g (mean 12.9 ± 4.3 g) and from 8.0 to 32.0 g (mean 16.1 ± 3.9 g), for *H. arenicola*, *H. atra*, *H. pardalis* and *H. verrucosa*, respectively. The size frequency distributions of the four species in Sunehriare were not different from those of Buleji (Kolmogorov-Smirnov test; Table 1).

Table 1. Comparisons between size-frequency distributions and median sizes for Sunahri and Buleji sea cucumbers from Karachi, Pakistan. *df* = degrees of freedom; Kolmogorov-Smirnov test: when $D_{max} > D_{m,n,\alpha}$ reject the null hypothesis (Ho: No difference between datasets).

	Locality	n	Mode (cm)	Size range (cm)	D_{max}	$D_{m,n,\alpha}$	Median size	<i>df</i>
<i>H. arenicola</i>	Sunehri	27	23.0	12.0-32.0	0.241	0.374	21.0	1
	Buleji	26	multiple	14.0-48.0			23.5	
<i>H. atra</i>	Sunehri	19	23.0	13.0-27.0	0.502	0.515	19.0	1
	Buleji	11	14.0	12.0-34.0			16.0	
<i>H. pardalis</i>	Sunehri	110	8.0	4.0-14.0	0.114	0.237	8.0	1
	Buleji	47	12.0	4.0-16.0			9.0	
<i>H. verrucosa</i>	Sunehri	28	12.0	8.0-19.0	0.181	0.347	12.0	1
	Buleji	34	12.0	5.0-17.0			12.0	

The Students *t*-tests showed that the four species grow allometrically ($b \neq 3, p < 0.05$), with negative allometric *b* values ranging from 0.84 to 1.74 (Table 2). No length-weight relationship showed *b* values near three (isometric value). In all cases, the relationship between length and weight was highly significant ($p < 0.001$; Figure 2).

Table 2. Length-weight relationship parameters for four species of sea cucumbers collected in Karachi, Pakistan. SE: standard error; CL: confidence limit; r^2 : determination coefficient; *r*: correlation coefficient; *a*: scaling constant; *b*: allometric growth coefficient; * $p < 0.001$.

Species	<i>a</i> ± SE	<i>b</i> ± SE	95% CL of <i>b</i>	r^2	<i>r</i>
<i>H. arenicola</i>	0.76 ± 0.19	1.37 ± 0.08	1.22-1.53	0.88*	0.94
<i>H. atra</i>	0.22 ± 0.05	1.74 ± 0.07	1.59-1.89	0.95*	0.97
<i>H. pardalis</i>	2.04 ± 0.10	0.86 ± 0.02	0.81-0.90	0.93*	0.97
<i>H. verrucosa</i>	2.05 ± 0.28	0.84 ± 0.05	0.73-0.95	0.83*	0.91

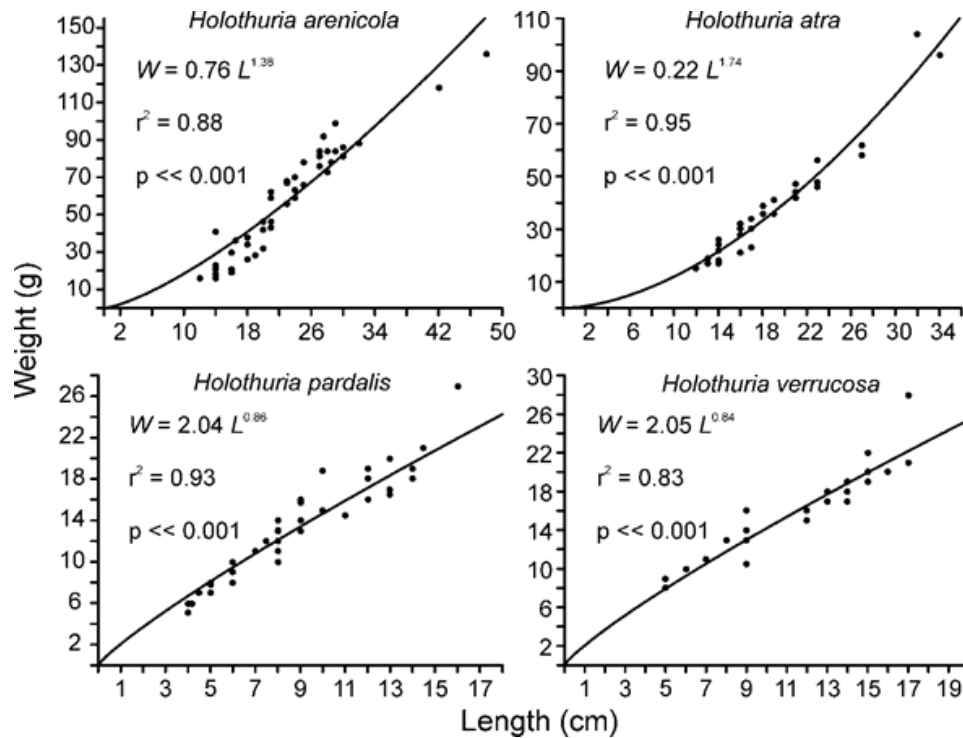


Figure 2. Length-weight relationships of four sea cucumbers species with commercial value collected in Karachi, Pakistan. W : weight; L : length; r^2 : determination coefficient.

For the four species, the lower b values occurred during post-monsoon and the higher b values during monsoon (Table 3). There were significant differences in the length-weight relationship of *H. arenicola* between pre-monsoon, monsoon and post-monsoon (Separate slopes model, $F_{2,47} = 12.18$, $p < 0.001$). Body weight was significantly higher during post-monsoon than during pre-monsoon and monsoon, when $\text{Log}_{10} L$ was used as a covariate (Tukey test, $p < 0.001$) (Figure 3a). According to the $\log K_{rel}$ vs $\log L$ plot, during post-monsoon, large individuals had a lower condition than small individuals; but during pre-monsoon and monsoon, they had a higher condition (Figure 3b).

Table 3. Length-weight relationships discriminated by climatic event for the four species of sea cucumbers collected in Karachi, Pakistan. SE: standard error; CL: confidence limit; r^2 : determination coefficient; a : scaling constant; b : allometric growth coefficient; * $p < 0.001$.

Species	Climatic event	$a \pm \text{SE}$	$b \pm \text{SE}$	95% CL of b	r^2
<i>H. arenicola</i>	Pre-monsoon	0.10 ± 0.04	1.97 ± 0.12	1.73 – 2.22	0.95*
	Monsoon	0.10 ± 0.09	2.09 ± 0.36	1.24 – 2.94	0.87*
	Post-monsoon	2.38 ± 0.66	1.06 ± 0.08	0.89 – 1.22	0.91*
<i>H. atra</i>	Pre-monsoon	0.15 ± 0.07	1.85 ± 0.15	1.50 – 2.19	0.93*
	Monsoon	0.09 ± 0.06	2.00 ± 0.21	1.45 – 2.56	0.94*

<i>H. pardalis</i>	Post-monsoon	0.48 ± 0.12	1.49 ± 0.08	1.32 – 1.67	0.97*
	Pre-monsoon	2.16 ± 0.11	0.83 ± 0.02	0.79 – 0.88	0.95*
	Monsoon	1.42 ± 0.32	1.05 ± 0.12	0.78 – 1.33	0.93*
<i>H. verrucosa</i>	Post-monsoon	1.86 ± 0.19	0.89 ± 0.04	0.80 – 0.98	0.91*
	Pre-monsoon	1.87 ± 0.37	0.87 ± 0.08	0.72 – 1.03	0.83*
	Monsoon	0.94 ± 0.38	1.15 ± 0.16	0.81 – 1.50	0.82*
	Post-monsoon	3.04 ± 0.53	0.67 ± 0.07	0.52 – 0.83	0.87*

The climatic event also had a significant effect on the length-weight relationship of *H. atra* (one-way ANCOVA, $F_{2,26} = 7.32, p < 0.05$; Figure 4a), and again body weight was significantly higher during post-monsoon than during pre-monsoon and monsoon, when $\text{Log}_{10}L$ was used as a covariate (Tukey test, $p < 0.001$). The $\log K_{rel}$ vs $\log L$ plot showed that large individuals had a higher condition than small individuals during the pre-monsoon but lower during monsoon and post-monsoon, however, these tendencies only were statistically significant during the post-monsoon (Figure 4b).

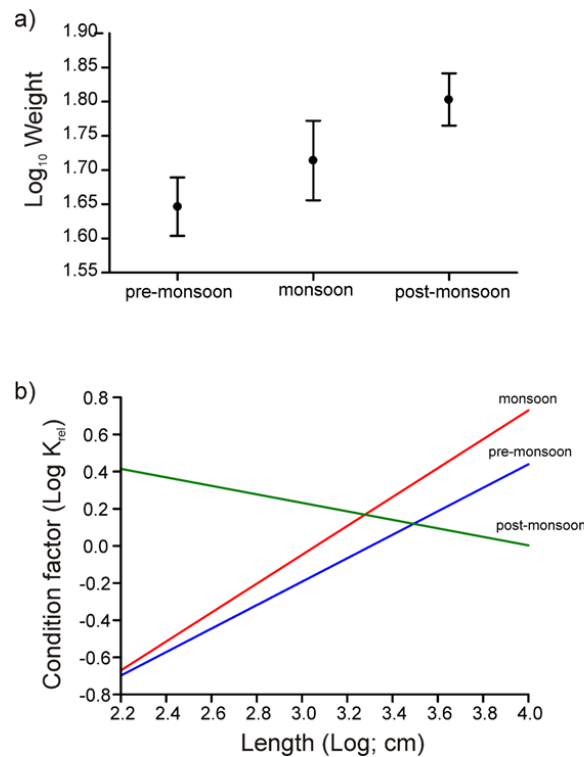


Figure 3. *Holothuria arenicola*. a) Log_{10} mean weight (vertical bars denote 0.95 confidence intervals) and b) Log-log plot of condition vs length calculated from the weight-length relationship of data taken during pre-monsoon ($r^2 = 0.51; p < 0.05$), monsoon ($r^2 = 0.58; p < 0.05$) and post-monsoon ($r^2 = 0.52; p < 0.05$) in Karachi, Pakistan.

Analysis of covariance found no significant difference in the length-weight relationships between climatic events for *H. pardalis* ($F_{2,153} = 3.00, p = 0.05$) and *H. verrucosa* ($F_{2,58} = 0.44, p =$

0.64). The $\log K_{rel}$ vs $\log L$ plot showed large specimens of *H. pardalis* had the higher condition than small specimens. In the case of *H. verrucosa*, small specimens had higher condition than large specimens (Figure 5).

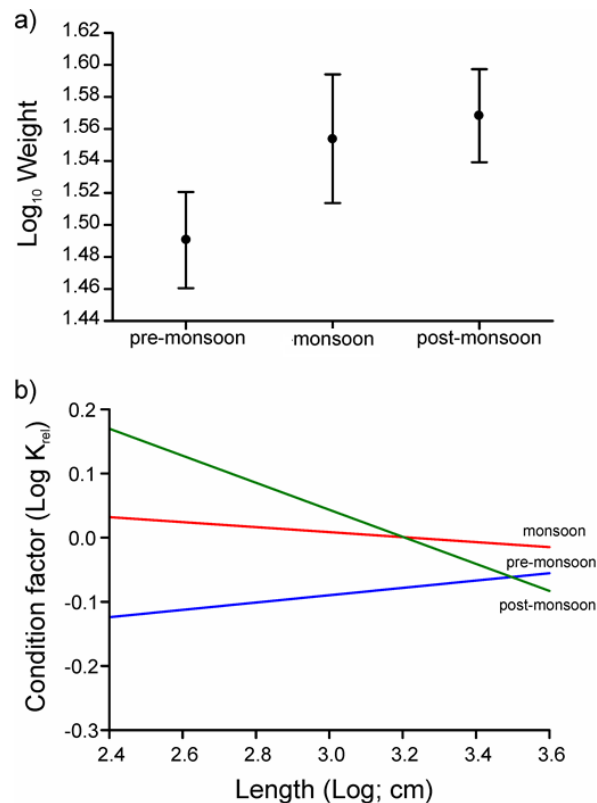


Figure 4. *Holothuria atra*. a) \log_{10} mean weight (vertical bars denote 0.95 confidence intervals) and b) Log-log plot of condition vs length calculated from the weight-length relationship of data taken during pre-monsoon ($r^2 = 0.01$; $p = 0.77$), monsoon ($r^2 = 0.01$; $p = 0.87$) and post-monsoon ($r^2 = 0.36$; $p < 0.05$) in Karachi, Pakistan.

The water temperature in the study area was higher during monsoon than during pre-monsoon and post-monsoon (Figure 6a). Only in *H. arenicola*, a significant negative correlation ($r = 0.34$, $p < 0.05$; Figure 6b) between temperature and K_{rel} was found.

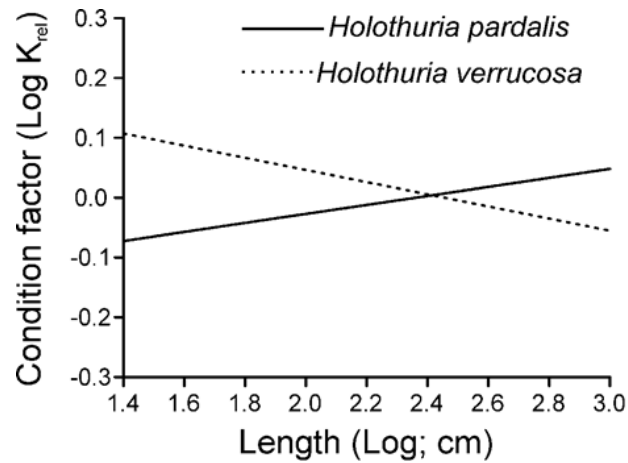


Figure 5. Log-log plot of condition vs length calculated from the weight-length relationships of data taken during collection period in Karachi, Pakistan.

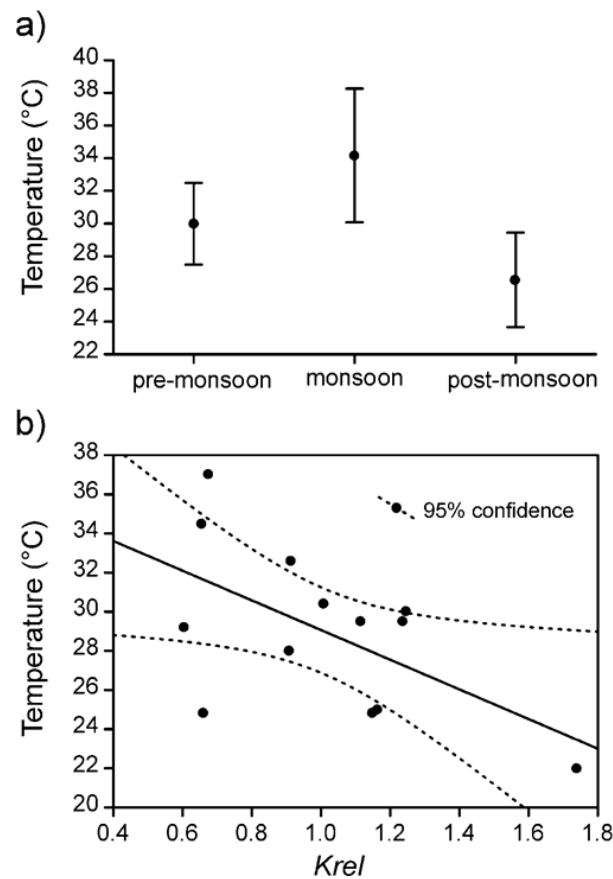


Figure 6. a) Mean temperature taken during pre-monsoon, monsoon and post-monsoon in Karachi, Pakistan; b) Log-log plot of condition vs length calculated from the weight-length relationships of data taken during collection period in Karachi, Pakistan.

Discussion

In our study, larger specimens of *H. arenicola* were registered than in the Mediterranean Sea on the Egyptian coast (length range: 5.0-21.0 cm; Abdel Razeq et al., 2010), even longer than in Karachi, Pakistan in 2011 and 2012 (length range: 2.7-41.6 cm; Siddique et al., 2014). The presence of smaller specimens of *H. arenicola* in Egyptian waters might be due to the over exploitation done by fishing (Abdel Razeq et al., 2007); occur the same with *Holothuria nobilis* (Selenka, 1867) on the Great Barrier Reef, where the average weight of specimens significantly reduces on fished reefs compared to reefs closed to fishing (Uthicke & Benzie, 2000).

The mean size of *H. atra* adult specimens was higher than mean size found by other authors for this same species (Conand, 1989: 13.3 cm; Ebert, 1978: 13.0 cm; Edwards, 1908: 16.37 cm); however, its mean weight was lower than that found by these authors. The lower weights may be due to that the fact the specimens from coastal waters of Pakistan in this study correspond to the small form of this species (Lee et al., 2014; Chao, 1993). According to Chao et al. (1994), the small form of *H. atra* is abundant in intertidal and shallow water habitats. In addition, it is possible that the specimens collected in the two rocky shores Sunehri and Buleji coast might be reproducing asexually (Chao, 1993), but there is no data available on this fact in Pakistan.

Mean length of *H. pardalis* was lower than the average body length reported of adult specimens for this species (roughly 12 to 25 cm; Purcell et al., 2012). Furthermore, 57% adult and 43% juvenile of *H. pardalis* were collected in our study, indicating that the habitat types of the Sunehri and Buleji coasts (rocky shores) are conducive for both. In India, the habitat of adult individuals of this same species is different from that of the juveniles (Gadhavi et al., 2014).

H. verrucosa was recently recorded for the first time from the coastal areas of Pakistan (Ahmed et al., 2016), its mean size and weight were 11.6 cm and 16.1 g, respectively, but no information on sizes is currently available for comparison with our results.

In the four species, growth was negative allometric ($b < 3$) this shows that large specimens changed their body shape to become more elongated (Froese, 2006). Namely, length increment was faster than weight increment. This type of growth occurs in many species of sea cucumbers (Table 4), and *H. pardalis* and *H. verrucosa* were for the first time recorded.

Because deposit-feeding sea cucumbers ingest sediments high in organic matter in the natural environment (Slater & Carton, 2009), the lower b values that occurred during post-monsoon in the four species of this study, likely to be due to an effect the climatic event on the food availability and quality of sediment. It has been shown that the grain size in marine sediments of Malaysia, can be higher during post-monsoon than pre-monsoon and that this can affect the content of organic matter in the sediment (Kamaruzzaman et al., 2010).

Therefore, an indicator of fatness or general “well-being” is utile in this case, such as the relative condition factor (K_{rel}), which indicated that during the post-monsoon, the condition of the bigger individuals of *H. arenicola* and *H. atra* was lower than that of the smaller individuals. These findings indicate a possible diminishing of the content of organic matter in the sediment during the post-monsoon, which can be affecting the “well-being” of the bigger sea cucumbers.

In the particular case of *H. arenicola* in Buleji, the higher gonad index values occur during summer (monsoon) and the lower during winter (post-monsoon) (Siddique et al., 2014),

coinciding in this study with the higher K_{rel} values and lower K_{rel} values, respectively. These results suggest that the reproduction of *H. arenicola* could be in synchrony with the abundance of food.

The temperature also plays an important role in the reproductive events and the abundance of food (Morgan, 2000), but only data of *H. arenicola* showed a significant negative correlation with the relative condition factor K_{rel} . The higher temperatures occurred during monsoon and the lower during post-monsoon, but the better condition of the individuals of *H. arenicola* occurred at temperatures between 22 to 31°C.

Table 4. Parameters from the length-weight relationships recorded for different sea cucumbers species.

Species	a	b	References
<i>Actinopyga echinites</i>	1.31	1.96	Purcell et al., 2009
	0.76	1.38	Purcell et al., 2009
<i>Actinopyga lecanora</i>	0.0096	1.626	Prescott et al., 2015
	0.44	1.53	Purcell et al., 2009
<i>Actinopyga mauritiana</i>	0.075	1.999	Prescott et al., 2015
	4.64	1.67	Purcell et al., 2009
	3.26	1.11	Purcell et al., 2009
	0.887	2.002	Trianni and Tenorio, 2011
<i>Actinopyga miliaris</i>	0.0101	1.482	Prescott et al., 2015
	19.47	1.2	Purcell et al., 2009
	7.30	0.93	Purcell et al., 2009
<i>Actinopyga palauensis</i>	27.18	1.23	Purcell et al., 2009
	5.40	1.05	Purcell et al., 2009
<i>Actinopyga spinea</i>	10.96	1.41	Purcell et al., 2009
	1.00	1.36	Purcell et al., 2009
<i>Apostichopus japonicus</i>	0.081	2.945	Lee et al., 2014
<i>Bohadschia vitiensis</i>	0.0197	2.064	Prescott et al., 2015
<i>B. vitiensis, B. argus</i>	0.0059	1.905	Prescott et al., 2015
<i>Bohadschia koellikeri</i>	0.0021	1.12	Prescott et al., 2015
<i>Bohadschia argus</i>	0.0003	1.49	Prescott et al., 2015
<i>Holothuria arenicola</i>	0.0033	1.855	Siddique et al., 2014
	0.76	1.38	This study

<i>Holothuria atra</i>	0.767	2.635	Prescott et al., 2015
	0.0038	2.13	Conand, 1989
	0.009	1.921	Eriksson, 2006
	0.22	1.74	This study
<i>Holothuria coluber</i>	0.0933	1.591	Prescott et al., 2015
<i>Holothuria edulis</i>	0.0203	1.336	Prescott et al., 2015
<i>Holothuria fuscogilva</i>	0.0011	1.689	Prescott et al., 2015
	119.28	0.9	Purcell et al., 2009
	30.60	0.75	Purcell et al., 2009
	0.0011	2.407	Conand, 1989
<i>Holothuria fuscopunctata</i>	0.0002	2.62	Purcell and Tekanene, 2006
	0.00043	2.50	Conand, 1989
<i>Holothuria lessoni</i>	0.37	2.41	Purcell et al., 2009
	2.15	1.20	Purcell et al., 2009
<i>Holothuria mammata</i>	0.71	1.75	Aydin, 2016
<i>Holothuria nobilis</i>	0.318	2.426	Kandan, 1994
	0.0017	2.34	Conand, 1989
<i>Holthuria pardalis</i>	2.04	0.86	This study
<i>Holothuria polii</i>	0.69	1.77	Aydin, 2016
<i>Holothuria sanctori</i>	3.22	1.18	Aydin, 2016
<i>Holothuria scabra</i>	1.77	1.88	Purcell et al., 2009
	1.19	1.26	Purcell et al., 2009
	1.107	1.87	Natan et al., 2015
	0.0033	2.178	Al-Rashdi et al., 2007
<i>Holothuria tubulosa</i>	0.1229	2.6526	Agudo, 2012 (cultured sandfish)
	0.0017	2.277	Conand, 1989
	0.0714	2.84	Pitt and Dinh, 2004
	0.69	1.74	Aydin, 2016
<i>Holothuria verrucosa</i>	6.87	1.005	Kazanidis et al., 2010
	2.05	0.84	This study

<i>Holothuria whitmaei</i>	0.9345	1.927	Prescott et al., 2015
	235.54	0.65	Purcell et al., 2009
	20.12	0.82	Purcell et al., 2009
<i>Isostichopus badionotus</i>	4.4	1.5	Poot-Salazar et al., 2014
	0.14	2.6	Poot-Salazar et al., 2014
<i>Isostichopus fuscus</i>	1.1421	1.8321	Herrero-Pérezrul and Reyes-Bonilla, 2008
<i>Pearsonothuria graeffei</i>	0.0738	2.495	Prescott et al., 2015
<i>Parastichopus californicus</i>	0.1313	2.310	Hannah et al., 2012
	0.0026	2.0	Humble, 2005
<i>Parastichopus parvimensis</i>	0.4	1.83	Chávez et al., 2011
<i>Stichopus chloronotus</i>	0.0372	2.275	Prescott et al., 2015
	0.6	2.02	Purcell et al., 2009
	0.71	1.37	Purcell et al., 2009
	0.009	1.917	Eriksson, 2006
<i>Stichopus herrmanni</i>	0.0621	1.515	Prescott et al., 2015
	5.71	1.63	Purcell et al., 2009
	7.85	0.97	Purcell et al., 2009
<i>Stichopus horrens</i>	0.0392	1.773	Prescott et al., 2015
<i>Stichopus regalis</i>	0.0024	2.112	Ramón et al., 2010
<i>Stichopus variegatus</i>	0.0004	2.49	Conand, 1989
<i>Thelenota ananas</i>	0.4356	0.935	Prescott et al., 2015
	15.91	1.44	Purcell et al., 2009
	3.42	1.13	Purcell et al., 2009
	0.0013	2.241	Conand, 1989
<i>Thelenota anax</i>	0.1851	1.393	Prescott et al., 2015

The differences of the length-weight relationships of *H. pardalis* and *H. verrucosa* were not significant between climatic events, but large specimens of *H. pardalis* had a better condition than that of the small specimens and vice-versa in specimens of *H. verrucosa*. Therefore, although both small and large sea cucumbers share the same habitat in the coastal waters of Karachi, Pakistan, size distribution before collecting them could be different perhaps by the characteristics of substratum type. This type of studies has been conducted for *Holothuria scabra*

in Solomon Islands, where it was shown that size distribution was a function of substratum type and depth (Mercier et al., 2000).

Conclusion

The commercially important sea cucumbers found in Coastal waters of Pakistan, grow allometric, form negative, namely, length increment is faster than weight increment. Variations of the parameter b and the relative condition factor K_{rel} that occur between climatic pre-monsoon, monsoon and post-monsoon seasons, indicate changes in the environmental variables of the habitat, which also could have relation with the life history of species, such as the reproductive period and the content of organic matter in the sediments.

Studies about environmental variables and characteristics of the substratum type, as well as the relationships of these with sizes distribution of the sea cucumbers are necessary for understanding the biology and ecology of the species distributed from Karachi coast- Northern Arabian Sea.

Acknowledgements

The researchers wish to acknowledge the Higher Education Commission of Pakistan, (Grant No. IPFP/HRD/HEC/1688) which supported by financially for sample collection of holothurians and also to acknowledge the Marine Reference Collection and Resources Centre, University of Karachi for providing laboratory facilities during the study.

References

- Abdel Razek, F.A., Mona, M.H., Abdel Rahman, S.H., El Gamal, M.M., Moussa, E.M. & Taha, S.M. (2010). Observations on the Abundance of Holothurian Species Along the Alexandria Coast of Eastern Mediterranean Waters. *Proceedings of the 89th CIESM Congress-Venice, May 10-14,2010*, Italy.
- Abdel Razek, F.A., Abdel Rahman, S.H., Mona, M.H., El-Gamal, M.M. & Moussa, R.M. (2007). An Observation on the Effect of Environmental Conditions on Induced Fission of the Mediterranean Sand Sea Cucumber, *Holothuria arenicola* (Semper, 1868) in Egypt. *SPC Beche de Mer Information Bulletin*, 26, 33-34.
- Ahmed, Q. & Ali, Q.M. (2014). Abundance and Distribution of Holothuroidea (Echinodermata) with Emphasis on Heavy Metals Accumulation in Organism and Its Habitat, *Project: Higher Education Commission of Pakistan*, (Grant No. IPFP/HRD/HEC/1688).
- Ahmed, Q., Ali, Q.M. & Conand, C. (2016). New Additions to the Holothurian Fauna of Pakistan: *Holothuria verrucosa*, *Holothuria cinerascens* and *Ohshimella ehrenbergii*. *SPC Beche-de-mer Information Bulletin*, 36, 20-23.
- Ahmed, Q., Ali, Q.M. & Bat, L. (2017). Assessment of Heavy Metals Concentration in Holothurians, Sediments and Water Samples from Coastal Areas of Pakistan (Northern Arabian Sea). *Journal of Coastal Life Medicine*, 5(5), 191-201.
- Ahmed, Q., Ali, Q.M., Mazlan, N. & Bat, L. (2018). First Record of a-Sexual Reproduction by Fission in *Holothuria (lessonothuria) verrucosa* (Selenka, 1867) from Coastal Waters of Karachi, Pakistan. *International Journal of Environment and Geoinformatics*, 5(1), 29-36.

- Al-Rashdi, K.M., Claereboudt, M.R. & Al-Busaidi, S.S. (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 Science*, 12, 43-51.
- Aydın, M. (2016). Sea Cucumber (Holothuroidea) Species of Turkey. *Turkish Journal of Maritime and Marine Sciences*, 2 (1), 49-58.
- Chao, S.M. (1993). Reproductive Biology of Sea Cucumbers In Southern Taiwan (Echinodermata: Holothuroidea), *Ph.D. dissertation. Tunghai University*, Taiwan.
- Chao, S.M, Chen, C.P. & Alexander, P.S. (1994). Reproduction and Growth of *Holothuria atra* (Echinodermata: Holothuroidea) at Two Contrasting Sites in Southern Taiwan. *Marine Biology*, 119, 565–570.
- Clarke, S. (2004). Understanding Pressures on Fishery Resources Through Trade Statistics: A Pilot Study of Four Products in the Chinese Dried Seafood Market. *Fish and Fisheries*, 5, 53-74.
- Conand, C. (1989). Les Holothuries Aspidochirotes du Lagon de Nouvelle-Calédonie: Biologie, Écologie et Exploitation, *Etudes et Thèses, ORSTOM*, Paris. 393 p.
- Ebert, T.A. (1978). Growth and Size of the Tropical Sea Cucumber *Holothuria (Halodeima) atra* Jager at Enewetak Atoll, Marshall Islands. *Pacific Science*, 32 (2), 183-191.
- Ebert, T.A. & Russel, M.P. (1994). Allometry and Model II Non-Linear Regression. *Journal of Theoretical Biology*, 168, 367-372.
- Edwards, C.L. (1908). Variation, Development and Growth in *Holothuria floridana* Pourtales and in *Holothuria atra* Jager. *Biometrika*, 6, 236-301.
- Froese, R. (2006). Cube Law, Condition Factor and Weight–Length Relationships: History, Meta-Analysis and Recommendations. *Journal of Applied Ichthyology*, 22, 241-253.
- Gadhavi, M.K., Kardani, H.K., Pathak, R.D. & Prajapat, P.C. (2014). Key Findings on Juvenile Settlement of Sea Cucumber *Holothuria pardalis* at Sikka Coast, Gulf of Kachchh, Gujarat, India, *Ecology. Environment and Conservation*, 20 (1), 165-168.
- Gayanilo, F.C. & Pauly, D. (1997). FAO-ICLARM Stock Assessment Tools, Reference Manual, *FAO Comput Inf Ser Fisheries*, 8, FAO, Rome, 261 p.
- Gerritsen, H.D. & 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.
- Haider, M.S., Sultana, R., Jamil, K., Lakht,-e-Zehra, Tarar, O.M., Shirin, K. and Afzal, W. (2015). A Study on Proximate Composition, Amino Acid Profile, Fatty Acid Profile and Some Mineral Contents in Two Species of Sea Cucumber. *The Journal of Animal and Plant Sciences*, 25 (1), 168-175.
- Hannah, L., Duprey, N., Blackburn, J., Hand, C.M. & Pearce, C.M. (2012). Growth Rate of the California Sea Cucumber *Parastichopus californicus*: Measurement Accuracy, and Relationships Between Size and Weight Metrics. *North American Journal of Fisheries Management*, 32, 167–176.
- Herrero-Pérezrul, M.D. & Reyes-Bonilla, H. (2008). Weight-Length Relationship and Relative Condition of the Holothurians *Isostichopus fuscus* at Espíritu Santo Island, Gulf of California, México. *Revista de Biología Tropical*, 56 (Suppl 3), 273-280.
- Kamaruzzaman, A., Waznah, S., Shahbudin, S., Jalal, K.C.A. & Ong, M.C. (2010). The Temporal Variation of Organic Carbon during the Pre-Monsoon and Post-Monsoon

- Seasons in Pahang River-Estuary, Pahang, Malaysia. *Oriental Journal of Chemistry*, 26 (4), 1309-1313.
- Kandan, S. (1994). Studies on Sea-Cucumbers of Minicoy, Lakshadweep. PhD Thesis, Cochin University of Science and Technology. *Central Marine Fisheries Research Institute Cochin*, 682 014, India, 291 p.
- Kazanidis, G., Antoniadou, C., Lolos, A.P., Neofitou, N., Vafidis, D., Chintiroglou, C. & Neofitou, C. (2010). Population Dynamics and Reproduction of *Holothuria tubulosa* (Holothuroidea: Echinodermata) in the Aegean Sea. *Journal of the Marine Biological Association United Kingdom*, 90 (5), 895-901.
- Le Cren, E.D. (1951). The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201-219.
- Lee, D., Kim, S., Park, M. & Yang, Y. (2014). Weight Estimation of the Sea Cucumber (*Stichopus japonicus*) Using Vision-Based Volume Measurement. *Journal of Electrical Engineering and Technology*, 9, 742-749.
- Marquardt, D.W. (1963). An Algorithm for Least-Squares Estimation of Non-Linear Parameters. *Journal of the Society for Industrial and Applied Mathematics*, 11, 431-41.
- Mercier, A., Battaglione, S.C. & Hamel, J.F. (2000). Settlement Preferences and Early Migration of Thetropical Sea Cucumber *Holothuria scabra*. *The Journal of Experimental Marine Biology and Ecology*, 249, 89-110.
- Morgan, A.D. (2000). Induction of Spawning in the Sea Cucumber *Holothuria scabra* (Echinodermata: Holothuroidea). *The World Aquaculture Society*, 31 (2), 186-194.
- Natan, Y., Uneputty, Pr A., Lewerissa, Y.A. & Pattikawa, J.A. (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.
- Poot-Salazar, A., Hernández-Flores, Á. & Ardisson, P.L. (2014). Use of the SLW Index to Calculate Growth Function in the Sea Cucumber *Isostichopus badionotus*. *Scientific Reports*, 4 (5151), 1-7.
- Prescott, J., Riwi, J., Steenbergen, D.J. & Stacey, N. (2015). Governance and Governability: the Small-Scale Purse Seine Fishery in Pulau Rote, Eastern Indonesia. In: Jentoft S, Chuenpagdee R (eds) *Interactive Governance of Small Scale Fisheries: Global Reflections. MARE Series 13. Springer*, New York, pp, 61-84.
- Purcell, S. & Tekanene, M. (2006). Ontogenetic Changes in Colouration and Morphology of White Teat Fish, *Holothuria fuscogilva*, Juveniles in Kiribati. *SPC Beche-de-Mer Information Bulletin*, 23, 29-31.
- Purcell, S.W., Gossuin, H. & Agudo, N.S. (2009). Status and Management of the Sea Cucumber Fishery of La Grande Terre, New Caledonia. *World Fish Center Studies and Review N° 1901, The World Fish Center, Penang, Malaysia*, 136 p.
- Purcell SW. (2010). Managing Sea Cucumber Fisheries with an Ecosystem Approach to Managing Sea Cucumber Fisheries, *FAO Fisheries and Aquaculture Technical Paper No.520, Rome, FAO*,157 p.
- Purcell, S.W., Samyn, Y. & Conand, C. (2012). Commercially Important Sea Cucumbers of the World, *FAO Species Catalogue for Fishery Purposes*, No. 6, FAO, Rome. 150 p.
- Purcell, S.W. & Agudo, N.S. (2013). Optimisation of Mesh Enclosures for Nursery Rearing of Juvenile Sea Cucumbers, *Plos One*, 8(5), e64103.doi:10.1371/journal.pone.0064103.

- Purcell, S.W., Mercier, A., Conand, C., Hamel, J.F., Toral-Granda, M.V., Lovatelli, A. & Uthicke, S. (2013). Sea Cucumber Fisheries: Global Analysis of Stocks, Management Measures and Drivers of Overfishing. *Fish and Fisheries*, 14 (1), 34–59.
- Purcell, S.W., Polidoro, B.A., Hamel, J.F., Gamboa, R.U. & Mercier, A. (2014). The Cost of Being Valuable: Predictors of Extinction Risk in Marine Invertebrates Exploited as Luxury Seafood. *Proceedings of the Royal Society of London. Series B*, 281, 20133296, doi: 10.1098/rspb.2013.3296.
- Ram, R., Chand, R.V. & Southgate, P.C. (2016). An Overview of Sea Cucumber Fishery Management in the Fiji Islands. *Journal of Fisheries and Aquatic Sciences*, 11, 191-205.
- Ramón, M., Lleonart, J. & Massutí, E. (2010). Royal Cucumber (*Stichopus regalis*) in the Northwestern Mediterranean: Distribution Pattern and Fishery. *Fisheries Research*, 105, 21-27.
- Ricker, W.E. (1973). Linear Regressions in Fishery Research. *Journal of the Fisheries Research Board of Canada*, 30 (3), 409-434.
- Ricker, W.E. (1975). Computation and Interpretation of Biological Statistics of Fish Populations. *Bulletin of the Fisheries Research Board of Canada*, 191,1-382.
- Sang, C. (1963). Biology of the Japanese Common Sea Cucumber *Stichopus japonicus* Selenka. *Pusan National University*, 236 pp.
- Siddique, S., Ayub, Z. & Siddiqui, G. (2014). Length-Weight Relationship and Condition Factor in *Holothuria arenicola* (Holothuroidea: Echinodermata) Found on Two Rocky Coasts of Karachi, Pakistan. *Pakistan Journal of Marine Sciences*, 23, (1and2), 51-63.
- Slater, M.J. and Carton, A.G. (2009). Effect of Sea Cucumber (*Australostichopus mollis*) Grazing on Coastal Sediments Impacted by Mussel Farm Deposition. *Marine Pollution Bulletin*, 58, 1123-1129.
- Sokal, R.R. & Rohlf, F.J. (1997). Biometry: the Principles and Practice of Statistics in Biological Research. *W. H. Freeman and Co*, New York.
- Uthicke, S. & Benzie, J.A.H. (2000). The Effect of Beche-de-Mer Fishing on Densities and Size Structure of *Holothuria nobilis* (Echinodermata: Holothurioidea) Populations on the Great Barrier Reef. *Coral Reefs*, 19, 271-276.
- Zar, J.H. (1984). Biostatistical Analysis, Second Edition. *Prentice-Hall International, Inc, Englewood Cliffs New Jersey 07632*, pp.718.