Research Article

Relationship of Water Physicochemical Factors with White Thread Fish *Holothuria leucospilota* (Brandt, 1835) Biomass in the Northern Waters of the Oman Sea

Seyed Ahmed Reza Hashemi[1], Teymour Aminrad[1], Asadullah Ali Muhammad[2*], Mastooreh Doustdar[3] and Parastoo Mohebi Derakhsh[3]

[1]Offshore Fisheries Research Centre, Iranian Fisheries Science Research Institute, Agricultural Research, Education and Extension Organization, Chabahar, Iran; [2]Fisheries and Coastal Development Department Government of Balochistan, Pakistan; [3]Iranian Fisheries Science Research Institute, AREEO, Tehran, Iran.

Abstract | Current study designed to assess the population characteristics of white threadsfish in northern Oman Sea (Iran) by sampling sea cucumbers at nine sites from March 2018 to March 2019. The sites included Aliabady, Ramin, Beries, Gurdium, Kachoo, Beries plane, Tis, Pasabandar and Pozm. 125 female and 121 male specimens were measured for total length and total weight, with mean ± standard deviation of 28 ± 4 (21 - 33) cm for males and 25 ± 6 (14 - 39) cm for females, and 421 ± 128 (191 - 770) g and 365 ± 231 (116 - 776) g, individually. Overall length and weight were not suggestively changed between the sexes (p > 0.05). Both sexes showed an allometric growth pattern between length and weight. The average estimated number of sea cucumber post Monsoon and per Monsoon was 1.85 million (1.22-2.48) and 1.73 million (1.97-1.49) in the eastern area of Sistan and Baluchestan province, respectively. The total biomass ranged from 601-372 tons, and the harvestable biomass in the two seasons was between 53-90 tons. Contrast worth of phosphate showed substantial differences among diverse stations (P<0.05), while further parameters did not show substantial differences between stations (P>0.05). Multi-layer artificial neural network analysis indicated that two parameters, phosphate and nitrate, had the greatest impact on sea cucumber biomass. To implement a maximum sustainable yield method for this fishery in Iran.

Received | August 07, 2023; **Accepted** | December 14, 2023; **Published** | February 29, 2024
***Correspondence** | Asadullah Ali Muhammad, Fisheries and Coastal Development Department Government of Balochistan, Pakistan; **Email:** asadcemb@gmail.com
Citation | Hashemi, S.A.R., T. Aminrad, A.A. Muhammad, M. Doustdar and P.M. Derakhsh. 2024. Relationship of water physicochemical factors with white thread fish *Holothuria leucospilota* (Brandt, 1835) biomass in the Northern waters of the Oman sea. *Sarhad Journal of Agriculture,* 40(1): 254-262.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40.1.254.262
Keywords | Biomass, Water physicochemical parameters, Artificial neural network, Maximum sustainable yield

Introduction

Sea cucumbers perform a vital ecological part in aquatic ecosystems, such as nutrient recycling (Shiell and Knott, 2010), and have significant economic value for coastal communities worldwide (Purcell, 2010). So, longstanding sustainability of holothurian fisheries is critical for environmental and socio-economic perspectives. However, many countries lack proper fishery management, leading to the depletion of natural populations. To minimize the overexploitation of natural stocks, international efforts have been made to promote aquaculture as an alternative. Moreover, holothurians has exceptional life-history characters, such as their susceptibility to overfishing is exacerbated by limited recruiting and dependent on density success in reproduction (Purcell, 2010).

Holothuria leucospilota (Brandt, 1835) belongs to the Phylum Echinodermata, Order Dendrochirotida, Family Holothuriidae and Class Holothuroidea. Most commercially harvested species of Holothuriidae and Stichopodidae mainly found in hot zones (Purcell *et al*., 2012).

Oman Sea is an area which links Strait of Hormuz and Arabian Sea in northern Indian Ocean, neighboring Iran, Oman, Pakistan and the United Arab Emirates. It has unique ecological conditions that support widespread diversity of aquatic species, providing livelihood, employment, and monetary activities for the local communities. Fishing has played an essential role in creating employ in coastline zones and generating financial actions for post-harvest processes (Taghavimotlagh and Shojaei, 2017).

Previous studies have investigated natural features of sea cucumbers (*H. leucospilota)* species in diverse parts over the globe (Uthicke *et al*., 2004a, Uthicke , 2004b; Conand, 2008; Choo, 2008; De Jesús-Navarrete *et al*., 2018; Dissanayake and Stefansson, 2010; Chávez *et al*., 2011; Purcell *et al*., 2009; Herrero-Perezrul *et al*., 1999; Skewes *et al*., 2002). However, unlawful fishing of *Holothuria leucospilota* has meaningfully increased recently in northern seawaters of Iran (Oman Sea), despite the species not being used for food in the region. Currently, there are no restrictions or specific management for *Holothuria leucospilota* in Oman Sea, despite its economic significance. Population stock of *H. leucospilota* is little known, and current study aims to investigate fish assessment methods and numerous life-history traits of *H. leucospilota* in Oman Sea to deliver vital data for recognizing and handling this species appropriately. Specifically, study will examine spawning period, gonado-somatic index, population structure, growth rate and size on initial maturity of *H. leucospilota* in Oman Sea. Furthermore, series of fisheries assessment data, including recruitment, biomass and mortality will be evaluated to assess the sustain population of *H. leucospilota* in Iran (Oman Sea).

Materials and Methods

Sample sites and specimen collection

Six sites were designated in northern Oman Sea (Iran) for sampling *Holothuria leucospilota* in fishing harbors of Ramin (60° 45´E, 25° 15´N), Pasabandar (61° 25´E, 25° 70´N), Kachoo (60° 55´E, 25° 16´N), Beris (61° 10´E, 25° 82´N), Aliabady (61° 05´E, 25° 10´N), Beris plane (61° 15´E, 25° 72´N) (Figure 1). Samplings were performed from March 2018 to March 2019.

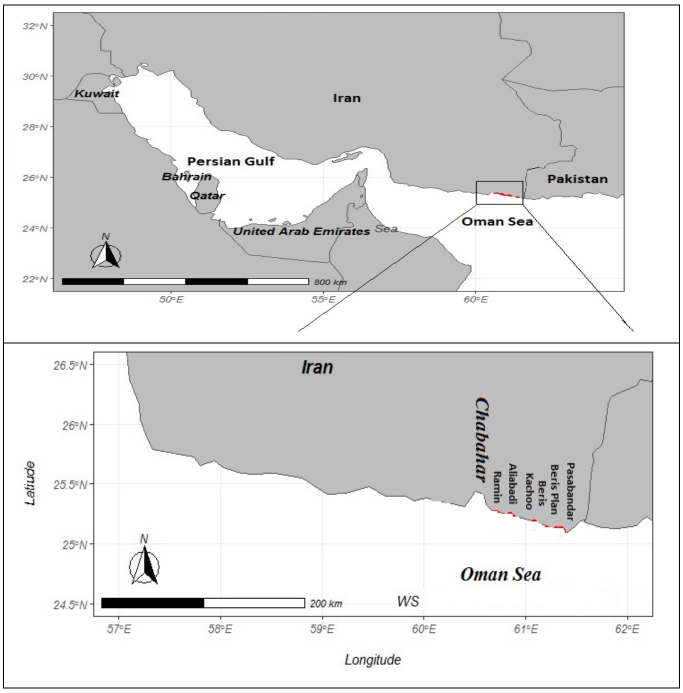

Figure 1: *Map of Holothuria leucospilota sampling stations in the northern Oman Sea (Iran).*

Sampling was conducted from March 2018 to March 2019 in sandy and pebble shore (subtidal areas) at depths of less than 10 meters at depths. Additionally, in the fishing area, organisms were caught with linear transect 2.0 meters wide and 50 meters long with the help of scuba divers. 242 specimens were collected of *H. leucospilota* species (Table 1), and length and weight of each specimen were measured.

Length and weight (Biometric measurements) were done on anesthetized sea cucumbers. Total length was assessed with biometric ruler by 1 mm accuracy (Figure 2), wet weight was measured to nearest 1 gram. The Equation 1 used to analyze LWR and wet weight, with Wi as sea cucumber weight (g), Li as the length (mm) of sea cucumber, a as a continuous number, b as a calculation power:

$$Wi = a \times Li^b \quad \ldots(1)$$

Table 1: *Density, Biomass and biometry of Holothuria leucospilota in each sampling locality in the northern Oman Sea (Iran).*

Station	Scanned area (m^2)	MW + SD (g)	ML + SD (cm)	Density (N/ 100m^2)	Biomass (g/100m^2)
Post Monsoon					
Ramin	100	1025±100	44±10	2	2050
Kachoo	100	0	0	0	0
Aliabady	100	220±50	42±10	2	1380
Beris	100	0	0	0	0
Beris plane	100	500	36	1	500
Pasabandar	100	350±30	26±4	3	1100
Per. Monsoon					
Ramin	100	350±60	31±7	5	2251
Kachoo	100	400±60	32±6	3	1391
Aliabady	100	390±70	33±5	2	840
Beris	100	470	35	1	470
Beris plane	100	0	0	0	0
Pasabandar	100	340±65	30±5	3	1400

Figure 2: *The Holothuria leucospilota (White threadsfish) in the northern Oman Sea (Iran).*

The Equation 2 was used to determine substantial variances among calculated b from Equation 1, b = 3 of sea cucumber in related growing, with S. dx as the standard deviation of the overall size normal log, S. dy as the standard deviation of the weight normal log, b as the slope, r^2 as the coefficient determination, N as the sample mass (Zar, 2010):

$$T=[(s.dx)/(s.dy)]\times[(lb-3l)/(\sqrt{(1-r2)}]\times[\sqrt{(n-2)}] \ldots(2)$$

To estimate the average number (N) of high-density (A) and low-density (B) sea cucumbers, stratified sampling was used due to the cumulative distribution of sea cucumbers, which varies greatly at different depths. Mean (X _), variance (S^2), and confidence limits (C. L.) for stratified sampling were calculated as follows (King, 2013):

$$X\_ = [X\_a (A) + X\_b (B)] / \text{Total area (TL)} \; S^2 = (S^2a / na) (A / \text{Total area})^2 + (S^2b / nb) (B / \text{Total area})^2$$

$$\text{Confidence interval (C. L.)} = X\_ \pm t \sqrt{S^2}$$

Biomass was estimated using the formula B = N x W⁻, B is the assessed biomass (g), N is the assessed abundance, W⁻ is the weight (g) of fish (Anderson and Neumann, 1996).

Two methods were used to evaluate maximum sustainable yield (MSY). First method (MSY1) is based on the exploration rate, U, which varies according to different species and is considered to be about 0.1 for this species (Perry *et al*., 1999):

$$MSY = U \times B$$

The second method (MSY2) estimates MSY based on X value (0.2) and natural mortality (M=0.9): MSY = x x M x B (Woodby *et al*., 1993).

Data collection

Water samples were collected by Nansen bottle from all places and analyzed of environmental parameters (Clesceri *et al*., 1989; Hashemi *et al*., 2015). Eighteen environmental parameters were measured during this study, including water temperature (WT), water salinity (WS), phosphorus (Po4), nitrite (No2), pH, total dissolved solid (TDS), electrical conductivity (EC), dissolved oxygen (DO) (Table 1). Six stations were designated for sampling in each season. The sample collected by divers, and the specimens were brought to the laboratory. (Overall length ±1 mm) and (overall weight with ±0.01 gram) were measured of all specimen.

Statistical analyses

To compare MSY values using the two methods (Method 1: MSY1, Method 2: MSY2) among female and male lengths and weights, Student's t-test with independent t-test was used, respectively. Data regularity was assessed by Kolmogorov–Smirnov test. ANN used to predict the biomass of fish populations based on environmental variables.

The ANN model consists of a network of connected nodes (neurons) set in consecutive sheets which passed data over concealed coating (Lek and Guegan, 2000). The correlation coefficient (R) among detected and assessed standards in the ANN testing and training for fish biomass was calculated (Zou *et al*., 2008).

Results and Discussion

Length frequency distribution

Length frequency distribution was resolute in male (n=121), female (n=125) *Holothuria leucospilota* specimens. The mean ± standard deviation (S.D.) of total length was 28 ± 4 cm (range: 21-33 cm) for males and 25 ± 6 cm (range: 14-39 cm) for females. The mean ± S.D. of total weight was 421 ± 128 g (range: 191-770 g) for males and 365 ± 231 g (range: 116-776 g) for females. There was no substantial change among length and weight in both sexes ($p > 0.05$), indicating that LWR between both sexes was similar.

Length–weight relationship

LWR between both sexes of *Holothuria leucospilota* was determined using the equation Wi = a × Li^b, Wi is weight and Li represents length of the specimen, a and b are constants. The values of a and b were found to be 1.059 and 1.73, respectively, and coefficient of determination (R^2) 0.72, indicating a strong relationship between length and weight. However, Student's t-test revealed the substantial change among the estimated value of b and the expected value of 3 ($p < 0.05$), representing an allometric development pattern in both sexes of *H. leucospilota* in northern seawaters of Oman Sea in Iran (Figure 3). These findings provide important information for understanding the growth and development of this species, and can be useful for developing effective management strategies for sustainable exploitation of the population.

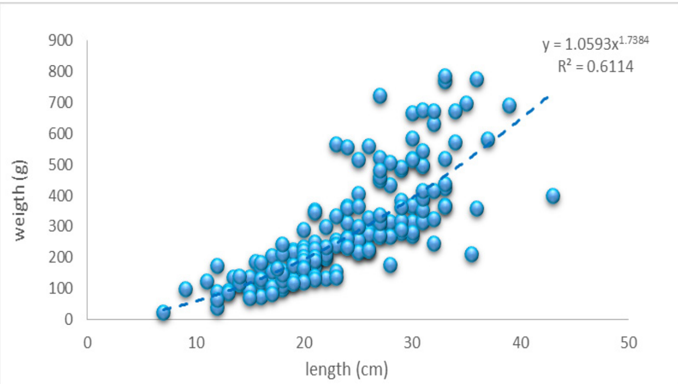

Figure 3: *Length weight relationship of total Holothuria leucospilota in the northern Oman Sea (Iran).*

Biomass

The biomass of white threadsfish in the northern Oman Sea was calculated for each station (Table 1). The least and maximum biomass of this species was observed in Ramin (2050 g/100m^2) and Beris (0 g/100m^2) during the post-monsoon season, and in Ramin (2251 g/100m^2) and Beris (0 g/100m^2) during the pre-monsoon season, respectively. However, the differences in biomass among the different stations were no statistically substantial (ANOVA, F=4.14, $P<0.05$). Mean (±S.E.) biomass of sea cucumber during the post-monsoon season was 838 ± 68 (g/100m^2) and during the pre-monsoon season in Shadegan was 601 ± 88 (g/100m^2). The differences in biomass between the two season was not statistically substantial ($P<0.05$).

In this study, two depth categories (0-5 meters and 5-10 meters) were used to estimate the density of white threads fish. The estimated average numbers of white threads fish during the post-monsoon and pre-monsoon seasons were 1.85 million (range: 1.22-2.48 million) and 1.73 million (range: 1.49-1.97 million), respectively, in the eastern area of Sistan and Baluchestan province. The total biomass during the two-season ranged from 601 to 372 tons, and the harvestable biomass ranged from 53 to 90 tons (Table 3). These results provide valuable information for managing the sustainable exploitation of white threads fish in the northern Oman Sea.

The ANN models and environmental parameters

Table 2 shows the physicochemical parameters measured at different stations. An important changes ($P<0.05$) were experimented for phosphate levels among different stations, while the other parameters not display important changes ($P>0.05$). Artificial neural network models were developed to investigate the relationship between the environmental parameters and sea cucumber biomass. The correlation coefficients ($P<0.05$) obtained from the testing and training procedures were 90% and 88%, respectively, indicating a good fit of the ANN models. The results of the multi-layer ANN show that phosphate and nitrate levels have the greatest impact on sea cucumber biomass (Figure 4).

This study provides valuable information on life-history traits, populace dynamics of *Holothuria leucospilota*, which is an economically and ecologically important species in northern and southern regions

Table 2: *Physic-chemical parameters in different station from the northern Oman Sea (Iran).*

Varible	Value	Ramin	Kachoo	Aliabady	Beris	Beris plane	Pasabandar	P-values
Do	Max	7	7.9	7.5	7.4	7.8	7.9	>0.05
	Min	6	6.5	7.4	6.5	7.4	7	
	Mean	6.8±1	7.5±0.2	7.5±0.1	7±0.6	7±0.6	7.5±0.6	
TDS	Max	4	4	2.8	3.5	3.3	3.2	>0.05
	Min	1	1.4	1.4	3.3	2.9	2.8	
	Mean	3.2±1	2.6±0.8	2.1±0.1	3.4±0.1	3.1±0.3	3±0.3	
PH	Max	8.3	8.3	8	8.2	8.2	8.1	>0.05
	Min	7.5	7	7	7	7.2	7.1	
	Mean	8.1±0.1	8.1±0.3	7.6±0.8	8.1±0.1	7.7±0.7	7.6±0.7	
Tem.	Max	23	29	29	27	27	27	>0.05
	Min	28	22	22	23	23	22	
	Mean	25±2	25±4	25±3	25±2	25±2	25±2	
Sal.	Max	40	39	40	40	40	38	> 0.05
	Min	37	38	38	37	37	37	
	Mean	37±7	38±1	39±1	38±2	38±2	37±1	
No2	Max	1.6	2	1.4	1.7	1	2	>0.05
	Min	1.3	0.4	0.4	1	0.3	0.2	
	Mean	1.5±0.1	1.3±1	0.9±0.4	1.4±1.1	0.4±0.3	1.4±1	
Po4	Max	1.2	1.7	1.8	2.8	4	1	<0.05
	Min	0.8	0.4	0.5	1	1	0.5	
	Mean	1±0.3	1.1±0.9	1.2±0.9	2±1	2.9±1	0.6±0.2	
EC	Max	6	2.7	4.2	5.2	4.9	4.7	>0.05
	Min	3	2.6	2.9	5	4.3	3.9	
	Mean	4.8±1	2.6±0.2	3.6±0.9	5.1±0.1	4.6±0.4	4.4±0.5	

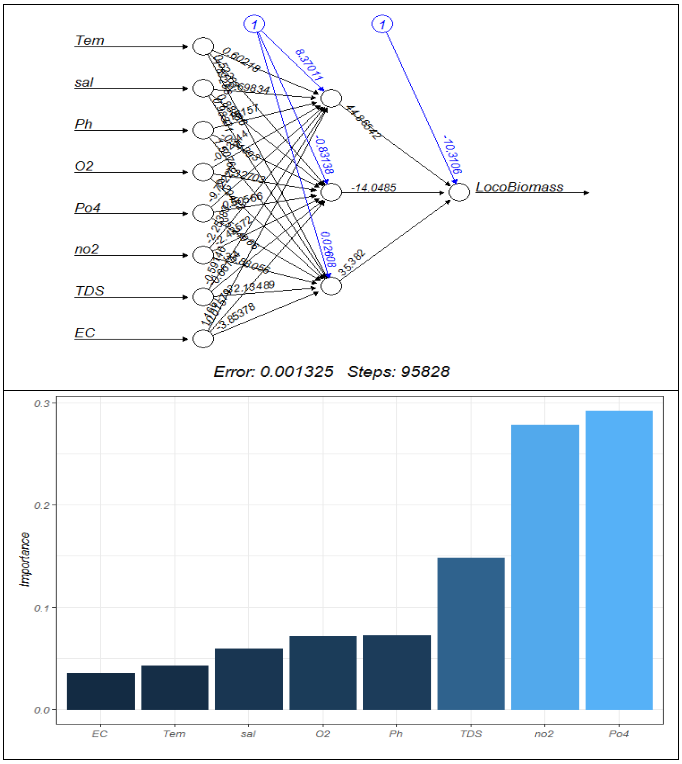

Figure 4: *Artificial neural network (ANN) with one input layer corresponding to the input (independent), one hidden layer and one output layer to estimate the output (dependent). Solid lines show connections between neurons. Bias neurons are also shown their input value is biomass.*

of Oman Sea in Iran. First broad study was studied on this species on Oman Sea in Iran.

Table 3: *Total number (million), total biomass (ton) and MSY of Holothuria leucospilota in the northern Oman Sea (Iran).*

Per Monson	Post Monson	Result
1.24(1.10– 1.38)	1.33 (1.42 – 2.20)	$\bar{X}$ (100 m2)
0.07	0.18	S2
0.27	0.42	S
1.73 (1.49 -1.97)	1.85 (1.48 – 2.22)	Total number (million)
433 (372 -494)	501 (401 -601)	Total biomass (ton)
65 (55- 74)	75 (60 -90)	MSY_1
61 (53 -70)	71 (57 – 85)	MSY_2

Sea cucumbers, including *Holothuria leucospilota*, belong to Echinoderm phylum and performed vital part in marine environments, particularly in biological substance processing. However, overfishing in a small scale of sea cucumbers may result in structural changes to environments (Uthicke *et al*., 2009). Therefore, understanding the life history and population dynamics of *Holothuria leucospilota* is crucial for developing effective management strategies towards safeguard the maintainable exploitation of *H. leucospilota*.

The L-W relationship

Growth curve (length and weight) of *H. leucospilota* seems to reduce later two years and allometric growth is typical in sea cucumbers, as shown by L-W relationship which demonstrated that female was weightier than males within similar size range because small individuals' growth relative than adul's individuals (Chávez *et al*., 2011; Al-Rashdi *et al*., 2007; Dereli *et al*., 2016; Herrero-Perezrul *et al*., 1999). Length-weight relationship of *Holothuria tubulosa* species was calculated as, W = 7.66 $L^{1.06}$ (R^2 = 0.52) (Dereli *et al*., 2016), *Parastichopus parvimensis* species W = 0.4 $L^{1.83}$ (Chávez *et al*., 2011), *Holothuria scabra* species W = 0.0033 $L^{2.17}$ (R^2 = 0.80) (Al-Rashdi *et al*., 2007), *Isostichopus fuscus* species W = 1.14 $L^{1.83}$ (Herrero-Perezrul *et al*., 1999). In fishery valuations, Length weight relationship is very important (Haimovic and Velasco, 2000). Martine (1994) described that "b" value in 2.5 to 4, isometric growth is "b=3. Practical regression "b" value displays body form that related by weight affected by environmental features spawning conditions, temperature, food supply, further aspects sex, age, type of fishing vessels, area of fishing and time (Lalèyè, 2006).

The ANN model

This study found an inverse relationship between the distribution of *H. leucospilota* sea cucumber species and increasing levels of phosphate and nitrite. In a study by (Shakoori *et al*., 2013), salinity, pH, water transparency, and temperature were found to significantly affect the distribution of sea cucumbers based on principal components analysis (PCA). However, ecosystems are highly complex with nonlinear relationships (Džeroski and Drummb, 2003), and environmental factors can have a profound effect on aquatic organisms biology, physiology and ecology. Therefore, the variability of aquatic animals can depend on changes in these variables (Džeroski and Drummb, 2003).

Based on the outcomes of the population correlations and ANN simulations, phosphate and nitrate concentrations have the most effects on sea cucumber population. ANN were shown to have more accurate in estimating the abundance of those organisms in the marine realm because of their capacity to stimulate non-linear systems (Zou *et al*., 2008). Environmental characteristics and sea cucumber biomass measurements taken at undisturbed reference sites may be used to create the ANN models, and differences between reference and test sites could be evaluated in the light of probable anthropogenic consequences.

Changes in sediment particle size can affect organisms by altering temperature, salinity, oxygen, and organic matter. Depth can also cause taxonomic changes. Type of bed and their depth are significant features that affect species of echinoderm and their communities (Ellis and Rogers, 2000). Populace mass might differ through diverse environments and depths (Kazanidis *et al*., 2010). Several studies have shown that smaller individuals tend to live in shallow water, while older individuals live in deeper water (Bulteel *et al*., 1992).

Sea cucumber density, maximum sustainable yield and biomass

During this study, average number (S.D) and biomass per square meter of *H. leucospilota* sea cucumbers were calculated as 0.014±0.009 and 6.69±4.97 g, respectively, which was somewhat lower than that recorded for commercial holothurians inhabitants in Turkey (Aegean Sea) 1.91 number/m^2, 106 g/m^2; (Aydin, 2018, 2019). The population density recorded in our survey (110–220 ind ha^{-1}) was higher compared with *Holothuria scabra* species experimented in Egypt 0-158 kg ha^{-1} (Lawrence *et al*., 2004) or in India 40-200 kg ha^{-1}; (James, 2001), but rather lesser than that documented in Mahout Bay, Oman 1770-4000 kg ha^{-1}; (Al-Rashdi *et al*., 2007) or in New Caledonia 10 - 6000 kg ha^{-1}; (Conand, 1989). However, some species of holothurians with hiding and protecting behavior ecological conditions and habitat suitability (Purcell *et al*., 2009) may influence sea cucumber masses while compared with new locations (Dissanayake and Stefansson, 2010). The patchy distribution and use of sampling techniques might principle of underestimation of densities of sea cucunbers (López-Rocha, 2011).

Fisheries models used to evaluate maximum sustainable yield or total allowable catch (TAC) for different sea cucumber fisheries. Due to model assumptions and problems such as the "Allee effect" unawareness, optimal catch value might less to the designed Maximum Sustainable Yield (Uthicke *et al*., 2004a, Uthicke, 2004b). Another study found that 5%

TAC might depleted the stock (Uthicke *et al*., 2004a, Uthicke, 2004b; Dissanayake and Stefansson, 2010). When using the TAC model lower exploitation rate be considered (1–4%). Instead of MSY for this stock fishery in Iran, monitoring of landings and regularization of reporting is also required. Biology information and management strategies are needed for sea cucumber management, and the lack of this information may cause overexploitation. In general, fishery sustainable management depends on reliable assessment of the stock.

Conclusions and Recommendations

The multi-layer artificial neural network analysis indicated that two parameters, phosphate and nitrate, had the greatest impact on sea cucumber biomass. This study results may assist in the sustainable exploitation and handling of this species stocks. To establish a system of (MSY) maximum sustainable yield for fishery stock in Iran, it seems that further work monitoring of landings and regulation of reporting is required.

Acknowledgements

Authors like to thanks Prof. Bahmani (manager IFSRI) and also thankful the specialists of IFSRI (Tehran), for helping the project work.

Novelty Statement

Length-weight relationship provide significant information to understand growth and development of fish species, and can be useful for developing effective management strategies for sustainable exploitation of the population.

Author's Contribution

Seyed Ahmed Reza Hashemi: Performed the experiment, Conceptualization, Execution, drafting the manuscript.
Teymour Aminrad: Helped in editing, supervision.
Asadullah Ali Muhammad: Helped in literature, format setting and proof reading.
Mastooreh Doustdar: Helped in writing and editing.
Parastoo Mohebi Derakhsh: Helped in writing and editing.

Conflict of interest
The authors have declared no conflict of interest.

References

Al-Rashdi, K.M., M. Claereboudt and S.S. Al-Busaidi. 2007. Density and size distribution of the sea cucumber, Holothuria scabra (Jaeger, 1935), at six exploited sites in mahout bay, Sultanate of Oman. Agric. Mar. Sci. 12: 43-45. https://doi.org/10.24200/jams.vol12iss0pp43-51

Anderson, R.O. and R.M. Neumann. 1996. Length, weight, and associated structural indices. In: B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland. pp. 447–482

Aydin, M., 2018. Biometry, density and the biomass of the commercial sea cucumber population of the Aegean Sea. Turk. J. Fish. Aqua. Sci., 19(6): 463-474.

Aydin, M., 2019. Density and biomass of commercial sea cucumber species relative to depth in the Northern Aegean Sea. Thar. Inter. J. Mar. Sci., 35: 541–550. https://doi.org/10.1007/s41208-019-00144-4

Bulteel, P., M. Jangoux and P. Coulon. 1992. Biometry, bathymetric distribution, and reproductive cycle of the holothuroid Holothuria tubulosa (Echinodermata) in Mediterranean seagrass beds. Mar. Ecol., 13: 53–62. https://doi.org/10.1111/j.1439-0485.1992.tb00339.x

Chávez, E., R. de Lourdes-Salgado and A.J.M. Palleiro. 2011. Stock assessment of the watery sea cucumber fishery (Parastichopus parvimensis) of NW Baja California. CalCOFI. Rep., 52: 136-147.

Choo, P.S., 2008. Population status, fisheries and trade of sea cucumbers in Asia. In: V. Toral-Granda, A. Lovatelli and M. Vasconcellos (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome, FAO. pp. 81-118.

Clesceri, L.S., A.E. Greenberg and R. Trussell. 1989. Standard methods for examination of water and sea water. 17th dition. APHA – AWWA – WPCF. IV, various paging. pp. 235.

Conand, C., 1989. Les holothuries aspidochirotes du lagon de Nouvelle Calédonie: biologie, écologie et exploitation. *Paris: ORSTOM*. pp. 393.

Conand, C., 2008. Population status, fisheries and trade of sea cucumbers in Africa and the Indian Ocean. In: V. Toral-Granda, A. Lovatelli and M. Vasconcellos (eds). Sea cucumbers. A global review of fisheries and trade. FAO Fisheries and Aquaculture Technical Paper. No. 516. Rome, FAO. pp. 143–193.

De Jesús-Navarrete, A., M. Poot and A. Medina-Quej. 2018. Density and population parameters of sea cucumber *Isostichopus badionotus,* (Echinodermata: Stichopodidae) at Sisal, Yucatan. Lat. Am. J. Aquat. Res., 46(2): 416-423. https://doi.org/10.3856/vol46-issue2-fulltext-17

Dereli, H., M. Culha, B. Ozalp and H. Tekinay. 2016. Reproduction and population structure of the sea cucumber *Holothuria tubulosa* in the Dardanelles Strait, Turkey. Med. Mar. Sci., 17(1): 47-55. https://doi.org/10.12681/mms.1360

Dissanayake, D.C. and S. Stefansson. 2010. Abundance and distribution of commercial sea cucumber species in the coastal waters of Sri Lanka. Aqua. Livest. Res., 23(1): 303–313. https://doi.org/10.1051/alr/2010031

Džeroski, S. and D. Drummb. 2003. Using regression trees to identify the habita preference of the sea cucumber (*Holothuria leucospilota*) on Rarotonga, Cook Islands. Ecol. Mod., 170: 219–226. https://doi.org/10.1016/S0304-3800(03)00229-1

Ellis, J.R., and S.I. Rogers. 2000. The distribution, relative abundance and diversity of echinoderms in the eastern English Channel, Bristol Channel, and Irish Sea. J. Mar. Biol. Assoc. Univ. King., 80: 127-138. https://doi.org/10.1017/S0025315499001642

Haimovici, M. and G. Velasco. 2000. Length weight relationship of marine from southern Brazil. NAGA. 23(1): 14-16.

Hashemi, S.A.R., R. Ghorbani, F. Kaymaram, S.A. Hossini, G. Eskandari and A. Hedayati. 2015. Fish Species Composition, Distribution and Abundance in Shadegan Wetland. Fish. Aquacult. J., 6: 128. https://doi.org/10.4172/2150-3508.1000128

Herrero-Perezrul, M.D., H. Reyes-Bonilla, F. Garcıa-Dominguez and C.E. Cintra-Buenrostro. 1999. Reproduction and growth of Isostichopus fuscus (Echinodermata: Holothuroidea) in the southern Gulf of California, Mexico. Mar. Biol., 135: 521–532. https://doi.org/10.1007/s002270050653

James, D.B., 2001. Twenty sea cucumbers from seas around India, Naga. The ICULAPM Quat., 24: 4-9.

Kazanidis, G., C. Antoniadou, A.P. Lolas, N. Neofitou, D. Vafidis, C. Chintiroglou and C. Neofitou. 2010. Population dynamics and reproduction of Holothuria tubulosa (Holothuroidea: Echinodermata) in the Aegean Sea. J. Mar. Biol. Assoc. UK, 90(05): 895–901. https://doi.org/10.1017/S0025315410000251

King, M., 2013. Fisheries biology and assessment and management. Fishing news press, pp. 340.

Lalèyè, P.A., 2006. Length-weight and length-length relationships of fish from the Ouémé River in Bénin (West Africa). J. Appl. Ichthyol., 22: 502-510. https://doi.org/10.1111/j.1439-0426.2006.00752.x

Lawrence, A.J., M. Ahmed, M. Hanafy, H. Gabr, A. Ibrahim and A.A.F.A. Gab-Allah. 2004. Status of the sea cucumber fishery in the Red Sea the Egyptian experience. FAO Fisheries Technical Paper No. 463. 425p. In: *Advances in Sea Sucumber Aquaculture and Management,* A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel and A. Mercier (Editors), pp 79-90. Geneva: FAO Fisheries Technical Paper.

Lek, S. and J.F. Guegan. 2000. Artificial neuronal networks, applications to ecology and evolution. Springer-Verlag. pp. 244. https://doi.org/10.1007/978-3-642-57030-8

López-Rocha, J.A., 2011. Distribución y abundancia del pepino de mar *Isostichopus badionotus* frente a lacosta de Sisal, Yucatán. Proc. Gulf. Caribb. Fish. Inst., 64: 153-160.

Martine, W.R., 1994. The Mechanics of environmental control of body form in fishes. Univ. Toro. Stud. Biol., 58: 1-91.

Perry, R.I., C.J. Walters and J.A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Rev. Fish. Biol. Fish., 9: 125–150. https://doi.org/10.1023/A:1008946522213

Purcell, S.W., 2010. Managing sea cucumber fisheries with an ecosystem approach. Edited/compiled by Lovatelli, A.; M. Vasconcellos and Y. Yimin. FAO Fisheries and Aquaculture Technical Paper. No. 520. Rome, FAO. pp. 157.

Purcell, S.W., H. Gossuin and N.N. Agudo. 2009. Status and management of the sea cucumber fishery of la Grande Terre, New Caledonia. Programme ZoNéCo. World Fish Center Studies and Reviews No. 1901. The WorldFish Center, Penang, Malaysia.

Purcell, S.W., Y. Samyn and C. Conand. 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes. No. 6. Rome, FAO. pp. 150.

Shakoori, A., S.M. Nabavi, P. Kochnin, A. Savari and E. Safaiei. 2013. The effect of environmental factors on the distribution of marine cucumbers in the subtidal region of Chabahar Bay. J. Mar. Sci. Tech., 12(3): 51-62.

Shiell, G.R. and B. Knott. 2010. Aggregations and temporal changes in the activity and bioturbation contribution of the sea cucumber *Holothuria whitmaei* (Echinodermata: Holothuroidea). Mar. Ecol. Prog. Ser., 415: 127-139. https://doi.org/10.3354/meps08685

Skewes, T., J. Kinch, P. Polon, D. Denis, P. Seeto, T. Taranto, P. Lokani, T. Wassenberg, A. Koutsoukos and J. Sarke. 2002. Research for sustainable use of beche-de-mer resources in Milne Bay Province, Papua New Guinea. CSIRO Division of Marine Research Final Report.

Taghavimotlagh, S.A. and M. Shojaei. 2017. Production model for management of fish stocks in the Persian Gulf and Oman Sea (Hormozgan province). Iran. J. Fish. Sci., 26(6): 93-102.

Uthicke, S., D. Welch and J.A.H. Benzie. 2004a. Slow Growth and lack of recovery in overfished Holothurians on the Great Barrier Reef: evidence from DNA fingerprints and repeated large-scale surveys. Cons. Biol. 18: 1395–1404. https://doi.org/10.1111/j.1523-1739.2004.00309.x

Uthicke, S., 2004b. Over fishing of holothurians: lessons from the Great Barrier Reef. In: Lovatelli A, Conand C., Purcell S., Uthicke S, Hamel J.F., Mercier A. (eds.) Advances in Sea Cucumber Aquaculture and Management, FAO Fisheries Technical Paper 463: 163–171.

Uthicke, S., B. Schaffelke and M. Byrne. 2009. A boombust phylum? Ecological and evolutionary consequences of density variations in echinoderms. Ecol. Mono. 79: 3–24. https://doi.org/10.1890/07-2136.1

Woodby, D.A., G.H. Kruse and R.C. Larson. 1993. A conservative application of a surplus production model to the sea cucumber fishery in Southeast Alaska. In: Kruse G., Eggers D.M., Marasco R.J., Pautzke C., Quinn T. (eds.) Proc. Internat. Symp. Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program Report 93-02. University of Alaska, Fairbanks, pp. 191–202.

Zar, J.H., 2010. Biostatistical analysis, 3rd edition. Prentice-Hall Inc., New Jersey, USA. pp. 662.

Zou, J., Y. Han and S.S. So. 2008. Overview of artificial neural networks. In: Artificial neural networks: methods and applications. Livingstone, D. (Ed.), 15-23, Humana Press, New York. ISBN: 978-1-58829-718-1.