Turk. J. Fish.& Aquat. Sci. 19(6), 463-474
http://doi.org/10.4194/1303-2712-v19_6_02

Turkish Journal of FISHERIES and AQUATIC SCIENCES

RESEARCH PAPER

Biometry, Density and the Biomass of the Commercial Sea Cucumber Population of the Aegean Sea

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Article History
Received 24 October 2018
Accepted 04 June 2018
First Online 05 June 2018

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Keywords
Aegean Sea
Sea cucumbers
Biometry
Density
Biomass

Abstract

This study focuses on the determination of the commercial sea cucumber biometry, density and biomass in the Aegean Sea region during the period from November 2014 to December 2015. The line transects (25 m x 4 m) method was carried between the depths of 1 to 20 m for the purpose of this study. All the sea cucumbers in a 100 m^2 area was collected by either SCUBA or hookah diving. A total of 6300 m^2 area was scanned and 3 different species of commercial sea cucumbers (*Holothuria tubulosa*, *Holothuria polii, Holothuria mammata*) were sampled at different depths. Mean gutted weight (MGW) was estimated as 68.08±36.14 g for *H. mammata*, 45.78±18.77 g for *H. polii* and 66.51±30.85 g for *H. tubulosa.* Within the study area, the density and biomas of the total sea cucumber stock were determined as 1.91 ind./m^2 and 106.56 g/m^2. For these three species living in the Aegean Sea region, it is found that the *H. tubulosa* (44%) and *H. polii* (43%) species have greater biomass compared with the *H. mammata* (13%). Region based density and the distribution of these three species are determined as well.

Introduction

Sea cucumber is a marine invertebrate typically found in tropical shallow coasts and coral reefs, but distributed over almost all type of marine ecosystems (Gilliland, 1993). They feed on dead organic matter and waste deposited on the sea bottom and work as natural recycling machines of the oceans (González-Wangüemert, Aydın, & Chantal, 2014; Purcell *et al.,* 2013). About 1200 known sea cucumber species exist in the world oceans, while 60 of them are commercially exploited (Conand, 1990; González-Wangüemert *et al.,* 2014).

Commercial sea cucumber fisheries are performed in many countries of the world (Conand & Byrne, 1994; Conand, 2006; Toral-Granda, Lovatelli, & Vasconcellos, 2008). Majority of the sea cucumber fisheries are carried out by Asian countries (Choo, 2008) in the regions of Pacific Islands (Kinch, Purcell, Uthicke, & Friedman, 2008) and Indian Ocean (Conand, 2008). Sea cucumber landed by Middle-West Pacific and Asian countries are primarily exported to in dried form (Aydın, 2008).

There are 185 species in the family Holothuriidae (Class Holothuroidea). 37 sea cucumber species belonging to 9 families are known in the Mediterranean Sea (Fischer, Schneider, & Bauchot, 1987). Aydın (2016) reported 8 species from the Northern Mediterranean and the Black Sea regions of Turkey. Most of these species, *Holothuria tubulosa,* Gmelin 1790; *Holothuria polii,* Delle Chiaje 1823; *Holothuria mammata,* Grube 1840; *Holothuria (Platyperona) sanctori,* Delle Chiaje 1823; *Holothuria forskali,* Delle Chiaje 1823; *Stichopus regalis,* Cuvier 1817; *Synaptula reciprocans,* Forsskål 1775 are distributed in the Mediterranean and Marmara Seas, while one of them; *Stereoderma kirschbergi,* Heller 1868 belongs to the Black Sea region only.

Sea cucumbers have been used as food source in many countries for centuries (Choo, 2008; Aydın, Sevgili, Tufan, Emre, & Köse, 2011). They are very rich in mucopolysaccharides chondroitinsulphate, protein, vitamin A, riboflavin, niacin, calcium, iron, magnesium and zinc (Choo, 2008; Aydın *et al*., 2011). Despite its remarkable nutritional value, they are not consumed as food in the Aegean Sea region and the entire capture is exported.

Sea cucumbers have been exported since 1996 from Turkey. Main commercial species are *H. tubulosa, H. polii, H. mammata* and *S. regalis*. Sea cucumber fisheries in Turkey started with the export of the *S. regalis* which was actually a bycatch of the trawl nets. The annual production of frozen and dried sea cucumber of Turkey for exportation has reached up to 500 tons (González-Wangüemert *et al.,* 2014). *H. tubulosa, H. polii* and *H. mammata* are preferred species for the export and caught by Hookah diving system (surface- air supplied diving) in the Aegean Sea (Aydın, 2017). Although there have been studies focusing on the heavy metal accumulations, population, reproduction and biometric traits of *H. tubulosa* (Bulteel & Jangoux, 1989; Bulteel, Jangoux, & Coulon, 1992; Simunovic & Grubelic, 1998; Simunovic, Piccinetti, Bartulovic, & Grubelic, 2000; Despalatovic, Grubelic, Šimunovic, Antolic, & Žuljevic, 2004; Kazanidis *et al*., 2010; Vafeiadou, Antoniadou, Vafidis, Fryganiotis, & Chintiroglou, 2010; Kazanidis, Lolas, & Vafidis, 2014; González-Wangüemert *et al.,* 2014; González-Wangüemert, Valente, & Aydın, 2015; Tunca, Aydın, & Şahin, 2016), a stock density estimate for the Aegean Sea Region has not been reported yet. Besides, knowledge on their biology concerning growth rates, population structure, biometry**,** density and range of size and weight along their geographical distribution is limited, while these parameters are fundamental for assessment and management of these resources.

The present study will be the first and most comprehensive one in the Aegean Sea Region focusing on the distribution and the density of the commercial sea cucumber species. The study region is an area which had been exploited for 4 years and fallowed for 3 years. Therefore, this investigation will provide basic information of sea cucumber fisheries for the evaluation of future fisheries activities and implementation of an effective management plan.

Materials and Methods

Study Area

This study was carried out in the Aegean Sea Region limited by the coordinates of 40^{0}00’35’’N - 26^{0}11’38” E and 38^{0}23’22’’N - 26^{0}16’38” E. There are 11 surveying stations located in the Aegean coast of Yeniköy (Çanakkale), Geyikli, Altınoluk, Güre, Gömeç, Ayvalık, Altınova, Şakran, Aliağa, Hekim Island and Ildır,

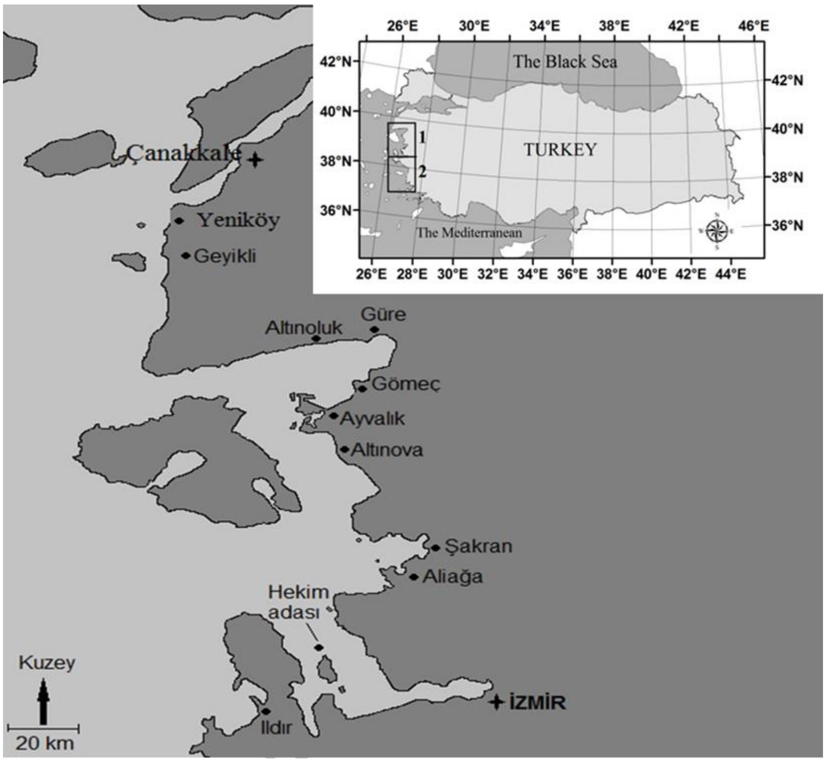

Figure 1. Sea cucumber fishing areas in Turkey; study area is indicated as 1.

given in the order from north to south (Figure 1). These locations, selected by consulting the local fishermen, are rich in sea cucumber population and utilized intensely during the fishing season. Samplings were made periodically between November 2014 and December 2015 (during good weather conditions only).

Species Studied

Seven species are identified in the study region, these are H*olothuria tubulosa*, *Holothuria polii, Holothuria mammata*, *Stichopus regalis*, *Holothuria sanctori*, *Holothuria forskali, Synaptula reciprocans.* However, only the commercially valuable ones; *H. tubulosa, H. polii, H. mammata;* are studied in the scope of this research.

Survey Methodology and Laboratory Study

The line transect method was applied between the depths of 1 to 20 meters for the purpose of determining the stock density (Talaeb, Ghirmay, Semere, & Yohannes, 2008; Kazanidis *et al*., 2010). A lead rope line was laid over the bottom and a total of 100 m^2 was searched within the neighborhood of the rope (~4 meters wide rectangle divided equally by the rope) by SCUBA or hookah supported diving at each station.

At each station, transect method is applied at least once for the 5, 10 and 15 m depths and repeated three times when possible, reaching a maximum scanned area of 900 m^2. All sea cucumbers collected from station were taken to the boat and were transported alive to the laboratory in sea water filled drums.

Species were identified from morphological characteristics according to Fischer *et al*., (1987), Aydın & Erkan (2015) and Aydın (2016). Sea cucumbers have the abilities of filling and emptying their bodies with water, self-ejection of internal organs through the anus, contraction and expansion; therefore, their morphometric dimensions are variable (González-Wangüemert *et al.,* 2014). Similarly, their alive and dead dimensions differ considerably. Due to this difference; after the gutted (removed alimentary canal, gonads and respiratory trees), specimens must be kept in sea water before the measurement with the aim of minimizing the errors related to this issue. The cucumbers were gutted through a 3 cm cut in the abdomen and the gutted weight (GW, g) was measured with the accuracy of 0.01 g. A contraction occurs in the length of the gutted specimen kept in marine water, therefore the gutted length (GL) is measured (with an accuracy of 0.1 cm) 1 minute after the gutted (on a measurement board) when the length of the specimen becomes stable.

The population density was estimated in terms of gutted weight and the number of individuals per square meter. As mentioned before, at least 3 transects were performed at each station for reliable and less erroneous results.

Length-Weight Relationship

The nonlinear relationship between the length and weight of the sea cucumber species is represented by the equation of $GW= a\ GL^b$ (Le Cren, 1951), where GW is the gutted weight (g), GL is gutted length (cm), "a" and "b" are the regression coefficients. The coefficients "a" and "b" in this relation were estimated by the least square method for three different species.

Statistical Analysis

The density and the biometry of the sea cucumbers in terms of species and stations were estimated using a descriptive analysis. Depending on the total number of samples, normality of the data were checked by either the Kolmogorov -Smirnov or the Shapiro Wilks tests. Revealing that not all of the data were normally distributed, binary and multiple comparisons were performed according to the Mann-Whitney U and Kruskal-Wallis tests respectively (Tunca *et al*., 2013). A significance level of P=0.05 was used in these analyses. All statistical analyses were performed using a statistical software (SPSS v.21, IBM, USA).

Results and Discussion

In this study a total of 65 samplings at 11 stations were performed in the Aegean Sea for the period between November 2014 and December 2015.

Density and Biometry

Sampling stations and the number of sea cucumbers collected at these locations for the study period are summarized in Table 1. For the 11 stations presented in the table, a total of 6300 m^2 area was scanned and 12013 sea cucumber individuals were collected. Sampling at each station involves subsets for different depths.

Mean gutted weight (MGW) and mean gutted length (MGL) for the combined total of the three species collected in this study were estimated as 55.88±28.12 g and 11.72±3.21 cm respectively. The frequency distribution of the gutted weight for this combined data is shown in Figure 2.

In the study area, the average number of sea cucumbers and the biomass per square meter was calculated as 1.91 and 106.60 g, respectively. The total number of sea cucumbers per square meter was calculated as 0.0008/m^2 by Talaeb *et al.,* (2008) for a study conducted in the coasts of North Africa while giving estimations for the different species; *H. scabra*, 0.03 for *H. atra*, 0.005 for *H. edulis*, 0.0003 for *H.*

Table 1. Density and biometry of commercial sea cucumbers in each sampling locality

Localities	N	Scanned area (m^2)	MGW±SE (g) Min-Max	MGL±SE (cm) Min-Max	g/m^2	N/m^2
			78.47±24.43	16.12±2.78	160.07	2.04
Yeniköy (1)	612	300	18.50-194.30	7-24.90		
			39.35±10.11	10.98±1.67	62.96	1.60
Geyikli (2)	480	300	13.20-78.20	6-17		
			111.48±28.44	18.86±3.31	137.86	1.24
Altınoluk (3)	371	300	31.20-226.80	8.70-27.30		
			44.24±18.67	11.39±2.69	101	2.28
Güre (4)	685	300	7.40-110	4-19.20		
			40.41±22.35	10.21±2.85	80.82	2
Gömeç (5)	600	300	6.90-107.80	3.40-17.60		
			29.77±16.26	9.53±2.48	73.05	2.45
Ayvalık (6)	736	300	8.90-192.50	4.30-21.60		
			56.57±20.58	11.12±2.45	129.80	2.29
Altınova (7)	2065	900	9-123	5-18.90		
			42.10±16.78	10.36±1.78	72.47	1.72
Şakran (8)	1549	900	12.50-146.50	6-18		
			75.69±30.51	13.63±3.40	130.09	1.72
Aliağa (9)	1547	900	22.20-224.20	8-27.30		
			47.82±17.47	10.64±2.10	85.07	1.78
Hekim Island (10)	1601	900	8.90-181.30	4-25		
			62.92±28.05	11.69±2.37	123.54	1.96
Ildır (11)	1767	900	23-222.60	6-20		
			55.88±28.12	11.72±3.21	106.56	1.91
Total	12013	6300	6-226.80	2-27.30		

N: number, SE: standard error, MGW: mean gutted *weight, MGL: mean* gutted *length,*
Min: minimum, Max: maximum

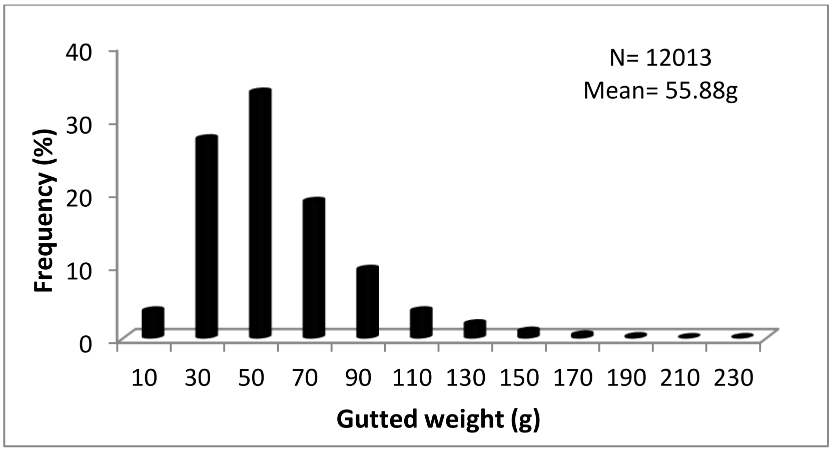

Figure 2. The frequency distribution of GW for commercial species in the Aegean Sea

fuscogilva and 0.0001 for *H. nobilis*. A study from Egypt by Lawrence *et al*., (2004) gives densities with the same magnitude of order; 0.016 for *H. atra*, 0.00012 for *H. fuscogilva*, 0.00007 for *H. nobilis.* Findings from these two studies are much lower than those found in our study. However, a more consistent result was reported by Navarro, García-Sanz, & Tuya (2013) for a study conducted in Gran Canaria with density values of 1.13 ind./m^2 for *H. sanctori*, 0.16 ind./m^2 for *H. mammata* and 0.04 ind./m^2 for *H. arguinensis*.

The GL– GW relationships were estimated as GW = 0.69 $GL^{1.74}$ (R^2 = 0.86) for *H. tubulosa,* GW = 0.69 $GL^{1.77}$ (R^2 = 0.72) for *H. polii*, GW = 0.71 $GL^{1.75}$ (R^2 = 0.91) for *H. mammata*. Negative allometric growth is estimated for all the three species (Figure 3).

Density and Biometry of H. mammata

Density and biometric features at different stations for the sampled *H. mammata* species in this study are presented in Table 2.

The total number of *H. mammata* species collected from the 11 stations is 1334 with density values of 14.42 g / m^2 and 0.21 ind. / m^2. These numbers are consistent with the results of Navarro *et al.,* (2013), who reported the density of the same

Table 2. Density and biometry of *H. mammata* at sampling localities

Localities	N	Scanned area (m^2)	MGW±SE (g) Min-Max	MGL±SE (cm) Min-Max	g/m^2	N/m^2
			87.38±23.26	16.18±3.32	32.04	0.37
Yeniköy (1)	110	300	23.3-158.50	7-27.90		
			39.50±8.17	11.14±1.69	6.45	0.16
Geyikli (2)	49	300	24-63	8-14		
			125.04±29.64	19.97±2.77	41.68	0.33
Altınoluk (3)	100	300	52-226.80	13-27.30		
			53.02±17.33	12.54±2.76	10.60	0.20
Güre (4)	60	300	26-103	6-18.7		
Gömeç (5)	0	300	-	-	-	-
Ayvalık (6)	0	300	-	-	-	-
			61.40±18.03	12±1.91	13.24	0.22
Altınova (7)	194	900	26.90-114.90	8-17		
			42.99±15.64	10.30±1.59	23.65	0.55
Şakran (8)	495	900	12.70-111.60	7.20-16.40		
			92.78±36.12	15.38±3.92	20.52	0.22
Aliağa (9)	199	900	31.60-197.60	8-27		
			73.55±17.05	13.34±1.58	3.84	0.05
Hekim Island (10)	47	900	37.90-118	9.6-16.40		
			105.99±42.38	14.98±2.26	9.42	0.09
Ildır (11)	80	900	51.20-222.60	10.60-20		
Total	1334	6300			14.42	0.21

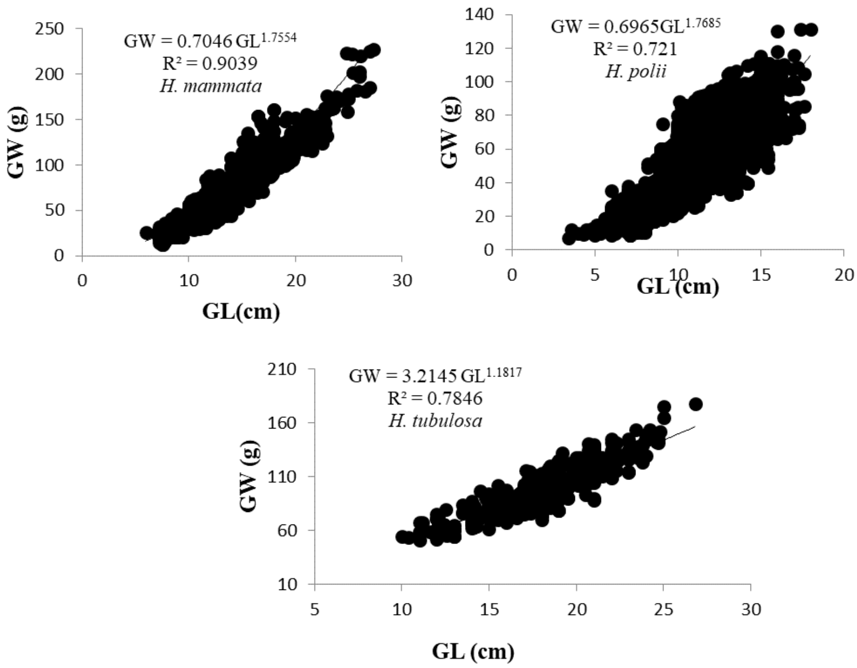

Figure 3. GL–GW relationship for three sea cucumber in the Aegean Sea

species in of Gran Canaria as 0.16 ind./m^2.

Since, the weight of the species has long been preferred to the species length in the analysis of the population dynamics of the sea cucumber (Conand,1981; Tuwo & Conand, 1992; Kazanidis *et al*., 2010; Prescott, Zhou, & Prasetyo, 2015), a similar approach is utilized in this study. Mean weights of sea cucumbers collected from Mallorca, Girona (Spain) and Kuşadası (Turkey) were reported as 84.69, 96.10 and 85.97g respectively by González-Wangüemert *et al*., (2016). In this study, MGW are calculated as Yeniköy: 87.38 g; Güre: 53.02 g; Altınova: 61.40 g; Şakran: 42.99 g; Aliağa: 92.78 g; Hekim island: 73.55 g; Ildır: 105.99 g; Geyikli 39.50 g and Altınoluk; 125.04 g. Differences between these studies can be resulted from many factors including population structure, species distribution, environmental conditions, food abundance and diversity.

Table 3. Density and biometry of *H. polii* at sampling localities

Localities	N	Scanned area (m²)	MGW ± SE (g) Min-Max	MGL ± SE (cm) Min-Max	g/m²	N/m²
Yeniköy (1)	30	300	58±11.48 39-85	13.61±1.53 11-16.90	5.80	0.10
Geyikli (2)	344	300	38.86±9.98 18.20-78.10	10.87±1.59 6-15.50	44.56	1.15
Altınoluk (3)	42	300	83.14±15.87 55.30-116	14.39±1.57 10.60-18	11.64	0.14
Güre (4)	310	300	34.91±10.94 10.10-69	10.07±1.74 6-14.90	36.08	1.03
Gömeç (5)	459	300	38.43±23 6.90-107.80	9.79±2.81 3.40-17.60	58.80	1.53
Ayvalık (6)	707	300	28.15±11.79 8.90-84	9.31±2.21 4.30-17.10	66.33	7.07
Altınova (7)	1170	900	51.36±20.22 9-111	10.07±2.08 5-15.80	66.77	1.30
Şakran (8)	75	900	28.76±10.12 14-75.40	8.26±1.18 6-12.40	2.40	0.08
Aliağa (9)	218	900	54.61±11.06 24.70-94	10.72±1.40 8-15.40	13.23	0.24
Hekim Island (10)	1371	900	44.03±13.20 8.90-98.2	10.26±1.76 4-16.70	67.07	1.52
Ildır (11)	1525	900	55.59±17.01 23-131.20	11.15±1.89 6-18	94.19	1.69
Total	6251	6300			45.42	0.99

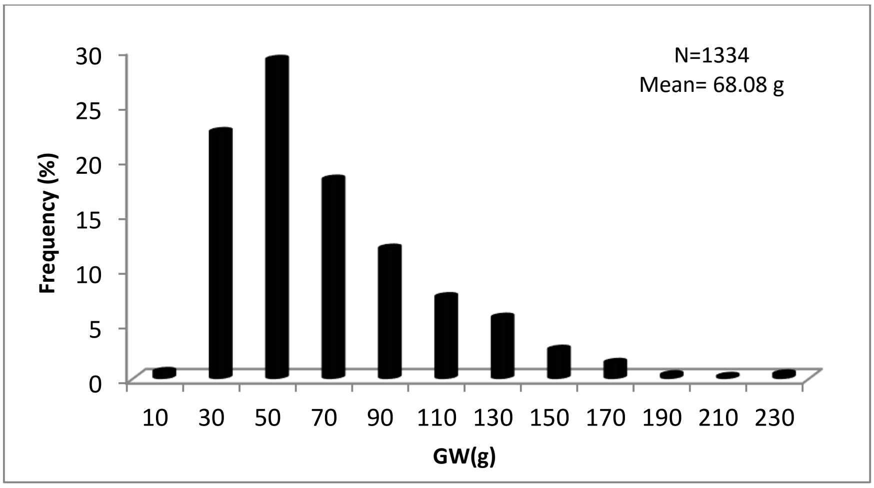

Figure 4. Frequency distribution of GW for *H. mammata*

Navarro *et al.,* (2013) reported the mean wet length as 23.40 cm for *H. mammata,* while Aydın & Erkan (2015) estimated the mean wet weight (without gutted) of *H. mammata* as 109.80 g for the same study region. Considering that MGW and MGL values (instead of wet weight and length) are estimated in this study, our results presented in Table 2 can be thought as in good agreement with those of the two studies given above. The frequency distribution of MGW for *H. mammata* is shown in Figure 4. The mean weight of *H. mammata* was calculated as 68.08±36.14 g.

The order for the species length among the stations according to the nonparametric comparison was found as; Altınoluk > Yeniköy > Aliağa = Ildır > Hekim Island = Güre (Güre = Altınova) > Altınova > Geyikli > Şakran. In terms of species weight the trend is similar; Altınoluk > Ildır > Yeniköy = Aliağa > Hekim Island > Altınova > Güre > Geyikli = Şakran (Figure 7).

Density and Biometry of H. Polii

Density and biometric features of *H. polii* species sampled at the 11 stations are shown in Table 3.

In a previous study by González-Wangüemert *et al*. (2016), 50 *H. polii* individuals in average were sampled at each of the 6 stations; the mean weights

Table 4. Density and biometry of *H. tubulosa* at sampling localities

Localities	N	Scanned area (m^2)	MGW ± SE (g) Min-Max	MGL ± SE (cm) Min-Max	g/m^2	N/m^2
Yeniköy (1)	472	300	77.69±24.39 18.50-194.30	16.27±2.63 8.60-24.80	122.23	1.57
Geyikli (2)	87	300	41.20±11.41 13.20-78.20	11.33±1.92 6.70-17	11.95	0.29
Altınoluk (3)	229	300	110.76±25.63 31.20-185	19.18±3.11 8.70-26.70	84.55	0.76
Güre (4)	315	300	51.74±20.70 7.40-110	12.47±2.86 4-19.20	54.32	1.05
Gömeç (5)	141	300	46.86±18.77 11.30-105	11.56±2.55 5-17.60	22.02	0.47
Ayvalık (6)	29	300	69.50±41.60 31.90-192.50	15.05±2.45 12-21.60	6.72	0.10
Altınova (7)	701	900	63.94±19.23 10.10-123	12.61±2.27 5.30-18.90	49.80	0.78
Şakran (8)	979	900	42.68±17.32 12.50-146.50	10.56±1.80 7.10-18	46.43	1.09
Aliağa (9)	1130	900	76.74±29.74 22.20-224.20	13.88±3.24 8.60-27.30	96.35	1.26
Hekim Island (10)	183	900	69.59±23.32 13.05-181.30	12.76±2.69 7-25	14.15	0.20
Ildır (11)	162	900	110.71±35.77 47-195.20	15.15±2.22 10-20	19.93	0.18
Total	4428	6300			46.75	0.70

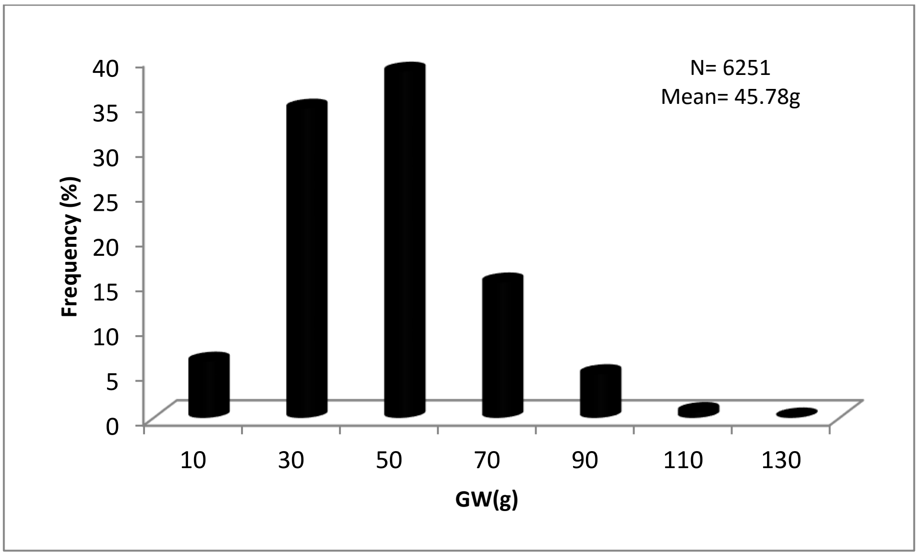

Figure 5. Frequency distribution of GW for *H. polii*

were reported as 40.09 g from Torre de la Horadada, 55.88 g from Mallorca, 41.06 g from Ischia, 71.39 g from Girona, 33.42 g from Crete, and 42.40 g from Kuşadası, located far south of the present study. In another study conducted in the Aegean Sea the mean weight of *H. polii* was estimated as 46.30 g (Aydın & Erkan, 2015). In this research, the MGW of *H. polii* was calculated as 68.08±36.14 g for the whole study region (Figure 5). With density values of 45.42 g / m^2 and 0.99 ind./m^2 for *H. polii,* the findings of our study are consistent with the findings of the above two. However, these results are quite different than the findings of Francour (1989) (for the Mediterranean Sea) with values of 25.10 g/m^2 and 1.60 ind./m^2 indicating that smaller individuals were sampled by Francour.

Station based averaged lengths are found as; Altınoluk > Yeniköy > Ildır = Geyikli > Aliağa > Hekim Island (Hekim Island = Güre) > Altınova (Güre = Altınova) > Gömeç > Ayvalık > Şakran while the weights can be given in the order; Altınoluk > Ildır = Yeniköy = Aliağa > Altınova > Hekim Island > Geyikli > Güre = Gömeç (Gömeç = Şakran) > Şakran = Ayvalık (Figure 7).

Density and Biometry of *H. tubulosa*

Table 5. Comparison of species in terms of biomass and abundance (P<0.05)

	Biomass			Number		
	Mean Rank	Sum of Ranks	P	Mean Rank	Sum of Ranks	P
H. mammata	8.55	94.00	0.033	8.27	91.00	0.020
H. polii	14.45	159.00		14.73	162.00	
H. mammata	8.09	89.00	0.014	8.05	88.50	0.013
H. tubulosa	14.91	164.00		14.95	164.50	
H. polii	10.91	120.00	0.670	12.59	138.50	0.431
H. tubulosa	12.09	133.00	ns	10.41	114.50	ns

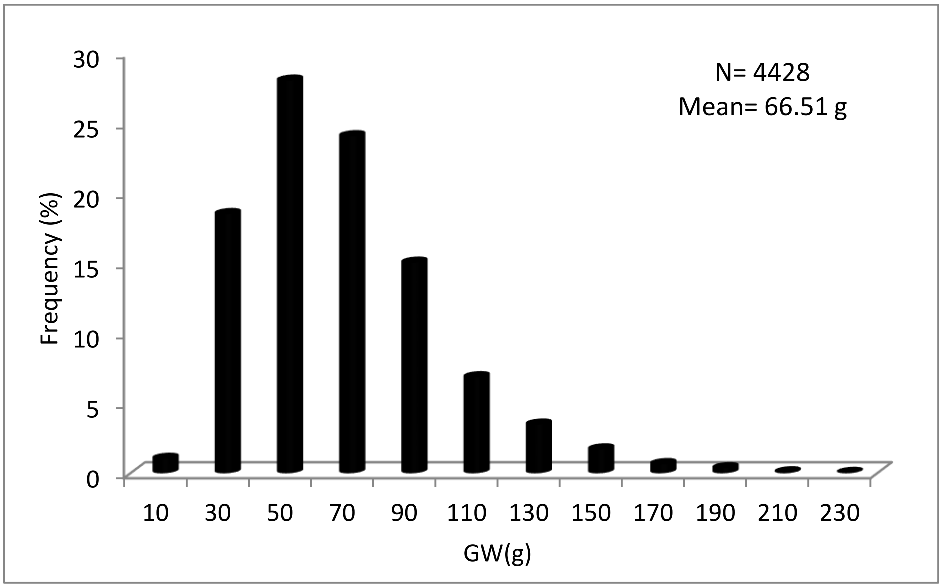

Figure 6. Frequency distribution of GW for *H. tubulosa*

Density and biometric features of *H. tubulosa* sampled at the 11 stations are shown in Table 4.

During the study, a total of 4428 *H. tubulosa* species were collected from 6300 m^2 area. Vafeiadou *et al*., (2010) reported mean weight and length values of 61.89 g and 10.26 cm for 350 *H. tubulosa* samples collected from the South Aegean Sea. This study showed a decrease in biometric measurements of *H. tubulosa* in the north – south direction. In this study, the largest two individuals were collected from the southernmost station (Ildır) and from a station (Altınoluk) at north with weights of 110.71 and 110.76 g respectively. The mean weights of 7 stations in the present study are above the value reported by Vafeiadou *et al*., (2010) and for the rest of the 4 stations the means are below the value of Vafeiadou *et al*., (2010). There is a wide range of values for the mean weight of *H. tubulosa* reported in the literature from different regions of the Mediterranean Sea such as; 83.70 g from the Aegean Sea by Aydın & Erkan (2015); 77.50 g from Torre de la Horadada, 124.07 g from Mallorca, 91.45 g from Ischia, 122.50 g from Girona, 28.64 g from Crete and 58.69 g from Kuşadası by González-Wangüemert *et al.,* (2016); 88.78 g from the Aegean Sea by González-Wangüemert *et al.,* (2014); 49.90 g from the Dardanelles Straits by Dereli, Culha, Culha, Özalp, & Tekinay, *et al*. (2016) and 108.40 g from the Greek coast by Kazanidis *et al*. (2010). In this study, the GW of samples collected from 11 stations varies between 41.20 and 110.76 g with a mean value of 66.51±30.85 g (Figure 6), which is quite different from the reported literature values. This difference could be explained by local environmental conditions (e.g. higher food availability in some areas) or different levels of fisheries pressure as explained by González-Wangüemert *et al.,* (2014). Moreover, it should also be considered that *H. tubulosa* population displays a superior growth performance in regions with high organic inputs (Vafeiadou *et al*., 2010).

Density of *H. tubulosa* in the study area was calculated as 46.75 g / m^2 and 0.70 ind. / m^2. In Greece coasts the density of this species was reported as a much lower value of 0.0993 ind./m^2. However, it is noteworthy that; in Greece, sea cucumber is either fished as a by-catch or collected by divers and used as bait in longline fishery, while it has been commercially exploited in Turkish coasts since 1996. Dereli *et al*., (2016) calculated the density as 0.21 ind./m^2. A study

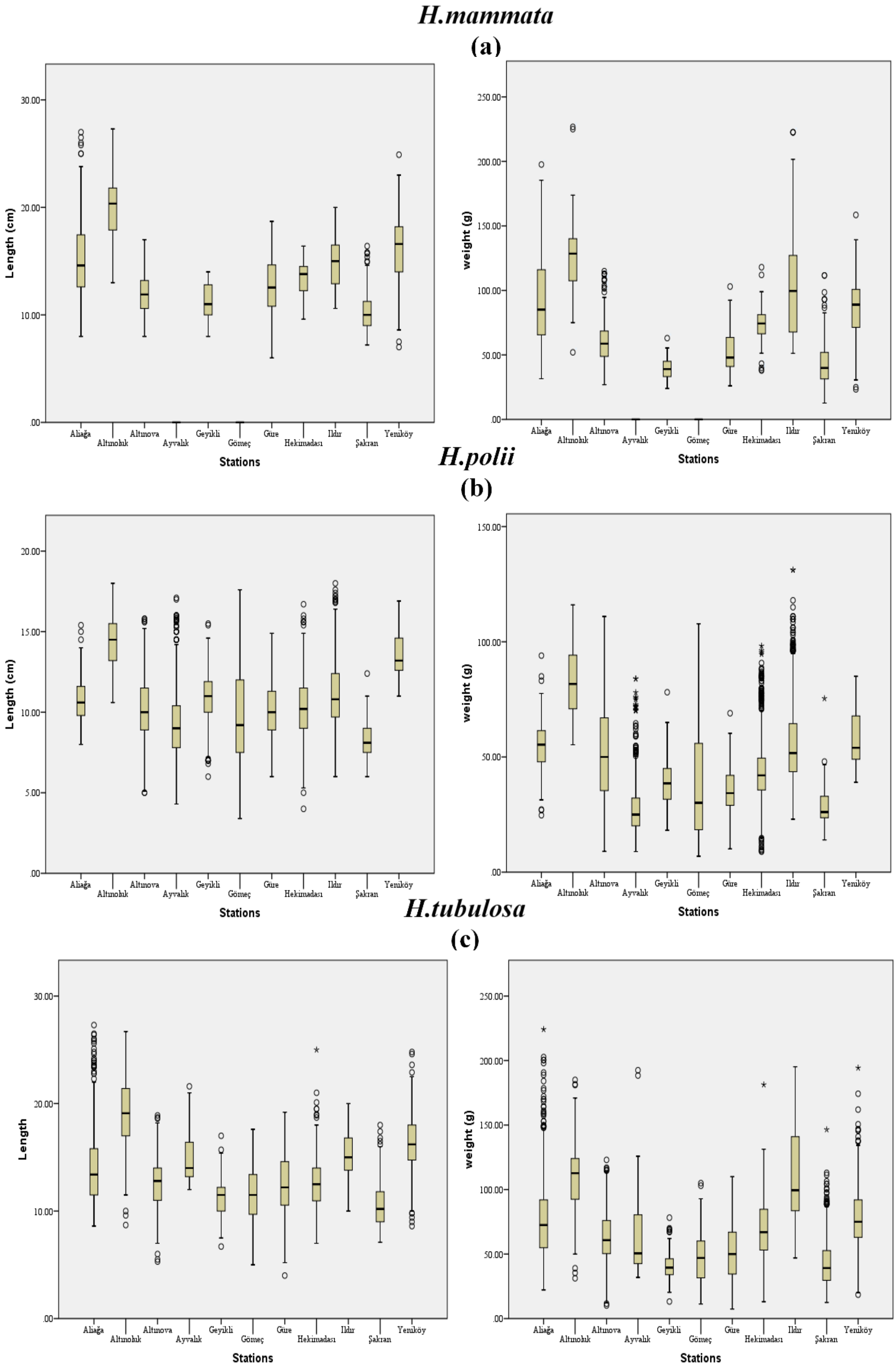

Figure 7. Boxplots representing the mean length (cm) and weight (g) for *H. mammata* (a) *H.polii* (b) and *H. tubulosa* (c) in sampling locations.

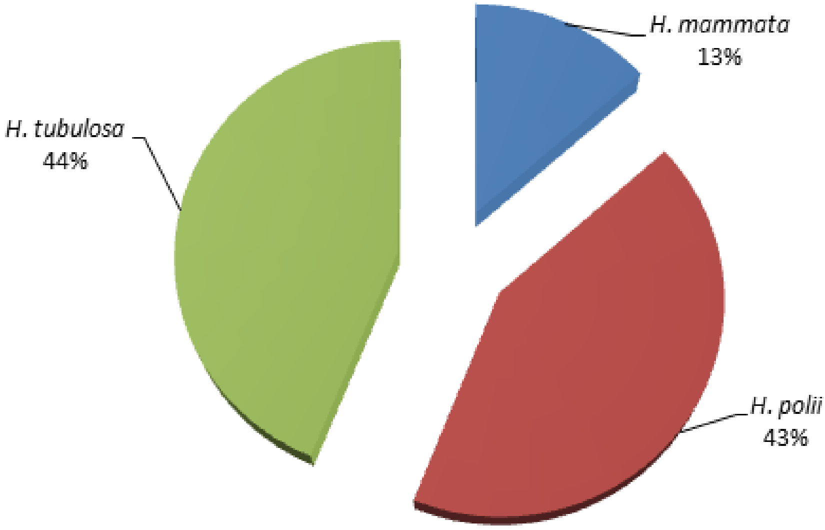

Figure 8. Percentages of species biomass in the study region.

from Gulf of Naples by Coulon & Jangoux (1993) estimated the density as 3.77 ind./m^2 on *Posidonia oceanica* at 8 m depth and 0.34 ind./m^2 at 30 m. An earlier study from reported the density from 0.17 to 0.34 ind./m^2 in various habitats (Gustato, Villari, Del Gaudio, & Pedata, 1982). Francour (1989) studied within a similar depth range with the present study and found the density values as 0.80 ind./m^2 and 14.80 g/m^2, which is comparable with our results in terms of number of individuals but with a greater biomass value as much three times.

Similar to *H. mammata*, the maximum and minimum *H. tubulosa* in terms of length and weight were sampled from Altınoluk and Şakran. There were no significant differences between Şakran, Geyikli and Gömeç in terms of weight. Length comparison gives the order; Altınoluk > Yeniköy > Ayvalık = Ildır > Aliağa > Hekim Island = Altınova = Güre > Geyikli = Gömeç > Şakran. While, the weight in descending order was; Altınoluk = Ildır > Yeniköy > Aliağa > Hekim Island = Ayvalık, Ayvalık = Altınova (Hekim Island > Altınova) > Güre > Gömeç > Geyikli = Şakran (Figure 7).

Biomass Comparison

Total number of collected *H. mammata* from the study region is 1334 with a biomass of 14.42 g/m^2. For *H. polii* and *H. tubulosa*, these values are 6251, 45.42 g/m^2 and 4428, 46.75 g / m^2 respectively. For the whole study region, the percent ratio in terms of biomass for these three species are 44% *H. tubulosa*, 43% *H. polii*, and 13% *H. mammata* (Figure 8).

Biomass and Individual Abundance Comparison

Comparison of the three species in terms of biomass and abundance for 11 stations are given in Table 5. *H. mammata* has the lowest biomass with a significant difference from the other two species ($P<0.05$). The biomass and abundance values for *H. polii* and *H. tubulosa* are *not* significantly different from each other. As seen from the Table 5, number of individuals per square meter shows a similar trend with the biomass.

Conclusion

The fishery for sea cucumber is allowed only in the Aegean Sea region by the Turkish regulations (Figure 1). This region is divided into two sub regions one of which is left as a recovery zone by turns (alternating every 4 years) to recover the stocks. A use of rotational zoning systems has been also reported as a successful method in management of sea cucumber stocks (Purcell, Eriksson, & Byrne, 2016). Prior to opening a fishing zone in Turkey, the status of the stocks (individual weights, lengths, biomass, distribution etc.) is checked by the ministry, and if it is appropriate, then fishing is allowed. Moreover, even in an open region, fisheries are not allowed during the reproduction period (June 1-November 1). Sea cucumber fishery vessels must be authorized by the ministry at the beginning of the fishing season.

In 2008, the mean weights of *H. polii, H. tubulosa* and *H. mammata* in the Aegean Sea region were estimated as 26.19, 47.64 and 59.72 g (Aydın & Emre, 2009). This region was open to sea cucumber fisheries between 2008 and 2012 and then closed for the following 4 years. The study region had therefore been in a fallow season for 3 years before this research. In this study, the gutted mean weights of *H. polii*, *H. tubulosa* and *H. mammata* were calculated as 45.78, 66.51 and 68.08 g, meaning a 46% weight increase in commercial sea cucumber in 2015 when compared with the 2008 data. Fishing pressure is steadily increasing (Kazanidis *et al.*, 2010; González-Wangüemert *et al.,* 2014). Biomass and density data obtained in the present study suggest that ongoing management (rotational fallowing together with the fishing ban during the reproduction period) in the Aegean Sea waters of Turkey seems to ensure a sustainable stock in the region. Yet, monitoring the population parameters, density and biometric traits of sea cucumber species, as in this study, has a key role for a sustainable fisheries management.

Acknowledgements

This study was supported by Ordu University Research Fund Project No. AR-1501

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