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İskenderun Körfezi (Kuzey-Doğu Akdeniz, Türkiye)'nde Dağılım Gösteren İstilacı Deniz Kestanesi *Diadema setosum* (Leske, 1778)'un Boy-Ağırlık İlişkisi

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ÖZ

Bu çalışmada, İskenderun Körfezi kıyılarındaki istilacı *Diadema setosum* türünün (Leske, 1778) boy-ağırlık ilişkisi ve gonadosomatik indeks değeri gibi bazı biyolojik parametrelerinin incelenmesi amaçlanmıştır. Bu nedenle, Eylül 2021'de İskenderun'un kayalık sahil kıyılarından toplam 117 örnek toplanmıştır. *D. setosum* türünün test (kabuk) çapı 24,32-81,1 mm arasında ve ortalama 51,8±1,18 mm olduğu belirlenmiştir. Örneklerin toplam ağırlığı 27,14-185,11 g arasında değişmiş olup, ortalama 84,64±2,77 g hesaplanmıştır. *D. setosum* türünün boy-ağırlık ilişkisi $W=0,7917*L^{1,1773}$ olarak tespit edilmiştir. Tür için tahmin edilen regresyon katsayısı (R^2) değeri 0,71'dir. *D. setosum* türünün negatif allometrik bir büyüme gösterdiği belirlenmiştir. Denizkestanesi türünün farklı gonadosomatik indeks (GSI) değerleri GSI1, GSI2 ve GSI3 sırasıyla %3,4±0,04, %8,91±0,09 ve %7,50±0,14 olarak belirlenmiştir. Bu çalışma, İskenderun Körfezi'nde dağılım gösteren istilacı denizkestanesinin (*D. setosum*) boy-ağırlık ilişkisi (LWR), boy-ağırlık frekansı ve farklı gonadosomatik indeks değerlerini kapsayan ilk ayrıntılı çalışmadır.

Length-Weight Relationship of Invasive Sea Urchin *Diadema setosum* (Leske, 1778) from Iskenderun Bay, North-Eastern Mediterranean, Turkey

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ABSTRACT

In this study, it was aimed to analyses some growth parameters of the invasive *Diadema setosum* (Leske, 1778) from Iskenderun Bay. For this reason, a total of 117 samples were collected in September 2021 from rocky shores coast of Iskenderun. The tests diameter in *D. setosum* was varied between 24.32 and 81.1 mm with an average of 51.8±1.18 mm in length. The total weight was changed between 27.14 and 185.11 g, and the average total weight was 84.64±2.77 g. The length-weight relationship of *D. setosum* was $W = 0.7917*L^{1.1773}$. The value of regression co-efficient (R^2) estimated for the species was 0.71. It was determined that *D. setosum* showed a negative allometric growth. Gonadosomatic indexes (GSI) was determined as 3.4±0.04%, 8.91±0.09%, and 7.50±0.14%, in GSI1, GSI2, and GSI3, respectively. This study is the first detailed study on the length-weight relationships (LWRs), length-weight frequency and gonadosomatic indexes of the invasive sea urchin (*D. setosum*) from İskenderun Bay, Northeastern Mediterranean.

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1. Introduction

Sea urchins from the genus Diadema are a widespread, abundant and ecologically essential genus of tropical sea urchins that covers nine extant species (Muthiga et al. 2020). *Diadema setosum* (Leske, 1778) (Echinodermata: Echinoidea: Diadematidae), is one of the regular echinoids circulated in the Indo-West Pacific Ocean. These species distributed in the Red Sea (Gulf of Suez, Gulf of Aqaba, Northern and Southern Red Sea), and the east coast of Africa to Japan and Australia (Lessios et al., 2001). The species was found for the first time in the Mediterranean Sea along the south-western coast of Turkey in 2006 (Yokes and Galil, 2006). *D. setosum* was also reported from the Hatay, Mediterranean coast of Turkey (Turan et al. 2011), Aegean Sea (Yapici et al. 2014) and Sea of Marmara (Artüz and Artüz, 2019).

This species has long dark spines and five white spots on its aboral side (Lessios et al.2001; Clark, 1925), and orange ring around its anal cone finishes the extraordinary visual elements. *D. setosum* is an omnivorous scrounger and detritus feeder, ingesting free substrate. The invasive sea urchin *(D. setosum)* lives the shallow sublittoral zone (0-20 m), but most frequently the species aggregates around 1-6 m. It desires rocky habitats and biogenic reefs, where it is hiding in crevices and under overhangs-particularly through intense lighting-though, *D. setosum* can also be found on sandy bottoms and seagrass meadows (Muthiga et al. 2020). The species reveals variable reproductive patterns in altered geographic regions, influenced by local ecological factors, like temperature, lunar phases and conspecifics and adults' densities. *D. setosum* is an epibenthic grazer that mainly environmental standing due to the high ranks of grazing gravity it forces on benthic communities. Because of high densities, the species may transform rocky shores to barrens (Muthiga et al. 2020), and strictly bioerode biogenic substrates, particularly coral reefs (Bronstein and Loya, 2014).

Length-weight relationships (LWRs) is very important measurement for many aquatic living organisms around the world (Bolger and Connolly, 1989; Diaz et al., 2000; Demirci et al., 2016; Demirci et al., 2018; Yeşilbudak, 2021). The LWRs of aquatic living organisms are useful in determining weight and biomass and allowing comparison of species life history, morphological features of populations living different areas, length and age assemblies. It is necessary for the management, protection of fisheries and sustainable ecosystem (Goncalves et al., 1997; Koutrakis and Tsikliras, 2003, Oscoz et al., 2005; Demirci et al., 2020). Several studies focused on length-weight and gonadosomatic index were reported in worldwide regarding this species. Also, they were also employed as bioindicator in genetics and pollution studies (Chen et al 2010; Rahman et al. 2012; Dumont et al. 2013; Qiu et al. 2014; Nhan et al. 2020). In Turkey, there were very few studies on biological parameters of sea urchins (Lök and Köse, 2006; Yokes and Galil, 2006; Turan et al. 2011; Küçükdermenci et al. 2015, 2018; Artüz et al. 2019; Karaaslan, 2019; Gezer, 2020) and an article has been found in literature on the length and weight of *D. setosum* species in the Iskenderun Bay (Şimşek et al. 2018). However, this study has reveals only max-min length and weight data are available.

Therefore, this study has given the first information about LWRs of *D. setosum* in the region. In this context, this study on the bioecology of the invasive species *D. setosum*, which is rapidly spreading off the coast of Iskenderun Bay, is intended to determine the state of the bay. Therefore, this study aims to reveal on length-weight relationships (LWRs), size frequency distribution and different gonadosomatic index (GSI) values of the invasive sea urchin in the Iskenderun Bay.

2. Material and Method

2.1. Study Area

The Iskenderun Bay characterized by its rectangular shape is located in the north-eastern corner of the eastern Mediterranean. The gulf is 2275 km^2, and ~65 km long, 35 km wide (Can et al. 2006; Demirhan et al. 2020). The average depth of the gulf is 70m, and it is one of the areas with a very wide continental shelf in the eastern Mediterranean Sea (Avşar, 1999). The gulf shows high productivity caused by local wind effects and movements such as upwelling and rich terrestrial nutrient inputs. Surface water temperature ranges from 16°C to 33°C, and salinity between 37‰ and 40‰ (Polat and Piner, 2002; Polat, 2009).

The Iskenderun Bay is a very important fishing area in the north-eastern Mediterranean. Sampling was conducted on the rocky shores of Iskenderun fishing port (n=117) in September 2021 (Figure 1). In this study process, the seawater of the Iskenderun Fishing Port region is a temperature of 28.4 ° C, salinity of 37.21 ‰, dissolved oxygen of 6.3 ppm and pH of 8.16.

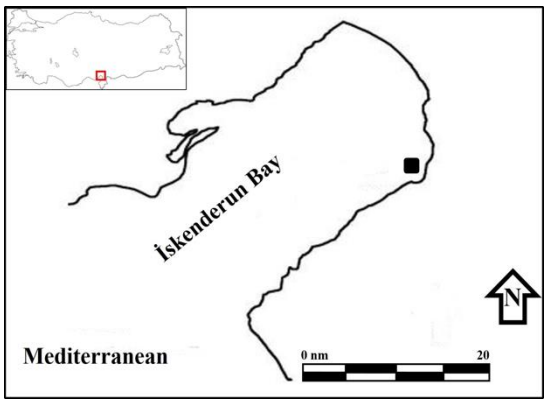

Figure 1. Study area (modified from Demirci et al. 2019)

2.2. Sample Collection

A total of 117 specimens were collected. All collected samples were transported to the laboratory. After that, all samples were measured to the nearest 0.01 mm total length (T) using digital vernier caliper and weighed to nearest 0.01 g (total weight). Biometric measurements of the sea urchins were made and the peristome was cut in two with the help of scissors. The fluid in the perivisceral space was drained, the digestive system was cleaned and the gonad lobes were reached. In the sea urchin test

(shell), the gonads were removed with forceps and weighed. The test diameter (perpendicular to the oral-aboral axis) and the length (by oral-aboral axis) were measured. Then, samples were dissected to eliminate all the subjects of the coelomic cavity and release the skeletal parts, including the test and Aristotle's lantern (Table 1).

Table 1. Descriptive statistics of *Diadema setosum* collected from Iskenderun Bay in September 2021.

Measurements	Mean±SE (mm)	Min-Max (mm)
Total Weight	84.65±2.77	27.14-185.11
Test Weight	32.72±1.21	9.79-79.34
Test Height	26.99±0.82	9.1-61.35
Test Diameter	51.8±1.18	24.32-81.1
Aristotle's Lantern Weight	6.03±0.33	2.4-9.6
Test Thickness	1.74±0.06	0.6-3.1
Gonad Length	20.38±0.79	6.69-45.49
Gonad Weight	3.04±0.11	1.2-7.68
Aristotle's Lantern Length	14.64±0.58	7.1-20.2

2.3. Analyses

The length-weight relationship (LWR) was calculated with equation $W = aL^b$, where W is the body weight (g) and L is the total length (mm) (Le Cren, 1951). This equation can be linearized as $W = a*L^b$, which '*a*' is the intercept and '*b*' is the slope (regression coefficient). According to the method, growth pattern is identifies as isometric when *b*=3, positive allometric when *b*>3 or negative allometric when *b*<3 (Rahman et al. 2012). The biometric measurements were made of using by Microsoft Excel Program 2016 version. Results were expressed as the Mean ± Standard Error.

The length and weight frequency data of *D. setosum* were examined using the SPSS Version 17.0.

Gonadosomatic index (GSI) calculated by using three different equations (Agatsuma, 1998; Gonor, 1972). Results were expressed as the Mean ± Standard Error.

$$GSI1 = \frac{wet\ gonad\ weight\ (g)}{total\ weight\ (g)} x100 \quad \text{(Agatsuma, 1998)}$$

$$GSI2 = \frac{wet\ gonad\ weight\ (g)}{test\ weight\ (g)} x100 \quad \text{(Gonor, 1972)}$$

$$GSI3 = \frac{wet\ gonad\ weight\ (g)}{test\ weight\ (g) + Aristotle's\ Lantern\ weight\ (g)} x100 \quad \text{(Gonor, 1972)}$$

3. Results

This study is the first study examining length-weight relationships, size frequency distribution and different gonadosomatic index (GSI) of *D. setosum* known as invasive and poisonous species from Iskenderun Bay. Biometric measurements of the species were the largest at 185.11 g and the smallest

at 27.14 g. The test diameter was maximum of 88.47 mm and minimum of 21.32 mm. As a result of the biometric measurements, the average length and weight of the Aristotle's lattern was 6.30±1.92 mm and 15.08±3.37 g, respectively (Table 1).

3.1. Length-Weight Relationships

LWRs of *D. setosum* was estimated as $W = 0.7917*L^{1.1773}$ ($R^2 = 0.7079$) (Table 2). The considered growth coefficient (*b*) was 1.1773 and the constant (*a*) was 0.7917. The LWR curves are existing in linear scale (Figure 2). The LWR outcomes were showed negative allometric (*b*<3) growth for *D. setosum*.

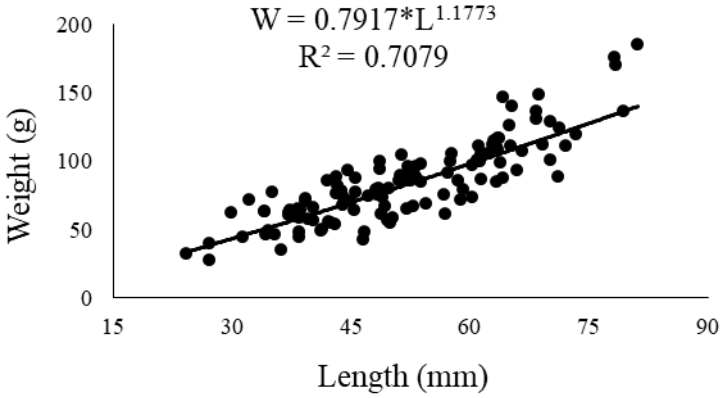

Figure 2. The length and weight relationship of *Diadema setosum* (n=117).

3.2. Weight and Average Test Diameter frequency distribution

The mean test diameter and weight of the population of *D. setosum* was 51.8±1.18 mm and 84.65±2.77 g, respectively (Table 1). The most common test diameter in the sample from Iskenderun Bay was 65 mm with an average of 51.84±1.18 mm (Fig 3A). The most frequent total body weight in the sample from Iskenderun Bay was 70 g and the average weight of the sample was 85.64±2.77 g (Fig. 3B).

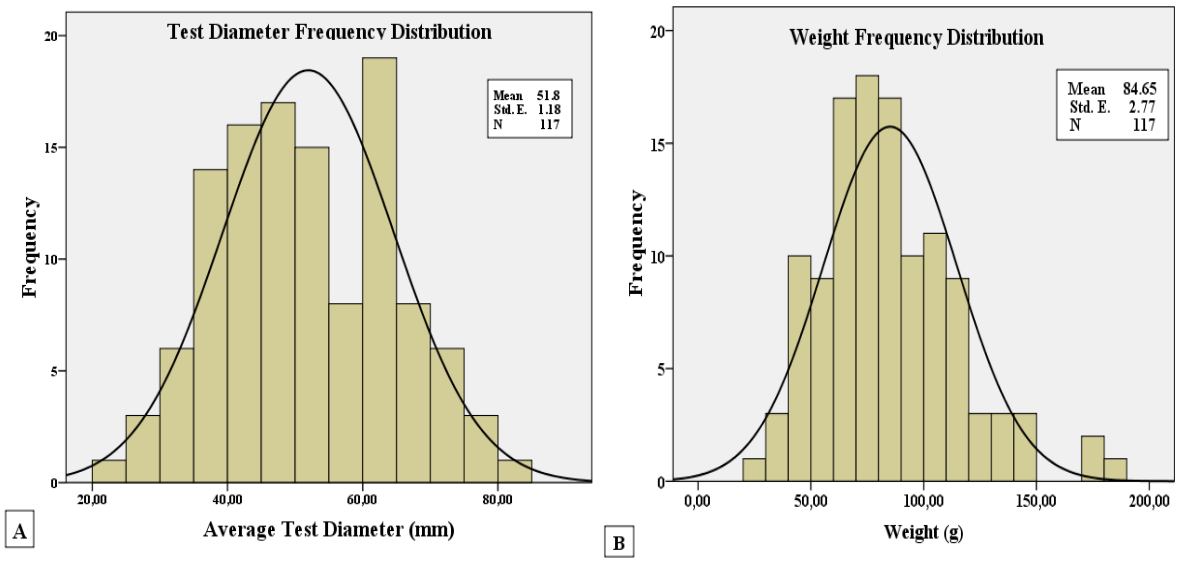

Figure 3. Test diameter frequency distribution (A) and weight frequency distribution (B) of *D. setosum.*

3.3. Gonadosomatic Indexes

Invasive sea urchin (*D. setosum*) calculated the gonadosomatic index based on different methods, and Figure 4 was also shown. Gonadosomatic index values were calculated at 3.4±0.04 %, 8.91±0.09 %, and 7.50±0.14 %, respectively, in GSI1, GSI2, and GSI3, and ranked as GSI2>GSI3>GSI1 (Figure 4).

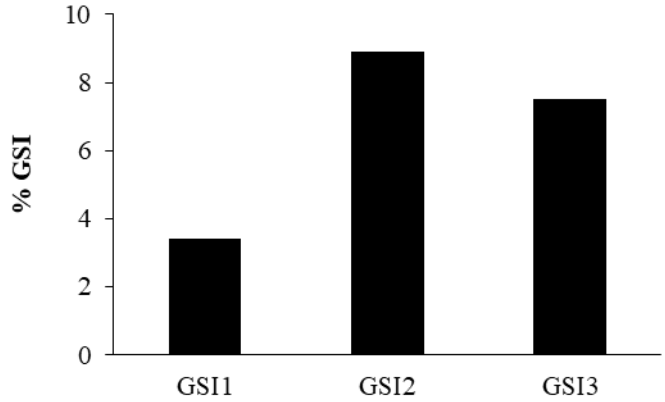

Figure 4. The change of *D. setosum* gonadosomatic index (GSI) according to different methods.

4. Discussion

Information on the length-weight relationships (LWRs), size frequency distribution and different gonadosomatic indexes (GSI) for this species is reported for the first time in the Iskenderun Bay. The size frequency distribution of *D. setosum* reveals that the length ranges from 24.32 to 81.1 mm and weight from 27.14 to 185.11 g (Table 1). According to the Smith and Kroh (2011), *Stomopneustes variolaris* from Visakhapatnam Coast (India) has a maximum shell length of 110 mm. According to

the De Zoysa et al. (2017), *S. variolaris* from Sri Lanka has a maximum shell length of 89 mm. According to the Sellem and Bouhaouala-Zahar (2021), *Paracentrotus lividus* sea urchin species from Tunisia's shallow coasts has a maximum shell length of 67.9 mm. According to the Rahman et al (2012), sea urchin *D. setosum* species from Pulau Pangkor, Peninsular Malaysia has a average shell length and total weight of 59.66 mm and 101.68 g, respectively. Lök and Köse (2006) investigated the gonadosomatic index change of *Arbacia lixula* and *P. lividus* sea urchin species from Urla-Iskele in Izmir Bay. As a result of the study, the maximum shell length and total weight of *A. lixula* sea urchin were 55.6 mm and 73.78 g, respectively. Maximum shell length and total weight of *P. lividus* sea urchin species are 73.3 mm and 96.12 g, respectively. According to the Köktürk (2014), sea urchin *P. lividus* species from Çanakkale coasts has an average weight and shell length of 36.12 g and 38.19 mm, respectively. Average Aristotle's lantern length of 14.89±0.40 mm (Köktürk, 2014). Siddique and Ayub (2016), *Echinometra mathaei* sea urchin species from Buleji rocky shore of Karachi in Pakistan has a shell length rages from 19 to 77.2 mm and total weight ranges from 13.3 to 121.6 g.

Among the invertebrates and fish species the value of the example (*b*) as 3 for the length-weight relationship showed that the growth in weight is isometric with the length, while *b* value not the same as 3 showed that the development is allometric. The present study revealed the *b* value (1.1773) was less than 3, which concludes that *D. setosum* from Iskenderun Bay were close to isometric growth in weight, because "*b*" exponent value usually lay between 2.5 to 4.0 and that depends on the age, sex or maturity of species. Tomšić et al. (2010), Rahman et al. (2012, 2013), De Zoysa et al. (2017) and Ballesteros (1981) also reported the LWRs values of the current study were higher than the others (Table 2). This influence of negative allometric growth of *D. setosum* in sea urchins may be the environmental parameters and feeding habits (Jones et al. 1999; Rahman et al. 2012). De Zoysa (2017), *S. variolaris* sea urchin species from Beruwala, Tangalle and Mt. Lavinia in Sri Lanka has a shell diameter of 6.70±1.26 cm, 6.54±2.71 cm and 5.55±1.04 cm, respectively. To till, there is limited data accessible on LWRs of the invasive sea urchin *D. setosum* in the Iskenderun Bay, except Şimşek et al. (2018), who recorded the mean length and weight of same species were 55.85 mm and 86.71 g, respectively.

Küçükdermenci and Lök (2016) reported four different gonadosomatic index changes of *A. lixula* sea urchin in Muğla locality GSI1 GSI2 GSI3 and GSI4 are 5.79%, 9.6%, 2.58% and 8.79%, respectively. Vafidis et al. (2020) reported the GSI values of *Sphaerechinus granularis* species as 0.316-3.264% in Pagasitikos Bay. Köktürk (2014) reported the gonad index value of *P. lividus* species as the highest 8.04%±0.59% and the mean 5.97±0.58% for the sea urchin in Çanakkale Güzelyalı coast. De Zoysa (2014) reported the gonad index changes of *S. variolaris* sea urchin in Sri Lanka at 3 different stations, Beruwala, Tangalle and Mt. Lavinia samples were recorded as 3.22±1.63, 3.44±1.89, and 5.95±3.26, respectively. Shpigel et al. (2004) revealed that GSI of *P. lividus* ranges between 6% and 12%. Arafa et al. (2012), reported that the gonadosomatic index value of *P. lividus* sea urchin species was the

highest (16.71%) and the lowest (7.12%) in the Gulf of Tunisia. Thai et al. (2019) determined the highest gonadosomatic index of *D. setosum* sea urchin species as 16.1% in Hon Son Island, Viet Nam. Kaneko et al. (2012) reported *D. setosum* sea urchin species gonadosomatic index changes (GSI) between 9.3-10.4% in the Nagasaki region of Japan. Results obtained in this study was similar to the previously reported LWRs and GSI values of the sea urchin species.

Table 2. Length-weight relationships and other parameters of sea urchin species in other region

Region	Species	N	a	B	R^2	References
Tossa de Mar (Gerona), Spain	*Paracentrotus lividus*	100	0.0032	2.479	0.92	Ballesteros, 1981
	Arbacia lixula	100	1.066	0.384	0.77	
	Sphaerechinus granularis	100	4.014	0.118	0.98	
Croatia, Eastern Adriatic	*Paracentrotus lividus*	1133	1.894	1.849	0,679	Tomšić et al. 2010
Pulau Pangkor, Malaysia	*Diadema setosum*	101	0.04	1.9049	0.6339	Rahman et al. 2012
Peninsular Malaysia	*Stomopneustes variolaris*	355	0.004	2.4396	0.77	Rahman et al. 2013
Aegen Sea, Turkey	*Paracentrotus lividus*	60	2.926	-0.366	0.95	Küçükdermenci and Lök, 2014
Mount-Lavinia, Sri Lanka	*Stomopneustes variolaris*	43	0.9953	2.6472	0.9360	D Zoysa et al. 2017
Beruwala, Sri Lanka		99	0.9651	2.6536	0.8600	
Tangalle, Sri Lanka		55	1.4665	2.4637	0.9402	
İskenderun Bay, Turkey	*Diadema setosum*	117	0.7917	1.1773	0.7079	This study

N: number of samples; a: intercept of the relationship; b: slope of the relationship; R^2: coefficient of correlation

5. Conclusion

This study is the first detailed study to which aimed to determine size frequency distribution, length-weight relationships (LWRs) and different gonadosomatic indexes (GSI) of invasive sea urchin, *D. setosum* from İskenderun Bay. More detailed studies needs to be conducted to access the population size and GSI for the proper reproduction season of invasive *D. setosum* individuals. Therefore, in combination with data from other to do studies LWRs and GSI, this study contributes to the scientific knowledge for appropriate controlling the policies and strategies aimed at reducing the invasive sea urchin.

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Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

In this study, the first author carried out field and laboratory studies of the study and wrote the article, while the second author planned the study and acted as the supervisor of the thesis.

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