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Research article

A study on some population parameters of spot-tail mantis shrimp (*Squilla mantis* L.; Crustacea: Stomatopoda) in Edremit Bay (Northern Aegean Sea)

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Abstract: This study was carried out for the determination of the biological characteristics of mantis shrimp (*Squilla mantis,* L.) in Edremit Bay. For this purpose, a total of 627 mantis shrimp were caught by the vessel Salih Reis from Edremit Bay between September 2014 and April 2015. The age and sex composition, total length, carapace length, and weight distributions, age-length, length-weight relationships, gonadosomatic index (GSI), von Bertalanffy growth parameters, mortality rates, and exploitation ratio (E) of the spot-tail mantis shrimp populations were presented. The total length values of the investigated individuals were found to be 9.0 - 20.8 cm, the carapace length values were between 2.0 - 5.4 cm, and their weights were between 6.5 - 78.0 g. It was determined that 35.5% of the population was made up of males and 64.5% were females, and the sex ratio was D: E = 1.81: 1. The age distribution of individuals was found to be between 1 and 4 years of age, and 4 years of age was dominant in the population. The total length - weight relationship was calculated as $W = 0.0106TL^{2.9469}$, the total length - carapace length relationship $CL = 0.3735TL^{0.8555}$ and the carapace length - weight relationship was calculated as $W = 0.7507CL^{2.8418}$. von Bertalanffy Growth Equation was calculated as $L_\infty = 21.64*[1-e^{-0.18*(t+1.03)}]$ for all spot-tail mantis shrimp. Total mortality rate (Z), natural mortality rate (M), fishing mortality (F), and Exploitation rate (E) were calculated as 0.67, 0.47, 0.20, 0.30, respectively. Exploitation rate showed that spot-tail mantis shrimp stock in Edremit Bay was not caught enough. It was found that spawning occurred from winter to spring.

Keywords: Edremit Bay, *Squilla mantis*, growth, gondosomatic index.

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Introduction

Shrimps have a wide distribution in fresh water, brackish water, and seas from the equator to the poles. They are very variable in size, ranging from a few mm to 35 cm. Currently a total of 485 species belonging to 115 genera, and 17 families of mantis shrimp has described in worldwide, only 300 of them are commercially significant (Kocataş et al., 1991), and they are present in Turkish waters as eight subclasses (Demirsoy, 2005).

The maximum length of this species is up to 20 cm. Mantis shrimp distribute in the Eastern Atlantic from the Gulf of Cadiz, Canary, Madeira Island, south to Angola, and the Mediterranean Sea (Vacelet et al., 1987). *Squilla mantis* prefers to live at 20 C^o (Cheung et al., 2013). Living habitat ranges from 0 to 200 m from the coast. While they burrow in the muddy and sandy bottoms during the day, they come out to hunt at night. They have excellent vision

for night predation and are strongly sedentary (Maynou et al., 2005).

Edremit Bay, situated along the coasts of Çanakkale and Balıkesir between Küçükkuyu and Ayvalık, is a place where two currents meet and is rich in plankton because of upwelling. In addition, because the bottoms are suitable for trawl fishing and the area is fed by waters rich in nutrients from erosion through the vicinity of the bay and the Black Sea, there is a rich bottom fish fauna. With these facilities, Edremit Bay has a high potential for sea food, especially fish (Bilecik, 1989; Toğulga, 1997). Therefore, it supports the most important fishing activity in the Aegean Sea of Türkiye. In spite of some investigations on by-catch of *mantis* in the Aegean and Mediterranean Seas (Akyol, 2003; Bozkurt, 2010; Acarlı et al., 2022), growth studies of this species are limited, except for those determined in Termaikos Gulf and İzmir Province by Kampouris et al. (2018) and Erdoğan Sağlam et al. (2018), respectively.

It is widely distributed in the eastern Atlantic and Mediterranean Seas and is commercially important in the Mediterranean. According to FAO, the majority of total annual production was provided in Italy, followed by Spain, France, and Croatia (Anonymus, 2011). The shrimp fisheries in Turkey rose by 5137 tonnes from 2000 to 2019 (Anonymus, 2020). There are some studies on *S. mantis*. Mantis shrimp are evaluated as discards in various fishing gears in the Turkish Seas (Başusta et al., 2002; Akyol and Kara, 2003; Aydın et al., 2005; Gökçe et al., 2005; Ertosluk, 2006; Yazıcı et al., 2006; Soykan et al., 2006; Begburs and Kebapçıoğlu, 2007; Ünlüoğlu et al., 2008; Bakır and Evirgen, 2010; Eryaşar, 2011; Anonymus, 2020) and were studied to determine some biological parameters in İzmir Province (Sağlam et al., 2018).

Population dynamics of mantis shrimp were investigated by Abello and Martin (1993), Righini and Baino (1996), Froglia (1996), Mannini and Massa (2000), Placenti (2005), Ragonese et al. (2012), Mili et al. (2013), Vila et al. (2013), and Kampouris et al. (2018).

Squilla mantis has economic value for Mediterranean countries. It is fished with shrimp nets as a discard species, and its income to the Turkish economy is 51.629.350 Liras (Anonymus, 2017). Growth and reproduction characteristics are necessary to be determined for the conservation of spot-tail mantis populations and sustainable fisheries. Neverthless, there are no publications related to population parameters of *S. mantis* in Turkey directly, except for the investigation carried out in İzmir Bay (Erdoğan Sağlam et al., 2018). Therefore, this study aimed to determine some biological data related to the spot-tail mantis shrimp resources in the northern Aegean Sea of Turkey. The information to be obtained from this study will be useful in monitoring and comparing the changes that may occur in Edremit Bay year by year and even in the planning of fishing strategies.

Material and Methods

A total of 627 *Squilla mantis* were caught with the commercial trawl vessel "Salih Reis" (9.5 m long, 115 hp) at a depth of 40 – 60 m. from Küçükkuyu in Edremit Bay, northern Aegean Sea. The haul duration was about 15 min and the boat speed was 2 mph. The trawl was equipped with a 40 mm stretched mesh at the cod-end. The sampling period was between the years of September 2014 and April 2015 (26º57'-26º34'E and 39º 17'-39º34' N) (Figures 1, 2). Because of trawl bans in Edremit Bay, sampling could not be done between May and August.

Figure 1. General morphology of *Squilla mantis* (Scale is 1 cm; Original photo by Sarıgöl)

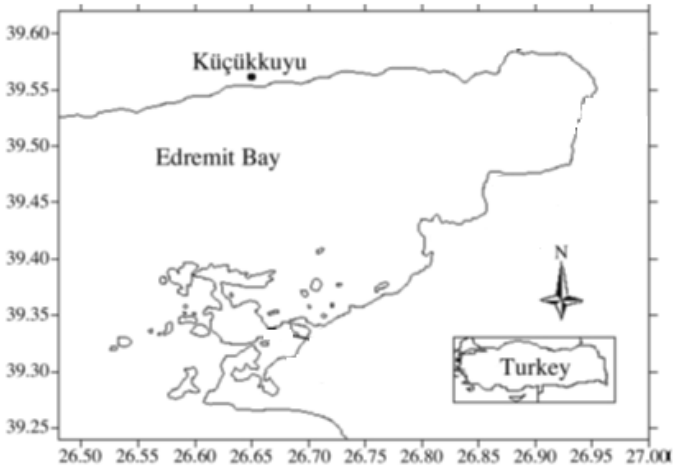

Figure 2. Map of Edremit Bay

Specimens were transported to the laboratory of Balikesir University, Faculty of Science and Arts, Department of Biology) in iced styrofoam boxes. The identification of the species was carried out according to Vacelet (1987) and Bisby et al. (2005). Sex of *S. mantis* is easily identified by the presence of a pair of copulatory organs arising from the base of the third pair of periopods corresponding to the 8th thoracic segment in the male and by the presence of the genital plate on the 6th thoracic segment sternite in the female (Abello and Martin, 1993; Wortham-Neal, 2002). The sex ratio is defined as the proportion of each sex, determined by macroscopic observation of gonads in a given population. The principal hypothesis supposes that there is equal sex ratio. This was evaluated with a chi-square test (χ^2). For each specimen, the total length (TL) was measured from rostrum to the the end of telson and the length of carapace from rostrum to the end of carapace with a caliper approximately to the nearest mm and the total weight (TW) to 0.1 g.

The age of specimens was determined using length-frequency data analyses (ELEFAN) using the Bhattacharya method in FISAT software (Gayanilo et al., 1989; Sparre and Venema, 1992). Growth was examined according to length and weight. For the estimation of individual growth rate, the von Bertalanffy growth equation for length was used: $Lt = L_\infty [1–e^{-k(t–to)}]$, where *Lt* is the total length at age *t*, *L*∞ the asymptotic total length, *k* is growth curvature parameter, and t_o the theoretical age when fish would have been at zero total length. The growth performance index (φ', phiprime) was employed to compare growth rates, with the formula: $\varphi' = \text{Log}k + 2\text{log}L_\infty$ (Munro and Pauly, 1989). Length –weight, carapace length–weight, and total length–carapace length relationships were derived as $W = a*TL^b$, $W = a*CL^b$ and CL = b*TL-a, respectively, in which the parameters of 'a' and 'b' were calculated by the least squares method. W, TL and CL are mentioned for total length and weight, and carapace length (Ricker, 1975).

For estimation of the spawning period, a gonadosomatic index was used, where GW is the gonad weight and W is the total weight (GSI = GW/W*100) (Daniel, 1989; Avşar, 2016).

The total instantaneous mortality (Z) was calculated by the linearized catch curve using fish captured with a multimesh gillnet. The natural mortality coefficient (M) was estimated from Pauly's tentative formula (Pauly, 1984): Log (M) = -0.0066-0.279log(L∞)+0.6543log(K)+0.4634 log (T), where T is the water average annual temperature of fish habitat. In this study, T was 18.5 ºC. Fishing mortality coefficient (F) was calculated using the below formula: Z = M + F, and the exploitation rate was calculated using the formula: E = F/F+M (Sparre and Venema, 1992). All descriptive statistics and graphs were calculated and prepared by Microsoft Excel and SPSS 18.

Results

Total length, carapace length and weight frequency distribution

The total lengths varied from 9.2 to 20.8 cm, while the carapace lengths ranged from 2.0 to 5.4 cm, respectively (Figures 3, 4). Weights ranged from 6.5 to 78.0 g for all individuals (Figure 5).

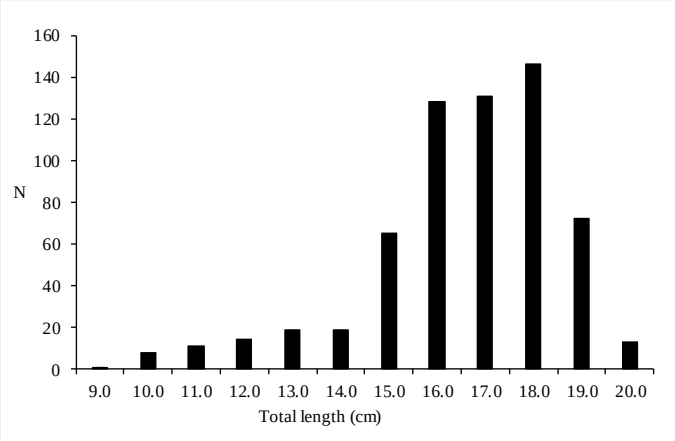

Figure 3. Total length frequence diagram of all *Squilla mantis* population from Edremit Bay.

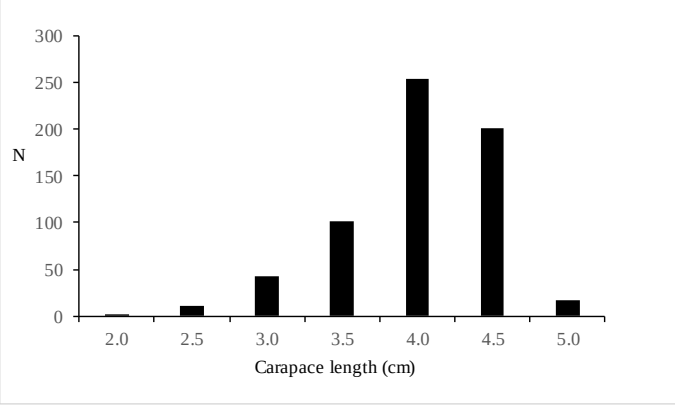

Figure 4. Carapace length frequence diagram of all *Squilla mantis* population from Edremit Bay.

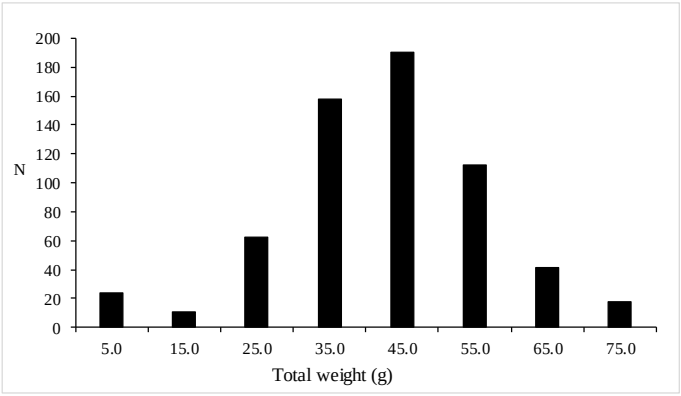

Figure 5. Weight frequence diagram of all *Squilla mantis* population from Edremit Bay.

Length–weight relationships

The total length-weight relationship was derived as W = 0.0106*$TL^{2.95}$ for both sexes (R^2 = 0.95). The relationship between total length-carapace was found to be CL = 0.3735*$TL^{0.86}$ (R^2 = 0.80) while the relationship between total carapace –weight was found to W = 0.7507*$CL^{2.84}$ (R^2 = 0.980). There is also a strong correlation between the total length and weight of *S.-mantis,* as shown by R^2 = 0.94 in Figures 6-8.

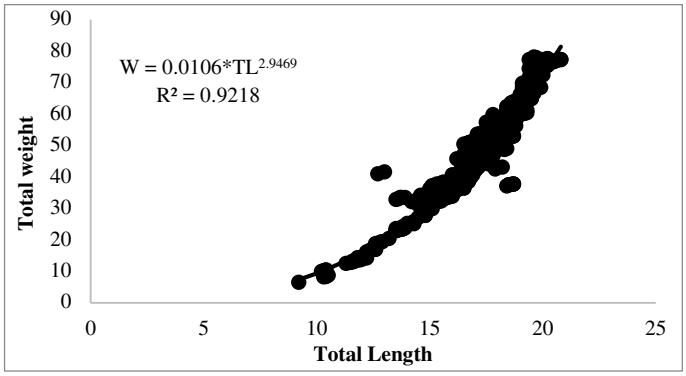

Figure 6. Total length and weight relationship of all *Squilla mantis* population from Edremit Bay.

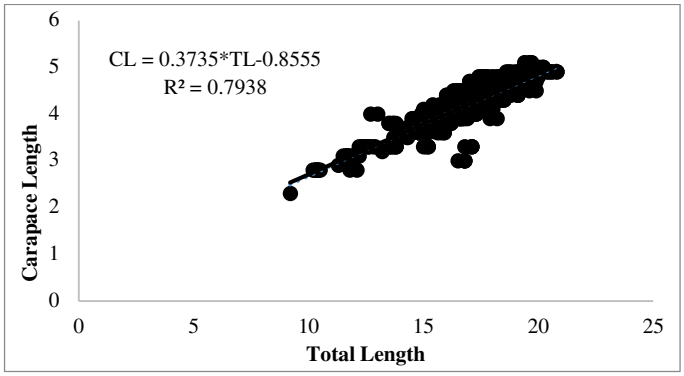

Figure 7. Total length and carapace relationship of all *Squilla mantis* population from Edremit Bay.

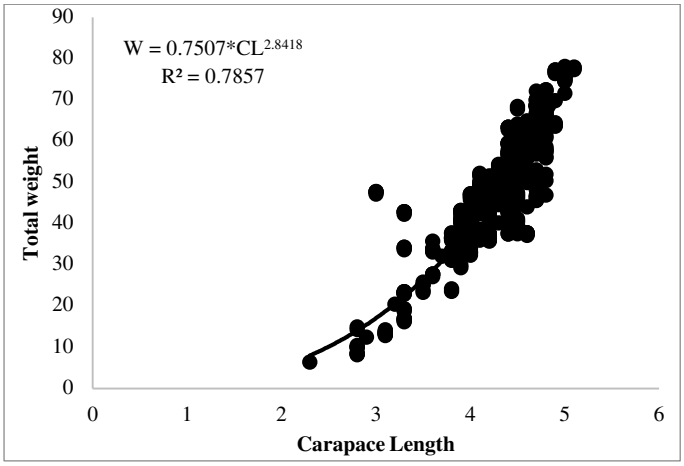

Figure 8. Total carapace and weight relationship of all *Squilla mantis* population from Edremit Bay.

Age composition and growth and sex ratio

Estimates of age and growth were obtained using Bhattacharya's length frequency distribution assortment method with the determination of the von Bertalanfy growth parameters. The length frequency distribution of *S. mantis* and age groups is presented in Figure 9. The age of captured spotail mantis ranged between 1 and 4, the fourth year class was dominant, and it can be stated that the population consisted of elder individuals. The mean total lengths for different age groups are shown in Table 1.

Table 1. Mean lengths at age (year) of *Squilla mantis* determined from Bhattacharya's method of separating length frequencies distribution.

Ages	Mean total length (cm)	Standard deviation	Population	Separation index
1	9.75	0.36	8.36	n.a
2	12.16	0.86	36.01	2.24
3	15.29	0.58	104.89	2.26
4	17.67	1.22	469.46	2.07

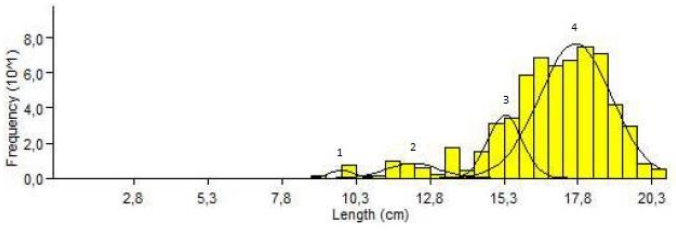

Figure 9. Age group composition of *Squilla mantis* from Edremit Bay using total length frequencies (Bhattacharya's Method).

During this study, a total of 627 spot-tail mantis shrimps were sampled, of which 404 (64.4%) were females and 223 (35.57%) were males. The population significantly ($\chi 2 = 0.193$, $p < 0.05$) diverts from the theoretical 1:1, and females are dominant in a 1.81:1 ratio (Figure10).

The predictive von Bertalanffy growth parameters for *S. mantis* were L∞ (21.64 cm), K (0.18), and t_o (-1.03 year), while the growth performance index (Φ) was 1.92 (Figure 11). and the instantaneous natural mortality (Z/year) was estimated as 0.67, the environmental average temperature for Edremit Bay (18.5 ^oC) was used to compute the natural mortality (M) of 0.47, and the instantaneous fishing mortality (F) was 0.20 (Pauly, 1984). The exploitation rate was 0.30. This showed that the spot-tail population was not exploited.

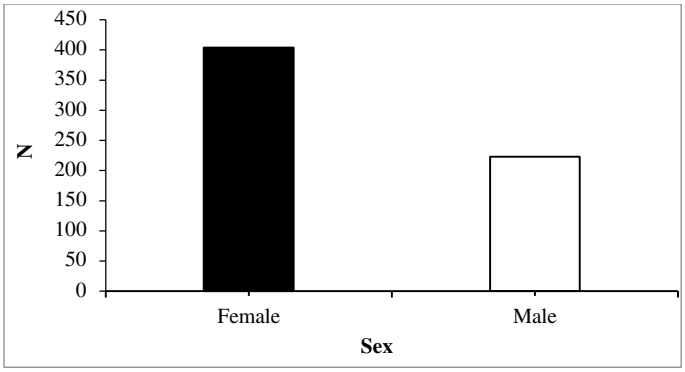

Figure 10. Sex ratio of all *Squilla mantis* population from Edremit Bay.

Discussion

The mean total length (Lt), carapace length (Lc), and mean weight of 627 *S. mantis* specimens are shown in Table 2. Differences in morphometric value may be attributed to bio-ecological aspects of the regions, especially temperature and food.

In this study, the male: female ratio was found to be 1:1.81. However, male:female ratios were defined as 1:1.12 by Mili et al. (2011), 1:1.33 by Ragonese et al. (2012), 1:1.42 by Erdoğan Sağlam et al. (2018), 1:1.31 by Kampouris et al. (2018). In these studies, no statistically significant difference was found between sex-ratios, except for the values estimated in Edremit Bay and Thermaikos Gulf of the northern Aegean Sea.

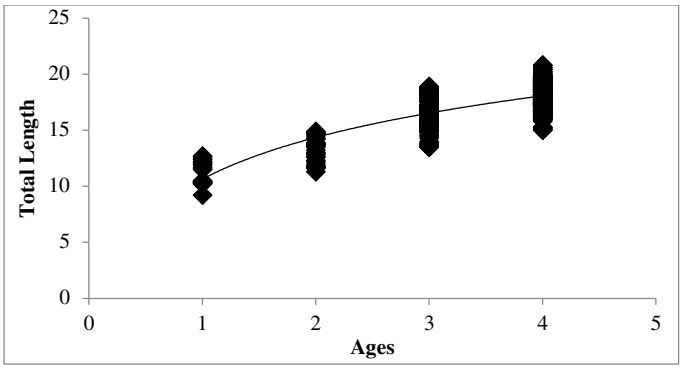

Figure 11. Age-length of all *Squilla mantis* population from Edremit Bay.

Table 2. Mean total length (cm), carapace length (cm) and total weight (g) of *Squilla mantis* in relevant literature

Sex	Mean total length	Carapace length	Weight (g)	Area	References
F	13.28±0.2 (9.5-16.3)	3.08±0.05 (2.25-3.8)	26.98±1.16 (9.68-50.5)	Algeria Coast	Kennouche and Kacimi (2021)
M	13.71±0.24 (9.5-17.3)	3.26±0.06 (2.35-4.15)	31.56±1.57 (8.88-61.56)	Algeria Coast	Kennouche and Kacimi (2021)
F+M	13.39±0.16 (6-18.5)	2.99±0.04 (2.35-4.5)	29.18±0.99 (8.88-61.56)	Algeria Coast	Kennouche and Kacimi (2021)
F	12.94 + 0.09 (5.60-18.50)	3.11 + 0.02 (1.10-4.50)	24.47 + 0.51 (1.60-72.00)	İzmir Bay	Erdoğan Sağlam et al. (2018)
M	12.05 + 0.10 (6.50-18.20)	2.90 + 0.02 (1.50-4.40)	18.84 + 0.47 (2.70-51.70)	İzmir Bay	Erdoğan Sağlam et al. (2018)
F+M	12.57 + 0.07 (5.60-18.50)	3.02 + 0.02 (1.10-4.50)	22.14 + 0.37 (1.60-72.00)	İzmir Bay	Erdoğan Sağlam et al. (2018)
F	-	3.83 ± 0.64 (2.07-5.50)	32.47 ± 15.66 (3.5-78.0)	North-west Aegean Sea	Kampouris et al. (2018)
M		4.07 ± 0.54 (2.23-5.68)	38.62 ± 14.28 (5.0-86.0)	North-west Aegean Sea	Kampouris et al. (2018)
Combined sex		3.93± 6.12 (2.07-5.68)	35.13 ± 15.37 (3.5-86.0)	North-west Aegean Sea	Kampouris et al. (2018)
F (n = 404)	16.96±2.01 (10.0-20.8)	4.21±0.40 (2.5-5.40)	46.23±0.85 (8.21-77.92)	North Aegean Sea (Edremit Bay)	This study
M (n = 223)	17.17±1.89 (9.2-20.2)	4.27±0.40 (2.0-5.40)	48.55±0.77 (6.5-78.0)	North Aegean Sea (Edremit Bay)	This study
Combined sex (n = 627)	17.04±1.8 (9.2-20.8)	4.25±0.38 (2.0-5.40)	47.04±0.75 (6.5-78.0)	North Aegean Sea (Edremit Bay)	This study

The length-weight relationship is very useful for fisheries research as it allows the easy conversion of length into weight and vice versa. The same equation is useful for the application of stock assessment models and for the comparison of geographical regions (Petrakis and Stergio 1995; Moutopoulos and Stergiou 2002; Froese, 2006). The R^2 was estimated at 0.92, indicating a high degree of positive relationship between length and weight of the population in Edremit Bay, with isometric growth (b = 2.95). Froglia (1996) found positive allometric growth for females and males (b = 3.04). Mili et al. (2011) studied off the Tunisian coasts (Gulf of Tunis, Gulf of Hammamet, and Gulf of Gabes) and calculated the total length-weight relationship (R^2 = 0.95) and for both sexes (b = 3.16), showing positive allometric growth. Mili et al. (2011) defined a strong total length-weight relationship (R^2 = 0.96) and for both sexes (b = 3.14, positive allometric growth). While Ragonese et al. (2012) presented a total length-weight relationship (R^2 = 0.97) and found positive allometric growth in females (b = 3.01) and males (b = 3.03), our finding is in harmony with that mentioned by Erdoğan Sağlam et al. (2018). The value b in fish differs according to species, sex, age, seasons, feeding, time of year, stage of maturity, growth increment or break in growth, fishing time, and vessels (Nikolsky, 1980; Froese, 2006). Growth patterns of aquatic biota in general can be caused by overfishing, biological competition, and/or predator-prey relationships (Mili et al., 2011).

In this study, GSI values were estimated over an 8-month period (Figure 12). Erdoğan Sağlam et al. (2018), Mili et al. (2011), and Carbonara et al. (2013) studied GSI over a 7, 12, and 24-month period, respectively, with the highest GSI values in spring. The spawning period observed in Edremit Bay is comparable with the findings in other Mediterranean areas (Maynou et al., 2004; Mili et al., 2011; Carbonara et al., 2013; Erdoğan Sağlam et al., 2018).

In terms of growth performances, the obtained asymptotic total length (TL_∞) values are not in accordance with those calculated by Froglia (1996) and Erdoğan Sağlam et al. (2018). The comparison of the brody growth coefficient (k) shows that the coefficient obtained in this study is lower than the coefficient on the southern coasts of Sicily and the Adriatic Sea. The first age values (t_0) have lower values for the Adriatic Sea, Gulf of Tunisia, and Aegean Sea. In this study, it is observed that asymptotic total length is higher than in other studies made in the Mediterranean Sea, except for the Central Adriatic Sea (Table 3, 4). This difference can be explained by the different environmental conditions such as temperature, salinity, food supply or fishing pressure (Erdoğan Sağlam et al., 2018).

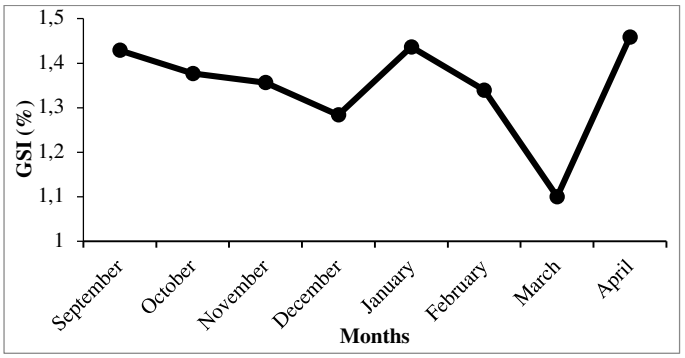

Figure 12. Seasonal variations in gonadosomatic index (GSI) of all *Squilla mantis* population from Edremit Bay.

In the Bhattacharya analysis, 1–4 age groups were detected. These results indicate that *S. mantis* can be considered a fast-growing species. The relative growth occurs quickly at a 2–3 age interval (Table 1). While in the southern coasts of Sicily, 1–3 ages were found for female and male samples (Ragonese et al., 2012), 0–2 ages and 0–3 ages were estimated for female and male samples in Tunisian coasts, İzmir Province, and Algeria, respectively (Mili et al., 2013; Erdoğan Sağlam et al., 2018; Kennouche and Kacimi, 2021).

The instantaneous mortality, fishing mortality, natural mortality, and exploitation rates of the previous studies are given in Table 5. Fishing mortality rates are lower than those estimated in other regions because *S. mantis* is considered a by-catch species in Edremit Bay.

The value of the exploitation rate (E) obtained in the present study (0.30) was lower than the optimal value of E = 0.50. (Pauly, 1994), which is in line with the catches actually observed in the field (under-exploited stock).

Conclusions

Squalia mantis which is caught as bycatch and discarded by commercial trawl and gillnet fisheries (Eryaşar, 2011). Utilisation of by-catch resources is strictly necessary, as they form a significant proportion of marine landings (Clucas, 1997). Although mantis shrimp can be used as a source of high quality protein, energy, and minerals for human consumption (Keshk and Emara, 2018), it has little commercial importance in Turkish markets. This may be attributed to its unknown nutritional value and its rarity in Turkey.

The fishery for *S. mantis* is not specifically regulated. It belongs to the general multi-species trawl fishery practised on continental shelves in the Mediterranean (Maynou et al., 2005), with seasonal changes in target species. Conversely, the use of heavy trawling gear, which damages the muddy bottom where *Squilla mantis* lives, can be a negative factor that hinders the conservation of this species.

For better management of *S. mantis* fisheries, it is important to improve the information base on this species (catches and landings, effort, prices), and monitoring abundance and population parameters.

Table 3. Spawning seasons of *Squilla mantis* at various localities according to the present and previous studies.

Reference	Locality	Months											
		J	F	M	A	M	J	J	A	S	O	N	D
Maynou et al. (2004)	Mediterranean												
Mili et al. (2011)	Mediterranean												
Carbonara et al. (2013)	Mediterranean												
Erdoğan Sağlam et al. (2018)	İzmir Bay												
This study	Edremit Bay												

Table 4. Some population parameters of *Squilla mantis* in the relevant literature.

Researchers	Sex	N	TL_{∞} (cm)	k	t_o	Locality
Abello and Martin (1993)	F	1768	20.0	1.30	-	Ebro Delta
Righini and Baino (1996)	F		22.0	1.45	-	Liguarian Sea
Froglia (1996)	F+M		41.5	0.49	-0.52	Central Adriatic Sea
Ragonese et al. (2012)	F+M	484	19.0	0.41	-0.52	Southern coasts of Sicily
Mili et al. (2013)	F	1564	17.9	1.44	-0.57	Gulf of Tunusia
Erdoğan Sağlam et al. (2018)		936	19.7	0.50	-0.37	Aegean Sea
Kennouche and Kacimi (2021)	F+M		19.0	0.48	-0.66	Algeriars Region
This study	F+M	627	21.6	0.18	-1.03	Edremit Bay

Table 5. Mortality rates of *Squilla mantis* in the relevant literature.

Researchers	Z	M	F	E	Locality
Froglia (1996)	2.89	1	1.89		Central Adriatic Sea
Ragonese et al. (2012)	0.98				Southern coasts of Sicily
Mili et al. (2013)					Gulf of Tunusia
Erdoğan Sağlam et al. (2018)	1.90	0.74	1.16		Aegean Sea
Kennouche and Kacimi, 2021	1.32	0.95	-		Algeriars Region
This study	0.67	0.47	0.20	0.30	Edremit Bay

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical Approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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References

Abelló, P., & Martín, P. (1993). Fishery dynamics of the mantis shrimp *Squilla mantis* (Crustacea: Decapoda) population off the Ebro Delta (northwestern Mediterranean). *Fisheries Research,* 16, 131-145.

Acarlı, D., Kale, S., & Çakır, K. (2022). Gökçeada Kıyılarındaki (Kuzey Ege Denizi, Türkiye) Trol Balıkçılığında Iskarta, Hedef Dışı ve Hedef Av İçin Birim Çabadaki Av Miktarı. *KSU Journal of Agricultural Natures*, 25(6), 1489-1501.

Ahyong, S., Boyko, C. B., Bailly, N., Bernot, J., Bieler, R., …. & Zullini, A. (2018). World Register of Marine Species. Available from https://www.marinespecies.org at VLIZ. Accessed 2023-06-01. doi:10.14284/170

Akyol, O., & Kara, A. (2003). An investigation on the determination of catch compositions of the bottom trawling and beach-seining in the Bay of Izmir (Aegean Sea). *Ege Journal of Fisheries and Aquatic Sciences*, 20, 321–328.

Anonymus. (2011). *Globefish European price report- analysis and information on world fish trade*. Rome: Food and Agriculture Organization of the United Nations, Fishery Statistics, Ankara.

Anonymus. (2017). *Fisheries Sstatistics*. Retrieved from http://www.tuik.gov.tr.

Anonymus. (2020). *Fisheries Statistics Turkish Statistical Institute.* Ankara.

Avşar, D. (2016). *Fisheries Biology and Population Dynamics*, Çukurova University Publications (in Turkish).

Aydın, C., Gurbet, R., & Ulas, A. (2005). Catch composition and effects on fishing area of beam trawl. *Ege Journal of Fisheries and Aquatic Sciences,* 22, 39–42.

Bakır, K. C., & Evirgen, F. (2010). Crustacean species of Izmir Bay. *Ege Journal of Fish and Aquatic Sciences*, 27, 79–90.

Başusta, N., Kumlu, M., Gökçe, M. A., & Göçer, M. (2002). Seasonal change and productivity index of species trawled in Yumurtalık Bay. *Ege Journal of Fisheries and Aquatic Sciences,* 19, 29–34.

Begburs, A., & Kebapçıoğlu, T. (2007). An investigation on catch composition of bottom trammel nets used in Antalya Boğazkent. *Ege Journal of Fisheries and Aquatic Sciences*, 24, 283–286.

Bilecik, N. (1989). *The culture of mussel* (in Turkish). Bodrum, Tarım Orman ve Köyişleri Bakanlığı Su Ürünleri Araştırma Enstitüsü Müdürlüğü, Seri A, Yayın No 2.

Bisby, F. A., Ruggiero, M. A., Wilson, K. L., Cachuela-Palacio, M., Kimani, S. W., Roskov, Y R., Soulier-Perkins, A., & van Hertum, J. (2005). Species 2000 & ITIS Catalogue of Life: 2005 Annual Checklist. CD-ROM; Species 2000: U.K. Reading.

Bozkurt, Ö. (2010). *Saros ve Gökova Körfezlerinde Trol Av Kompozisyonu ve Karşılaştırması.* Yüksek Lisans Tezi. Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü, İzmir.

Carbonara, P., Casciaro, L., Gaudio, P., Palmisano, M., Zupa, W., & Spedicato, M. T. (2013). Reproductive cycle and length at first maturity of *Squilla mantis* in The Central-Western Mediterranean. Proceedings of the of 44 Congresso della Società Italiana di Biologia Marina 14-16 Maggio, 14-16 Maggio, pp: 172-173, Roma.

Cheung, W. L., Watson, R., & Pauly, D. (2013). Signature of ocean warming in global fisheries catch. *Nature*, 497, 365-368. https://doi.org/10.1038/nature12156

Clucas, I. (1997). *A Study of the options for utilization of bycatch and discards from marine capture fisheries*. In: FAO fisheries circular. No. 928, Rome, Food and Agricultural Organization.

Demirsoy, A. (2005). *Basic principles of life*, II/invertebrata. Meteksan Publishing.

Deniel, C, 1989. *Modalites de l'ovogenese et de la ponte, fecondite du chinchard Trachurus trachurus du golfe de Gascogne.* Rapport final, IFREMER–UBO n 88.5.51.2003, 1–27.

Ertosluk, O. (2006). Beach-seine fishery in Urla Region, Izmir Bay (Aegean Sea). *Ege Journal of Fisheries and Aquatic Sciences*, 23, 435–439.

Eryaşar, A. R. (2011). Determination of catch and discard compositions in trawl fisheries in Mersin Bay (Eastern Mediterranean). MSc thesis. Mersin University, Graduate School of Natural and Applied Sciences Institutes, Fisheries, Turkey.

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

Froglia, C. (1996). Growth and behavior of *Squilla mantis* (mantis shrimp) in the Adriatic Sea. EU Study DG XIV/MED/93/016, Final Report.

Gayanilo, F. C., Jr Soriano, M., & Pauly, D. (1989). A draft guide to the Complete ELEFAN. ICLARM Software 2.

Gökçe, G., Metin, C., Aydın, I., & Bayramic, I. (2005). The common squid (*Loligo vulgaris* Lam. 1798) fishery with shrimp trammel net in Izmir Bay. *Ege Journal of Fisheries and Aquatic Sciences*, 22, 419–422.

Kampouris, E. T., Kouroupakis, E., Lazaridou, M., & Batjakas, E. (2018). Length-weight relationships of *Squilla mantis* (Linnaeus, 1758) (Crustacea, Stomatopoda, Squillidae) from Thermaikos Gulf, North-West Aegean Sea, Greece. *International Journal of Fisheries and Aquatic Studies*, 6(6), 241-246

Kennouche, H., & Kacimi, A. (2021). Growth estimation and Length–weight relationsiips of spottail mantis shrimp (*Squilla mantis*, Linneaus 1758) in the Algiers Region (southwest of Mediterranean Sea). *Applied Ecology and Environmental Research*, 19(6), 5083-5101.

Keshk, S A., & Emara, H. (2018). Utilization of whole mantis shrimp (*Squilla mantis*) as an edible fish powder for the preparation of value-added products. *Journal of Alexandria Science Exchange*. 39(4), 771-782. https://doi.org/10.26608/asejaiqjsae.2018.23689

Kocataş, A., Katağan, T., Uçal, O., & Benli, H. A. (1991). *Türkiye Karidesleri ve Karides Yetiştiriciliği*. T.C. Tarım ve Köy İşleri Bakanlığı, Su Ürünleri Araştırma Enstitüsü Müdürlüğü, 4, 1-144.

Mannini, P., & Massa, F. (2000). *Brief overview of Adriatic fisheries landing trends* (1972–97). Report of the First Meeting of the Adriamed Coordination Committee, 36–54.

Maynou, F., Abelló, P., & Sartor, P. (2005). A review of the fisheries biology of the mantis shrimp, *Squilla mantis* (L., 1758) (Stomatopoda, Squillidae) in the Mediterranean. *Crustaceana*, 77(9), 1081-1099.

Mili, S., Bouriga, N., Missaoui, H., & Jarboui, S. (2011). Morphometric, reproductive parameters and seasonal variations in fatty acid composition of the mantis shrimp *Squilla mantis* (Crustacea: Stomatopoda) in the Gulf of Gabes (Tunisia), *Journal of of Life Sci*ences, 5, 1058-1071.

Mili, S., Ennouri, R., Jarboui, O., & Missaou, H. (2013). Distribution and abundance of the mantis shrimp *Squilla mantis* (Crustacea: Stomatopoda) in Tunisian Waters: Gulfs of Tunis, Hammamet and Gabes. *Greener Journal of Life Sciences,* 1(1), 001-013.

Moutopoulos, D. K., & Stergiou, K. I. (2002). Length-Weight and Length-Length Relationships of Fish Species from Aegean Sea (Greece). *Journal of Applied Ichthylogy*, 18, 200-203.

Munro, J. L., & Pauly, D. (1989). A simple method for comparing the growth of fishes and invertebrates. *ICLARM Fishbyte*, 1(1), 5-6.

Nikolsky, G. (1980). *Theory of fish population dynamics as the biological background for rational exploitation and management of fishery resources*. Otto Koeltz Science Publishers.

Pauly, D, (1984). *Fish population dynamics in tropical waters: a manual for use with programmable calculators*. ICLARM Stud. Rev. (8).

Pauly, D, (1994). Review of J.C. Brêthes & R.N. O'Boyle (eds.) Méthodes d'évaluation des stocks halieutiques. *Archieves of Fishery and Marine Research*, 42(2), 205-206.

Petrakis, G., & Stergiou, K. I. (1995). Weight-length relationships for 33 fish species in Greek waters. *Fisheries Research*, 21(3-4), 465-469.

Placenti, V. (2005). *Demersal fishery in the Ligurian Sea. Bio-economic modelling of Mediterranean Fisheries*. BEMMFISH (Q5RS-2001 – 01533), Final Report of the Project, 229–240.

Ragonese, S., Morara, U., Canali, E., Pagliarino, E., & Bianchini, M. L. (2012). Abundance and biological traits of the spot-tail mantis shrimp, *Squilla mantis* (L., 1758) (Crustacea: Stomatopoda), off the southern coast of Sicily. *Cahiers de Biologie Marine*, 53, 485–493

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, Bulletin 191.

Righini, P., & Baino, R. (1996). Parametri popolazionistici della pannocchia (*Squilla mantis*, Crustacea, Stomatopoda). *Biology of Marine Mediterranean.* 3, 565–566.

Erdoğan Sağlam, N., Sağlam, Y. D., & Sağlam, C. (2018). A study on some population parameters of mantis shrimp (*Squilla mantis* L. 1758) in Izmir Bay (Aegean Sea). *Journal of the Marine Biological Association of the United Kingdom*, 98(4), 721-726. https://doi.org/10.1017/S0025315416001983.

Soykan, O., Kınacıgil, H. T., Tosunoğlu, Z. (2006). By-catch in Taşucu Bay (Eastern Mediterranean) shrimp trawls. *Ege Journal of Fisheries and Aquatic Sciences*, 23, 67–70.

Sparre, P., & Venama, S. C. (1992). *Introduction to Tropical Fish Stock Assessment*. Part 1. Manual, FAO Fisheries Technical Paper, 306. No. 1, Review 1, Rome, FAO.

Toğulga, M. (1997). Investigations of biology and population dynamics of mullet (*Mullus barbatus*, Linne 1758) in İzmir Bay. *Ege Journal of of Science*, 1, 175-194.

Torcu, H., & Aka, Z. (2000). A Study on the Fishes of Edremit Bay (Aegean Sea), *Turkish Journal of Zoology*, 24(1), 45-61.

Ünlüoğlu, A., Akalın, S., & Türker Çakır, D. (2008). A study on the demersal fisheries resources of Edremit Bay. *Ege Journal of Fisheries and Aquatic Sci*ences, 25, 63–69.

Vacelet, J. (1987). *Eponges*. In Fischer, W., M. L. Bauchot and M. Schneider. (1987). Fiches FAO d' identification des espèces pour les besoins de la pêche. (Revision 1). Méditerranée et mer Noire. Zone de pêche 37. Volume I. Végëtaux et Invertébrés. (Publication préparée par la FAO, résultant d'un accord entre la FAO et la Commission des Communautés européennes (Project GCP/INT/422/EEC) financëe conjointement par ces deux organisations. FAO, Rome, Italy, vol.1: 137-148.

Vila, Y., Sobrino, I., & Jimenez, M. P. (2013). Fishery and life history of spot-tail mantis shrimp, *squilla mantis* (Crustacea: Stomatopoda), in the Gulf of Cadiz (eastern central Atlantic). *Scientia Marina*, 77, 137–148.

Wortham-Neal, J. L. (2002). Reproductive morphology and biology of male and female mantis shrimp (Stomatopoda: Squillidae). *Journal Crustacean Biology,* 22(4), 728-741.

Yazıcı, M. F., Işmen, A., Altınagaç¸ U., & Ayaz, A. (2006). A study on the catch composition and bycatch of shrimp beam trawl in the Sea of Marmara. *Ege Journal of Fisheries and Aquatic Sciences*, 23, 269–275.