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Comparison of length-weight relationships of three economically important shrimp species in Iskenderun Bay, Northeastern Mediterranean

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A B S T R A C T

This study investigates the length-weight relationships (LWR) of three economically important shrimp species (*Farfantepenaeus aztecus*, *Penaeus semisulcatus*, and *Metapenaeus monoceros*) in İskenderun Bay, Northeastern Mediterranean, using data collected between October 2023 and November 2024 with trammel net. A total of 579 specimens were analyzed, with *F. aztecus* contributing the highest sample size (238 individuals), followed by *P. semisulcatus* (214) and *M. monoceros* (127). Carapace length (CL) and weight (W) measurements revealed interspecies differences. The average carapace length was 5.66±0.05 mm for *F. aztecus*, 6.63±0.06 mm for *P. semisulcatus*, and 5.08±0.06 mm for *M. monoceros*. Average weights were 32.81±1.12 g, 39.68±1.23 g, and 31.48±1.05 g, respectively. Growth patterns, determined by the parameter *b*, showed distinct gender differences. Females generally exhibited negative allometric growth, while males displayed either isometric or positive allometric growth, depending on the species. Statistically significant differences in growth types were observed, particularly in *M. monoceros* males ($p<0.05$). These results provide crucial insights into the population dynamics and ecological adaptations of shrimp in İskenderun Bay. The findings contribute to understanding the species' growth characteristics, supporting the development of sustainable fisheries management strategies in the region.

INTRODUCTION

Shrimp play a significant role in traditional small-scale fisheries worldwide, including in the Mediterranean and İskenderun Bay (Demirci et al., 2018). Their nutritional value and high economic importance make them a cornerstone of marine resources in these regions (Doğan et al., 2022; Uğurlu, 2025). Additionally, research on the catch composition and catch per unit of effort (CPUE) of penaeid shrimps in from İskenderun Bay provides insights into the species abundance and distribution, further underscoring their significance in local fisheries (Can et al., 2004). Shrimp species found in İskenderun Bay include *Penaeus semisulcatus* (Green Tiger Shrimp), *Farfantepenaeus aztecus* (Brown Shrimp), *Metapenaeus monoceros* (Speckled Shrimp), *Metapenaeus stebbingi*, *Parapenaeus longirostris* (Deepwater Pink Shrimp), *Melicertus kerathurus*, and *Metapenaeopsis japonicus* (Japanese Shrimp) (Can et al., 2004). The shrimp stocks in the region are influenced by the interaction between various migratory and native species, creating a dynamic structure that affects the biodiversity of the ecosystem and the sustainability of the stocks (Manaşırlı et al., 2018).

Length-weight relationship (LWR) studies are a necessary analytical tool for the conservation of marine ecosystems and fisheries resources, for understanding the biological characteristics of species and for developing sustainable fisheries policies. Such studies are expected to contribute to the implementation of more effective conservation and management strategies by providing valuable information to local fisheries management authorities and related institutions (Rodríguez-García, 2023). The length-weight relationship also provides information on the population dynamics of a species (Kalaycı et al., 2007). In shrimp, length measurements are typically conducted using the carapace length. This measurement is often used in fisheries research, as it provides a reliable parameter. For most shrimp species, the carapace length corresponds to approximately half of the total body length (Silva et al., 2021). The exponential mathematical function established between carapace length and shrimp weight is widely applied in shrimp biology studies due to its accuracy and simplicity.

Gender-specific differences in growth patterns have become an increasing focus in decapod research. Variability in LWRs between male and female shrimp is often attributed to reproductive investment, energy allocation, and morphological differences. Females typically allocate more energy to gonad development, egg production, and brooding, which can suppress somatic growth and result in negative allometric growth (Li et al., 2016). In contrast, males may exhibit isometric or even positive allometric growth, depending on ecological pressures and mating strategies, including investment in structures such as the appendix masculina or petasma (Herrera et al., 2018; Schram and von Vaupel Klein, 2023).

İskenderun Bay presents a unique ecological setting where both native and invasive shrimp species co-exist, and where environmental parameters such as temperature, salinity, and fishing intensity can fluctuate widely (Demirci et al., 2020; Akar et al., 2022; Demirhan et al., 2022). These factors, in combination with species interactions, may drive differences in growth dynamics not only between species but also between sexes within the same species (Manaşırlı et al., 2018; Can et al., 2021). For this reason, updated region-specific LWR data are essential to support accurate stock assessments, estimate biomass, and guide sustainable exploitation practices for key commercial species. In recent years, the most commonly caught species in traditional fisheries in İskenderun Bay include *P. semisulcatus*, *M. monoceros* and *F. aztecus* (Demirci et al., 2023). The Atlantic-origin *F. aztecus* was first recorded in Antalya Bay in 2010 and has since rapidly spread across the Mediterranean (Gökoğlu et al., 2010; Saoud and Davis, 2003; Anderson, 2014). *M. monoceros* and *P. semisulcatus* are commercially valuable species in the eastern Mediterranean, but its population has declined due to overfishing (Bayhan, 2023; Can et al., 2021). İskenderun Bay is a critical area for studying the population structures of these species and developing sustainable fisheries management strategies.

This study aims to investigate the length-weight relationships of economically significant penaeid shrimp species (*P. semisulcatus*, *M. monoceros*, and *F. aztecus*) in İskenderun Bay, providing updated insights into their growth patterns and biological characteristics. What distinguishes this study from previous research is its emphasis on evaluating potential differences in growth parameters across different years, as well as assessing variations in nutritional status among species. Incorporating these aspects will enhance our understanding of temporal and ecological influences on shrimp populations, thereby supporting science-based fisheries management strategies and the sustainable utilization of regional marine resources. By highlighting interannual variability and nutritional conditions, this study aims to offer a more comprehensive perspective on shrimp ecology, aiding fisheries management authorities in making informed decisions to ensure the long-term sustainability of local shrimp stocks.

MATERIAL AND METHODS

The study was conducted in İskenderun Bay, a region renowned for its small-scale fisheries along Türkiye's eastern Mediterranean coast. Samples were collected using trammel nets between October 2023 and November 2024 from multiple locations in İskenderun Bay, including Arsuz, Dörtyol, Gölovası, İskenderun, Karataş, Konacık, and Yumurtalık. A total of 579 shrimp samples were obtained through routine fishing operations using standardized trammel nets deployed consistently across all sampling sites. The use of trammel nets ensured the unbiased capture of shrimp species, facilitating accurate comparisons of numerical abundance among the studied species. Based on the samples collected, *F. aztecus* emerged as the numerically most abundant species, followed by *P. semisulcatus* and *M. monoceros*.

Figure 1. Distribution of fishing shelters in Iskenderun Bay

The distinction between male and female in shrimps is made as follows. The female reproductive organ is called thelycum (egg-laying structure located in the lower abdomen), and the male reproductive organ is called petesma (mating organ found near the pleopods) (Schram, and von Vaupel Klein, 2023). Thelycum is an opening in the lower abdomen where eggs are laid. This structure plays an important role in the mating and spawning processes of female shrimps. The male reproductive organ, known as the petasma, is located on the lower abdomen and near the fins. It serves as a mating organ. It is also characterized by a two-legged structure that protrudes prominently in male shrimps and separates them from female shrimps. In shrimp, weight is typically determined based on carapace length, which refers to the length of the shell covering the head part of the shrimp. This relationship is represented by the following equation: Total carapace lengths (CL) and weights (W) were measured to the nearest mm and g, respectively. The LWR of shrimp species (*F. aztecus, P. semisulcatus* and *M. monoceros*) was calculated with the parameters proposed by Ricker (1975), $W = a * CL^b$, using the log-transformation equation: $\log(W) = \log(a) + b \log(CL)$ where W is weight, L is length and a and b are constants.

where:

W represents the weight of the shrimp (in grams), measured with a precision of two decimal places, CL denotes the carapace length of the shrimp (in cm), measured using a digital caliper, a and b are constants specific to the shrimp species.

Estimation of b: The slope b is estimated from the linear regression analysis.

Standard Error of b: The standard error SE_b of the slope b is obtained from the regression analysis. This value quantifies the variability in the estimate of b.

Determination of Critical Value: The critical t-value is selected based on the desired confidence level (e.g., 95%) and the degrees of freedom.

Calculation of the Confidence Interval: The confidence interval for b is calculated using the formula: $b \pm t\ SE_b$, where:

b is the estimated slope, t is the critical t-value, SE_b is the standard error of the slope.

Interpretation: The confidence interval provides the range within which the true value of b lies at the specified confidence level. This range is used to classify the growth type as isometric, negative allometric, or positive allometric based on whether the interval includes, lies below, or lies above the theoretical value of b=3.

RESULTS

The present study reports the length-weight relationships (LWR) of three shrimp species *F. aztecus, P. semisulcatus,* and *M. monoceros* based on 579 specimens collected between October 2023 and November 2024 from various locations in İskenderun Bay, including Arsuz, Dörtyol, Gölovası, İskenderun, Pirinçlik, Karataş, Konacık, and Yumurtalık.

According to the updated statistical analysis, significant differences in both length and weight were found between male and female individuals for all three shrimp species (p=0.05). In *F. aztecus*, based on 149 males and 89 females, highly significant differences were observed in carapace length and weight. Similarly, in *M. monoceros*, with 62 males and 65 females analyzed, both length and weight differed significantly between sexes. For *P. semisulcatus*, the analysis of 107 males and 107 females also revealed statistically significant differences in length and weight. These findings clearly indicate that male and female individuals exhibit distinct biometric characteristics across all species, supporting the necessity of analyzing data separately by sex to ensure accurate biological interpretation.

The data reveals the carapace length and weight statistics for three shrimp species. *F. aztecus* has the highest total number of individuals (238), with an average carapace length of 5.66 mm (ranging from 4.87 mm to 7.71 mm) and an average weight of 32.81 g (minimum 20 g, maximum 80.1 g). *M. monoceros* is represented by 127 individuals, showing the smallest average carapace length of 5.08 mm (range: 3.40 mm to 5.90 mm) and an average weight of 31.48 g (minimum 10 g, maximum 50.9 g). *P. semisulcatus* includes 214 individuals and exhibits the largest average carapace length of 6.63 mm (range: 4.74 mm to 7.56 mm) and the highest average weight of 39.68 g (minimum 15 g, maximum 77.3 g). These figures highlight interspecies differences in size and weight distribution (Table 1).

Table 1. Range and mean values for carapace length and weight of F. *aztecus, P. semisulcatus*, and *M. monoceros* in the İskenderun Bay of North East Mediterranean, 2023-2024.

Species	Number			Carapace Length (mm)			Weight (g)		
	Total	Male	Female	Average	Min	Max	Average	Min.	Max.
F. aztecus	238	149	89	5.66±0.05	4.87	7.71	32.81±1.12	20	80.1
M. monoceros	127	62	65	5.08±0.06	3.40	5.90	31.48±10.5	10	50.9
P. semisulcatus	214	107	97	6.63±0.06	4.74	7.56	39.68±1.23	15	77.3

Table 2 presents data on the relationship between weight and carapace length for three different species (*F. aztecus, M. monoceros*, and *P. semisulcatus*) in male and female individuals. The parameters "a" and "b" were provided, along with the growth type. In *F. aztecus*, negative allometric growth was observed for females (b=2.68±0.07), while isometric growth was identified for males (b=2.94±0.12), with the T-test result found to be not significant (p=0.606). For *M. monoceros*, negative allometric growth was recorded in females (b=2.68±0.74), whereas isometric growth was determined in males (b=3.09±0.26), with the T-test result deemed significant (p=0.004). In *P. semisulcatus*, isometric growth was observed in females (b=2.87±0.12), while positive allometric growth was detected in males (b= 3.31±0.1), and the T-test result was found to be significant (p=0) (Figure 2). These findings indicate that statistically significant differences were detected in certain species and between genders.

Table 2. Length-weight relationships of shrimp caught by gillnet fishing in İskenderun Bay

Species	Gender	a	b	T-Test p-value	Growth Type
F. aztecus	F	0.31	2.68 ± 0.07	0	A(-)
	M	0.19	2.94 ± 0.12	0.606	I
	F+M	0.19	2.94±0.039	0	A(-)
M. monoceros	F	0.65	2.68 ± 0.74	0.829	A(-)
	M	0.35	3.09 ± 0.26	0.004	I
	F+M	0.73	2.57 ±0.15	0	A(-)
P. semisulcatus	F	0.22	2.87 ± 0.12	0.145	I
	M	0.09	3.31 ± 0.1	0	A(+)
	F+M	0.11	3.25±0.06	0	A(+)

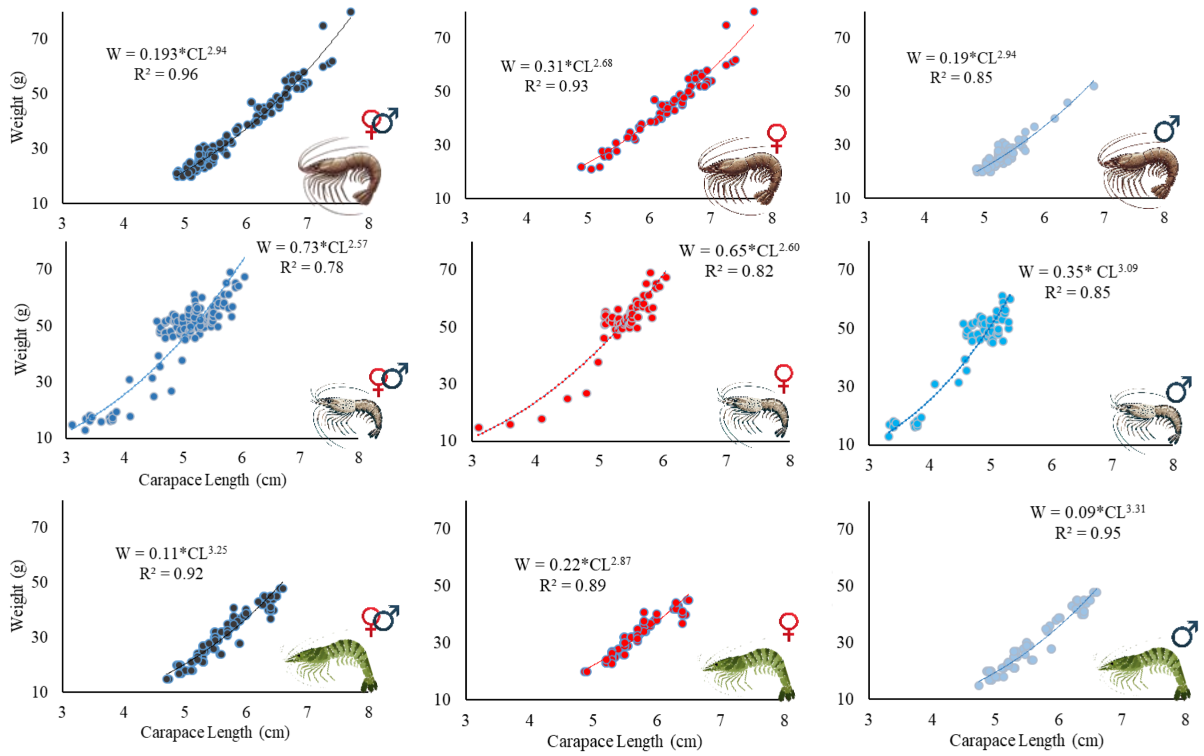

Figure 2. Length-weight relationship graphs of shrimp species caught by trammel net fishing in İskenderun Bay (:*F. aztecus* : *M. monoceros* : *P. semisulcatus*)

DISCUSSION

The dynamic and variable structure of shrimp stocks in the İskenderun Gulf is reflected in the sample sizes of this study. While *P. semisulcatus* is the most commonly caught species in the region, it has been replaced by *F. aztecus* in traditional shrimp fishing using trammel nets. The first length-weight data for *F. aztecus* in this fishing area have been presented through this research. The length-weight relationships of the *P. semisulcatus* and *M. monoceros* have also been revealed.

The notable finding in the study results is the difference in growth patterns between female and male individuals for each species. Females generally exhibit negative allometric growth, while males tend to show either isometric or positive allometric growth. The differences in length-weight relationships in female shrimp are influenced by factors such as reproductive biology, physiological requirements, and ecological adaptations. During the reproductive period, energy resources are allocated to egg production and maturation, which limits weight gain and results in negative allometric growth (Li, et al 2016). Additionally, the growth dynamics, and consequently the relationship between length and weight, are affected by the strategies females use to avoid predators and their habitat preferences. Metabolic rates and molting processes are also identified as significant factors determining the growth rates of females. Therefore, the negative allometric growth observed in female shrimp is attributed to the distribution of energy between reproduction and growth, as well as ecological adaptations. Furthermore, the larger size of females and the tendency of smaller individuals to exhibit isometric growth are considered expected characteristics of population dynamics (Karachle and Stergiou, 2012). The growth differences between male and female shrimp are explained by variations in reproductive strategies. Female shrimp grow larger, allowing them to carry and protect more eggs, which increases reproductive success. Their abdominal structures grow proportionally (isometric growth) to support egg carrying. In contrast, male shrimp remain smaller, conserving energy and avoiding predators more effectively. Additionally, male reproductive structures, such as the appendix masculina, exhibit positive allometric growth, enhancing their mating success. The mating strategy of males prioritizes agility and the ability to locate females rather than physical size (Herrera, et al., 2018).

Table 3 presents the length-weight relationships of some shrimp species in İskenderun Bay, compared across different habitats. Studies were conducted with various genders, locations, and specific length-weight parameters. The findings of this study reveal both intraspecific and inter-habitat differences when compared to other studies. For example, the species *P. semisulcatus* displays positive allometric growth in the Red Sea (Yemen) but shows isometric growth in İskenderun Bay. This result reflects the influence of habitat conditions on the growth parameters of shrimp (Mehanna, 2000; Mohamed and El-Aiatt, 2012; Abdul-Wahab, 2014; Hussein et al., 2021).

Table 3. Comparison of length-weight relationships of some shrimp species in Iskenderun Bay with different habitats

Species	Gender	a	b	Location	References
P. semisulcatus	F+M	0.344	3.43	Yemen, Red Sea	Abdul-Wahab (2014)
	F+M	0.0065	3.07	Suez Bay	Mehanna (2000)
	M	0.175	2.97	North Sinai, Egypt	Hussien et al. (2016)
	F	0.117	3.258		
	F	0.0003	2.87	Egypt	Mohamed and El-Aiatt (2012)
	M	0.0002	2.99		
	F	0.239	2.87	İskenderun Bay	This study
	M	0.087	3.31		
F. aztecus	F	0.0164	2.73	Türkiye	Anonymous (2024)
	M	0.009	2.97		
	M	0.781	2.84	United States	
	F	0.71	2.94		
	M	0.312	2.68	İskenderun Bay	This study
	F	0.191	2.94		
M. monoceros	F	0.00927	2.92	Saurashtra, India	Dineshbabu (2006)
	M	0.00357	3.29		
	F	0.00008	2.81	Kakinada, India	Rao (1988)
	M	0.00003	3.15		
	F	0.0001	2.78	Malindi-Ungwana Bay, Kenya	Kaka et al. (2019)
	M	0.0002	3.02		
	F	0.0135	2.78	İskenderun Bay, Türkiye	Manaşırlı (2014)
	M	0.006	2.85		
	M	0.35	3.09	İskenderun Bay, Türkiye	This study
	F	0.65	2.60		

The species *F. aztecus* demonstrates various growth tendencies across the United States and Türkiye, while in İskenderun Bay, females exhibit negative allometric (NA) growth, and males display isometric (I) growth. Particularly in the United States, studies have shown positive allometric growth in females. These differences may be explained by environmental factors, fishing pressure, and habitat conditions (Anonymous, 2024).

For *M. monoceros*, studies in India found "b" values around 2.95 for females and 3.15 for males, indicating a trend of positive allometric growth. In contrast, in İskenderun Bay, females showed negative allometric growth (NA), while males exhibited positive allometric growth. These observed growth patterns among species are thought to be associated with differences in sea temperature, food availability, and habitat structure (Can et al., 2021)

In the Malindi-Ungwana Bay, studies have shown that *Penaeus monodon*, *M. monoceros*, and *Fenneropenaeus indicus* exhibit positive allometric growth patterns. Specifically, *P. monodon* demonstrated higher b values during the Northeast Monsoon (NEM) season (b=3.53) and the Southeast Monsoon (SEM) season (b=3.71), indicating larger sizes during these periods. Conversely, *M. monoceros* displayed negative allometric growth during the SEM season with a b value of 2.59, while *F. indicus* showed positive allometric growth at station S5 during the SEM season with a b value of 3.46 (Kaka et al., 2019).

In the waters of Maharashtra, research on species such as *Penaeus merguiensis*, *M. monoceros*, *M. affinis*, *M. brevicornis*, *Parapeneopsis stylifera*, *P. sculptilis*, and *Solenocerra crassicornis* revealed significant differences in length-weight relationships between males and females. For instance, in *M. monoceros*, males had a b value of 2.9064, while females had a b value of 3.0730, indicating that females tend to reach larger sizes. These findings are important for fish stock assessments and biomass estimations (Mane et al., 2019).

In the Iko River Estuary of Nigeria, studies on species including *Penaeus atlantica*, *Penaeus kerathurus*, *Penaeus setiferus*, *P. sculptilis*, *P. monodon*, *Nematopalaemon hastatus*, and *Macrobrachium rosenbergii* showed significant positive correlations in length-weight relationships (r^2>0.5). The growth coefficient (b) values ranged from 2.102 to 3.574, indicating allometric growth patterns. Condition factor analyses revealed that females generally had higher K values than males, suggesting that heavier individuals of the same length were in better condition (Udoinyang et al., 2016).

CONCLUSION

This study provides insights into the length-weight relationships (b-values) of *F. aztecus*, *P. semisulcatus*, and *M. monoceros* in the İskenderun Bay ecosystem. Observed gender-based differences in growth patterns suggest varying energy allocation strategies, with females generally exhibiting negative allometric growth and males showing isometric or positive allometric growth. These findings may reflect the influence of reproductive biology and ecological roles on growth dynamics. Differences in b-values and size characteristics among species appear to be influenced by habitat conditions and growth strategies. *M. monoceros*, being naturally smaller, demonstrates lower carapace lengths and weights, which might align with its ecological adaptations. In contrast, *F. aztecus* is noted for its faster growth rates, potentially indicative of efficient energy use and adaptability to local conditions. Meanwhile, the relatively larger size of *P. semisulcatus* could reflect favorable habitat conditions or different ecological strategies. These results highlight the importance of continuous monitoring of growth parameters to better understand the ecological dynamics of shrimp populations in İskenderun Bay.

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Compliance with Ethical Standards

Authors' Contributions

AD: Design, Data collection, Data analysis, Writing

BFÖ: Investigation, Data collection, Data analysis,

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The authors declare that formal consent is not required for this type of study.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

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REFERENCES

Abdul-Wahab, M. M. (2014). Population dynamics of the shrimp *Penaeus semisulcatus* in the Yemeni Red Sea waters. *Iranian Journal of Fisheries Sciences*, *13*(3), 585-596.

Akar, Ö., Demirci, A., Şimşek, E., Mazlum, Y., & Demirci, S. (2022). Management of fishing ports on the financial performance of the Türkiye fishery sector; A case of fishing ports in Hatay province. *Journal of Anatolian Environmental and Animal Sciences*, *7*(3), 281-288. https://doi.org/10.35229/jaes.1117772

Al-Beak, A., Ahmed, M., Khaled, A., Hassan, M., & Yasser, M. (2024). Estimation of growth, population parameters, and exploitation rate of *Penaeus semisulcatus* (De Haan, 1844) in Bardawil Lagoon, North Sinai, Egypt. *Mediterranean Aquaculture Journal*, *10*(2), 36-43. https://doi.org/10.21608/maj.2024.334696

Anderson, A. N. (2014). Development of an alternative bait for the Louisiana commercial blue crab (*Callinectes sapidus*) fishery. [Ph. D. Thesis, Louisiana State University].

Anonymous (2024). Length-weight relationships of *Penaeus aztecus* Retrieved on 20.05.2025 from SeaLifeBase. https://www.sealifebase.se/PopDyn/LWRelationshipList.php?ID=14595andGenusName=PenaeusandSpeciesName=aztecusandfc=9

Bayhan, Y. K. (2023). Growth, reproduction and mortality rates of Green Tiger Prawn *Penaeus semisulcatus* De Haan, 1844 (Decapoda: Penaeidae) from the North-Eastern Mediterranean Coast of Turkey. *Acta Zoologica Bulgarica, 75*(3), 377-385

Bayhan, Y. K., Ünlüer, T., Özdöl, M., Ataoğlu, H., & Çiçek, E. (2023). Growth, reproduction, and mortality rates of *Metapenaeus monoceros* (Fabricius, 1798) in 1981-1982 from the north-eastern Mediterranean coasts of Turkey. *Cahiers de Biologie Marine, 64*, 115-124. https://doi.org/10.21411/CBMA.E6EDB8B2

Can, M. F., Mazlum, Y., Yılmaz, A. B., & Öksüz, A. (2021). A meta analysis on the heavy metal content of two shrimp species, *Penaeus semisulcatus* (de Hann, 1844) and *Metapenaeus monoceros* (Fabricius, 1798) from İskenderun Bay. *KSU Journal of Agriculture and Nature, 24*(4), 834-849. https://doi.org/10.18016/ksutarimdoga.vi.811212

Demirci, A., Demirci, S., & Şimşek, E. (2023). Determination of the relationship between total length and body width of two shrimp species for use in selective shrimp grids in trawl fishing in İskenderun Bay. *4th International Congress on Engineering and Life Science*, pp 113-118.

Demirci, A., Şimşek, E., Can, M. F., Akar, Ö., & Demirci, S. (2020). Has the pandemic (COVID-19) affected the fishery sector in regional scale? A case study on the fishery sector in Hatay province from Turkey. *Marine and Life Sciences, 2*(1), 13-17.

Demirci, A., Şimşek, E., Demirci, S., Akar, Ö., & Bayraktar, O. (2018). Direct analyze of different sorting grids effects on shrimp trawl selectivity; an experimental assessment with a flow channel. *International Congress on Engineering and Life Science*, pp 420-422.

Demirhan, S. A., Alkan, A., & Şimşek, E. (2020). Artificial reef application from the Iskenderun Bay, Northeastern Mediterranean, Turkey; an experimental study. *Sakarya University Journal of Science, 24*(1), 49-54. https://doi.org/10.16984/saufenbilder.527933

Dineshbabu, A. P. (2006). Length-weight relationship and growth of the speckled shrimp *Metapenaeus monoceros* off Saurashtra coast. *Journal of the Marine Biological Association of India*, *48*(2), 180-184.

Doerr, J. C., Liu, H., & Minello, T. J. (2016). Salinity selection by juvenile brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) in a gradient tank. *Estuaries and Coasts, 39*(3), 829-838. https://doi.org/10.1007/s12237-015-0019-3

Doğan, S., Duysak, Ö., Duysak, T., & Uğurlu, E. (2022). Oxidative stress parameters, metal accumulation and health risk assessment in Deep Water Rose Shrimp (*Parapenaeus longirostris*, H. Lucas 1846) in the Turkish Mediterranean Sea Coasts. *KSU Journal of Agriculture and Nature, 25*(4), 838-846. https://doi.org/10.18016/ksutarimdoga.vi.978862

Gökoğlu, M., Deval, M. C., Froglia, C., Kaya, Y., & Güven, O. (2010). An unexpected find of the atlantic shrimp, *Farfantepenaeus aztecus* (Ives, 1891) (Decapoda, Penaeidae) in Antalya Bay, Eastern Mediterranean Sea. *Crustaceana, 83*(12), 1531-1537.

Hepper, B. T. (1966). Measurement of carapace length and total length in the crawfish, *Palinurus vulgaris*. *ICES Journal of Marine Science, 30*(3), 316-323. https://doi.org/10.1093/icesjms/30.3.316

Herrera, D. R., Davanso, T. M., & Costa, R. C. (2018). Relative growth and morphological sexual maturity of the caridean shrimp *Nematopalaemon schmitti* (Decapoda: Caridea: Palaemonidae) in an upwelling region in the Western Atlantic. *Invertebrate Reproduction and Development, 62*(1), 56-62. https://doi.org/10.1080/07924259.2017.1398190

Hussien, M. S., El Ganainy, A. A., Abdel Hakim, N. F., Zaghloul, A. M., & Abdel Azim, A. (2016). Fisheries biology of the green tiger prawn (*Penaeus semisulcatus*) and peregrine shrimp (*Metapenaeus stebbingi*) from Bardawil lagoon, North Sinai, Egypt. *African Journal of Biological Sciences, 12*(1), 11-19.

Kaka, R. M., Jung'a, J. O., Badamana, M., Ruwa, R. K., & Karisa, H. C. (2019). Morphometric length-weight relationships of wild penaeid shrimps in Malindi-Ungwana Bay: Implications to aquaculture development in Kenya. *Egyptian Journal of Aquatic Research*, *45*(2), 167-173. https://doi.org/10.1016/j.ejar.2019.06.003

Kalaycı, F., Samsun, N., Bilgin, S., & Samsun, O. (2007). Length-weight relationship of 10 fish species caught by bottom trawl and midwater trawl from the Middle Black Sea, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences, 7*(1), 33-36.

Karachle, P. K., & Stergiou, K. I. (2012). Morphometrics and allometry in fishes. In Wahl, C. (Ed.) *Morphometrics*, InTech, pp. 65-86.

Li, Y., Zhou, F., Ma, Z., Huang, J., Jiang, S., Yang, Q., Li, T., & Qin, J. G. (2016). Length–weight relationship and condition factor of giant tiger shrimp, *Penaeus monodon* (Fabricius, 1798) from four breeding families. *SpringerPlus, 5*, 1279. https://doi.org/10.1186/s40064-016-2979-6

Manaşırlı, M. (2014). Population dynamics of the *Metapenaeus monoceros* (Fabricius, 1798) in North-eastern Mediterranean Sea. *Iranian Journal of Fisheries Sciences, 13*(4), 955-966.

Manaşırlı, M., Özyurt, C. E., Kıyağa, V. B., Avşar, D. (2018). The Growth Parameters of the Mediterranean Shrimp (*Penaeus kerathurus* Forskal, 1775) in the Iskenderun Bay. *Ecological Life Sciences, 13*(1), 15-26. https://doi.org/10.12739/NWSA.2018.13.1.5A0090

Mane, S., Sundaram, S., Hule, A., Sawant, M., and Deshmukh, V. D. (2019). Length weight relationship of commercially important penaeid prawns of Maharashtra, India. *International Research Journal of Science and Engineering, 7*(1), 35-40.

Mehanna, S. F. (2000). Population dynamics of *Penaeus semisulcatus* in the Gulf of Suez, Egypt. *Asian Fisheries Science, 13*, 127-137.

Mohamed, S., & El-Aiatt, A. (2012). Population dynamics and fisheries management of *Penaeus semisulcatus* exploited by shrimp trawl of Bardawil Lagoon, North Sinai, Egypt. *Egyptian Journal of Animal Production, 49*(Suppl. Issue), 185-191.

Özyurt, C. E., Taşlıel, A. S., Kiyağa, V. B., Akamca, E., and Büyükdeveci, F. (2009). Characteristics of shrimp catching with trammel nets in Iskenderun Bay. *Journal of FisheriesSciences.com, 3*(4), 310-317. https://doi.org/10.3153/jfscom.2009035

Rao, G. S. (1988). Length-weight relationship and other dimensional relationships of *Metapenaeus monoceros* from the Kakinada coast. *Indian Journal of Fisheries, 35*(3), 211-215.

Rodríguez-García, C., Castro-Gutiérrez, J., Domínguez-Bustos, Á. R., García-González, A., & Cabrera-Castro, R. (2023). Every fish counts: Challenging length–weight relationship bias in discards. *Fishes, 8*(5), 222. https://doi.org/10.3390/fishes8050222

Saoud, I. P., & Davis, D. A. (2003). Salinity tolerance of brown shrimp *Farfantepenaeus aztecus* as it relates to postlarval and juvenile survival, distribution, and growth in estuaries. *Estuaries, 26*(4), 970-974. https://doi.org/10.1007/BF02803355

Schram, F. R., & von Vaupel Klein, J. C. (Eds.). (2023). The natural history of the Crustacea: Reproduction. Springer. https://doi.org/10.1007/978-3-031-20966-6_6

Silva, A. R. D., Lopes, A. E. B., Grabowski, R. C., & Castilho, A. L. (2021). Weight/carapace length relationship and condition factor of the roughneck shrimp, *Rimapenaeus constrictus* (Stimpson, 1874), on the southeastern Brazilian coast. *Anais da Academia Brasileira de Ciências, 93*(2), e20190570. https://doi.org/10.1590/0001-3765202120190570

Udoinyang, E. P., Amali, O., Iheukwumere, C. C., & Ukpatu, J. E. (2016). Length-weight relationship and condition factor of seven shrimp species in the artisanal shrimp fishery of Iko river estuary, southeastern Nigeria. *International Journal of Fisheries and Aquatic Studies, 4*(2), 109-114.

Uğurlu, E. (2025). Utilizing mussel and shrimp shell waste for chitin and chitosan extraction: a pathway to eco-friendly bioplastics. *Biomass Conversion and Biorefinery*, https://doi.org/10.1007/s13399-025-06816-x