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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Expansion of the Distribution Range and Size of the Invasive Blue Crab on the Turkish Coast of the Black Sea

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Abstract: The blue crab *Callinectes sapidus* (Rathbun, 1896) is an endemic species with broad salinity tolerance specific to the Western Atlantic Ocean, including a wide distribution range extending to the Black Sea, including the coastal waters of Turkey. This study encompasses a monitoring effort where blue crab specimens were collected in a region stretching from Taskana Cape (Ünye, Ordu) to the Georgian border along the coast of the Black Sea in Turkey. The study period spans from 2017 to 2024. According to the analysis results, the carapace width of 16 blue crab samples ranged from 14.8 to 20.3 cm, with male individuals observed to have larger sizes compared to females. Notably, among the examined females, it was observed that two individuals carried eggs, supporting reproductive success in the region. Additionally, the study reports the discovery of the largest blue crab recorded so far on the Turkish Black Sea coast, with a carapace width of 20.3 cm and a weight of 565.1 g. A male specimen sampled from the Rize region indicates the expansion of the species distribution to the easternmost part of the Black Sea. These findings significantly contribute to our understanding of the distribution and size increase of blue crabs in the Black Sea. The presence of larger sizes in males and the occurrence of excessively large females suggests the potential existence of a successful adaptation and a self-sustaining population. Consequently, this study highlights the importance of a cautious approach in fisheries biology and ecosystem management, emphasizing that the blue crab could impact the Black Sea ecosystem as an invasive species. Thus, it contributes to providing information and conservation strategies.

Keywords: *Callinectes sapidus*, brachyuran, range expansion, maximum size record, Türkiye.

Karadeniz'in Türkiye Kıyılarında İstilacı Mavi Yengecin Yayılış Alanının ve Boyut Aralığının Genişlemesi

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Öz: Mavi yengeç (*Callinectes sapidus* Rathbun, 1896), Batı Atlantik Okyanusu'na özgü geniş tuzluluk toleransına sahip endemik bir türdür; Türkiye'nin kıyı suları da dahil olmak üzere Karadeniz'e kadar geniş bir yayılım alanına sahiptir. Bu çalışma, mavi yengeç örneklerinin, Türkiye'nin Karadeniz kıyısında, Taşkana Burnu'ndan (Ünye, Ordu) Gürcistan sınırına kadar uzanan bölgede toplandığı bir izleme çalışmasını içermektedir. Çalışma 2017 ila 2024 yılları arasındaki dönemi kapsamaktadır. Analiz sonuçlarına göre, 16 mavi yengeç örneğinin kabuk genişliği 14,8 ila 20,3 cm arasında değişmekte olup, erkek bireylerin dişilere göre daha büyük boyutlara sahip olduğunu gözlenmiştir. Özellikle, incelenen dişiler bireylerden ikisinin yumurta taşıdığı gözlemlenmiş ve bu durum bölgedeki üreme başarısını desteklemektedir. Ayrıca çalışma 20,3 cm kabuk genişliği ve 565,1 g ağırlığında birey ile Türkiye'nin Karadeniz kıyılarında şimdiye kadar kaydedilen en büyük mavi yengecin keşfini de rapor etmektedir. Rize bölgesinden örneklenen bir erkek birey, türün Karadeniz'in en doğu kısmına kadar yayılım alanının genişlediğini göstermektedir. Bulgular, mavi yengecin Karadeniz'deki dağılımı ve boyut artışına ilişkin anlayışımıza önemli katkılarda bulunmaktadır. Erkeklerde gözlemlenen daha büyük boyutlar ve aşırı iri dişilerin varlığı, başarılı adaptasyonu ve kendi kendini idame ettirebilen bir populasyonun potansiyel olarak varlığını düşündürmektedir. Sonuç olarak, mavi yengecin istilacı bir tür olarak Karadeniz ekosistemini etkileyebileceği ve bu nedenle balıkçılık biyolojisi ve ekosistem yönetimi açısından ihtiyatlı bir yaklaşımın önemini vurgulayan bu çalışma, bilgi sağlama ve koruma stratejilerine katkıda bulunmaktadır.

Anahtar Kelimeler: *Callinectes sapidus*, Brachyuran, coğrafi alan genişlemesi, maksimum boyut kaydı, Türkiye.

INTRODUCTION

The blue crab *Callinectes sapidus* (Rathbun, 1896), is originally indigenous to the western Atlantic Ocean (Nehring, 2011), distinguished by its euryhaline characteristics, enabling adaptation to both marine and brackish environments. Adult and juvenile blue crabs are commonly found in lagoons, estuaries, and coastal ecosystems (Epifanio, 2019). After mating, females migrate to shore to spawning. Larvae that switch to benthic life prefer brackish waters to complete the maturation phase (Kennedy & Cronin, 2007). The first record of the blue crab in Europe dates to the Atlantic coast of France in the early 1900s. The blue crab, which is thought to have entered Europe and Asia accidentally or deliberately, has rapidly expanded its habitat on both the Mediterranean and Black Sea coasts over time. Blue crab specimens have been reported in various regions, including the Mediterranean Sea, the Aegean Sea, the Marmara Sea, and the Black Sea (Zaitsev & Öztürk, 2001).

The first recorded appearance of blue crabs in the Turkish coastal waters of the Black Sea occurred on the western coast in 2013 (Yağlıoğlu et al., 2014). Ak et al. (2015) recorded the first occurrence of blue crabs in the southeastern most part of the Black Sea, specifically in Trabzon, Türkiye. Aydın (2017) reported the initial presence of two blue crab individuals, one female and one male, on the Central Black Sea coast. Subsequent hydraulic drainage studies conducted in the Black Sea by Ceylan (2020) indicated a gradual expansion of the blue crab species along the Turkish coast of the Black Sea. Based on phylogenetic similarities, Öztürk et al. (2020) reported that the current blue crab population in the Black Sea migrated from the Aegean Sea, establishing a thriving population. This study aims to document the discovery of the largest blue crab on the Black Sea coast from Türkiye, supplementing existing size records (Ak et al., 2014; Aydın, 2017; Ceylan, 2020; Gül et al., 2021). The significance of this finding lies in its contribution to our comprehension of the species' distribution and ecological role in the region, facilitating biodiversity monitoring and informing potential conservation strategies.

MATERIAL AND METHOD

The study area encompasses the Black Sea region from Taşkana Cape (Ünye, Ordu) to the Georgian border. Data were collected from blue crab individuals obtained through commercial fishing activities and experimental biodiversity surveys conducted between 2017 and 2024. The species identity of the captured specimen was determined following the methods outlined by Ogburn et al. (2011). To confirm the scientific name, SeaLifeBase (Palomares & Pauly, 2023) was referenced. External morphological measurements include carapace width (CW; spines included), and the carapace length (CL) measured by using a digital caliper (accuracy of 0.01 mm) by Bagheri et al. (2020) (Figure 1A, B). Sex identification was established through visual inspection of the specimen's abdomen shape, following the criteria defined by Van Engel (1990) (Figure 1C). The total wet weight (TW) of the sample was determined using a digital balance with an accuracy of 0.01 grams.

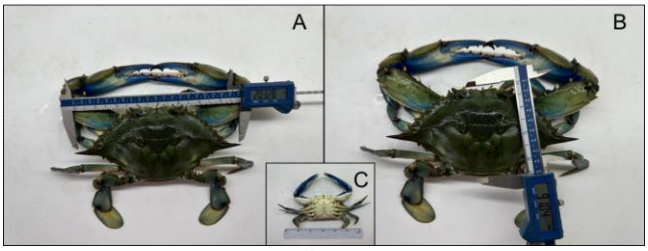

Figure 1. The male specimen (C) of blue crab with carapace width (A) and carapace length (B) measurements, sampled from the Black Sea coast on October 18, 2023.

The assessment of the size-weight relationship (LWR) employed Pauly's power equation: $W=a\times CW^{b}$. In this equation, '*a*' and '*b*' serve as regression parameters, signifying the intercept (initial growth coefficient) and slope (growth coefficient), respectively. The logarithmic form of this equation, $\ln(TW)=\ln a+b\ln(CW)$, is outlined by Ricker (1975). Subsequently, 95% confidence limits (*CI*) were calculated for parameters *'a'* and *'b'*, and the coefficient of determination (r^2) was employed to evaluate the correlation between TW and CW. Pauly's *t*-test was then conducted to determine if the *b*-value coefficient significantly deviated from 3 (Pauly, 1984), helping ascertain whether species growth is isometric or allometric (Sokal & Rohlf, 1969). Additionally, the calculation of Fulton's coefficient of condition factor (K) was performed using the formula $K=100[TW/(CW)^3]$ (Froese, 2006).

RESULTS AND DISCUSSION

A total of 16 blue crabs were sampled in this study, comprising seven females and nine males. The combined average CW for both sexes was determined to be 18.0 cm, accompanied by an average TW of 351.5 g. Notably, males exhibited a larger size, with an averaged 18.7 cm, compared to females (17.0 cm) (Table 1). The investigation further identified a male blue crab specimen with a noteworthy CW of 20.3 cm, captured on October 18, 2023, from the Black Sea coast in the Gulf of Fatsa (41°04'01"N − 37°29'34"E) during the commercial rapa whelk (*Rapana venosa*) fisheries. The specimen was captured at a depth of 12 meters using a beam trawl, composed of a frame (4 m length and 40 cm height) forming the general beam structure and a bag of 1.5 m in length behind it (mesh size 72 mm). Hitherto, this

individual stands as the largest ever recorded off the Turkish coast of the Black Sea. Comparative records of the size and weights recorded for blue crab species in coastal waters of the Black Sea are given in Table 2. The observed size ranges align with previously documented size ranges (Ak et al., 2014; Aydın, 2017; Ceylan, 2020; Gül et al., 2021), and the recording of the largest blue crab for the Turkish coast of the Black Sea within the study's scope emphasizes the species' ability to expand its size range. The identification of two ovigerous females, with carapace widths of 16.5 cm and 20.0 cm, holds significance in comprehending the reproductive dynamics of the population. The fact that these females surpass the mature size (Lm = 12.8 cm in CW) (Palomares & Pauly, 2023) suggests the likelihood of sustainable reproduction. Moreover, the diversity in regions from which the females were sampled implies a widespread reproductive capability, contributing to the species' establishment in the Black Sea. The increase in size range, survival to advanced sizes, and the presence of reproductively capable females are all indicative of a well-established and potentially self-sustaining population. This study and recent reports show that blue crab species have the chance to survive until they reach large sizes. Reports indicate that this species can attain a maximum size of 20.5 cm in the Black Sea, as cited by Zaitsev (1998). The factors that have led to the identification of this substantial individual within our study area, specific to both the species and location, are characterized by a range of intricate and multifaceted influences. The presence of suitable habitats and favorable environmental conditions may probably substantially contribute to the impressive growth of blue crabs. Collectively, factors create a conducive environment that enhances the availability of food resources, ultimately fostering an ideal setting for robust growth (Pauly, 1984).

Table 1. Population structure and estimated length-weight relationship parameters of the blue crab population in the Black Sea.

	Female	Male	Combined
Population structure			
Sample size (*n*)	7	9	16
Mean carapace width	17.0 cm	18.7 cm	18.0 cm
(with range)	(14.8 – 20.0)	(16.1 – 20.3)	(14.8 – 20.3)
Mean weight	241.9 g	436.7 g	351.5 g
(with range)	(165.0 – 400.2)	(210.0 – 565.1)	(165.0 – 565.1)
Regression parameters			
LWR equation		W = 64.33CW – 804.83	
Coefficient (r^2)		0.74	
Pauly's *t*–test		*t*-test, t_{16} = 1.318, p > 0.05	
Growth type		Isometric	

Table 2. Size and catch data for blue crabs previously recorded off the Turkish coast of the Black Sea (The * symbol represents the maximum size sample recorded in this study).

Location	Sex	CW (cm)	CL (cm)	TW (g)	Depth (m)	Fishing method	References
Trabzon	Female	19.1	9.00	545.0	8-12	Gillnet	Ak et al. (2014)
Ordu	Male	19.4	8.40	269.4	2-10	Trammel net	Aydın (2017)
	Female	19.6	7.83	449.2			
Sakarya	Female	18.9	8.34	272.1	7	Hydraulic dredge	Ceylan (2020)
	Female	15.7	7.01	166.9	11		
Ordu	Female	20.0	8.10	406.2	2	Trammel net	Gül et al. (2021)
Ordu*	Male	20.3	9.10	565.1	12	Beam trawl	This study

The calculated LWR equation (TW = 64.33CW – 804.83; n = 16) provides a mathematical expression of the relationship between CW and TW for the combined sexes. However, it is essential to note the limitation imposed by the small sample size (n < 10) for each sex. While the equation serves as an initial approximation, a larger sample size in future studies holds improve the accuracy and reliability of this relationship. The Pauly *t*-test results indicating isometric growth suggest that the blue crab population in the Black Sea exhibits a proportional increase in size and weight during its development. Isometric growth implies that the relative proportions of body parts remain constant, signifying a balanced development (Aydın, 2018; Hegele-Drywa et al., 2014). The calculated K values of 4.84 for females, 6.51 for males, and an average of 5.78 for combined sexes provide valuable insights into the overall health and well-being of the blue crab population in the Black Sea. These condition estimates serve as an indicator of the population's response to environmental conditions, food availability, and various ecological factors. A high K value greater than "1" generally suggests that the population is thriving under the existing environmental conditions, encompassing factors such as temperature, water quality, habitat structure, food availability, fishing pressure, predation, and reproductive capacity (Froese, 2006; Karadurmuş, 2021). The condition factor, in this context, provides a holistic measure of the population's overall fitness and adaptation to its environment. Future research should aim to expand the sample size to enhance the robustness of the LWR equations. Additionally, investigations into the specific environmental factors influencing the condition would contribute to a more comprehensive understanding of the population dynamics.

The sudden increase in the number of blue crab individuals, especially from 2023 onwards, indicates a

successful colonization along the Turkish coast of the Black Sea. This expansion is further supported by the discovery of a male individual with a size of 18.1 cm in the Rize region (41°02'34"N − 40°30'17"E) on January 4, 2024, indicating the species' presence in the easternmost part of the Black Sea. The sample was caught at a depth of 11 meters as a discard during commercial fishing activity using a trammel net with a 38 mm mesh opening. The transformation of the Black Sea, characterized as the "Mediterraneization" phenomenon (Oral et al., 2013; Aydın & Sözer, 2016), is altering its physical, chemical, and biological properties. This ongoing process may create favorable living conditions for the recently introduced blue crab in the region. There is no recorded prey-predator relation in the region, however, there may be predator-induced pressure associated with dolphins, sharks, soles, halibut, turbot, and bluefish species (Palomares & Pauly, 2023). The fact that crabs, including the blue crab, are not consumed as human food in the region may have contributed to the growth of the species. Moreover, blue crabs are not the primary focus of commercial fishing activities; instead, they are often incidentally caught termed as bycatch, and subsequently released. This incidental capture and release practice may offer blue crabs a better chance of survival when compared to species that face significant fishing pressure as their main target. The existence of shelf regions characterized by steep rocky cliffs and substantial artificial structures, such as those associated with road construction, land acquisition, and airport development along the Turkish coast of the Black Sea, may serve as protective environments for these individuals. These conditions likely facilitate the survival and growth of the blue crabs (Aydın, 2018).

Overfishing and unsustainable fishing practices have long been a source of strain on the region's marine ecosystem. This situation has led to depleted fish populations, which, in turn, make it increasingly challenging for fishermen to maintain viable operations. In response to the declining fish stocks, a notable shift has occurred toward beam trawl fisheries targeting rapa whelk (Aydın et al., 2016; Demirel et al., 2021). With the growing prevalence of trawling operations, there is an observable increase in the frequency of encounters with blue crab species, as reported by local fishermen and documented in scientific research. Gül et al. (2021) reported the first existence of female blue crabs with eggs in the Black Sea. This discovery was important evidence of the adaptations of the species to the Black Sea ecosystem. Blue crabs have significant influence as predators within benthic communities, exerting a notable impact on their diversity and structural composition. As opportunistic benthic omnivores, they exhibit a diverse diet, consuming a wide array of available food sources within their habitat (Mancinelli et al., 2016). While the blue crab plays a pivotal role in benthic food chains in the western Atlantic, its status as an invasive species in the Black Sea and its potential adverse effects on local aquatic ecosystems should not be neglected.

CONCLUSION

Therefore, updating the geographical distribution and maximum size data of marine species in a region is crucial for fisheries science. This study provides new geographical areas, maximum size records, and basic population parameters for the resident population of blue crabs on the Black Sea coast of Türkiye, which are necessary for stock assessment models. Such data is vital for understanding growth patterns, conservation, and ecosystem management. This record can be cited by other researchers, advancing knowledge of this species.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

The authors designed and wrote the study together.

Conflict of Interests: The authors declare that there is no conflict of interest.

Statement on the Welfare of Animals: This study does not imply any responsibility for animal welfare.

Statement of Human Rights

This study does not involve human participants.

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