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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Distribution of the critically endangered fan mussel *Pinna nobilis* population in the Çanakkale Strait and Marmara Sea

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Abstract: This study was conducted with the primary objective of determining the presence of both healthy and impacted *Pinna nobilis* populations along the European coasts of the Sea of Marmara, followed by the identification of *P. nobilis* abundance and survival rates in the region encompassing the Çanakkale Strait and the southern coasts of the Sea of Marmara. Underwater surveys were randomly conducted at 19 distinct stations, including 8 stations along the European coasts of the Sea of Marmara, 7 stations along the southern coasts of the Sea of Marmara, and 6 stations within the Çanakkale Strait. SCUBA diving equipment was utilized to record information on habitat structure, water temperature, depth, and visibility at each station. The transect length during underwater surveys and the number of transects at each station were determined based on the condition of the seabed and the size of the area, respectively. Throughout the study period (September 2021 and October 2023), water temperature fluctuated between 17.5°C and 26.6°C. At the end of the study, a total of 395 individuals (147 live, 248 dead) were observed, with live individuals exhibiting total lengths ranging from 16.4 cm to 50.9 cm. This study represents the first investigation into the spatial distribution of *P. nobilis* along the European coast of the Marmara Sea. The study contributes significantly to enhancing our understanding of the ecology of *P. nobilis* populations in both the Sea of Marmara and the Çanakkale Strait. Additionally, recommendations for the rehabilitation of impacted populations and the conservation of healthy populations have been provided for decision-makers and fisheries managers.

Keywords: *Pinna nobilis*, survival, density, conservation, mortality, attachment

INTRODUCTION

Pinna nobilis Linnaeus 1758 is endemic to the Mediterranean and exhibits a fan-shaped morphology, reaching lengths of up to 120 cm (Zavodnik et al., 1991). Found in seagrass meadows (*Posidonia oceanica* and *Cymodocea nodosa*) within sandy, sandy-muddy, and gravelly areas, these organisms partially embed themselves into the substrate from the umbo region, securing their attachment to the substrate through byssus threads (Tebble, 1966; Zavodnik et al., 1991; Acarli et al., 2011; Hendriks et al., 2011; Prado et al., 2014; Kurtay et al., 2018). Owing to its carbonate-hardened surface, *P. nobilis* provides a habitat for numerous substrate-dependent species (Acarlı et al., 2010).

P. nobilis possesses the ability to filter water, contributing to the quality of the surrounding water by reducing organic and inorganic material through its filtration process (Vicente et al., 2002; Basso et al., 2015; Natalotto et al., 2015). Furthermore, it is hypothesized to have the capacity to regulate regional water characteristics (Trigos et al., 2014). In laboratory conditions, individuals with a length of 30 cm have been reported to filter more than 2500 liters of water per day, a process dependent on their physiological energy requirements (Caballero, 2021).

In 2016, cases of *P. nobilis* mortality reaching 100% were first reported in Spain, followed by subsequent occurrences along other Mediterranean coasts, including France, Tunisia, Morocco, Cyprus, the Adriatic Sea, and the Aegean Sea (Vázquez-Luis et al., 2017; Catanese et al., 2018; Carella et al., 2019; Katsanevakis et al., 2019; Acarlı et al., 2020). Subsequently, the IUCN elevated the conservation status of *P. nobilis* to “Critically Endangered” due to these mass mortalities. *Haplosporidium pinnae* parasite was initially identified as the causative agent for these mass mortalities (Catanese et al., 2018). Later studies reported the involvement of different pathogens in conjunction with *H. pinnae* in these mass mortalities (Carella et al., 2019, 2020; Lattos et al., 2021a, b; Pensa et al., 2022).

Nevertheless, live populations of *P. nobilis* still exist in shallow bays, coastal lagoons (Katsanevakis et al., 2007; Ruitton and Lefebvre, 2021; García-March et al., 2020; Çınar et al., 2021a; Katsanevakis et al., 2022; Nebot-Colomer et al., 2022; Peyran et al., 2022; Papadakis et al., 2022), the Çanakkale Strait (Acarlı et al., 2021), and the Sea of Marmara (Çınar et al., 2021a; Acarli et al., 2021; Acarlı et al., 2022a; Karadurmuş and Sarı, 2022) in the Mediterranean region.

The Sea of Marmara, situated between the Black Sea and the Aegean Sea, functions as an inland sea influenced by the Black Sea, Aegean, and Mediterranean. The saline waters of the Mediterranean (up to 40‰) mix with the less saline waters of the Black Sea (approximately 20‰) through subsurface currents and form the surface currents in the waters of the Sea of Marmara. The Marmara ecosystem, encompassing biological components from both seas, is recognized as an ecological corridor and is considered unique (İşinibilir-Okyar et al., 2015; Demirel et al., 2023). Despite encountering environmental disasters such as mucilage in the Sea of Marmara (Balkis-Ozdelice et al., 2021), it has been reported to continue harboring healthy populations of the endangered *P. nobilis* species (Acarli et al., 2021).

Identifying healthy populations, revitalizing damaged populations, and rehabilitating them are crucial aspects. Although studies have been conducted on the presence of the species in some parts of the southern coast of the Çanakkale Strait and the Sea of Marmara, there is no information available regarding the situation on the European coast of the Sea of Marmara. Therefore, this study was conducted initially to determine the presence of healthy and damaged *P. nobilis* populations on the European coast of the Sea of Marmara. Subsequently, it aimed to assess the abundance and survival rate of *P. nobilis* on the southern coast of the Sea of Marmara Çanakkale Strait.

MATERIAL AND METHODS

This study was conducted at 19 different stations located in the Çanakkale Strait, the European coast of the Sea of Marmara, and the Anatolian coast (Figure 1). Additionally, observational dives were carried out at three different stations in the Çanakkale Strait, where healthy *P. nobilis* populations were reported by Acarlı et al. (2021, 2022a) and Acarli et al. (2021) (checkpoint stations: 10, 21, 22). A two-year monitoring program was conducted between September 2021 and October 2023. Water temperature, salinity, and depth were recorded using YSI probe and Oceanic GEO2. SCUBA equipment was employed for underwater observations in the study area. The substrate structure at the stations was determined as gravel, gravel with macroalgae, sandy, *Cymodocea nodosa*, *Posidonia oceanica*, and rocky.

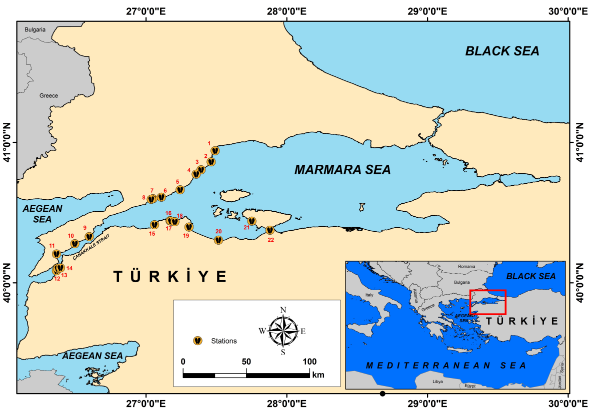

Figure 1. Map of the study area

The study area was systematically surveyed by a trained scientific diver, initiating the survey at a depth of 0.5 m perpendicular to the shoreline for each designated station. The transect underwater visual census method was employed for data collection, with transect lines initially planned at a standard distance of 50 m and a width of two meters on each side. However, variations in transect line distances occurred due to specific conditions at each station, including habitat structure, depth zone, and underwater visibility. At each station, a minimum of one transect was executed to assess the presence or absence of the *P. nobilis* population. Within each transect, a meticulously examined area of 200 m² was considered, and the number of transects ranged from 1 to 6. In instances where no *P. nobilis* individuals were initially observed, additional transects were undertaken. The decision to conduct supplementary transects was contingent upon factors such as habitat structure, depth zone, and underwater visibility, as delineated in Table 1. However, in cases where no individuals were detected in these supplemental transects, no further transect activities were pursued.

All shells of both living and deceased *P. nobilis* individuals were measured for their widths, and subsequently, their total volumes were calculated using the formula established by Acarli et al. (2018) as follows:

$$TL = 2.74W + 2.018 \qquad (1)$$

In this equation, TL denotes the total length, and W represents the width of the specimen. A one-way analysis of variance (ANOVA) was executed to compare the variations in lengths of *P. nobilis* among different stations. The population density for each station was determined by computing the number of individuals per 100 m². To assess potential differences in the population density (ind./100 m²) of *P. nobilis* among stations, permutational analysis of variance (PERMANOVA) was employed. The PERMANOVA analysis was carried out using Past (v4.08) (Hammer et al., 2001). The Euclidean distance matrix was applied, and groups were delineated based on the presence or absence of specimens at the stations. The stations, where *P. nobilis* was identified (8 levels), were designated as a fixed factor in conducting the PERMANOVA.

RESULTS

Table 1 provides information about the surveyed area, maximum depth, underwater visibility, temperature, salinity, and habitat structure of the investigated stations in the study. Among these, stations numbered 1, 2, 3, 5, 6, 13, 16, 17, 19, and 20 did not exhibit any presence of *P. nobilis* individuals. These stations were characterized by a predominant sandy substrate in terms of habitat structure. In contrast, stations numbered 4, 7, 8, 9, 11, 12, 13, 15, and 18 revealed the presence of *P. nobilis* individuals in habitats characterized by sandy substrate, *C. nodosa*, and to a lesser extent, *P. oceanica*.

Observations (monitoring dives) conducted at stations 10, 21, and 22 did not reveal any signs of intense mass mortality, indicating a healthy population. Furthermore, the presence of young individuals (>15 cm) recruiting to the population was noted at these stations. During underwater surveys, a total of 147 living individuals and 282 deceased individuals were identified (Table 2). Observations throughout the study revealed that the highest number of living individuals was recorded at station 9, while the highest number of deceased individuals was documented at station 12. The lengths of living individuals ranged from 16.4 to 50.9 cm at stations 8 and 4, respectively, whereas the lengths of deceased individuals varied between 30.1 and 68.2 cm at stations 15 and 9, respectively. Furthermore, stations 4 (100%) and 9 (94.9%) were identified as having the highest survival rates.

Table 1. Stations, surveyed area (m^2), maximum depth (m), horizontal underwater visibility (m), temperature (°C), salinity (‰), and observed habitat structure during underwater surveys conducted between September 2021 and October 2023 in the study area

Sta. No	Date	Surveyed Area (m²)	Max. Depth (m)	Underwater Visibility (m)	Temperature (°C)	Salinity (‰)	Habitat Structure
1	August 2022	1000	8	2.0	25.8	20.2	Gravel (10%), Sandy (80%), Rocky (10%)
2	August 2022	2000	9	4.0	26.6	20.6	Gravel (5%), Sandy (95%)
3	August 2022	1000	11	6.5	25.6	20.6	Gravel with macroalgae (10%), Sandy (90%)
4	August 2022	750	9	7.5	25.8	20.2	Gravel with macroalgae (90%), Sandy (10%)
5	August 2022	1000	7	4.0	25.5	19.9	Gravel (70%), Sandy (10%), *C. nodosa* (20%)
6	September2021	1500	7	5.0	24.4	20.02	Gravel (10%), Sandy (20%), *C. nodosa* (70%)
7	September 2021	500	8	7.0	24.8	20.09	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
8	September 2021	750	5	3.5	24.7	20.09	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
9	October2023	1250	11	6.0	22.6	24.7	Sandy (10%), *C. nodosa* (90%)
10*	July 2023	750	9	3.0	27.9	18.3	*Posidonia* sp. (30%), *Zostera* sp. (70%)
11	October2023	500	7	4.0	18.0	22.4	Sandy (10%), *C. nodosa* (80%), *P. ocenica* (10%)
12	October2023	1000	4	2.0	22.2	24.6	Sandy (10%), *C. nodosa* (90%)
13	October2023	250	7	7.0	20.0	30.0	Shell fragments (85%), Sandy (5%), *C. nodosa* (10%)
14	October2023	750	4	2.5	20.0	26.9	Gravel (80%), Sandy (10%), *C. nodosa* (8%), *P. ocenica* (2%)
15	September 2021	1000	12	10.0	17.5	20.0	Gravel (20%), Sandy (10%), *C. nodosa* (70%)
16	September 2021	1500	7	3.0	23.3	20.0	Gravel (30%), Sandy (30%), *C. nodosa* (40%)
17	September 2021	1000	6	4.0	24.7	20.5	Gravel (20%), Sandy (40%), *C. nodosa* (20%)
18	September 2021	1000	8	3.0	24.6	20.7	Gravel (10%), Sandy (10%), *C. nodosa* (80%)
19	September 2021	1200	3.5	2.0	25.2	19.9	Sandy (100%)
20	September 2021	1000	10	2-7	21.6	20.0	Sandy (70%), *C. nodosa* (30%)
21*	July 2023	1250	13	6.0	27.0	19.4	Gravel (10%), *C. nodosa* (90%)
22*	July 2023	500	10	2.0	26.6	18.6	Gravel (10%), Sandy (20%), *C. nodosa* (70%)

*Checkpoint stations previously studied by Acarlı et al. (2021, 2022a) and Acarli et al. (2021)

Table 2. Number of alive and dead individuals, minimum shell length (L_{Min}), and maximum shell length (L_{Max}) of *Pinna nobilis* individuals

Stations	N	Alive N	L_{Min}(cm)	L_{Max}(cm)	Mean±SD	Dead N	L_{Min}	L_{Max}	Mean±SD
4	21	21	27.8	50.9	42.7±7.0	0	-	-	-
7	41	21	22.9	35.0	27.3±6.7	20	33.0	45.1	38.2±3.8
8	32	26	16.4	45.1	34.6±6.7	6	32.7	56.4	39.9±8.5
9	59	56	18.5	47.3	37.9±5.4	3	39.6	68.2	50.7±15.3
11	21	4	29.2	40.7	34.6±5.8	17	42.6	53.3	47.5±5.4
12	92	0	-	-	-	92	33.0	53.6	42.3±4.7
14	26	11	31.9	39.6	34.9±2.3	15	31.8	40.5	35.4±4.5
15	72	8	21.5	44.8	30.2±8.4	64	30.1	54.5	35.5±4.7
18	31	0	-	-	-	31	31.0	42.0	37.35±4.7

The population density across stations, encompassing both living and deceased individuals, was determined to range between 2.8 ind./100 m² (gravelly habitat) and 8.2 ind./100 m² (seagrass habitat). The lowest population density was observed at station 4, while the highest population density was identified at station 7. It has been observed that *P. nobilis* is densely distributed in seagrass habitats while scarce or no populations are found in gravelly or sandy habitats. However, stations 12 and 18 exhibited a mortality rate of 100% (Figure 2).

Furthermore, the population demonstrated a concentrated distribution at depths between 2 and 4 m, with a decrease in the number of individuals as depth increased (Figure 3).

The results of the PERMANOVA, aimed at assessing variations in population density across stations, indicated a statistically significant difference in the population density of *P. nobilis* among the surveyed stations ($p<0.01$). The total sum of squares was 1196, with a within-group sum of squares of 229.1. The resulting pseudo-F value was 4.641, and the associated p-value was determined to be 0.0001.

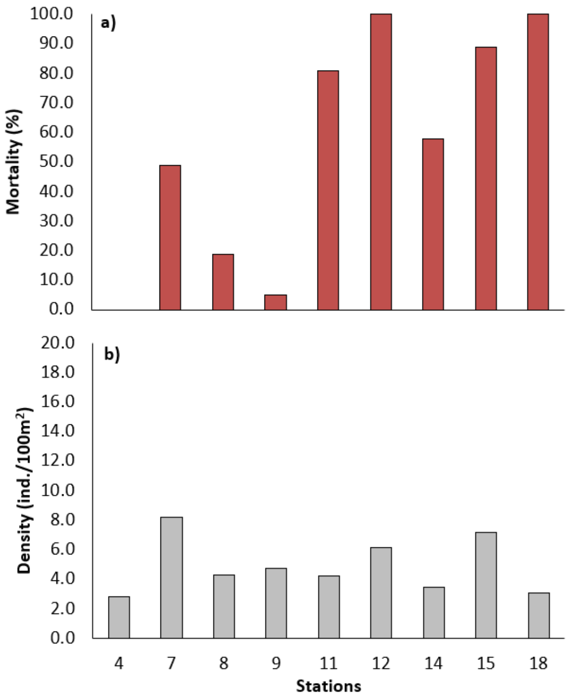

Figure 2. Population density (a) and mortality rates (b) of *Pinna nobilis* at stations

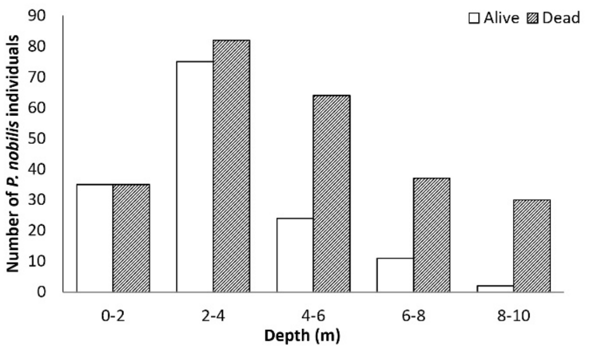

Figure 3. Frequency distribution of alive and dead *Pinna nobilis* individuals by depth (m)

DISCUSSION

P. nobilis is distributed in various seas surrounding Türkiye, excluding the Black Sea coast, including the Mediterranean, Aegean, and Marmara Seas, as well as the shallow waters of the Çanakkale Strait, encompassing sandy areas, seagrass beds, and calcium carbonate formations (locally called as 'tragana'). The northernmost reported point of its distribution in Turkish waters is the vicinity of the Marmara Sea near the Istanbul Strait (between Kızkulesi and Tophane) (Çınar et al., 2021a). Despite reports of intensive mortality cases in *P. nobilis* stocks at different points along the Aegean Sea coast of Türkiye, healthy *P. nobilis* beds have been identified in various locations in the Marmara Sea (Öndes et al., 2020a; Acarlı et al., 2021, 2022a; Çınar et al., 2021a). Acarlı et al. (2021) reported 100% mortality at the entrance of the Çanakkale Strait, connecting the Aegean and Marmara Seas, while a 90.38% survival rate was observed at station 10 in the Çanakkale Strait (checkpoint station). Similarly, Öndes et al. (2020a) identified a 90.48% survival rate at station 21 (checkpoint station). The lowest survival rate in the Çanakkale Strait was reported as 0.32% by Özalp and Kersting (2020). Additionally, mass mortalities have been reported in some stations in the Marmara Sea (Çınar et al., 2021b) and the Çanakkale Strait (Özalp and Kersting, 2020; Künili et al., 2021).

This study fills a gap in the literature by providing survival rates at stations along the European coast of the Marmara Sea, where no information was previously available. Survival rates were determined as 100%, 81.25%, and 51.22% at stations 4, 7, and 8, respectively. No dead or living individuals were encountered at five stations along the European coast of the Marmara Sea (stations 1, 2, 3, 5, and 6). In contrast, variable survival rates were observed at stations along the Çanakkale Strait and the Asian coasts of the Marmara Sea. Despite similar findings reported by different researchers in relatively close areas (Çınar et al., 2021a, b; Acarlı et al., 2021, 2022a, b), examinations of these studies reveal differences in the numbers of living and dead individuals, population density (ind./100 m^2), and survival rates.

Furthermore, three different locations previously studied by Acarlı et al. (2021, 2022a) and Acarli et al. (2021) (Çanakkale Strait: station 10; Marmara Sea: stations 21 and 22) were designated as checkpoint stations in the current study, and no mass mortality was encountered during observation dives conducted in 2023. This highlights the crucial role of factors such as the spread or transport of the disease (Vázquez-Luis et al., 2017), environmental factors like wind direction, and current regimes that enhance the spread (Acarlı et al., 2022a) in the occurrence of mass mortalities in *P. nobilis* populations distributed in different areas. On the other hand, Çınar et al. (2021b) reported an 88% mortality rate during the period of mucilage occurrence, whereas Acarli et al. (2021) determined a mortality rate of 35.9% before the mucilage period (for the year 2020) and 16.1% during the mucilage period (for the year 2021). Acarlı et al. (2022b) proposed that this phenomenon is attributed to the influx of Aegean Sea water, carried by bottom currents through the Çanakkale Strait, reaching the island region in the southern part of the Marmara Sea. Moreover, despite high mortality rates observed in the same region, the presence of healthy populations in certain areas is believed to be due to different current regimes and prevailing northward winds (Acarlı et al., 2022b). The current study's observations near stations with intensive mortalities (stations 10, 21, and 22) still show a significantly high number of healthy individuals, supporting this assumption.

The youngest individuals identified in the study were determined to have lengths of 16 cm and 18.5 cm at stations 7 and 24, respectively. These individuals exhibited thin and transparent shells. It has been observed that in the cultivation of this species, they reach a length of 150 mm at the end of the first year (Kožul et al., 2011; Acarlı et al., 2011; Demirci and Acarli, 2019). Hence, on the basis of the morphological characteristics of these individuals, it can be concluded that they are part of the previous year's cohort and are one year old. Acarlı et al. (2021) and Acarli et al. (2021) reported the detection of newly recruited individuals into the stock, emphasizing the dynamic nature of the population. Additionally, newly settled individuals were commonly observed at stations designated as checkpoint stations. The observation of this phenomenon in the Marmara Sea is of great significance. This is because, during the mucilage period observed from the fall of 2020 through 2021, researchers noted that *P. nobilis* spat could not attach to collectors left to gather juveniles (Personal observation). In other words, the identification of newly recruited healthy individuals after the mucilage formation period is promising, indicating that there is still hope for the sustainability and continuity of *P. nobilis* populations in the Marmara Sea. This finding suggests that efforts can be made to ensure the healthy maintenance and continuity of stocks in the face of environmental challenges, such as mucilage events.

The population density varied between 2.8 ind./100 m² and 8.2 ind./100 m² (by excluding practically zero densities). Rabaoui et al. (2010) indicated that the population density was zero in very shallow waters (<0.3 m depth) and increased in the 0-6 m depth. Rabaoui et al. (2010) noted the average and maximum measured densities were 1.5 and 56 ind./100 m^2, respectively. In addition, several studies reported different densities in the Mediterranean Sea. Mean densities were reported as 11.5 ind./100 m^2 in Mljet National Park, Croatia (Šiletić and Peharda, 2003), 0.57 ind./100 m^2 in Souda Bay, Greece (Katsanevakis and Thessalou-Legaki, 2009), 11.6 ind./100 m^2 in Gulf of Oristano, Sardinia, Italy (Addis et al., 2009), 2.5 ind./100 m^2 in Tunisia coast (Rabaoui et al., 2008), 0.02 ind./100 m^2 in Lake Faro (Sicily, Italy) (Donato et al., 2021), 2.21 ind./100 m^2 in the shallow sites of Isla del Barón and 4.95 ind./100 m^2 Pueblo Cálido in the Mar Menor lagoon, located in the southeast of the Iberian Peninsula, (Nebot-Colomer et al., 2022). On the other hand, in the Marmara Sea, Acarlı et al. (2022a) noted that the highest mean population density was 27 ind./100 m^2 which is very close to Öndes et al. (2020a) with 25.2 ind./100 m^2. However, Öndes et al. (2020b) stated that there was an exceptional population density of 100 ind./100 m^2 in the Aegean Sea. Acarli et al. (2021) recorded that the maximum population density reached 112 ind./100 m^2 in the Ocaklar Bay, southern part of the Marmara Sea. Çınar et al. (2021b) mentioned that population density varied from 0.3 ind./100 m^2 to 12 ind./100 m^2 along the coastlines of islands in the southern part of the Marmara Sea. Çınar et al. (2021a) affirmed that the average density ranged from 6 ind./100 m^2 to 240 ind./100 m^2 in the Marmara Sea (along the coastlines of islands in the southern part of the Marmara Sea). Densities depend largely on sampling design and field size; both vary significantly across studies.

In this study, it has been determined that *P. nobilis* individuals exhibit a dense distribution up to a depth of 6 meters. Generally, the depths at which this species is distributed show regional variations. Vázquez-Luis et al. (2014) reported that the highest densities are mostly limited to shallow coastal regions, with the expected maximum density being below 20 meters, and densities decreasing with increasing depth. Similarly, Basso et al. (2015) documented that there was a decreasing trend in the number of individuals with increasing depth, with higher densities in the first 10-12 m. It has also been observed that *P. nobilis* densely distributed in seagrass habitats while scarce or no population has been observed in gravelly or sandy habitats. Many researchers have reported the dense distribution of *P. nobilis* populations within seagrass meadows (Coppa et al., 2010; Basso et al., 2015; Tatton et al., 2019; Acarli, 2021; Acarlı et al., 2021). Basso et al. (2015) compared 24 scientific papers based on 77 observations and noted that *P. nobilis* were most frequently observed in *P. oceanica* beds with an average of 8.06±2.35 ind./100 m^2, while in *Cymodocea* meadows with averages of 11.06±1.82 ind./100 m^2. The widespread occurrence of *P. nobilis* individuals, especially in environments with seagrasses such as *P. oceanica* and *C. nodosa*, suggests that this species has a high oxygen demand. In other words, it is evident that *P. nobilis* thrives in areas where water quality is relatively good. Likewise, Rabaoui et al. (2010) indicated that the density increased with the distance from the city and it was attributed to pollution. Similarly, in the present study, the highest number of live individuals was observed among *C. nodosa* and *P. oceanica* seagrasses. The lowest number was found in sandy habitats, possibly due to the vulnerability of young individuals with thin and fragile shells to water movements and potential predators in sandy habitats.

However, individuals among seagrasses may exhibit a higher survival rate due to both increased protection against predators and less impact from water movements. Similarly, researchers have reported higher densities of *P. nobilis* populations in sheltered biotopes with weak hydrodynamics (low wave motion and low current velocity) and substrates composed of rocky, gravel, and biodegraded material along with *P. oceanica* and *C. nodosa* (Rabaoui et al., 2008, 2009; Hendriks et al., 2011; Acarlı et al., 2022a). On the other hand, Çinar and Bilecenoglu (2023) observed two cases related to predation pressure by the spiny sea star *Marthasterias glacialis* on *P. nobilis* juvenile individuals. Acarlı et al. (2022b) reported that no *P. nobilis* individuals were observed in all stations dominated by the north wind on the coast of the Kapıdağ Peninsula (southern Marmara Sea). Therefore, this ecosystem type is considered highly favorable for the settlement and survival of Pinnidae spat.

In the current study, the majority of *P. nobilis* individuals at all stations were observed to be oriented perpendicular to the shore. This positioning can be explained as a reduction in the potential effects by minimizing the exposed surface area subjected to hydrodynamic forces, aiming to alleviate the stress created by wave motion.

Following mass mortalities observed at different locations in the Mediterranean, the focus has shifted towards identifying healthy *P. nobilis* populations. Despite reports of mass mortalities at various points in the Marmara Sea and the Çanakkale Strait, the documentation of the presence of healthy and dynamic populations is crucial for the continuity of the species. This study identified healthy populations at 9 researched stations (4, 7, 8, 9, 11, 13, and 15) and 3 checkpoint stations (10, 21, and 22). To ensure species sustainability, it is essential to continuously monitor populations identified as healthy in the Marmara Sea. Additionally, it is recommended to establish special environmental protection areas, such as marine parks, to conserve these habitats. Furthermore, the collection of young individuals using collectors in these areas and their transplantation to suitable locations with protected systems on the seafloor should be undertaken to ensure the conservation of the species.

CONCLUSION

This research represents the first exploration of the spatial distribution of *P. nobilis* along the European coast of the Marmara Sea. Healthy populations at 12 researched stations during the two-year monitoring study and no mass mortality was encountered during observation dives conducted in 2023 at checkpoint stations. It has also been observed that individuals of *P. nobilis* are densely distributed extending to a depth of 6 meters. In spite of reports indicating widespread mortalities at different locations in the Marmara Sea and the Çanakkale Strait, documenting the existence of thriving and dynamic populations is essential for the species' continuity. While the lowest numbers were found in sandy habitats, individuals among seagrasses exhibited a higher survival rate possibly due to both increased protection against predators and less impact from water movements. The identification of recently recruited, healthy individuals following the mucilage formation period is promising, suggesting that there is still optimism for the sustainability and persistence of *P. nobilis* populations in the Marmara Sea. This study significantly contributes to advancing our comprehension of the ecology of *P. nobilis* populations in both the Sea of Marmara and the Çanakkale Strait. Therefore, recommendations for the restoration of affected populations and the preservation of healthy populations should be applied by decision-makers and fisheries managers.

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AUTHORSHIP CONTRIBUTIONS

Sefa Acarlı: Conceptualization, Writing-Original draft, Writing-Review and Editing, Supervision, Deniz Acarlı: Methodology, Writing-Original draft, Semih Kale: Writing-Original draft, Writing-Review and Editing, Formal analysis.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

All relevant data is in the article.

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