

Abundance of the Sea Urchin (*Paracentrotus lividus* Lamarck, 1816) Along the Northeastern Coasts of the Sea of Marmara

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Abstract: A study was conducted on the abundance of sea urchin (*Paracentrotus lividus* Lamarck, 1816) on the North East coast of the Marmara Sea between August-September 2023 and August-November 2024. Visual count transects method was conducted at 19 stations on the Anatolian side of Istanbul and 1 station in Armutlu, Yalova, using ABC (mask, fins and snorkel) at depths of 0-3 metres. The highest number of individuals in the study area in 2023 was Pendik-Yunus 1 station, with an average of 5 individuals per square metre, and in 2024, the highest number of individuals was Tuzla station, with an average of 18 individuals per square metre.

For sustainable urchin fishery management with an ecosystem approach, the stock status of the species in the region should be known. According to the available literature, it is aimed to reach these data, which are unknown for the Marmara Sea, within the scope of this study

Keywords: *Paracentrotus lividus*, abundance, the Marmara Sea, ecosystem-based fisheries management

Marmara Denizi Kuzeydoğu Kıyılarında Deniz Kestanesinin (*Paracentrotus lividus* Lamarck 1816) Bolluğu

Özet: 2023 yılı Ağustos-Eylül ve 2024 yılı Ağustos-Kasım ayları arasında Marmara Denizi'nin kuzeydoğu kıyılarında deniz kestanesi (*Paracentrotus lividus* Lamarck, 1816) bolluğu üzerine bir çalışma gerçekleştirilmiştir. İstanbul'un Anadolu Yakası'nda yer alan 19 istasyon ile Yalova'nın Armutlu ilçesindeki 1 istasyonda, 0–3 metre derinlik aralığında ABC (maske, palet ve şnorkel kullanılarak) ile transekt yöntemi kullanılarak görsel sayımlar yapılmıştır. 2023 yılı verilerine göre çalışma alanında en yüksek birey sayısına sahip istasyon, metrekare başına ortalama 5 birey ile Pendik-Yunus 1 istasyonu olmuştur. 2024 yılında ise en yüksek birey sayısı, metrekare başına ortalama 18 birey ile Tuzla istasyonunda tespit edilmiştir.

Ekosistem temelli sürdürülebilir deniz kestanesi avcılığı yönetimi için, türün bölgedeki stok durumunun bilinmesi gerekmektedir. Mevcut literatür dikkate alındığında, Marmara Denizi için bilinmeyen bu verilerin elde edilmesi, bu çalışmanın temel hedefleri arasında yer almaktadır.

Anahtar Kelimeler: *Paracentrotus lividus*, bolluk, Marmara Denizi, ekosistem temelli balıkçılık yönetimi

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1. Introduction

The Sea of Marmara, which connects to the Mediterranean via the Çanakkale Strait and to the Black Sea via the Istanbul Strait, is Turkey's only inland sea (Gazioğlu et al., 2002). It spans approximately 70 km in width and 250 km in length, covering a surface area of about 11,500 km² (Chiggiato et al., 2012). Although the Sea of Marmara constitutes only approximately 4% of the Mediterranean's surface area, it accounts for about 10-15 % of Turkey's fisheries production (TÜİK, 2022). The Marmara Sea, a region of significant ecological importance, serves as a crucial breeding and migration habitat for a variety of marine organisms, thereby demonstrating notable biodiversity. By the EBSA (Ecologically or Biologically Significant Areas) criteria, the Marmara Sea fulfils all of the criteria at the "high" classification level (Yukse, 2021). The primary reason for the Marmara Sea's high biodiversity is its two-layered hydrographic structure, characterized by a pronounced pycnocline at approximately 25 meters in depth. The upper layer consists of less saline waters (~18 psu) originating from the Black Sea, while the lower layer contains more saline waters (~38 psu) of Mediterranean origin (Ünlüata et al., 1990; Beşiktepe et al., 1994). The research shows that the residence time of the upper layer water is approximately 4-5 months, while the lower layer water has a residence time of about 6-7 years (Besiktepe et al., 1994).

The Marmara Sea experienced a significant ecological event in 2021, characterised by the presence of dense mucilage (Gundogdu et al., 2024), which also affected the North Aegean Sea (Aslan et al., 2021). The reasons for this phenomenon are multifaceted, including non-ecosystem-based urbanization, inadequate treatment of domestic and agricultural waste products, as well as industrial effluents produced by the increasingly dense human population in the provinces surrounding the Marmara Sea (Balık and Ayyıldız, 2019). Other contributing factors include over-fishing, and increasing surface water temperature compared to the surrounding seas (Öztürk et al., 2021). As a result of this disaster, in 2021, "The Marmara Sea, Islands and the Turkish Straits System" was declared a special protection area (Ministry of Environment, Urbanization and Climate Change, 2021). In the framework of the Marmara Sea Action Plan (MDEP), which will be prepared later, for the ecosystem basis of the fishing activities carried out in the Marmara Sea, as of 15.05.2022, commercial sea urchin and sea cucumber fishing/gathering in the Marmara Sea and Istanbul and Çanakkale Straits has been banned by the Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture with a letter sent on 9. 05.2022 by the Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture (in accordance with paragraph 30 of article 48 of Communiqué No. 5/1 on the Regulation of Fishing for Commercial Purposes) (Aslan, 2022).

Sea urchins play an important key role in restoring the ecological balance of the Sea of Marmara by consuming excess algae in the Sea of Marmara, which has been disturbed by mucilage (Migliaccio et al., 2016; Ceccherelli et al., 2022; Aslan-Cihangir and Pancucci-Papadopoulou, 2012). There are important trade-offs between fisheries, urchin density, and macroalgae density, both because of the marine plants they consume and because of the many fish and invertebrates they feed on, such as the striped seabream, gilt-headed bream, white seabream and black seabream (Aslan, 2022). A decrease in regular sea urchin populations often results in the overgrowth of macroalgae, whereas an increase in their populations may lead to the formation of barren zones dominated by sea urchins due to excessive grazing on macroalgae (Sala et al., 1998; Guidetti et al., 2005; Guidetti and Dulčić, 2007; Giakoumi et al., 2012; Filbee-Dexter and Scheibling, 2014; Alcoverro et al., 2002).

The gonads of *Paracentrotus lividus* are an economic species consumed as food (Palacín et al., 1998) due to their gastronomic flavour and protein value (Mataix-Verdu, 1993; Sağlam et al., 2013), which is lower than shrimps and crabs but higher than oysters and mussels. To meet the intense demand of the food and beverage industry, *P. lividus* has been overfished in the Mediterranean.

P. lividus Lamarck, 1816 is also threatened by stock status and temperature changes (Grosso et al., 2022; Paredes et al., 2022). For this reason, it has led to the extinction of populations in some regions, especially in Europe (Torres et al., 2019). Many countries have banned fishing or set quotas for this species in order to ensure stock control and sustainable fishing activities (Farina et al., 2020). The fishing of sea urchins, known as aphrodisiacs on the coasts of Türkiye, started in the 1980s in Ayvalık between January and April by free diving or using sea urchin scoops (Demir et al. 2013; Aslan 2022). In the early days, *P. lividus* was marketed to restaurants in metropolitan cities such as Istanbul and Izmir, but since 2020, it has been under intense fishing pressure due to foreign market demand (Farina et al., 2020; Aslan, 2022). The Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquaculture has introduced some regulations on the commercial fishing of sea urchin in the territorial waters of our country as of March 2022 due to the increasing fishing demand and export quantities of *P. lividus*. Fishing is only allowed by diving method from fishing boats that have obtained a fishing "permit certificate" from the Provincial Directorates according to Annex 2 of the Communiqué No. 5/1 on the Regulation of Fishing for Commercial Purposes (Aslan, 2022).

P. lividus, which is under protection according to the BERN Convention, has lost its habitat on the southern coasts of the Mediterranean Sea due to global climate change and the poisonous invasive alien sea urchin (*Diadema setosum*) and is under fishing pressure in the Aegean Sea (Yeruham et al., 2015; Aslan, 2022). According to the available literature, the only study on the population of this species, which has a great economic value as well as ecological importance, in the Turkish seas was conducted by Aslan (2022) in Gökçeada and there is no study on the stock status in the Marmara Sea, where fishing is prohibited.

This study aimed to reveal the abundance of *P. lividus*, one of the ecologically and economically important treasures of the Marmara Sea, which is in a delicate balance, on the northeastern coasts without harming the habitat of the species.

2. Materials and Methods

P. lividus were counted by visual counting technique at 20 stations (Figure 1) between August-September 2023 and August-November 2024 (Table 1) using ABC (mask, flippers and snorkel). All *P. lividus* specimens observed in 3 m wide transect areas to the left and right of a 20 m length (6x20 m) transect parallel to the shore at 0-3 m depth, each meter of which was marked, were recorded in the underwater notebook. Observations at each station were out in 3 consecutive repetitions. A total area of 360 m² is scanned in each station and a total area of 7200 m² is scanned for the year 2023. In Kadıköy-Öreke, Kadıköy-Öreke East, Kadıköy-Moda2 and Kadıköy Deniz Kulübü stations, no counts could be made for 2024 due to weather conditions and a total area of 5760 m² was surveyed.

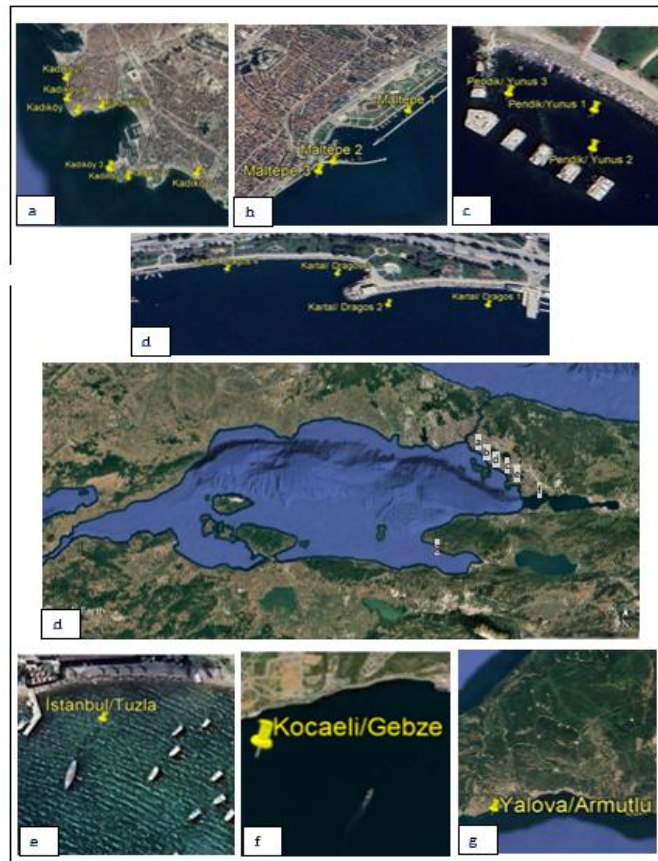


Figure 1. The stations carried out a visual census study. a) Kadıköy b) Maltepe c) Pendik. d) Marmara Sea e) Tuzla f) Gebze g) Armutlu.

Table 1. Names, coordinates and dates of the visual counting stations.

STATIONS	SUB-STATIONS	COORDINATIONS	Date
İstanbul/Tuzla:	Mercan	N 40°49'12.9396"	13 August 2023
		E 29°16'28.2252"	22 August 2024
İstanbul/Pendik	Yunus-1	N 40°52'54.2748"	15 August 2023
		E 29°12'24.516"	06 August 2024
	Yunus-2	N 40°52'53.238"	
		E 29°12'24.0264"	
	Yunus-3	N 40°52'53.8608"	
		E 29°12'22.6476"	
İstanbul/Kartal:	Water Sports	N 40°54'03.2292"	17 August 2023
		E 29°09'12.4596"	24 July 2024
	Sailing	N 40°54'03.0492"	
		E 29°09'11.0592"	
	Marina Inside-1	N40°54'05.4756"	
		E 29°09'05.1768"	
	Marina Inside-2	N40°54'05.6304"	
		E 29°08'57.7248"	
İstanbul/Maltepe:	İdealtepe	N 40°56'29.1768"	14 August 2023
		E 29°06'07.5456"	29 July 2024
	Embankment	N 40°56'39.498"	
		E 29°06'09.5832"	
	Küçükyalı Dalgakıran	N 40°56'42.3492"	
		E 29°06'07.3008"	
İstanbul/Kadıköy:	Caddebostan Beach	N 40°58'04.3644"	18 August 2023
		E 29°03'05.49"	05 August 2024
	Fenerbahçe	N 40°58'03.1692"	16 August 2023
		E 29°01'51.7836"	24 November 2024
	Öreke	N 40°58'03.1692"	
		E 29°01'51.7836"	
	Öreke East	N 40°58'46.0956"	
		E 29°01'43.0788"	
	Moda-2	N 40°58'41.7072"	

		E 29°01'21.7128"	
	Moda Deniz Kulübü	N 40°57'56.6712"	16 August 2023
		E 29°02'02.1372"	18 November 2024
	Moda-1 Right	N 40°58'50.0196"	
		E 29°01'11.9532"	
	Moda-1 Left	N 40°59'07.062"	
		E 29°01'11.8128"	
Yalova/Armutlu	Armutlu	N 40°31'40.8288"	17 November 2023
		E 28°45'16.5708"	31 May 2024

In this study, *P. lividus* individuals were recorded once a year over two consecutive years (2023 and 2024) using the visual census method with ABC equipment (mask, snorkel, fins) at depths of 0–3 meters, parallel to the shoreline. At each of the 20 stations, surveys were conducted along a 20-meter rope marked at each meter. The survey area covered 3 meters on each side of the rope, totaling 120 m² per station, with three consecutive repetitions. A total area of 2,280 m² was surveyed at 20 different stations. Abundance was assessed using the SACFOR scale (Strong and Johnson, 2020), and densities were expressed as individuals per square meter (ind/m²) with standard deviation ($\pm$ SD). *P. lividus* was the only Echinoidea species encountered. The highest average density was observed at Tuzla in 2024 (17.69 ind/m²), and the lowest at Marina İç-2 station (0.02–0.16 ind/m²). An overall increase in abundance was recorded across all stations in 2024 compared to 2023, likely influenced by the suspension of sea urchin harvesting activities and increased algal food availability following the mucilage incident in the Sea of Marmara.

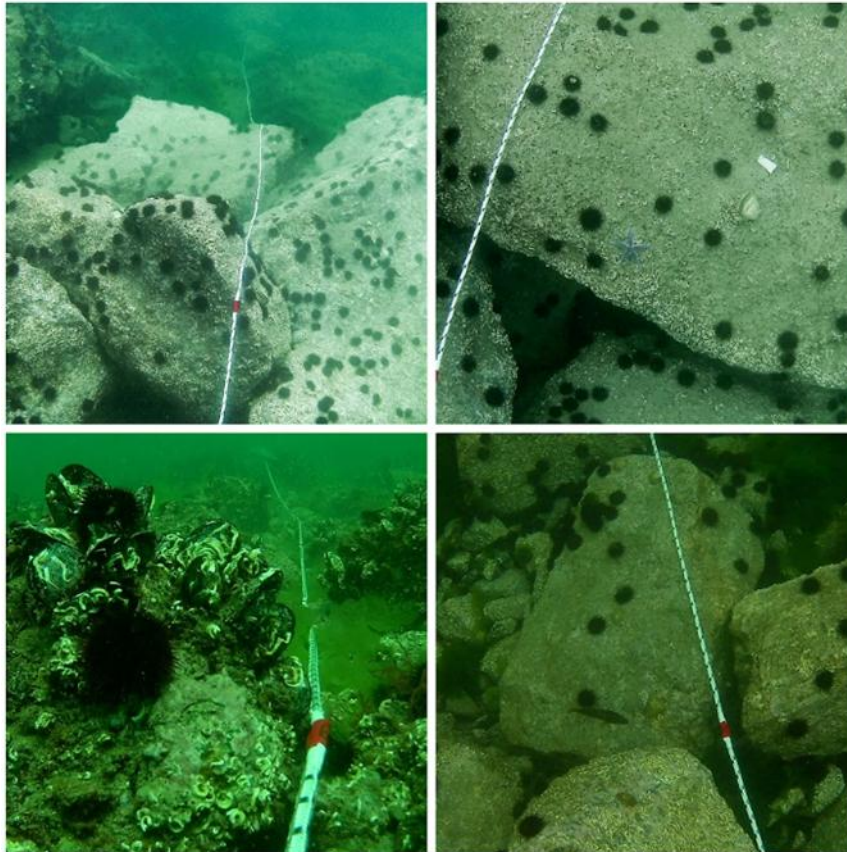


Figure 2. Underwater visual census study (Pendik station on 15 August 2024).

Individuals counted along the marked rope at the indicated stations were recorded according to the SACFOR scale (Strong and Johnson, 2020). According to the SACFOR scale, 100-999 individuals per square meter are described

as "Very Abundant (S)", 10-99 individuals as "Abundant (A)", 1-9 individuals as "Common (C)"; 1-9 individuals per 10 square meters as "Frequent (F)", 1-9 individuals per 100 square meters as "Occasional (O)", and 1- 9 individuals per 1000 square meters as "Rare (R)" (Aslan, 2022).

3. Results

Findings in 2023, according to the results of the visual census, the Pendik-Yunus 1 station had the highest number of individuals with an average of 5 individuals per square meter, followed by Maltepe-Küçükyalı and Tuzla stations with 4 and 3 individuals, respectively. No individuals were found at Kadıköy-Caddebostan Beach 2, Kadıköy-Öreke, KadıköyModa1 stations. In 2024, Tuzla station had the highest number of individuals with an average of 18 individuals per square metre, followed by Maltepe-Küçükyalı station with 10 individuals and Pendik-Yunus1 station with 9 individuals.

Table 3. SACFOR value at stations.

Station Name	Date	Average Abundance $\pm$ SD m^{-2}	SACFOR Values
Tuzla	13 August 2023	3,14 $\pm$ 0,30	C
	22 August 2024	17,69 $\pm$ 0,17	A
Yunus-1	15 August 2023	4,85 $\pm$ 1,66	C
	06 August 2024	9,28 $\pm$ 0,14	C
Yunus-2	15 August 2023	0,01 $\pm$ 0	R
	06 August 2024	0 $\pm$ 0	R
Yunus-3	15 August 2023	1,1 $\pm$ 0,02	C
	06 August 2024	1,58 $\pm$ 0,14	C
Su Sporları	17 August 2023	0,45 $\pm$ 0,05	O
	24 July 2024	0,3 $\pm$ 0	F
Yelken	17 August 2023	0,04 $\pm$ 0	O
	24 July 2024	0,46 $\pm$ 0,02	O
Marina İçi-1	17 August 2023	0,17 $\pm$ 0	O
	24 July 2024	1,86 $\pm$ 0,09	O
Marina İçi-2	17 August 2023	0,02 $\pm$ 0	O
	24 July 2024	0,16 $\pm$ 0	O
İdealtepe Dolgu	14 August 2023	0,36 $\pm$ 0,06	O
	29 July 2024	0 $\pm$ 0	O
Küçükyalı Dalgakıran	14 August 2023	0,05 $\pm$ 0	O
	29 July 2024	3,53 $\pm$ 0,11	C
Küçükyalı	14 August 2023	4,2 $\pm$ 0,16	C

	29 July 2024	$10,48 \pm 0,35$	A
Caddebostan Plajı	18 August 2023	0 ± 0	R
	5 August 2024	$0,11 \pm 0$	O
Fenerbahçe	16 August 2023	$0,4 \pm 0,03$	F
	18 November 2024	$1,94 \pm 0,02$	C
Öreke	16 August 2023	0 ± 0	R
		-	-
Öreke Doğu	16 August 2023	0 ± 0	R
		-	-
Moda-2	16 August 2023	$1,36 \pm 0,01$	C
		-	-
Moda Deniz Kulübü	16 August 2023	0 ± 0	R
		-	-
Moda-1 Sağ	16 August 2023	0 ± 0	R
	18 November 2024	$0,22 \pm 0,62$	O
Moda-1 Sol	16 August 2023	0 ± 0	R
	18 November 2024	$0,41 \pm 0,02$	O
Armutlu	17 November 2023	$4,02 \pm 0,11$	C
	31 May 2024	$8,43 \pm 0,22$	C

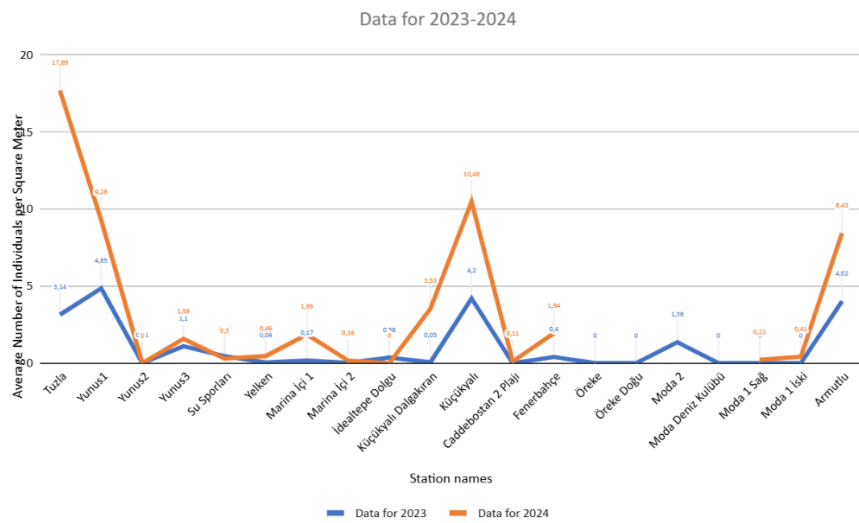


Figure 3. Average number of sea urchin individuals per m² according to stations.

According to the results of this study, the highest density of *P. lividus* species was found at Yunus-1 station (4.85

ind/m²), which has a rocky habitat type, during the observations made by the transect method at 0-3 meters depth in 2023. After Yunus-1 station, the highest density was observed at Küçükyalı station (4.2 ind/m²), which is also a rocky habitat type. In 2024, the densest stations where *P. lividus* species were found were Tuzla station (17.69 ind/m²) and Küçükyalı station (10.48 ind/m²). No *P. lividus* species were found at İdealtepe Dolgu station, which is located very close to Küçükyalı station.

In the study conducted in 2023 and 2024 at Yunus 1, Yunus 2, Yunus 3, Yelken, Marina Inside-1, Marina Inside-2, İdealtepe Dolgu and Armutlu stations, the SACFOR value was the same.

4. Discussion

There are approximately 800 species of sea urchins in the world, which are members of the *Echinodea* group (Byrne, 1990). In Turkey, there are 20 species of sea urchins (Aslan 2005, 2024). Except the invasive and poisonous *Diadema setosum* and two other irregular species *Brissopsis atlantica mediterranea* (Mortensen, 1927), *Spatangus subinermis* (Pomel, 1887), 17 of these species are found in the Marmara Sea. There are two dominant urchin species in the littoral zone of the Sea of Marmara. These are the purple sea urchin *P. lividus* and the black sea urchin *Arbacia lixula* (Linnaeus, 1758). *A. lixula* lives on vertical and semi-vertical rocks at depths of 2-15 meters (Gianguzza et al., 2010). It is omnivorous (Wangensteen et al., 2011; Agnetta et al., 2011). *P. lividus* generally inhabits rocky and stony substrates in the sublittoral zone, but is also found in deep water (Cherbonnier, 1956; Tortonese, 1965). *P. lividus* is an indicator species for healthy marine ecosystems, responding sensitively to changes such as seawater temperature increase, acidification, and invasive species (Aslan, 2022). Many different test colours are observed, ranging from brown tones to green. It has been determined that there is no relationship between the depths they are found in and the colours (Boudouresque, 2001).

The sea urchin species, which is in high demand in the Far East and several European countries due to its gonads as a source of polyunsaturated omega-3 fatty acids and protein, was not fished in Türkiye until 2022. According to the data of BSGM based on SUBIS Transport documents, the sea urchin catches, which was 14,190 kg in 2019, 40,900 kg in 2020, 125,778 kg in 2021, increased to 1,411,231 kg in 2022. In 2022, after the fishing regulation introduced by the ministry in 2022, the number of vessels that received sea urchin fishing permits in 2022 was 292, while it decreased to 140 in 2023 and 72 in 2024. In 2023, the amount of sea urchins caught was 416450 kg and in 2024 it decreased to 191,047 kg (BSGM, 2025). The exportation of these sea urchin gonads, which are not consumed in Turkey, is primarily directed towards various countries, particularly Italy, Greece, Spain, and Japan. In 2022, when both catch and export volumes reached their peak, the country generated an economic contribution of €8,329,338 from these exports."

In line with the Marmara Sea Action Plan (MSAP), commercial harvesting of sea urchins in the Marmara Sea and the straits of Istanbul and Çanakkale was banned as of May 15, 2022, by the Ministry of Agriculture and Forestry, Fisheries and Aquaculture Department (Notification 09.05.2022 under Article 48/30 of the Communiqué No. 5/1 on Commercial Fishing Regulations). There is considerable interest and pressure from the fishing community regarding the lifting of the sea urchin *P. lividus* fishing ban in the Marmara Sea. Additionally, illegal harvesting of *P. lividus* by local fishers in the Marmara region is frequently reported. Due to the absence of scientific studies on the stock status and reproductive periods of *P. lividus* in the Sea of Marmara, it is currently not possible to implement an ecosystem-based fisheries management approach grounded in scientific evidence for this species (Aslan, 2005; Aslan-Cihangir and Pancucci-Papadopoulou, 2012; Aslan-Cihangir, 2012; Öztoprak et al., 2014; Aslan, 2022, Aslan, 2024).

In the present study conducted in the Sea of Marmara, the first visual census targeting *P. lividus* was performed across 20 stations in Tuzla, Pendik, Kartal, Maltepe, Kadıköy (Istanbul) and Armutlu (Yalova) from 2023 to 2024. It was observed that *P. lividus* was the only Echinoidea species detected in these stations. In 2023, the highest density of *P. lividus* was recorded at Maltepe/Küçükyalı (4.2 ind/m²), and the lowest at Marina İç-2 (0.02 ind/m²). In 2024, the maximum was at Tuzla (17.69 ind/m²), and the minimum again at Marina İç-2 (0.16 ind/m²). A clear increase in the abundance of *P. lividus* from 2023 to 2024 was observed at all stations except for two locations, namely Su Sporları and İdealtepe. Factors affecting sea urchin abundance generally include food availability, physico-chemical water parameters, substrate structure, fishing pressure, and pollution (Tortonese et al., 1987; Byre, 1990). In the Sea of Marmara, stations with intense small-scale fishing activities included Tuzla/Mercan, Kartal/Su Sporları, Kartal/Yelken, Kartal/Marina-1, Kartal/Marina-2, and Maltepe/Küçükyalı. Notably, a stream flows into the sea at Maltepe/Küçükyalı station, where a heavy sewage odor was recorded in both years. A similar trend was reported by Bayed et al. (2005), who observed increasing sea urchin densities closer to sewage discharge points. Following the mucilage event observed in the Sea of Marmara in 2021, significant increases in macroalgal biomass were recorded due to excessive nutrient input (Aslan et al., 2021; Özalp, 2021; Topçu and Öztürk, 2021). During this period, in which sea urchin harvesting was prohibited, the abundance of available nutrients led to an increase in the population of the species. This situation once again highlighted the ecological importance of herbivorous sea urchins in controlling eutrophication in the Marmara Sea. However, due to the high density of sea urchins, it is essential to continuously monitor the area to determine whether overgrazing is occurring and whether barren rocky zones caused by sea urchin activity are forming.

The results of this study, which evaluates data collected in 2023 and 2024, were further compared with the most recent field observations conducted on 23 September 2025 at the Tuzla, Yunus 1–2–3, Su Sporları (Water Sports), Yelken (Sailing), and Marina İçi 1 and 2 stations. Due to intense algal proliferation and the presence of mucilage, sea urchin counts could not be performed at the Tuzla and Yunus 1–2–3 stations. At the stations where observations were possible, the following densities of *P. lividus* individuals per m² were recorded: 0.60 ± 0.02 at Su Sporları, 0.80 ± 0.03 at Yelken, 2.72 ± 0.03 at Marina İçi-1, and 0.52 ± 0.02 at Marina İçi-2. A considerable increase in *P. lividus* density per square meter was detected across all surveyed stations compared to previous years. Notably, the species' abundance category shifted from “occasional” to “common” at Marina İçi-1 and from “occasional” to “frequent” at Su Sporları. However, despite this increase, the grazing pressure exerted by *P. lividus* populations remains insufficient to counterbalance the excessive algal biomass accumulation resulting from elevated organic matter inputs into the Sea of Marmara. These findings suggest that effective top-down control by sea urchins hasn't yet been established in the region.

Aslan (2022) conducted visual surveys to determine *P. lividus* density along the coasts of Gökçeada at 10 stations in July–August 2012 and at 15 stations in July and October 2018. In Laz Bay, 4 ind/m² were recorded in 2012, and in 2018, the highest densities were 5 ind/m² at Kuzulimanı (112–120 m segment) and at Kokina III (0–52 m segment).

Addis et al. (2009) observed the highest *P. lividus* density at Porto Palma (5.11 ± 0.70 ind/m²) and the lowest at Teulada (1.95 ± 0.22 ind/m²) in heavily fished Sardinian waters. Their study helped define the spatial population structure of *P. lividus* under fishing pressure.

In addition, at Tuzla station—one of the areas where *P. lividus* was most densely distributed—ind of anemone species *Anemonia viridis* and *Sagartia* sp. were observed at a density of 1 individual per 6 m². Although no previous study has been found on the ecological relationship between these anemones and *P. lividus*, McLaren et al., (2024) emphasized that sea urchin population patterns cannot be solely explained by biogeographic proximity and provided key insights into herbivore dynamics in transition zones such as subtropical reefs in Eastern Australia.

5. Conclusion

P. lividus is a species of critical ecological importance in marine ecosystems. Therefore, the existing fishing ban in the Sea of Marmara and the Turkish Straits should be regularly revised in light of updated scientific assessments, particularly those addressing the impacts of the mucilage phenomenon. Fisheries management across all marine regions should adopt an ecosystem-based approach, and urgent regulatory frameworks including fishing seasons, size limits, and catch quotas, must be established specifically for the Sea of Marmara. Scientific studies aimed at assessing the current stock status of commercially valuable sea urchin populations in the Marmara Sea, the Straits, and the Aegean Sea should be prioritized to inform sustainable management strategies.

Moreover, regional variations in Gonadosomatic Index (GSI) values need to be explored in areas that have not yet been studied, and reproductive periods should be clearly defined to avoid overlap with fishing seasons. In response to increasing market demand and the depletion of natural stocks, the development of aquaculture practices should be actively supported. Since the market value of sea urchins typically peaks during their reproductive period, the implementation of rotational fishing practices in selected regions should be considered to reduce ecological pressure. All harvested individuals must be accurately and consistently recorded to ensure transparency and traceability in the supply chain.

Strict enforcement of the ban on destructive fishing gears such as dredges, trawls, and other mechanical harvesting methods remains essential for the sustainability of sea urchin fisheries. Furthermore, monitoring and enforcement mechanisms must be strengthened, institutional collaboration enhanced, and effective deterrent sanctions applied against illegal fishing activities. Lastly, sea urchin harvesting should be restricted to licensed vessels employing hand collection through diving. Licensing should be based on the Territorial Use Rights for Fisheries (TURF) framework to ensure equitable and sustainable resource allocation (Aslan, 2022).

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7. Compliance with Ethical Standard

a) Author Contributions

B.D. was responsible for field-based visual assessments and drafted the initial version of the manuscript. H.A.

conceptualized the study's methodological framework and led the writing of the final manuscript. Both authors critically revised the text and approved the final version for submission.

b) Conflict of Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Statement on the Welfare of Animals. This study did not include any experimental work involving animals; therefore, no statement on animal welfare is required.

c) Statement of Human Rights

As no human subjects were involved in the research, ethical approval and a statement of human rights are not required.

d) Declaration of Not Using AI

As no artificial intelligence tools were used in the research, a declaration of AI use is not required.

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