

Article

New Records of *Magallana gigas* and *Callinectes sapidus* from the Romanian Black Sea Coast Based on Citizen-Reported Observations: Contributions to Marine Biodiversity Monitoring

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Abstract

The number of alien species recorded in the Black Sea has increased over recent decades, raising concerns regarding their long-term ecological consequences. Among the taxa currently extending their distribution within the basin are the Pacific oyster, *Magallana gigas*, and the Chesapeake blue crab, *Callinectes sapidus*. This study presents new records of both species from the Romanian Black Sea coast obtained through citizen-reported observations. Five specimens of *M. gigas* collected from Constanța and Mangalia harbours were examined, together with one ovigerous female specimen of *C. sapidus* collected from Vadu Beach. In addition, two male *C. sapidus* records from Sinoe Lake were documented and validated based on photographic evidence. The finding of *M. gigas* in Mangalia Harbour extends the known distribution of the species along the Romanian coastline and suggests that the species is more widespread than previously documented. The occurrence of an ovigerous *C. sapidus* female confirms that reproduction is taking place in Romanian Black Sea waters. Morphometric measurements and reproductive traits were within the ranges reported from other Black Sea and Mediterranean populations. While none of these species can currently be regarded as invasive in Romanian coastal waters due to the absence of documented ecological impacts, the increasing frequency of records suggests that both warrant continued monitoring. The results further indicate that citizen-reported observations, when validated by specialists, can complement conventional surveys and provide valuable information on the occurrence and spread of conspicuous alien marine species, thereby supporting sustainable marine biodiversity monitoring and informed ecosystem management.

Keywords: alien species; citizen-reported observations; Pacific oyster; Chesapeake blue crab

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1. Introduction

Invasive alien species are widely recognised as one of the major drivers of biodiversity loss, generating substantial ecological and economic impacts worldwide. In marine ecosystems, biological invasions are primarily facilitated by anthropogenic activities, including commercial shipping, aquaculture, the aquarium and bait trades, food transport,

and canal construction, posing significant risks to ecosystem structure, functioning and the provision of ecosystem services [1–3].

Given the complexity of invasion processes, species invasiveness must be evaluated by considering not only establishment success and dispersal capacity, but also the magnitude of potential impacts on native communities and ecosystem functioning [4].

For this study, an alien species is considered established when evidence demonstrates successful reproduction and the persistence of a self-sustaining population in the study area. The term expanding is used when an extension of the known distribution range is documented. The term potentially invasive is applied to alien species that have demonstrated invasive behaviour in other regions and show evidence of establishment or spread in Romanian coastal waters, but for which local ecological impacts have not yet been documented. The term invasive is used for alien species whose ecological impacts have been demonstrated within the study area.

In recent decades, the Black Sea has experienced a progressive increase in the number and diversity of alien species, reflecting the growing influence of anthropogenic activities and regional biogeographical processes. The introduction of alien species into the basin is primarily facilitated through three major pathways: maritime transport, which remains the dominant vector; intentional or accidental human introductions; and Mediterraneanisation, a process through which Mediterranean species overcome ecological barriers within the Bosphorus Strait and subsequently establish populations in the Black Sea [5].

An assessment of alien species revealed that most of the marine invertebrates recorded in Romanian and Bulgarian waters belong to the phylum Arthropoda [6].

Among the alien species that have shown an increasing number of records in the Black Sea basin in recent years are the Pacific oyster, *Magallana gigas*, and the Chesapeake blue crab, *Callinectes sapidus*.

Native to the northwestern Pacific, particularly the coastal waters of Japan and the Korean Peninsula, *M. gigas* is a highly resilient bivalve species that has been intentionally introduced to numerous regions worldwide for aquaculture purposes. Its remarkable ecological plasticity, including broad tolerance of environmental variability, temperature fluctuations, and elevated turbidity, together with rapid growth rates and high reproductive capacity, has contributed significantly to its successful establishment beyond its native range. Formerly known as *Crassostrea gigas*, the Pacific oyster is currently one of the most extensively cultivated shellfish species globally and has become established in a wide variety of coastal and estuarine ecosystems outside its native distribution [7].

M. gigas was introduced to Europe to compensate for the decline of native oyster stocks and support aquaculture. Following the collapse of native *Ostrea edulis* populations and subsequent declines of *Crassostrea angulata* in France, *M. gigas* was introduced through the “Resur” programme and has since spread extensively, forming naturalised populations along most of the European coastlines [8].

In the Black Sea, *M. gigas* was also introduced to support aquaculture and compensate for the decline of the native oyster *O. edulis*, which had been severely affected by predation from the invasive gastropod *Rapana venosa* in connection with other factors. The first living specimens were recorded in Romanian waters in 2003 [9].

C. sapidus Rathbun, 1896 (Brachyura: Portunidae), commonly known as the Chesapeake blue crab, is an opportunistic euryhaline species native to the western Atlantic, ranging from Nova Scotia to northern Argentina. Due to its broad environmental tolerance and ecological plasticity, the species occupies a variety of coastal habitats, particularly estuaries, lagoons and shallow marine waters, and supports economically important commercial and recreational fisheries throughout its native distribution range [10,11]. Outside its native western Atlantic distribution, *C. sapidus* has become one of the most widespread alien decapod crustaceans in European waters. Its capacity to tolerate a wide

range of environmental conditions, combined with high dispersal and reproductive abilities, has contributed to its invasion success and raised concerns regarding its potential impact on native biodiversity and ecosystem functioning [12].

The species has successfully expanded its distribution across numerous marine ecosystems, becoming established in the Mediterranean, Baltic, Black, and Azov Seas, demonstrating a remarkable capacity for dispersal and adaptation [11,13–15]. Although sporadic occurrences of *C. sapidus* have been documented along the Romanian coast over the past two decades [16–19], comprehensive data regarding its reproductive establishment and population dynamics remain limited. Given their ongoing expansion and potential ecological implications, continuous monitoring of *M. gigas* and *C. sapidus* is essential for improving our understanding of their distribution patterns, establishment dynamics and potential impacts on native ecosystems along the Romanian Black Sea coast.

This study aimed to document new records of *M. gigas* and *C. sapidus* from the Romanian Black Sea coast based on citizen-reported observations subsequently validated by specialists. In addition, the study illustrates how validated citizen-reported observations can complement conventional monitoring efforts by contributing occurrence data for alien marine species.

2. Materials and Methods

2.1. Study Area and Sampling Strategy

The observations analysed in this study were obtained through citizen-reported records collected between August 2025 and September 2025, within the framework of the OBAMA-NEXT project (Observing and Mapping Marine Ecosystems–Next Generation Tools), which promotes public participation in marine biodiversity monitoring and encourages the reporting of unusual marine species by coastal stakeholders, including fishermen, recreational divers, and residents. Although no standardised sampling protocol was applied for the observations presented herein, participants were informed about the project objectives and encouraged to report observations of uncommon or potentially alien marine species. During this period, a total of eight public reports were received, all of which were retained for the study after meeting our strict validation criteria. Our established exclusion criteria ruled out any reports lacking high-resolution visual evidence, missing precise geographical coordinates, bearing signs of unauthentic or internet-sourced origins, or representing duplicate submissions of the same individual; however, no reports needed to be excluded as all eight submissions successfully satisfied these quality and authenticity standards.

The biological material analysed in the laboratory consisted of five specimens of *Magallana gigas* and one ovigerous female of *Callinectes sapidus* provided by citizens through outreach activities aimed at increasing awareness of marine biodiversity and alien species monitoring. The oyster specimens were collected by professional scuba divers from Constanta and Mangalia harbours after observing an unusual bivalve attached to artificial substrates.

The physical specimen of the ovigerous female blue crab was provided by a local resident from Vadu Beach. In addition to these physical samples, local fishermen from Sinoe Lake (coastal lagoon) submitted high-resolution photographs and geographical coordinates of two male blue crabs (Figure 1).

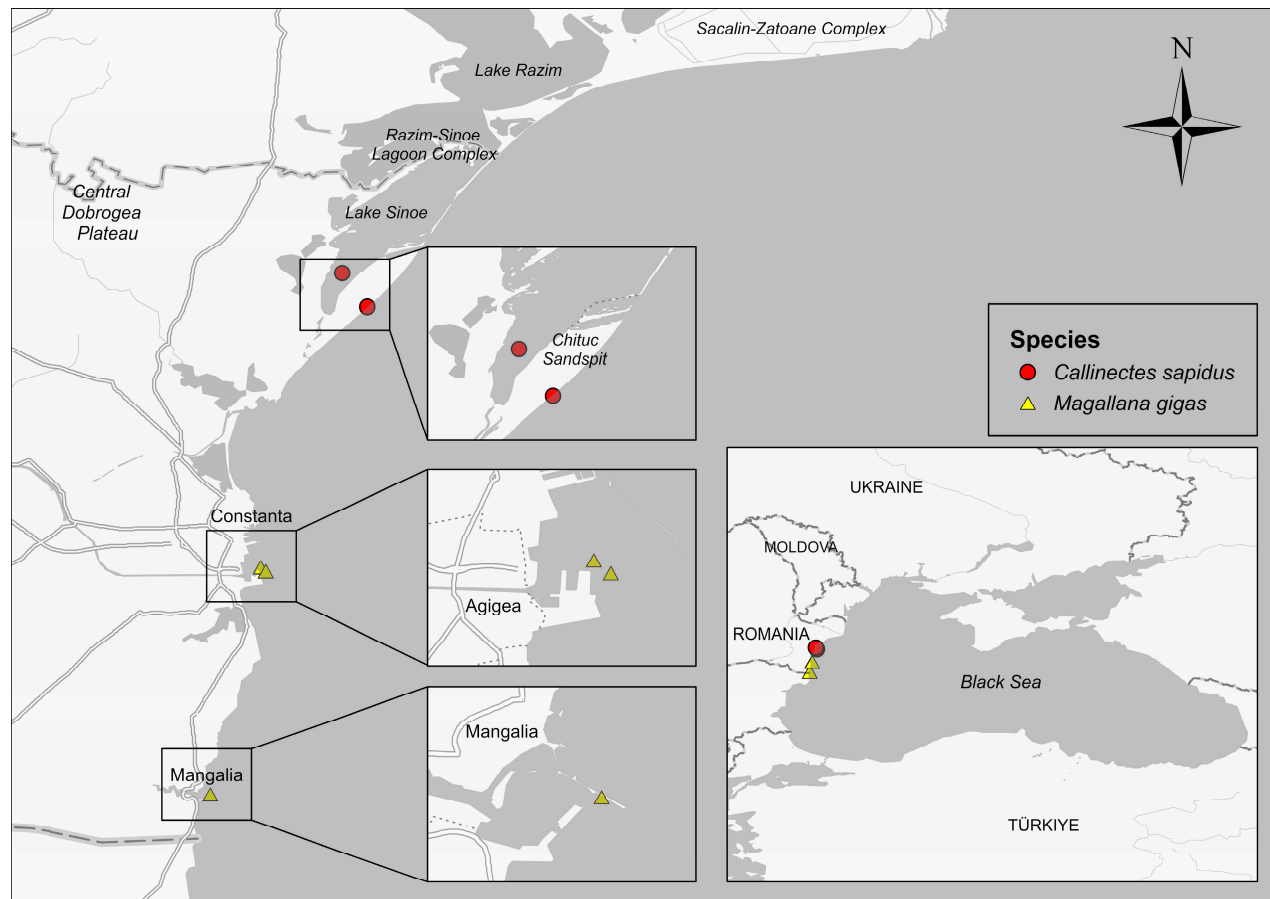


Figure 1. Occurrence of alien species (*M. gigas* and *C. sapidus*) along the Romanian Black Sea Coast.

2.2. Taxonomic Confirmation

All records included in the study were subsequently validated by NIMRD specialists. For the photographic records submitted by the fishermen, we examined the visible features using descriptive taxonomic keys. By assessing distinct, species-specific morphological traits (e.g., carapace morphology, abdominal shape, cheliped finger pigmentation), we successfully confirmed the identity of the photographed crabs as male *C. sapidus*.

Species identification was based on external morphological characteristics described in the relevant taxonomic literature. *M. gigas* was identified according to shell morphology, including valve shape, sculpture, coloration and adductor muscle scar characteristics [20–23].

C. sapidus was identified using diagnostic characters of the carapace, chelipeds, swimming legs and colour pattern following published identification keys [10,24,25].

2.3. Measurements and Analyses

Measurements were taken with a digital caliper (Sylvac S_Cal EVO Smart, Sylvac, SA, Yverdon, Switzerland; resolution 0.01 mm, accuracy ± 0.02 – 0.03 mm) and a digital balance (A&D EK-610i, A&D Company, Tokyo, Japan; readability 0.01 g, linearity ± 0.02 g). Total wet weight was calculated as the sum of the whole wet weight and the oyster tissue wet weight.

Five specimens of the Pacific oyster, *M. gigas*, were collected from the harbour areas of Constanta and Mangalia, located along the Romanian Black Sea coast, and subsequently transported to the laboratory for further analyses (Figure 2). Species identification was based on the morphological characteristics described in the literature [20–23].

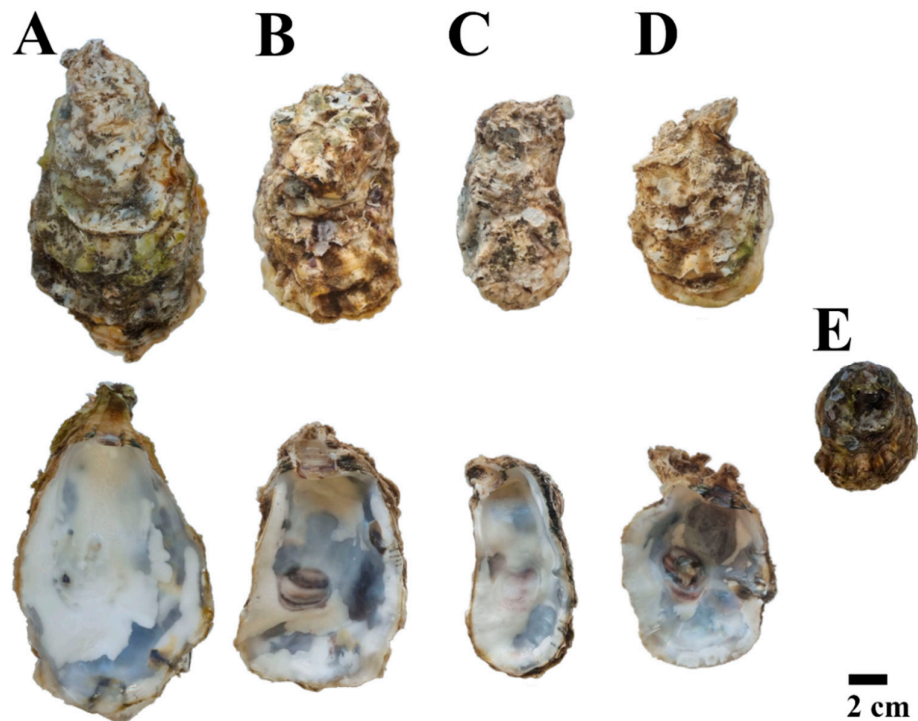


Figure 2. Left cupped valves of five *Magallana gigas* from Constanta (A–C,E) and Mangalia (D) harbours; outer surfaces shown for all specimens; inner surfaces shown for (A–D).

Prior to morphometric analyses, all specimens were carefully cleaned to remove attached biofouling organisms. Shell height (SH), shell length (SL), and shell width (SW) were measured according to Galtsoff [26]. In addition, total wet weight, shell wet weight, and soft tissue wet weight were recorded whenever possible. The soft tissues were separated from the shells and weighed individually.

A single ovigerous female of the Chesapeake blue crab, *C. sapidus*, was collected on 26 August 2025 from Vadu Beach, located in the northern Romanian Black Sea coastal sector. Two additional male specimens from Sinoe Lake were reported by local fishermen, who provided photographic documentation allowing reliable species identification. The ovigerous female was transported to the laboratory, identified following [10,24,25], photographed, and subjected to detailed morphometric analyses. The following measurements were recorded: carapace width including lateral spines (CW), carapace length excluding the epistomial spine (CL), metagastric area length (MAL), posterior and anterior metagastric area widths (pMAW and aMAW), lengths of pereopods P1–P5, and chela length, width, and depth. Specimen size class was determined following the standard metrics established for the species' native range by Harding [27], which classifies individuals as small (<80 mm CW), medium (80–120 mm CW), or large (>120 mm CW), to facilitate comparison with native populations, as a specific standardized size classification for Black Sea individuals is currently unavailable. Reproductive status (immature, mature, or ovigerous) was assessed following Fisher [28]. Following morphometric processing, the female *C. sapidus* specimen was preserved in ethanol and formally deposited as a voucher specimen in the Zoobenthic Collection of the National Institute for Marine Research and Development (NIMRD) 'Grigore Antipa' under the catalog code NIMRD-MZB-2025-201.

Total wet weight and egg mass wet weight were recorded. Eggs were carefully removed from the pleopods, washed thoroughly, and passed through a 60 µm sieve prior

to weighing. Egg Mass Index (EMI) was subsequently calculated following Kevrekidis et al. [29].

$$\text{EMI}(\%) = \frac{\text{egg mass weight}}{\text{total body weight}} \times 100 \quad (1)$$

Embryonic development was assessed according to the nine-stage classification proposed by Kelly and Taylor [30] based on progressive yolk utilization and the sequential development of embryonic structures. To link macroscopical field observations with microscopic development, egg coloration was used as a complementary preliminary indicator of developmental stage and was classified into three categories following Marchessaux et al. [31]: initial (yellow), intermediate (orange), and pre-hatching (dark brown). Accordingly, the broad macroscopical pre-hatching (dark brown) category was explicitly validated microscopically to establish its direct correspondence with the precise diagnostic features of Stage 9.

Egg diameter, expressed in micrometres (μm), was determined following detachment of the eggs from the pleopods using a 5% sodium hypochlorite solution. The egg mass was homogenized by gentle agitation and subdivided into three subsamples of 100 eggs each, which were subsequently examined in a Bogorov counting chamber to account for intra-clutch variability in egg size [31]. In total, 300 eggs were imaged and measured under an Olympus SZX10 stereomicroscope (Olympus Co., Tokyo, Japan) fitted with an SC50 digital camera and analysed using CellSens Entry software (v. 1.16; Olympus Co., Tokyo, Japan). Descriptive statistics (mean, standard deviation, minimum, and maximum) were computed from the pooled measurements of all eggs.

A total of 300 eggs were subsequently measured under an Olympus SZX10 stereomicroscope (Olympus Co., Tokyo, Japan) equipped with an SC50 camera, using CellSens Entry software (v. 1.16; Olympus Co., Tokyo, Japan); the mean, standard deviation, minimum, and maximum egg diameters were computed from the pooled measurements of all eggs.

Sampling locations and species occurrences along the Romanian coast were mapped using ArcGIS Pro (v. 3.0.1; Esri Inc., Redlands, CA, USA). Photographic plates illustrating the examined specimens were compiled and edited using GIMP (v. 3.0.4; GNU Image Manipulation Program, Berkeley, CA, SUA).

3. Results

3.1. Occurrence and Distribution of *Magallana Gigas* on the Romanian Black Sea Coast

To date, nine records of the Pacific oyster, *M. gigas*, have been reported from the Romanian Black Sea coast (Table 1), indicating the gradual establishment of the species in the region. Notably, a relatively small wild population was discovered in 2017 in the vicinity of Agigea Harbour (Constanta, Romania), providing evidence of successful local establishment. The documented occurrences are summarized below:

Table 1. Documented wild occurrences of *M. gigas* in the Romanian Black Sea waters.

No.	Location	Year	No. of. Indv.	Source
1	Constanta Harbour	2025	4	Present study
2	Mangalia Harbour	2025	1	Present study
3	Constanta Harbour	2023	1	[32]
4	Agigea Harbour	2021	colony; proof of reproduction (juveniles present)	[33]
5	Agigea Harbour	2017	colony; avg. density: 1.16/m ²	[34]
6	Constanta	2004	live isolated specimens	[35]
7	Romanian Black Sea waters	2003	live isolated specimens	[9]

8	Romanian Black Sea waters	1995	presence mentioned	[9]
9	Romanian Black Sea waters	1980	presence mentioned	[35]

3.2. Morphometric Characteristics of *M. gigas*

The specimens analysed in the present study exhibited a wide variation in size. The largest individual, collected from Constanta Harbour, exhibited a shell height of 166.06 mm and a total wet weight of 396.60 g, whereas the smallest specimen from the same location measured 65.02 mm in shell height and weighed 68.80 g (Table 2).

Table 2. Biometric characteristics of wild *M. gigas* individuals recorded in the Romanian Black Sea waters in 2025.

Specimen No.	Location	Coordinates (°N, °E in DD)	Reported By	Length (mm)	Height (mm)	Width (mm)	Wet Weight (g)	Oyster Tissue Wet Weight (g)	Total Wet Weight (g)
1	Constanta Harbour	44.112474; 28.666181	commercial diver	74.89	131.76	52.28	361.40	36.03	397.43
2	Constanta Harbour	44.112474; 28.666181	commercial diver	55.14	116.06	41.49	201.90	23.18	225.08
3	Constanta Harbour	44.107273; 28.673243	commercial diver	94.60	166.06	61.73	334.20	62.40	396.60
4	Constanta Harbour	44.107273; 28.673243	commercial diver	46.87	65.02	35.30	N/A	N/A	68.80
5	Mangalia Harbour	43.800667; 28.596618	commercial diver	73.60	98.97	44.26	N/A	N/A	N/A

N/A: Data unavailable. Specimens 4 and 5 experienced mortality during laboratory acclimation before wet weight, tissue wet weight, and total wet weight (specimen 5 only) could be recorded.

3.3. Occurrence and Distribution of *C. sapidus* on the Romanian Black Sea Coast

Until 2025, ten records of *Callinectes sapidus* have been reported from Romanian Black Sea waters, indicating the continuous occurrence and progressive establishment of the species along the coast. The documented occurrences are summarised below (Table 3).

Table 3. Records of the blue crab *Callinectes sapidus* along the Romanian coastline (1998–2025).

Location	Coordinates (°N, °E in DD)	Year	Sex	No. of Indv.	Reported By	CL (mm)	CW (mm)	Source
Sinoe lake	44.516337; 28.778833	2025	male	2	fishermen	N/A	N/A	Present study (Photo & coords)
Vadu	44.469421; 28.813200	2025	ovig. female	1	fishermen	70.71	183.34	Present study (Physical specimen)
Sacalin	N/A	2025	male	5–12	scientific researchers	N/A	N/A	[17]
Sfântu Gheorghe	44.865338; 29.624264	2022	male	1	fishermen	N/A	N/A	[16]
Mamaia bay	N/A	2020	male	1	fishermen	100	205	[36]
23 August	N/A	2003	male	1	commercial diver	N/A	191	[37]
Mangalia-Cap Aurora	N/A	2002	male	1	fishermen	98	223	[18]
Agigea	N/A	2000	female	1	fishermen	N/A	N/A	[38]

Mangalia	N/A	1999	female	1	fishermen	80	186	[19]
23 August	N/A	1998	male	1	resident	85	196	[39]

N/A: Precise geographic coordinates were not reported in the cited references. Similarly, N/A in the carapace length (CL) and carapace width (CW) columns denotes that these measurements were not reported.

3.4. Morphometric and Reproductive Characteristics of the Ovigerous Female

The collected specimen was identified as an ovigerous female of *C. sapidus* (Figure 3), with a total wet weight of 275.34 g. Morphometric measurements revealed a carapace length (CL) of 70.71 mm and a carapace width (CW, including lateral spines) of 183.34 mm. The metagastric area measured 12.22 mm in length (MAL), with posterior and anterior widths of 14.66 mm (pMAW) and 28.71 mm (aMAW).

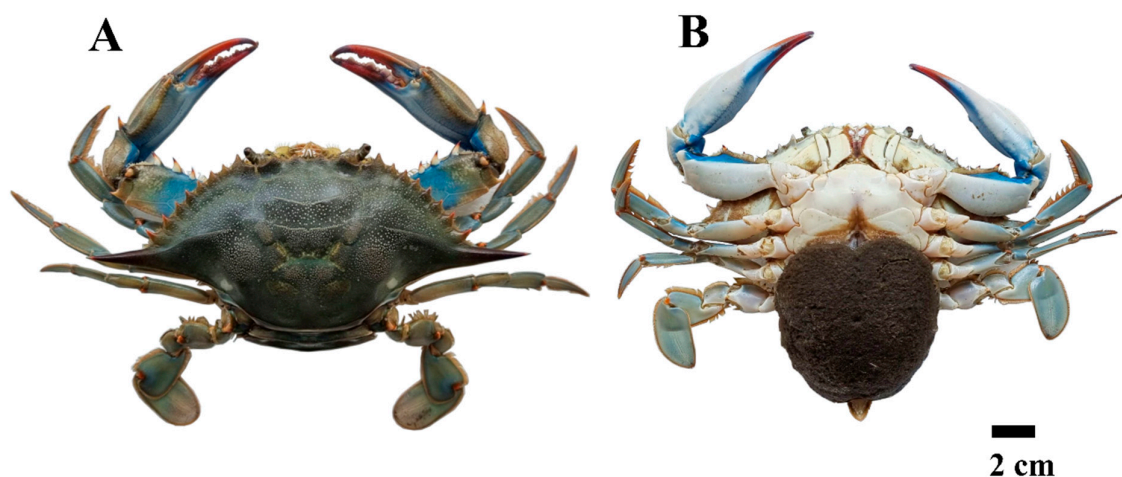


Figure 3. Ovigerous female of *Callinectes sapidus* from Vadu, Romania. Dorsal (A) and ventral (B) views.

The dimensions of the metagastric area were consistent with the diagnostic characteristics provided in published taxonomic keys for *C. sapidus*, further confirming species identification in conjunction with the remaining morphological characters. Based on the defined size groups, the individual was classified as large. Detailed measurements of the pereopods and chelae are presented in Tables 4 and 5.

Table 4. Pereopod lengths (mm) of the female *Callinectes sapidus* collected at Vadu, Romanian Black Sea.

Pereopods	Left	Right
P1 (Cheliped)	191.17	194.48
P2	115.56	115.50
P3	112.66	110.59
P4	94.28	93.62
P5	90.96	89.58

Table 5. Chela measurements (mm) of the female *Callinectes sapidus* collected at Vadu, Romanian Black Sea.

Chela	Left	Right
Dactylus length	39.45	40.28
Dactylus height	6.36	7.77

Dactylus depth	6.02	6.61
Propodus length	79.54	81.13
Propodus height	21.44	23.29
Propodus depth	16.86	19.50

The egg mass weighed 35.97 g, and egg diameter ranged from 234.76 to 319.94 μm , with a mean of $265.96 \pm 16.41 \mu\text{m}$ ($n = 300$). The EMI value was 13.06%. The egg embryonic development stage was pre-hatching (stage III) based on clutch color (dark brown) and stage 9 according to Kelly and Taylor's nine-stage classification [30], as indicated by the presence of distinct chromatophores and elliptical dark eyes. The single ovigerous female recorded in this study appeared in late summer.

4. Discussion

The present study highlights the value of combining citizen observations with targeted field investigations for the detection and monitoring of alien marine species. The newly documented records of *Magallana gigas* and *Callinectes sapidus* along the Romanian Black Sea coast not only confirm the continuous presence of these species in the region, but also provide new insights into their distribution, establishment status and reproductive biology.

The findings should be interpreted primarily as occurrence records contributing to baseline knowledge on the distribution of these species along the Romanian Black Sea coast, rather than as evidence of population status, abundance, or ecological impact.

The presence of *M. gigas* in both Constanta and Mangalia harbours suggests a broader distribution of the species along the Romanian Black Sea coast than previously recognised.

While based on only five opportunistically collected specimens, the presence of multiple size classes potentially points to localized survival under regional environmental conditions and warrants further investigation into possible repeated recruitment events. Until now, Constanta Harbour was considered the only location hosting a self-sustaining wild population of *M. gigas* in Romanian waters. The record from Mangalia Harbour extends the known distribution of the species southwards and may reveal an ongoing expansion process. At present, it remains unclear whether the occurrence of *M. gigas* in Mangalia Harbour results from an independent introduction event associated with yachts and recreational vessels arriving from different geographical regions or from the southward expansion of the population already established in Constanța Harbour through the dispersal of planktonic larvae transported by coastal currents. Both scenarios appear plausible and cannot be excluded based on the currently available data.

Regarding the morphological characteristics of the collected individuals, we observed considerable variation in physical dimensions across the sample (Table 2). Notably, both the largest and smallest specimens were collected from Constanța Harbour (Figure 2). Overall, the observed dimensions are consistent with previous reports from wild *M. gigas* populations along the Romanian Black Sea coast, where shell heights have been documented to vary between 52 and 186 mm. This similarity suggests that the specimens analysed in the present study fall within the expected size spectrum of established populations occurring in the region [34].

Relative to breeding populations of *M. gigas* reported from the southern Black Sea, which exhibited mean shell heights of $59.57 \pm 13.65 \text{ mm}$ (range: 24.09–98.17 mm) [40] and $33.3 \pm 7.24 \text{ mm}$ (range: 9.67–65.38 mm) [41]; the specimens collected from Romanian Black Sea waters were markedly larger. These findings indicate that *M. gigas* is capable of attaining substantial growth in Romanian coastal environments and are consistent with previous records of large individuals from the western Black Sea (Table 2).

Comparisons with previously published age–size relationships for *M. gigas* suggest that the analysed specimens were approximately one to five years old. However, these estimates remain indicative, as oyster growth can vary substantially among populations in response to local environmental conditions and habitat characteristics [41–43].

While *M. gigas* has previously been classified in the Black Sea as an established species with localised reproduction (category C3) [34,44], the occurrence of wild individuals beyond previously documented introduction sites may indicate an ongoing expansion of its distribution range. The persistence of these specimens under local environmental conditions further highlights the species' ecological plasticity and capacity to acclimatize to Black Sea coastal habitats. The naturalisation of the species and the potential expansion of its distribution range could be facilitated by shifting regional environmental trends, such as rising sea surface temperatures, which are known to favor the successful development and settlement of larvae [45]. However, alongside climatic influences, anthropogenic vectors such as intense maritime shipping traffic and localized habitat modifications within coastal harbors must also be considered as crucial concurrent drivers of this expansion.

If the species continues to expand its distribution in the Romanian Black Sea sector, ecological implications similar to those reported in other regions could emerge and should be investigated in future studies [46]. Although the densities currently recorded along the Romanian coast remain low, future population expansion could potentially lead to the formation of larger oyster aggregations capable of modifying habitat structure and influencing native benthic communities, including populations of the Mediterranean mussel, *Mytilus galloprovincialis*. At present, however, there is no evidence of such effects in Romanian coastal waters.

Compared to *M. gigas*, whose current distribution along the Romanian coast appears to be associated with the establishment of localised wild populations, the distribution dynamics of *C. sapidus* are primarily driven by its high mobility, broad environmental tolerance and considerable dispersal capacity. The new records reported in the present study provide additional evidence regarding the establishment and reproductive status of this species in Romanian Black Sea waters.

The earliest record of an ovigerous female blue crab (*C. sapidus*) in the Black Sea basin was reported by Uzunova [47] from Varna Bay (Bulgaria), based on six specimens caught by fishermen in 2005, including five males and one egg-bearing female. Subsequent records include findings from Ordu (Turkey) in 2020 [48], and from Chornomorsk (Ukraine) in 2024 [49].

The present record counts as the most recent observation of an ovigerous *C. sapidus* female in the Black Sea basin. Together with previous reports of ovigerous females recorded in June, the late-August observation documented in this study contributes valuable information on the reproductive phenology of the species in the region. Nevertheless, additional data across different seasons and years are required to better characterize reproductive timing, brooding frequency, and spawning patterns of *C. sapidus* in the Black Sea.

A comparison of carapace dimensions among ovigerous *C. sapidus* females reported from the Black Sea revealed that the specimen examined in the present study (CL = 70.71 mm, CW = 183.34 mm) was smaller than previously documented ovigerous females from Turkey (CL = 81.03 mm, CW = 200 mm) and Ukraine (CL = 77.64 mm, CW = 204 mm). Furthermore, the recorded specimen exhibited the smallest carapace dimensions reported to date among both male and female blue crabs documented in Romanian waters, where carapace length and width have been reported to range between 70.71–100 mm and 183.34–223 mm, respectively.

Fecundity was not estimated because the specimen carried a late-stage egg mass corresponding to the pre-hatching developmental phase. At this advanced stage of embryogenesis, eggs are more prone to detachment and loss during handling and processing,

potentially resulting in an underestimation of total fecundity. Consequently, no reliable estimate of egg number could be obtained without compromising the accuracy of the assessment [50]. Consequently, reproductive investment was evaluated using the Egg Mass Index (EMI), which represents a reliable proxy for fecundity when direct egg counts cannot be accurately determined. The EMI value obtained in the present study (13.06%) was remarkably similar to the highest value reported for *C. sapidus* females collected from the northwestern Aegean Sea (Eastern Mediterranean), where an EMI of 13.34% was recorded in June. This similarity suggests a comparable allocation of reproductive resources despite differences in geographic location and environmental conditions [29]. The lowest EMI value (4.18%) in their study was recorded for females sampled in August.

The ovigerous female examined in the present study exhibited a mean egg diameter of 265.96 μm , lower than the values reported for ovigerous females from the Turkish coast (mean: 281 μm ; range: 261.7–309.5 μm) and the Ukrainian coast (mean: 303.1 μm ; range: 237–379 μm). In contrast, the wet egg mass weight (35.97 g) was higher than that reported for the Turkish specimen (33.84 g), and lower than the value recorded for the Ukrainian specimen (48 g). These differences may be partially explained by variation in embryonic developmental stage among the examined females. Both Turkish and Romanian specimens carried brown to dark-brown egg masses corresponding to advanced developmental stages, during which partial egg loss may occur before hatching. In comparison, the Ukrainian specimen carried an orange egg mass, indicative of an earlier stage of embryonic development, which may account for its greater clutch weight.

The increasing number of *C. sapidus* records in the Black Sea, likely associated with rising seawater temperatures and ongoing changes in regional hydrological conditions, suggests that environmental conditions are becoming increasingly favourable for the establishment and expansion of this species [6]. Enhanced thermal regimes may facilitate larval development, prolong the reproductive season and increase juvenile survival, thereby promoting population growth and dispersal throughout the basin and may indicate an emerging ecological threat. The occurrence of *C. sapidus* in Sinoe Lake is of particular interest because the species is commonly associated with estuarine and coastal lagoon environments throughout both its native and introduced range. The Razim–Sinoe lagoon complex, which comprises extensive brackish-water habitats characterised by relatively low hydrodynamic stress, abundant food resources and suitable nursery areas, may provide favourable conditions for the establishment of local populations.

In the Mediterranean Sea, the blue crab is categorised among the top 100 Worst Invasive Alien Species due to the large number of records [51,52].

In contrast to the Mediterranean Sea, where *C. sapidus* has become one of the most successful and widespread marine invaders, forming abundant populations in numerous coastal and lagoon ecosystems, its establishment in the Romanian sector of the Black Sea appears to be at an earlier stage. Nevertheless, the occurrence of reproductively active individuals, together with the increasing number of recent records, suggests that the species deserves continued attention and monitoring.

A similar situation was previously observed in the case of *M. gigas*. The species was initially considered unlikely to reproduce successfully under Black Sea environmental conditions, yet subsequent studies demonstrated the existence of self-sustaining populations supported by natural recruitment. This example illustrates how alien species that initially appear sporadic may become progressively established over time, highlighting the importance of long-term monitoring and early assessment of potential ecological consequences.

Given that both *M. gigas* and *C. sapidus* are species of recognised commercial value in other regions, future studies could also evaluate their potential socio-economic significance in the Black Sea. However, the currently available data are insufficient to assess

either ecological impacts or management and utilisation options in Romanian coastal waters.

In addition to documenting new records of these species, the present study illustrates the potential value of citizen-reported observations for documenting the occurrence of alien marine species. The detection of *M. gigas* in Mangalia Harbour and the reporting of reproductively active *C. sapidus* individuals demonstrate how observations made by recreational divers, fishermen and other coastal stakeholders can contribute useful information that complements conventional scientific surveys.

At the same time, the scientific utility of such observations depends on appropriate expert validation. The verification of species identity and the assessment of supporting evidence are essential steps for ensuring data reliability and facilitating the integration of citizen-generated records into biodiversity monitoring programmes. When combined with conventional monitoring approaches, validated citizen-reported observations can increase surveillance effort, improve the detection of newly arriving alien species and provide additional information on changes in species distribution.

Although such observations cannot replace systematic scientific surveys, particularly when quantitative assessments of abundance, population dynamics or ecological impacts are required, they represent a valuable complementary source of information. In regions such as the Black Sea, where the introduction and spread of alien species remain ongoing processes, the involvement of coastal stakeholders may support long-term biodiversity monitoring and contribute to evidence-based management through the provision of verified occurrence records.

Even if the present study is based on a limited number of observations, the records provide valuable information on the occurrence, distribution, and reproductive status of two alien species of interest in the Romanian Black Sea sector. The integration of citizen-reported observations with scientific validation proved effective in complementing conventional monitoring efforts and expanding the spatial coverage of data collection. This approach represents a cost-effective and sustainable tool for supporting long-term biodiversity monitoring, early detection of non-indigenous species, and evidence-based management of marine ecosystems [53]. Continued engagement of coastal stakeholders, including fishermen, divers, and local communities, may further strengthen monitoring capacity and contribute to the sustainable management and conservation of Black Sea biodiversity.

5. Conclusions

The records presented here contribute to the current knowledge of the occurrence of *Magallana gigas* and *Callinectes sapidus* along the Romanian Black Sea coast. The finding of *M. gigas* in Mangalia Harbour extends the currently documented distribution of the species in Romanian waters, while the occurrence of an ovigerous *C. sapidus* female provides additional evidence that reproduction may occur in the region. Together with recent observations reported from neighbouring areas, these records highlight the need for continued monitoring of both species and their potential future expansion in the western Black Sea.

There is insufficient information to assess the effects of either species on native communities and ecosystem functioning in Romanian waters. Nevertheless, the continued appearance of new records, including observations from lagoon environments such as the Razim–Sinoe complex, indicates that further changes in their distribution may be expected. Future studies should focus on documenting population trends, reproductive activity and habitat use, while combining field surveys with verified observations provided by divers, fishermen and other coastal users. Such information is required to better un-

derstand the trajectory of these populations and their potential role within the Black Sea ecosystem.

Given the opportunistic nature of the observations and the limited number of specimens examined, the findings should be considered as a contribution to baseline knowledge rather than a comprehensive assessment of the distribution, abundance, or ecological status of these species. Nevertheless, the study demonstrates the value of citizen science as a sustainable and cost-effective approach for supporting long-term marine biodiversity monitoring, early detection of alien species, and evidence-based management of coastal ecosystems.

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