sustainability

Article

From Isolated Valves to a Potential Marine Living Resource: History, Documented Distribution and Sustainable Population Enhancement Possibilities of the Smooth Scallop (*Flexopecten glaber*) on the Romanian Coast

Cristian Danilov [1], Magda Nenciu [1], George Țiganov [1], Adrian Filimon [2], Mihaela-Cosmina Tănase [2] and Victor Niță [1,*]

[1] Marine Living Resources Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanța, Romania; cdanilov@alpha.rmri.ro (C.D.); mnenciu@alpha.rmri.ro (M.N.); gtiganov@alpha.rmri.ro (G.Ț.)

[2] Marine Biology and Ecology Department, National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., 900581 Constanța, Romania; afilimon@alpha.rmri.ro (A.F.); mtanase@alpha.rmri.ro (M.-C.T.)

* Correspondence: vnita@alpha.rmri.ro

Abstract: Until recently, the smooth scallop *Flexopecten glaber* (Linnaeus, 1758) was considered absent from Romanian Black Sea waters, as only isolated valves were documented on beaches of the southern coast. Yet, in 2020, the first living specimens were collected by dredging at 25 m depth in Mangalia. Moreover, in the past three years, a considerable number of live individuals were also retrieved from beam-trawling operations targeting the gastropod *Rapana venosa* (Valenciennes, 1846) along the Romanian coast, indicating that there is a stable population here. This remarkable expansion of *F. glaber* in Romanian waters may be explained as a consequence of the Black Sea's recovery from eutrophication, reduced predatory pressure from the declining population of *R. venosa* and changing climate conditions. Our research aimed at using all this novel information to document for the first time the occurrence and distribution of this bivalve on the Romanian coast, also considering perspectives for the development of a new type of shellfish mariculture, avoiding any pressure on the natural stock. In total, 386 *F. glaber* individuals were sampled during 2020–2023, at depths between 22.5 and 33.3 m. The abundance and biomass per station oscillated between 5 and 319 specimens and 51.5 and 7377 g, respectively. A subsample of 122 specimens was preserved and analyzed in the laboratory, revealing an average shell length of 53.54 mm (±4.13 SD) and an average shell height of 49.54 mm (±3.64 SD). The smooth scallop has both ecological and economic value, which makes it a viable candidate for sustainable aquaculture by collecting spat from the most abundant areas and subsequently placing "seedlings" in the appropriate polygons for stock recovery. Ultimately, commercial exploitation from aquaculture installations can be considered, provided a permanent healthy *F. glaber* population is established on the Romanian coast.

Keywords: smooth scallop; recovery; distribution; marine living resources; sustainable aquaculture

check for updates

Citation: Danilov, C.; Nenciu, M.; Țiganov, G.; Filimon, A.; Tănase, M.-C.; Niță, V. From Isolated Valves to a Potential Marine Living Resource: History, Documented Distribution and Sustainable Population Enhancement Possibilities of the Smooth Scallop (*Flexopecten glaber*) on the Romanian Coast. *Sustainability* **2024**, *16*, 3924. https://doi.org/10.3390/su16103924

Academic Editor: Tim Gray

Received: 12 April 2024
Revised: 29 April 2024
Accepted: 6 May 2024
Published: 8 May 2024

1. Introduction

The smooth scallop, *Flexopecten glaber* (Linnaeus, 1758), is the only representative of the Pectinidae Family within the Black Sea. Originating from the Mediterranean, the Black Sea scallop is believed to have been established around 7000 years ago [1]. Designated as a subspecies, *Flexopecten glaber ponticus* (Bucquoy, Dautzenberg & Dollfus, 1889) is the recognized taxonomic classification for the Pectinidae species inhabiting the Black Sea [2]. Nevertheless, both morphological and genetic analyses have indicated no differences between Black Sea scallops and their counterparts in the Mediterranean Sea [1,3].

The Black Sea scallop has been recorded at various occurrence frequencies and abundance values along the entire Black Sea coast, as recently documented [4]. However, two patterns emerge in the Black Sea smooth scallop's evolution. Firstly, certain regions, such as the southern, eastern (Central and North Caucasus) and northern (Crimea) sectors, demonstrate similar long-term dynamics in scallop population development. Historically, *F. glaber* was abundant enough along the Crimean coast and in Sevastopol Bay to support commercial harvesting operations [5]. Lately, there has been a significant decline in the scallop population across its former habitats, leading to its inclusion in the Red List of Crimea and Sevastopol [6,7]. In the southern part (i.e., the Turkish coast), *F. glaber* was a characteristic species in some benthic habitats. However, data from the southern region are primarily representative of the first half of the 20th century, with limited information available in recent years. In the eastern area, encompassing the Kerch pre-strait area and adjacent regions within the strait, scallop abundance has recorded a consistent decline over the past decade, culminating in the absence of records since the 1960s [4].

Conversely, other areas, particularly the western and northwestern sectors of the Black Sea, exhibit historically poor development of scallop populations. In the northwestern part, the smooth scallop was documented in benthic habitats but never as a characteristic species [4]. In the Black Sea, the smooth scallop has been recorded in a range of habitats, including both soft sediments and hard substrates, at depths between 0 and 48 m [4,8]. While habitat type may not be a limiting factor, salinity and dissolved oxygen levels appear to play crucial roles in its distribution [9]. Recently, in Bulgarian waters, an abundant population of *F. glaber* was discovered, marking the first occurrence since the 1960s [8].

Along the Romanian coast, the first record of living Black Sea scallops occurred in 2020, when the first living specimens were collected by dredging at 25 m depth in Mangalia (southern part of the coast) [10]. This finding led to its inclusion in the Red Book of Romania, classified as Critically Endangered (CR) [11]. In the past three years, a considerable number of live *F. glaber* specimens were also by-caught by beam-trawling targeting the gastropod *Rapana venosa* (Valenciennes, 1846) along the entire Romanian coast, indicating that there is a stable population here. Under these circumstances, the current research aimed at using all this novel information to document for the first time the occurrence and distribution of the smooth scallop on the Romanian coast, characterizing the species' influencing environmental factors, spawning specificities, also considering perspectives for the development of a new type of shellfish mariculture, avoiding any pressure on the natural stocks.

2. Materials and Methods

2.1. Sampling and Study Area

The smooth scallop sample collection was performed during research surveys along the entire Romanian coast targeting rapa whelk (*R. venosa*) in 2020, 2021, 2022 and 2023, respectively, in the frame of a dedicated project aimed at assessing the stock of this gastropod in the Black Sea basin [12]. *F. glaber* specimens appeared as by-catch during the surveys. The gear used was a customized Turkish design beam trawl [13]. The mesh size of the codend was 72 mm (diamond stretched) and the nets were made of polyamide netting (nylon). A 40 mm mesh size cover netting was used around the codend to retain the specimens escaping from the sampling gear. The stretched length of the 40 mm cover was 1.5 times longer than the 72 mm survey net (Supplementary Materials S1). The gear was towed from the aft of NIMRD's "Steaua de Mare 1" research vessel (570 HP engine) and connected to a winch with a 12 mm warp diameter. The warp length was adjusted to 3–5 times the water depth so that the gear remained in good contact with the sea bottom. Each haul performed had a duration of 30 min at a trawling speed of 2 knots.

A total number of 51 stations were sampled yearly in the Romanian area in order to provide wide and homogeneous coverage of the continental shelf (Figure 1). The surveys were carried out on 3 water depth strata—5–15 m, 15–25 m and 25–35 m, respectively—covering a total research area of more than 5500 km^2 (Table 1). The swept area covered by each haul ranged between 0.006 and 0.017 km^2.

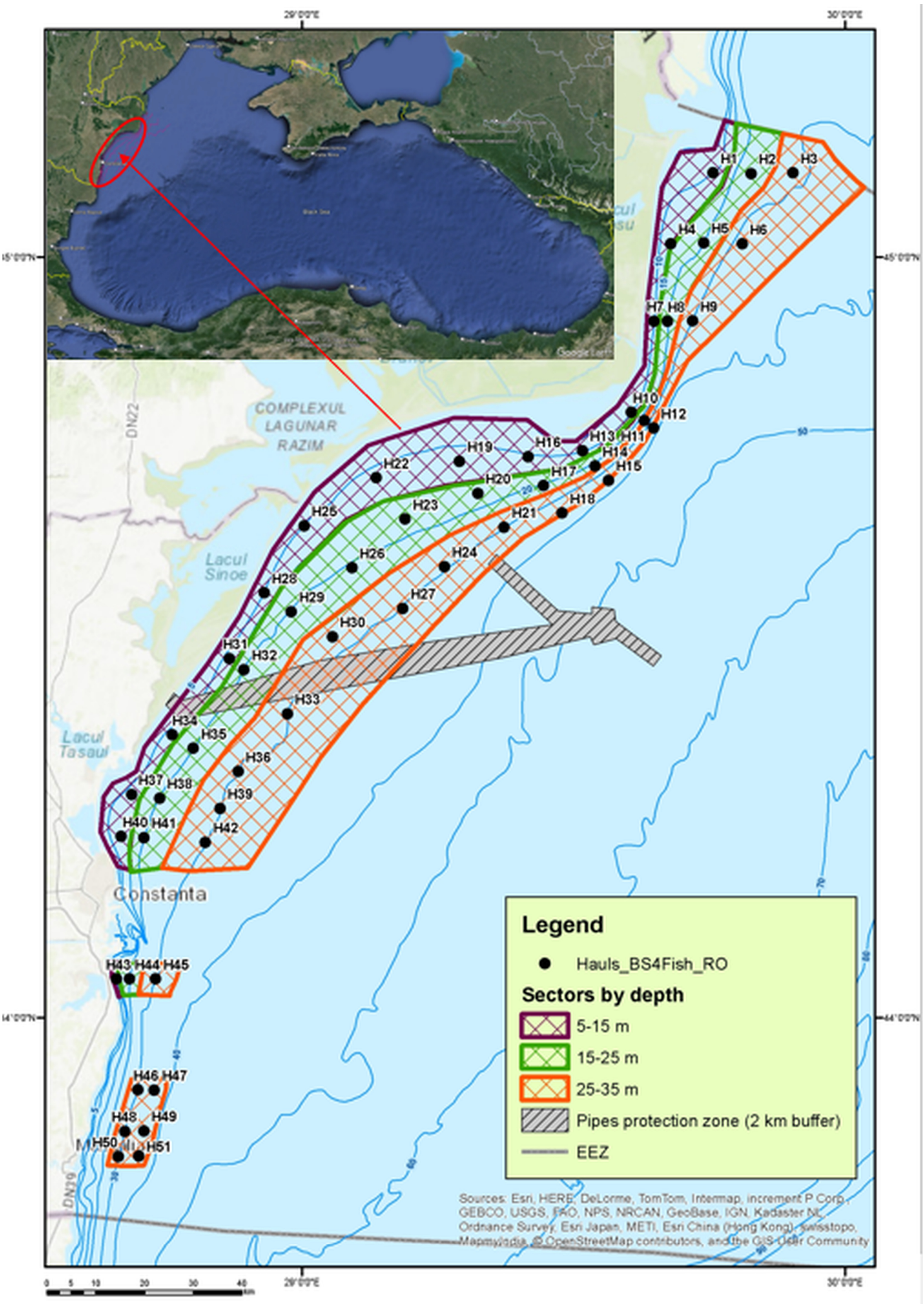

Figure 1. Map of the sampling stations along the Romanian coast.

Table 1. Area covered by the beam-trawling surveys (on depth strata).

Depth Strata	Area (sqkm)
5–15 m	1418.0
15–25 m	1662.4
25–35 m	2437.3
Total	**5517.7**

2.2. Biometrics and Age Reading

After each haul operation ended, the catch was sorted by species. All the catch was weighed and measured for total length and weight according to the FAO Technical Guidelines 2020 [14]. The by-caught scallops were measured in the field using a manual caliper, weighted on a Kadda electronic balance and subsequently released (Supplementary Materials S2).

For a comprehensive analysis of population characteristics, a subsample of 122 individuals was preserved in 70% ethanol and transported to the laboratory. Additional measurements were performed using a carbon fiber composite digital caliper (model X0027BRMP7, RoHS, accuracy ±0.1 mm), for more reliability. Within the laboratory, morphological parameters, specifically shell height (H) and length (L), were assessed, for the larger left (upper) shell of each specimen (Figure 2 left). The measurements were systematically organized into size classes, divided at 2 mm intervals (Figure 2 center). Afterward, the scallops were scrubbed with a brush to clean any epibiotic deposit, and the rings on the upper shell were marked with a pencil (Figure 2 right). The biological age of the individuals was estimated based on the number of annual rings [15].

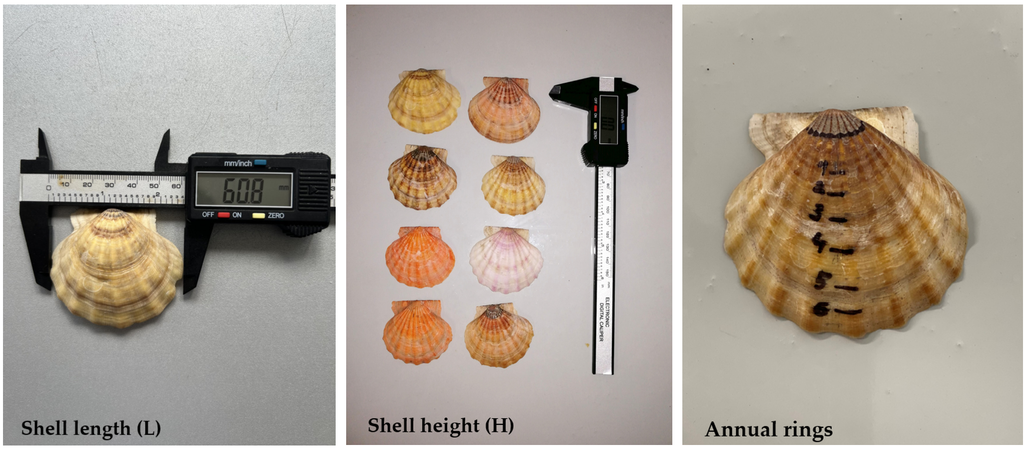

Figure 2. Smooth scallop shell height (H) and length (L) measurement (**left**); size class division (**center**); age reading by counting annual rings (**right**) (original photos).

The relationship between shell length (L) and shell height (H) was established based on the allometric equation:

$$y = a \times x^b \quad (1)$$

2.3. Statistical Analysis and Map Generation

The initial phase of data handling involved inputting the raw data into Microsoft Excel 2016 (KB4011684), where pre-processing and organization procedures were carried out. Subsequently, statistical analysis and visualization of the processed data were conducted using the Excel 2016 software package. The results encompass numerical data presented in a structured format. Mean values were calculated for each dataset, with associated standard deviations (SD) provided to convey the variability within the samples.

Distribution maps were created using the ArcMap 10.x Software (ESRI product).

3. Results

During the investigated period (2020–2023), *F. glaber* specimens were retrieved as by-catch in beam-trawl hauls for *R. venosa* along the entire Romanian coast, generally at depths between 20 m and 35 m (Figure 3). During the 2020 survey, 5 smooth scallop individuals were recorded in 2 stations, at depths ranging from 24.5 to 33.3 m. In 2021, 44 *F. glaber* specimens were identified in 6 stations at water depths between 23.5 m and 31.4 m. Further, 2022 was the year with the highest number of live smooth scallop specimens collected (319), found in 9 stations, at depths ranging from 22.4 m to 32.4 m. In 2023, 18 *F. glaber* individuals were identified in a single station, at a depth of 26.5 m (Supplementary Materials S3).

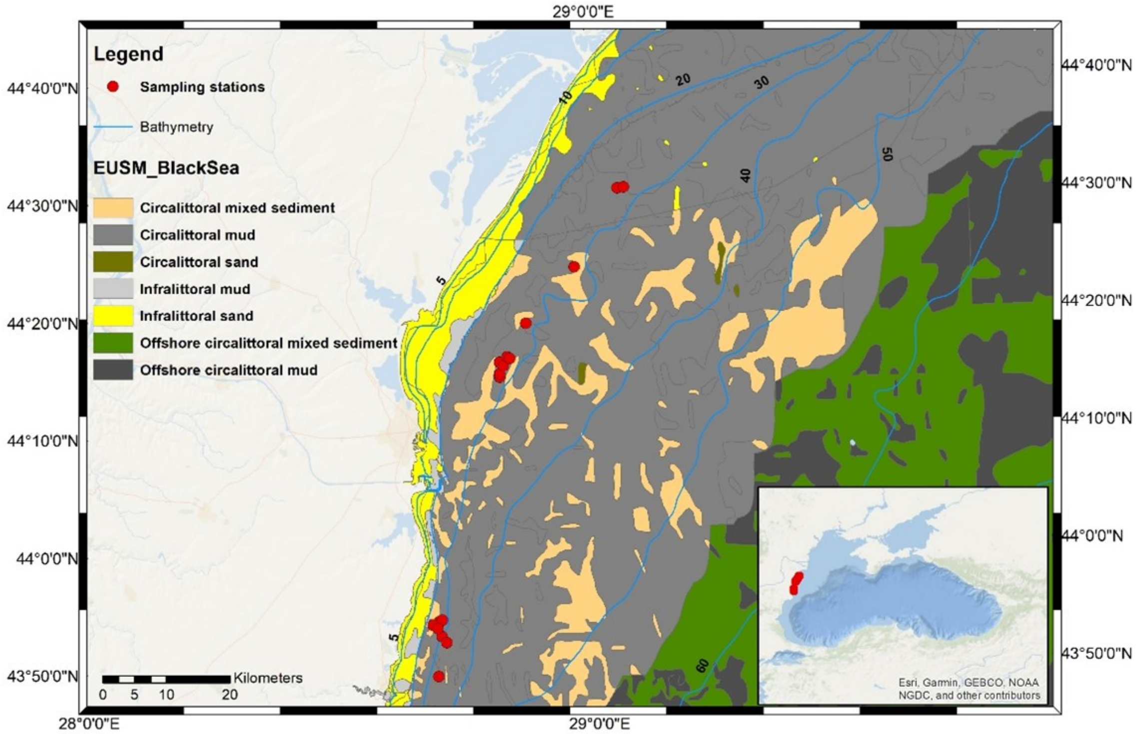

Figure 3. Sampling stations where live *F. glaber* individuals were identified during 2020–2023, referenced to habitat type on the Romanian continental shelf.

Regarding the habitat type preference of the smooth scallop, the majority of *F. glaber* specimens were found on circalittoral mixed sediments and circalittoral muds (Figure 3).

The abundance and biomass of *F. glaber* oscillated in the period 2020–2023 between 5 and 319 specimens (Figure 4 left) and 51.5 and 7377 g (Figure 4 right), respectively, with a peak in 2022 for both parameters considered. Concerning the spatial distribution, most specimens (>100) were recorded in the central part of the coast (off the Mamaia–Năvodari area), with significant occurrences (60–100 individuals) in the southern sector (off Mangalia), as well. The fewest *F. glaber* specimens were documented closer to the Danube mouths, off the Vadu–Portița area.

The shell length (L) of the analyzed specimens ranged between 36.8 and 63.6 mm, with an average length of 52.80 mm (±4.41 SD). The shell height (H) ranged from 35.8 to 58.1 mm, with a mean value of 48.78 mm (±3.76 SD). The size distribution was dominated by specimens within the length class of 53–55 mm (20%) and the height class of 49–51 mm (28%) (Figure 5). On average, shells were longer than higher with 4.01 mm (±1.70 SD). Just one individual was higher than longer (+0.6 mm).

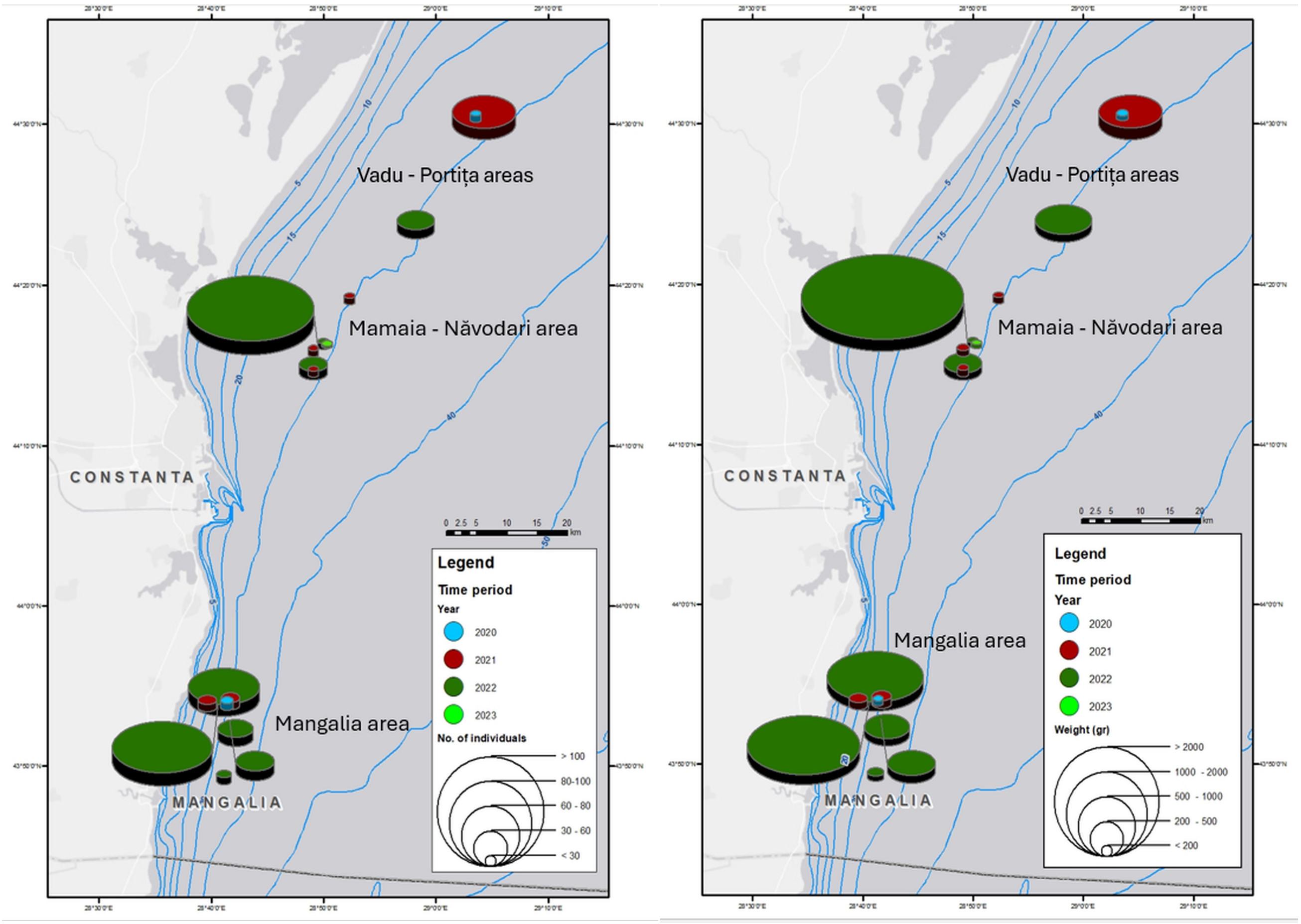

Figure 4. Distribution of *F. glaber* abundance (**left**) and biomass (**right**) along the Romanian coast during 2020–2023.

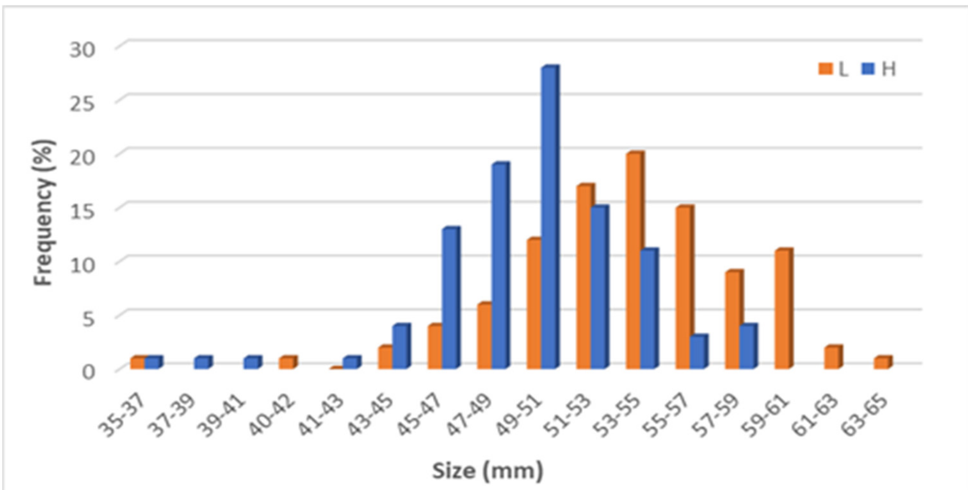

Figure 5. *F. glaber* size distribution on length and height classes.

The relationship between two size variables (i.e., H and L) was examined using the allometric Equation (1). The growth coefficient (b) was determined to be close to 1, with a value of 0.84. This suggests an allometric growth pattern, where an increase in length leads to a proportional increase in height, but at a slightly lesser rate (i.e., negative allometry of height) (Figure 6).

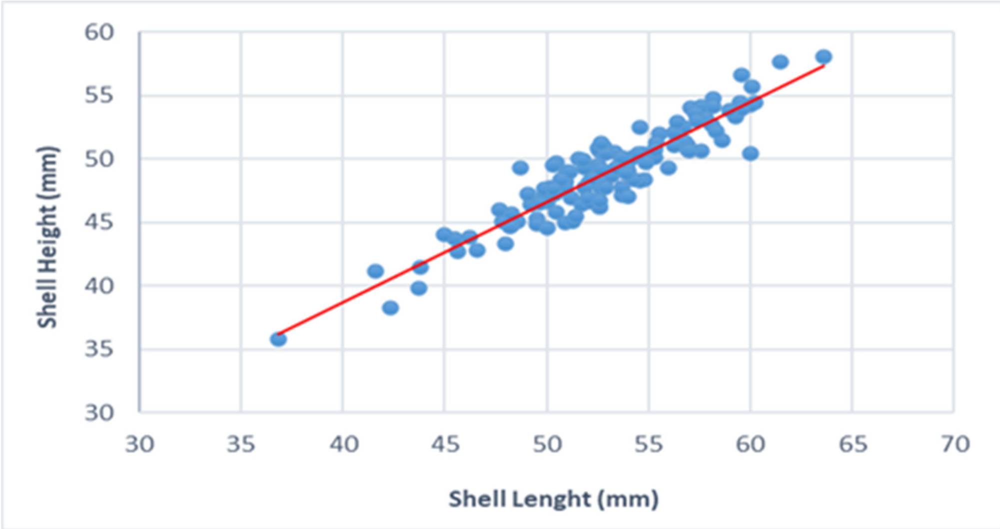

Figure 6. Length–height relationship of *F. glaber* specimens at the Romanian coast.

Analyses of the 122 *F. glaber* individuals brought to the laboratory revealed ages ranging from 5 to 9 years old. A significant share of the sampled population (56%; N = 68) fell within the 7-year age class, followed by the 6-year class (23%; N = 28) and 8-year age class (18%; N = 22). The size classes representing 5 and 9 years old exhibited the lowest representation (3%; N = 4) of the total number (Figure 7).

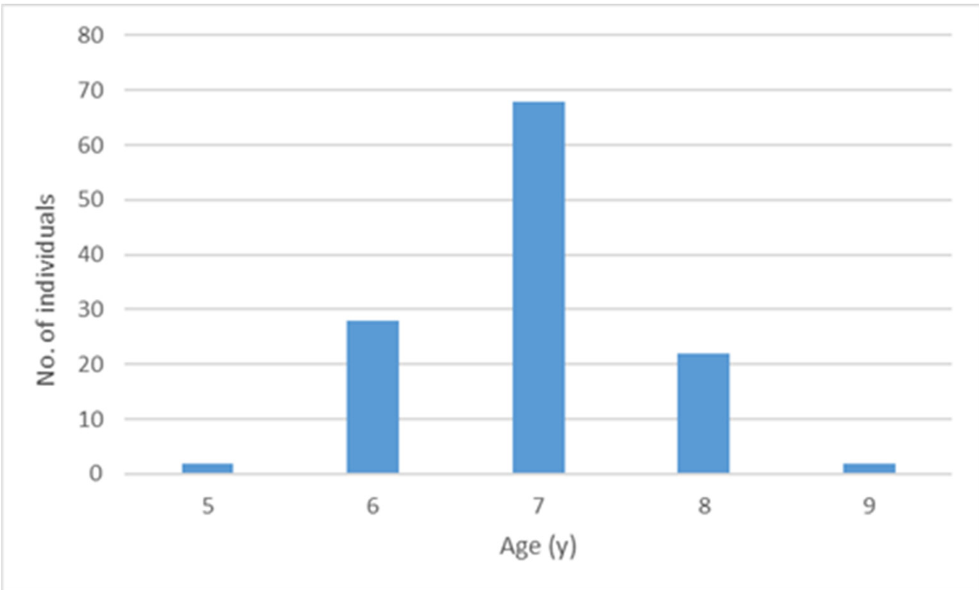

Figure 7. Age distribution of *F. glaber* specimens sampled on the Romanian coast.

In this study, individuals aged 5 years exhibited dimensions ranging from 35.8 to 38.3 mm, while those aged 6 years had dimensions spanning between 39.8 to 56.6 mm. At 7 years of age, the individuals reached sizes of 44.6 to 57.6 mm, which increased slightly at 8 years to 45.8 to 58.1 mm. Finally, individuals aged 9 years showed dimensions ranging from 50.4 to 50.6 mm (Figure 8).

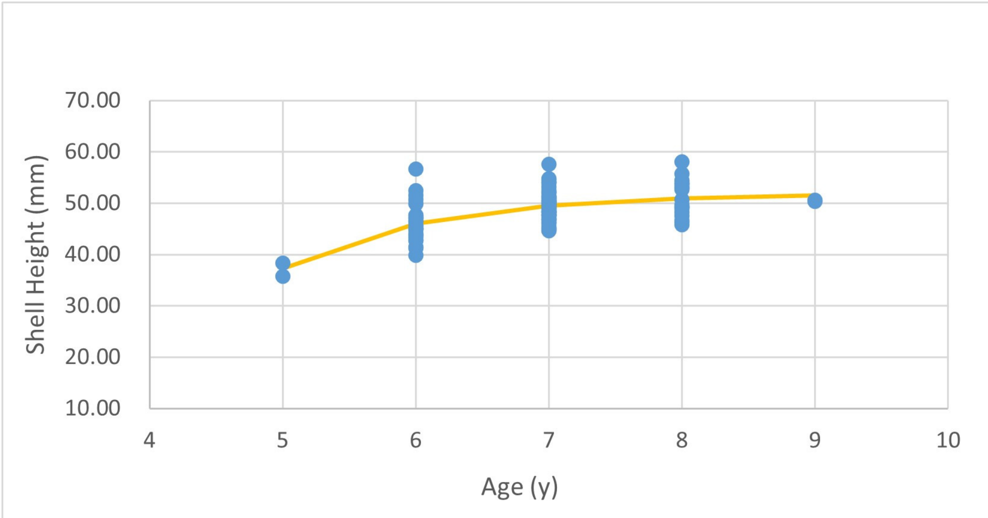

Figure 8. Size at age for *F. glaber* derived from the application of the von Bertalanffy growth function to a sample of 122 individuals collected in Romanian waters.

The investigated shells displayed six color morphs (Figure 9, left). The most frequent were brown (39%), multi-colored (32%) and off-white (11%) shells (Figure 9, right).

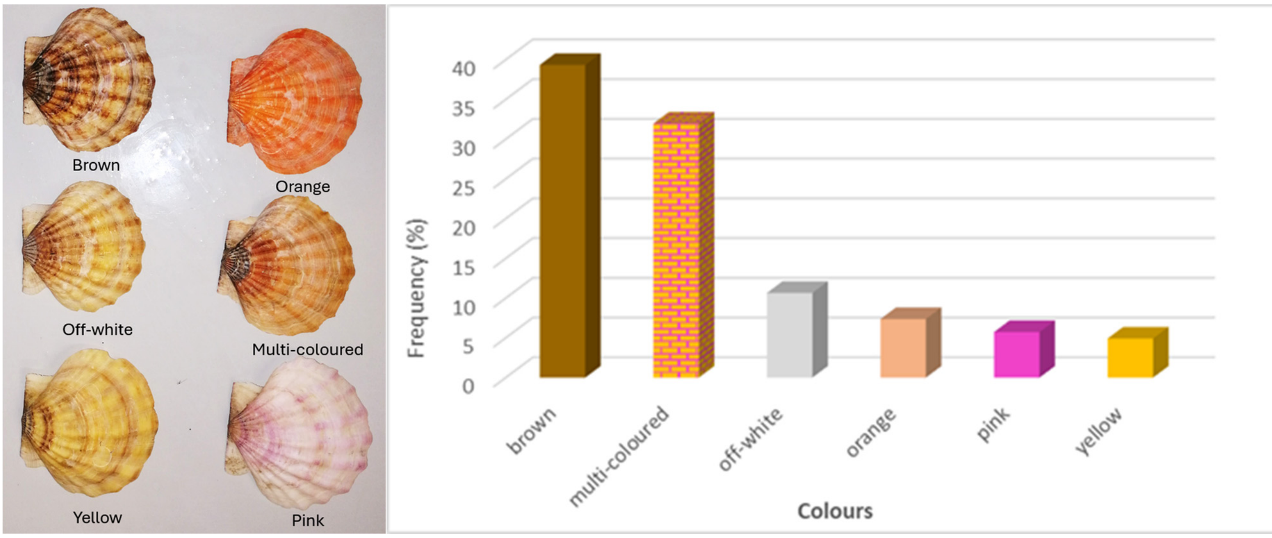

Figure 9. Color morphs identified in *F. glaber* specimens on the Romanian coast (total number of individuals analyzed N = 122).

4. Discussion

The recovery of Black Sea scallop populations, following a significant decline, has piqued the interest of the scientific community, as evidenced by the emergence of publications in recent years [1,3,4,8]. On the Romanian shelf, however, before June 2020, *F. glaber* was documented solely as isolated shells on beaches. The reporting of isolated shells persisted across several studies [16–20], until the recent discovery of living specimens in the Mangalia area [10].

The occurrence of *F. glaber* in regions historically characterized by poor development, or in areas where it was previously absent, is frequently associated with environmental recovery following eutrophication (nutrient levels have constantly decreased in recent years [21]), declining populations of *R. venosa* due to economic harvesting and changing climate conditions, particularly seawater warming trends [4,8].

The biology and ecology of this species are incompletely understood in both the Mediterranean and Black Sea basins [22].

In the Mediterranean Sea, *F. glaber* is commonly found inhabiting sedimentary habitats at depths ranging from 5 to 900 m [23]. In the Black Sea, the smooth scallop was found in the depth range of 0–48 m [4,8]. During this study, the trawling activities took place between the 5 and 35 isobaths. Smooth scallops were primarily found within a narrow depth band from 20 to 35 m, inhabiting circalittoral soft-bottom benthic habitats, comprising mud and mixed sediments. This preference for such habitats aligns with findings reported in Bulgaria [8]. Notably, the presence of smooth scallops on hard substrates or within seagrass meadows has not been documented in Romania yet, unlike the observations made in Bulgaria or Ukraine [8,24].

As a habitat generalist species, the occurrence of *F. glaber* at depths exceeding 20 m could be attributed to the freshwater discharge from the Danube River (impacting salinity level, particularly within the 0–20 m depth) rather than to habitat type [25]. As for the maximum depth at which the smooth scallop can be found in Romanian waters, definitive assertions cannot be made at the moment. For this, research efforts should be extended to greater depths.

Among environmental factors, salinity and dissolved oxygen levels seem to be the most important limiting factors for smooth scallop distribution. Most scallop species inhabit fully saline waters and are incapable of colonizing low-salinity environments. Salinity not only limits the spatial distribution of bivalves but also impacts various aspects of their biology, including feeding, reproduction, growth, respiration, osmoregulation and interactions with parasites and diseases [15]. For Black Sea scallops, optimal salinity conditions fall within the range of 16–17‰ [9]. During our investigations, the salinity levels where the smooth scallop was found ranged between 16.4 and 18.6‰, which indicates proper conditions for development (Supplementary Materials S3).

Concerning the size of *F. glaber* individuals on the Romanian coast, the maximum shell length of smooth scallops (63.6 mm) exceeded those reported in Bulgaria (53.48 mm) [8] and Crimea (53.4 mm) [24,26], respectively. The maximum age (9 years) of specimens from Romania was similar to the maximum age found in Bulgaria [8]. The minimum length and age could not be compared with other studies from the Black Sea due to the use of a sampling gear with a mesh size of 40 mm (thus smaller), and younger scallops were not retained and documented.

With reference to shell color, the number of morphs found in our samples was comparable to the ones documented on the Bulgarian coast: six morphs in Romania compared to seven in Bulgaria [8]. The only color not identified in our samples was violet. This similarity indicates a rather homogeneous population in the north-western Black Sea area.

Smooth scallops (*F. glaber*) are simultaneous hermaphrodite species, characterized by rapid sexual maturation [27]. In the Mediterranean Sea, this species reproduces from April to September [22]. In the plankton of the Black Sea, veliger larvae of *F. glaber* are found from June to August [28]. The duration of larval life in marine bivalves ranges from three to five weeks, influenced by environmental conditions such as temperature, salinity and food availability [15]. In the Black Sea, the length of the meiosis stages, embryonic and larval development and the description of larvae at the veliger stage are provided based on cultivated material from Sevastopol Bay [29]. The age and size at first maturity for *F. glaber* were observed to be 9–10 months (22.4–25.1 mm shell height) in the Adriatic Sea [22].

Based on data from both the present study and research conducted in 2020, when the species was initially discovered in samples, it can be asserted that a stable population of *F. glaber* exists along the Romanian coast, thriving in favorable conditions for reproduction and development. Compared to 2020, there has been an observed expansion of the population along the Romanian littoral. Furthermore, individuals found in 2020 were predominantly aged 3–4 years, whereas in the current study, individuals aged 9 years were discovered, indicating continuity in the development of individuals.

Bivalves are essential marine organisms due to their ecological and commercial relevance, which are appreciated for their taste and nutritional qualities [30]. Among them, scallops are considered a delicacy worldwide and they represent an important part of the global seafood market and support both commercial fisheries and aquaculture developments globally [31]. In the past 10 years, the consumption of Pectinidae has increased and they are now an important part of the European seafood market [32]. Scallops are popular among consumers both fresh and frozen; consequently, their rearing may be economically profitable and able to provide a desirable product for human consumption with high market value [33]. The organoleptic characteristics (taste, texture, firmness, etc.) and the high market value of *F. glaber*, comparable to those of the great Mediterranean scallop [*Pecten jacobeus* (Linnaeus, 1758)], make this species of great interest for the development of shellfish culture [22]. In addition, smooth scallops have shown high growth and survival performance, early maturation and intensive breeding [34].

Similarly to other Black Sea riparian countries [35], bivalve culture in Romania is limited to mussels (*Mytilus galloprovincialis* Lamarck, 1819) and some isolated attempts for Pacific oyster rearing [*Magallana gigas* (Thunberg, 1793)] [36]. Whereas *F. glaber* is an edible mollusk with considerable market value, it can be considered a viable candidate for diversifying shellfish aquaculture in the region, given the increasing social acceptability of seafood consumption [37]. As a potential candidate for aquaculture purposes, the smooth scallop may offer good prospects for rearing, considering not only its commercial value, but also that its use in aquaculture might contribute to a reduction in the negative impacts of fishing gears on the sea bottom [22]. The main hindrance to scallop aquaculture is a reliable and sufficient supply of seedlings [38], which can be obtained either by spat collection from the natural environment or by controlled spawning under laboratory conditions.

The deployment of artificial collectors at sea is a widespread technique for settling wild scallop spat and subsequently culturing different pectinid species worldwide [33,34,39–41]. Natural recruitment may ensure the permanent availability of scallop spat, addressing the problem of high seedling variability, which is a major constraint for scallop aquaculture activities. Due to biofouling, collectors are only effective for a limited period and must be deployed for a beneficial timeframe to become enticing for spat attachment [30,42,43]. Consequently, the pursuit of commercial bivalve culture calls for a good understanding of recruitment timing.

Scallop spawning season follows a latitudinal trend, with acute seasonality and synchronism at higher latitudes, that becomes longer and less synchronized as latitudes decrease [44]. In the north-western Adriatic, spawning is documented to occur mostly between July and September, with minor spawning events between April and May [22]. The settlement of viable larvae occurs some weeks after the species spawning period [41]. In the Ionian Sea, spawning is reported between February and early August; the larvae swim for three to four weeks before settling, at water temperatures ranging from 15 °C to 18 °C [34]. In the Turkish Aegean (Izmir Bay), two spawning peaks were determined, in November/December and July/August, respectively, at water temperatures ranging from 12 °C to 28 °C [45]. In the Black Sea, the spawning period of the smooth scallop peaks in June and July [29], when seawater temperature is usually around 25 °C [46].

There are several collector types that can be used for smooth scallop spat settlement. The Turkish model [45] consists of individual collector systems made from 50 cm x 20 cm polyethylene mesh bags set on polyvinyl chloride (PVC) pipes, with a mesh size of the polyethylene bag of 5 × 4 mm. The collector system is designed as a surface and bottom collector. The bags are tied to the pipes with a plastic rope at 15 cm intervals. Two PVC pipes are attached to the main rope at depths of 1 and 5 m, with the surface and bottom collectors attached on either side. A buoy (20 L) at the top and an anchor (100 kg) are used to keep each system stable in the water [43]. Alternatively, the Greek model [34] proposes spat collectors made of 40 cm × 60 cm crop sacks filled with plastic net (mesh size 5 × 7 mm, area 40 × 100 cm), hung at 1, 4 and 8 m depth from each of four 8 m long polypropylene ropes placed vertically at 2 m of each other on a classic shellfish longline installation [47]. A weight is set at the bottom end of each vertical rope to maintain the position of the collector sacks [34]. Another version of collectors set on longlines consists of 28 cm × 53 cm net bags (4 mm mesh size), filled with a 5 m long tubular net that has a 5 cm mesh opening, which is commonly used for mussels. This internal net (called a "filler") is folded and rolled up on itself to convey volume to the collector. Each set of collectors consists of a rope on which 10 net bags are placed 1 m from each other. The upper end of each rope is then tied to a longline submerged at 4 m depth so that collectors remain submerged from 5 to 14 m [41]. Using any of the collectors described, the highest number of spat settled closer to the seabed and density decreased towards the surface [34,41,45]. This tendency of spat to settle in deeper substrates may be explained by the need to avoid strong wave action, water turbulence and excessive fouling [48,49].

It is essential to deploy the collectors two weeks before the larvae settle to ensure that a microfilm coating forms [45]. Whereas peak spawning of Black Sea *F. glaber* is expected in July, the collectors should be deployed at sea in mid-June, aiming to maximize spat recruitment. In order to reach maturity and a shell length of about 40 mm, the collectors should be kept immersed for 2–2.5 years [50].

Laboratory/hatchery culture is another method of obtaining scallop spat, with the French experience being the reference standard for scallop hatcheries in Europe [51–53]. Before spawning, mature scallops collected from the wild are placed in a conditioning system with controlled light, temperature and food supply to ensure the production of viable larvae in the hatchery. Hatcheries typically use continuous flow-through systems (with or without sand on the tank bottom [54–56]. The conditioning of broodstock is carried out for 11–12 weeks at temperatures of 12–15 °C using a diet of multi-species microalgal mix [27,52]. If spawning does not occur naturally, scallops may be subjected to external stimuli (such as mechanical or electrical shock, intense illumination, use of ammonium hydroxide and variation of water pH) [57] or hormone (estradiol) injections [58]. After spawning, larvae are grown in flow-through cylindrical tanks with conical bottoms [52]. For the attachment and metamorphosis of pediveligers, circular sieves with a mesh bottom and airlift downwelling are used [52]. Subsequently, after reaching 3–4 mm shell height, the spat is transferred to grow-out collectors at sea [59]. The major drawbacks of hatchery production are large variations in larval production between years, bacterial infections and high maintenance costs [52]; thus, a spat collection from the wild seems to be the most feasible solution.

The smooth scallop has both ecological and economic value, which makes it a suitable candidate for aquaculture by collecting spat from the most abundant areas identified within this study, growing them out until reaching maturity and subsequently placing "seedlings" into appropriate polygons for stock recovery. After careful monitoring certifying that *F. glaber* has established a permanent and healthy population on the Romanian coast, sustainable commercial exploitation from aquaculture installations can be considered, adding value to the productive sector and introducing a highly appreciated seafood species.

5. Conclusions

The recent discovery of a significant number of live *F. glaber* individuals along the Romanian coast confirms the fact that smooth scallops are a constant presence in the marine fauna of the area. This occurrence in a region where it was previously absent may be attributed mainly to a post-eutrophication recovery. According to our investigations, *F. glaber* specimens sampled from Romania seem to be larger than those measured in other Black Sea areas, which suggests that the species found propitious environmental conditions to develop here. In order to accurately map the distribution and abundance and assess the stocks of this bivalve at the Romanian coast, dedicated studies are essential and envisaged in the future. Moreover, the smooth scallop has both ecological and economic value, which makes it a viable candidate for aquaculture by collecting spat from the most abundant areas and subsequently placing "seedlings" into appropriate polygons for stock recovery. As a possible candidate for aquaculture, the smooth scallop may provide good opportunities for rearing, considering not only its commercial worth, but also how its usage in aquaculture may contribute to a reduction in the destructive effects of fishing gear on the sea floor. Ultimately, after scientifically acknowledging that a healthy and thriving *F. glaber* population is established here, commercial exploitation from aquaculture installations can be considered, thus providing a valuable alternative marine living resource.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16103924/s1, Supplementary Materials S1: beam trawl used for smooth scallop sampling (original photos); Supplementary Materials S2: on-board length and weight measurements of *F. glaber* specimens (original photos); Supplementary Materials S3: coordinates and environmental parameters of the smooth scallop sampling during 2020–2023.

Author Contributions: Conceptualization, V.N. and M.N.; Methodology, C.D., G.Ţ., A.F. and M.N.; Investigation, C.D., G.Ţ., A.F. and M.-C.T.; Resources, C.D., A.F., M.N. and V.N.; Data Curation, A.F., M.N. and V.N.; Writing—Original Draft Preparation, C.D., G.Ţ., A.F. and M.N.; Writing—Review and Editing, V.N. and M.N.; Supervision, V.N.; Project Administration, V.N. and G.Ţ.; Funding Acquisition, V.N. and G.Ţ. All authors have read and agreed to the published version of the manuscript.

Funding: The scallop sampling was funded by FAO/GFCM under the framework of the project MTF/INT/943/MUL—Baby 33, entitled "GFCM 2030 Strategy Operationalized through Selected Activities for Sustainable Fisheries and Aquaculture in the Mediterranean and the Black Sea—Rapa Whelk Research Surveys in the Coastal Waters of Romania". Data analysis, processing and interpretation were funded by the Romanian Ministry of Research, Innovation and Digitization, grant number PN23230301, under the framework of the NUCLEU SMART-BLUE Programme.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

Acknowledgments: The authors kindly thank Alina Spînu and Silvia Oprea for the creation of *F. glaber* distribution maps.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Bondarev, I.P. Taxonomic Status of *Flexopecten glaber ponticus* (Bucquoy, Dautzenberg & Dollfus, 1889)—The Black Sea *Flexopecten glaber* (Linnaeus, 1758) (Bivalvia: Pectinidae). *Mar. Biol. J.* **2018**, *3*, 29–35.
2. WORMS. *Flexopecten glaber ponticus* in World Register of Marine Species. Available online: https://www.marinespecies.org/aphia.php?p=taxdetails&id=394257 (accessed on 4 April 2024).
3. Slynko, Y.V.; Slynko, E.E.; Schurov, S.V.; Ryabushko, V.I. The Black Sea *Flexopecten* Species-Complex (Mollusca: Bivalvia: Pectinidae): Shell Morphology and 16S rDNA Variation. *Ecol. Mont.* **2020**, *32*, 10–18. [CrossRef]
4. Revkov, N.; Revkova, T. Long-term Variations in the Black Sea Population of Smooth Scallop, *Flexopecten glaber* (Linnaeus, 1758) (Bivalvia: Pectinidae): A Review. *Turk. J. Fish. Aquat. Sci.* **2023**, *23*, TRJFAS22610. [CrossRef]
5. Milashevich, K.O. *Molluscs of the Black and Azov Seas. Fauna of Russia and Neighboring Countries: Mollusks of the Russian Seas. Part 1*; Imperatorskaya Akademiya Nauk: Petrograd, Russia, 1916; 312p. (In Russian)
6. Revkov, N.K. *The Black Sea Scallop Flexopecten glaber ponticus* Bucquoy, Dautzenberg et Dollfus, 1889. In *Red Book of the Republic of Crimea. Animals*; Ivanov, S.P., Fateryga, A.V., Eds.; PP ARIAL LLC: Simferopol, Ukraine, 2015; 389p. (In Russian)
7. Revkov, N.K. The Black Sea Scallop Flexopecten glaber (Linnaeus, 1758). In *Red Book of Sevastopol*; Kaliningrad: Sevastopol, Ukraine, 2018; 347p. (In Russian)
8. Todorova, V.R.; Panayotova, M.D.; Bekova, R.I.; Prodanov, B.K. Recovery of *Flexopecten glaber* (Linnaeus, 1758) (Bivalvia: Pectinidae) in the Bulgarian Black Sea Waters: Recent Distribution, Population Characteristics and Future Perspectives for Protection and Commercial Utilization. *Acta Zool. Bul.* **2022**, *74*, 437–444.
9. Nevesskaya, L.A. *Late Quaternary Bivalve Mollusks of the Black Sea, their Systematics and Ecology*; Nauka: Moscow, Russia, 1965; 391p. (In Russian)
10. Filimon, A. First Record of *Flexopecten glaber* (Linnaeus, 1758) (Bivalvia: Pectinidae) from the Romanian Black Sea Shelf. *Cercet. Mar.-Rech. Mar.* **2020**, *50*, 186–191.

11. Murariu, D.; Maican, S. (Eds.) *The Red Book of Invertebrates of Romania*; The Publishing House of the Romanian Academy: Bucharest, Romania, 2022; 401p.
12. GFCM BlackSea4Fish. Beam Trawl Surveys for Black Sea Rapa Whelk Guidelines and Methodologies. 21p. Available online: https://gfcmsitestorage.blob.core.windows.net/website/Rapa%20whelk%20Survey%20Protocol.pdf (accessed on 14 March 2024).
13. Kaykaç, M.H.; Zengin, M.; Özcan-Akpınar, İ.; Tosunoğlu, Z. Structural Characteristics of Towed Fishing Gear Used in the Samsun Coast (Black Sea). *Ege J. Fish. Aqua. Sci.* **2014**, *31*, 87–96. [CrossRef]
14. Carpentieri, P.; Bonanno, A.; Scarcella, G. *Technical Guidelines for Scientific Surveys in the Mediterranean and the Black Sea*; FAO Fisheries and Aquaculture Technical Papers No. 641; FAO: Rome, Italy, 2016; 108p. [CrossRef]
15. Gosling, E. *Bivalve Molluscs. Biology, Ecology and Culture*; Blackwell Publishing Ltd.: Oxford, UK, 2003; 456p. [CrossRef]
16. Borcea, I. Note sur les moules et sur les facies ou biocenoses a moules de la region littorale roumaine de la Mer Noire. *Ann. Sci. Univ. Jassy. Tome. XIV* **1926**, *14*, 129–139.
17. Antipa, G. *Marea Neagră. Vol I. Oceanografia, Bionomia şi Biologie generală a Mării Negre*; Imprimeria Națională: Bucharest, Romania, 1941; 313p. (In Romanian)
18. Grossu, A.V. *Fauna Republicii Populare Române. Mollusca. Vol. III, Fascicula 2. Gastropoda: Prosobranchia şi Opisthobranchia*; Romanian Academy Publishing House: Bucharest, Romania, 1956; 220p. (In Romanian)
19. Grossu, A.V. Catalogue of the Molluscs from Romania. *Trav. Mus. Hist. Nat. "G. Antipa"* **1993**, *33*, 291–366.
20. Grossu, A.V.; Cărăuşu, A. Contribution à la connaissance des mollusques de la côtte occidentale de la Mer Noire. *Lucrările Stațiunii Zoologice Marine Agigea* **1959**, 213–222.
21. Lazăr, L. Eutrophication Indicators. In *Report on Marine and Coastal Environment State in 2022*; Internal Report National Institute for Marine Research and Development "Grigore Antipa": Constanța, Romania, 2023; pp. 32–35.
22. Marčeta, T.; Da Ros, L.; Marin, M.G.; Codognotto, V.F.; Bressan, M. Overview of the Biology of *Flexopecten glaber* in the North-Western Adriatic Sea (Italy): A Good Candidate for Future Shellfish Farming Aims? *Aquaculture* **2016**, *462*, 80–91. [CrossRef]
23. Poppe, G.T.; Goto, Y. *European Seashells, Vol. I*; Verlag Christa Hemmen: Wiesbaden, Germany, 1991; 352p.
24. Bondarev, I.P. New Data on the Morphological Variability of the Shell of *Flexopecten glaber* (Linnaeus, 1758) (Bivalvia, Pectinidae) in the Black Sea. *Ruthenica* **2020**, *30*, 103–113. [CrossRef] [PubMed]
25. Karageorgis, A.P.; Kourafalou, V.H.; Anagnostou, C.; Tsiaras, K.P.; Raitsos, D.E.; Papadopoulos, V.; Papadopoulos, A. River-induced Particle Distribution in the Northwestern Black Sea (September 2002 and 2004). *JGR Oceans* **2009**, *114*, C12003. [CrossRef]
26. Revkov, N.K.; Pirkova, A.V.; Timofeev, V.A.; Ladygina, L.V.; Schurov, S.V. Growth and Morphometric Characteristics of the Scallop *Flexopecten glaber* (Bivalvia: Pectenidae) Reared in Cages off the Coast of Crimea (Black Sea). *Ruthenica* **2021**, *31*, 127–138. (In Russian) [CrossRef]
27. Le Pennec, M.; Robert, R.; Avendaño, M. The Importance of Gonadal Development on Larval Production in Pectinids. *J. Shellfish Res.* **1998**, *17*, 97–101.
28. Zakhvatkina, K.A. Larvae of Bivalve Mollusks—Bivalvia. *Guide Identif. Fauna Black Azov Seas* **1972**, *3*, 250–271. (In Russian)
29. Pirkova, A.V.; Ladygina, L.V. Meiosis, Embryonic, and Larval Development of the Black Sea Scallop *Flexopecten glaber ponticus* (Bucquoy, Dautzenberg & Dollfus, 1889) (Bivalvia, Pectinidae). *Mar. Biol. J.* **2017**, *2*, 50–57. [CrossRef]
30. Prato, E.; Biandolino, F.; Parlapiano, I.; Gianguzza, P.; Fanelli, G. The Recruitment of Scallops (and beyond) by Two Different Artificial Collectors (Gulf of Taranto, Mediterranean Sea). *Aquac. Res.* **2015**, *47*, 3319–3331. [CrossRef]
31. Shumway, S.E.; Parsons, G.J. *Scallops: Biology, Ecology, Aquaculture, and Fisheries*; Elsevier Science: Oxford, UK, 2016; 1214p.
32. Manthey-Karl, M.; Lehmann, I.; Ostermeyer, U.; Rehbein, H.; Schroder, U. Meat Composition and Quality Assessment of King Scallops (*Pecten maximus*) and Frozen Atlantic Sea Scallops (*Placopecten magellanicus*) on a Retail Level. *Foods* **2015**, *4*, 524–546. [CrossRef]
33. Papa, L.; Prato, E.; Biandolino, F.; Parlapiano, I.; Fanelli, G. Strategies for Successful Scallops Spat Collection on Artificial Collectors in the Taranto Gulf (Mediterranean Sea). *Water* **2021**, *13*, 462. [CrossRef]
34. Tsiotisios, D.; Tzovenis, I.; Katselis, G.; Geiger, S.P.; Theodorou, J.A. Spat Settlement of the Smooth Scallop *Flexopecten glaber* (Linnaeus, 1758) and Variegated Scallop *Chlamys varia* (Linnaeus, 1758) in Amvrakikos Gulf, Ionian Sea (Northwestern Greece). *J. Shellfish Res.* **2016**, *35*, 467–474. [CrossRef]
35. Vural, P.; Acarli, S. Monthly Variations of Protein and Amino Acid Composition of the Smooth Scallop *Flexopecten glaber* (Linnaeus 1758) in the Çardak Lagoon (Lapseki-Çanakkale). *Cah. Biol. Mar.* **2021**, *62*, 195–204. [CrossRef]
36. Massa, F.; Aydın, I.; Fezzardi, D.; Akbulut, B.; Atanasoff, A.; Beken, A.T.; Bekh, V.; Buhlak, Y.; Burlachenko, I.; Can, E.; et al. Black Sea Aquaculture: Legacy, Challenges & Future Opportunities. *Aquac. Stud.* **2021**, *21*, 181–220. [CrossRef] [PubMed]
37. Nenciu, M.; Niță, V.; Massa, F.; Fezzardi, D.; Fourdain, L. Let's Talk Seafood: Romanian Acceptability of Marine Aquaculture at a Glance. *Cercet. Mar.-Rech. Mar.* **2021**, *51*, 156–177. [CrossRef]
38. Bourne, N.F. The Potential for Scallop Culture—The Next Millenium. *Aquac. Int.* **2000**, *8*, 113–122. [CrossRef]
39. Guo, X.; Luo, Y. Scallop Culture in China. In *Scallops: Biology, Ecology and Aquaculture*, 2nd ed.; Shumway, S.E., Parsons, G.J., Eds.; Elsevier: Boston, MA, USA, 2006; pp. 1143–1161.
40. Kosaka, Y.; Ito, H. Japan. In *Scallops: Biology, Ecology and Aquaculture*, 2nd ed.; Shumway, S.E., Parsons, G.J., Eds.; Elsevier: Amsterdam, The Netherlands, 2006; pp. 1093–1142.
41. Marčeta, T.; Marin, M.G.; Codognotto, V.F.; Bressan, M. Settlement of Bivalve Spat on Artificial Collectors (Net Bags) in Two Commercial Mussel Parks in the North-Western Adriatic Sea. *J. Mar. Sci. Eng.* **2022**, *10*, 210. [CrossRef]

42. Margus, D. Settlement of Pectinid larvae in the Krka River estuary of Yugoslavia. In *Scallop Biology and Culture*; Shumway, S.E., Sandifer, P.E., Eds.; World Aquaculture Society: Baton Rouge, LA, USA, 1991; pp. 37–42.
43. Mattei, N.; Pellizzato, M. A Population Study on Three Stocks of a Commercial Adriatic Pectinid (*Pecten jacobaeus*). *Fish. Res.* **1996**, *26*, 49–65. [CrossRef]
44. Iglesias, P.; Louro, A.; Roman, G. Settlement of Queen Scallop *Aequipecten opercularis* on Artificial Substrates in Aldan, Ria de Pontevedra, Galicia, NW Spain. *J. Shellfish Res.* **2010**, *29*, 827–832. [CrossRef]
45. Yigitkurt, S.; Kırtık, A.; Kurtay, E.; Ugur, S.; Durmaz, Y. Spat Efficiency of the Smooth Scallop *Flexopecten glaber* in the Aegean Sea, Türkiye. *Oceanol. Hydrobiol. Stud.* **2019**, *51*, 298–307. [CrossRef]
46. Vlăsceanu-Mateescu, E.; Lazăr, L. Seawater Temperature. In *Report on Marine and Coastal Environment State in 2022*; Internal Report National Institute for Marine Research and Development "Grigore Antipa": Constanța, Romania, 2023; pp. 56–61.
47. Niță, V.; Nenciu, M. *Practical Guideline for Shellfish Culture*; CD Press Publishing: Bucharest, Romania, 2020; ISBN 978-606-528-510-1. 81p. (In Romanian)
48. Pearce, C.M.; Manuel, J.L.; Gallager, S.M.; Manning, D.A.; O'Dor, R.K.; Bourget, E. Depth and Timing of Settlement of Veligers from Different Populations of Giant Scallop *Placopecten magellanicus* (Gmelin) in Thermally Stratified Mesocosms. *J. Exp. Mar. Biol. Ecol.* **2004**, *312*, 187–214. [CrossRef]
49. Slater, J. Development and Application of Techniques for Prediction of the Scallop *Pecten maximus* (L.) Spatfall. *J. Shellfish Res.* **2006**, *25*, 795–806. [CrossRef]
50. Shcherban, S.A.; Melnik, A.V. Size and Age Characteristics and Phenotypic Peculiarities of Somatic Growth of the Black Sea Mollusk *Flexopecten glaber ponticus* (Bivalvia, Pectinidae). *Biol. Bull. Russ. Acad. Sci.* **2020**, *47*, 920–929. [CrossRef]
51. Dao, J.C.; Fleury, P.G.; Barret, J. Scallop Culture in Europe. In *Stock Enhancement and Sea Ranching*; Howell, B., Moksness, E., Svasand, T., Eds.; Fishing News Books; Blackwell Science Ltd.: Oxford, UK, 1999; pp. 423–435.
52. Andersen, S.; Christophersen, G.; Magnesen, T. Spat Production of the Great Scallop (*Pecten maximus*): A Roller Coaster. A Review. *Can. J. Zool.* **2011**, *89*, 579–598. [CrossRef]
53. Strand, Ø.; Louro, A.; Duncan, P.F. European Aquaculture. In *Scallops: Biology, Ecology, Aquaculture, and Fisheries*; Shumway, S.E., Parsons, G.J., Eds.; Elsevier Science: Oxford, UK, 2016; pp. 859–890.
54. Robert, R.; Gerard, A. Bivalve Hatchery Technology: The Current Situation for the Pacific Oyster *Crassostrea gigas* and the Scallop *Pecten maximus* in France. *Aquat. Living Resour.* **1999**, *12*, 121–130. [CrossRef]
55. Helm, M.M.; Bourne, N.; Lovatelli, A. *Hatchery Culture of Bivalves. A Practical Manual*; FAO Fish. Tech. Pap. No. 471; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2004; 201p.
56. Magnesen, T.; Bergh, Ø.; Christophersen, G. Yields of Great Scallop, *Pecten maximus*, Larvae in a Commercial Flow-through Rearing System in Norway. *Aquacult. Int.* **2006**, *14*, 377–394. [CrossRef]
57. Comely, C.A. Larval Culture of the Scallop *Pecten maximus* (L). *ICES J. Mar. Sci.* **1972**, *34*, 365–378. [CrossRef]
58. Wang, C.; Croll, R.P. Effects of Sex Steroids on Spawning in the Sea Scallop, *Placopecten magellanicus*. *Aquaculture* **2006**, *256*, 423–432. [CrossRef]
59. Louro, A.; Chistophersen, G.; Magnesen, T.; Roman, G. Suspension Culture of the Great Scallop *Pecten maximus* in Galicia, NW Spain: Intermediate Primary Culture of Hatchery Produced Spat. *J. Shellfish Res* **2005**, *24*, 61–68. [CrossRef]