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THE CURRENT STATUS OF *POLITITAPES AUREUS* (MOLLUSCA: BIVALVIA) IN THE COASTAL ZONE OF SFAX, TUNISIA (CENTRAL MEDITERRANEAN)

Abdelkarim DERBALI, Aymen HADJ TAIEB & Wassim KAMMOUN
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

ABSTRACT

The clam Polititapes aureus *is one of the most abundant shellfish species in southern Tunisian waters. Its potential future commercial value is key resource for artisanal fisheries. This study was conducted to assess stocks and develop a management plan for natural clam populations along the Sfax coast. The results revealed significant density fluctuations across the study area, which was divided into six main sites, with stock density ranging from 0 to 6 ind.m^{-2} and biomass values varying between 0 and 41 g.m^{-2}. Total biomass reached 70.1 tons, with an abundance exceeding 16.58 million individuals across 3,867 hectares. Sampled individuals measured between 3 and 32.9 mm in size. Key environmental factors were identified, with several abiotic parameters found to have a significant impact on the distribution of clam species. Conservation guidelines are proposed to restore its stocks to sustainable levels.*

Key words: bivalve, *Polititapes aureus*, stock assessment, distribution, size structure, South Tunisia

STATO ATTUALE DI *POLITITAPES AUREUS* (MOLLUSCA: BIVALVIA) NELLA ZONA COSTIERA DI SFAX, TUNISIA (MEDITERRANEO CENTRALE)

SINTESI

La vongola gialla Polititapes aureus *è una delle specie di molluschi più abbondanti nelle acque della Tunisia meridionale. Il suo potenziale valore commerciale futuro è una risorsa chiave per la pesca artigianale. Questo studio è stato condotto per valutare gli stock e sviluppare un piano di gestione delle popolazioni di vongole lungo la costa di Sfax. I risultati hanno rivelato significative fluttuazioni di densità in tutta l'area di studio, che è stata suddivisa in sei siti principali, con una densità di stock che varia da 0 a 6 ind.m^{-2} e valori di biomassa che variano tra 0 e 41 g.m^{-2}. La biomassa totale ha raggiunto 70,1 tonnellate, con un'abbondanza superiore a 16,58 milioni di individui su 3.867 ettari. Sono stati identificati i fattori ambientali chiave che hanno un impatto significativo sulla distribuzione delle specie di vongole e proposte linee guida di conservazione per riportare gli stock a livelli sostenibili.*

Parole chiave: bivalvi, *Polititapes aureus*, valutazione degli stock, distribuzione, struttura dimensionale, Tunisia meridionale

INTRODUCTION

The clam *Polititapes aureus* (syn. *Venerupis aurea*, Gmelin 1971) is a Mediterranean endemic species that is widely distributed throughout western Europe (World Register of Marine Species). It is the most common marine mollusk species inhabiting the intertidal zones of the southern Tunisian coast, particularly the vast mudflats and sandy beaches that provide optimal habitat for infaunal bivalves (Ben Salem *et al.*, 2002). This species is commonly found in sandy to silty-sandy sediments, inhabiting estuaries, bays, and coastal lagoons from mid-tidal to shallow subtidal zones (Derbali, 2024). Due to its economic importance, *P. aureus* has attracted significant research interest, particularly in regions of high abundance, such as Egypt (Kandeel, 2013, 2018; Fouda & Abou-Zied, 1990).

In Tunisia, fishery represents a vital socio-economic activity, particularly for rural and disadvantaged communities, and especially those reliant on clam harvesting (Ben Mohamed & Derbali, 2024). Since 2017, however, a gradual stock depletion has been observed. The decline has been attributed to pollution, deterioration of water quality, climate change impacts, and inadequate fishing practices targeting the clam *Ruditapes decussatus* (Linnaeus 1758) - a species heavily exploited from wild populations (Gharbi *et al.*, 2023). Unfortunately, the most biologically productive coastal zones coincide with areas of significant industrial activity (Ben Mohamed & Derbali, 2024).

To prevent further stock depletion and ensure the sustainability of the sector, Tunisian authorities have established a comprehensive institutional and regulatory framework aligned with international standards. They also oversee and regularly monitor the harvest season and have launched several development projects.

Therefore, future exploitation should be carefully planned, starting with a thorough study on *P. aureus* in the present study area. Several studies have been conducted on its reproductive biology and growth in southern Tunisian waters (Derbali, 2022, 2024). Although stock assessment is essential for understanding dynamics, as well as for the management and conservation of marine bivalve populations, only one study has specifically examined *P. aureus* populations to date (Derbali & Jarboui, 2021). The present study therefore aims to update existing information and provide new data on the current status of *P. aureus* along the Sfax coast, focusing on population structure, geographical distribution, and stock size in relation to specific abiotic factors.

MATERIAL AND METHODS

Study area

The Sfax region, encompassing southern Tunisia and the northern part of the Gulf of Gabes, extends along 135 km (Fig. 1). The continental shelves are wide and shallow, with a topographically regular structure (Ben Othman, 1973). Substrates consist primarily of muddy sand, some of which are covered by the seagrasses *Cymodocea nodosa* (Ucria) Ascherson and *Nanozostera noltei* (Hornemann) Tomlinson & Posluszny. The gently sloping seabed reaches a depth of 60 m approximately 110 km offshore (Ben Othman, 1973). The intertidal zone is an important source of natural resources for both professional and recreational fishers. This extensive intertidal sand and mudflat zone is heavily utilized for clam harvesting activities, primarily targeting *R. decussatus*.

Field sampling

Field sampling was conducted over a two-year period (2021–2022) in the coastal zone of Sfax (southern Tunisia). The study area was divided into six distinct sampling sites based on clam distribution (Fig. 1). Transects were surveyed during low tide across the sampling area. Samples were collected at 50-meter intervals along each transect line, from extreme high tide to extreme low tide marks. Along the transects, 4–10 replicates were taken using 0.25 m² quadrats and a shovel. The collected specimens were immediately fixed in a 7% formaldehyde solution and subsequently transferred to the laboratory for analysis.

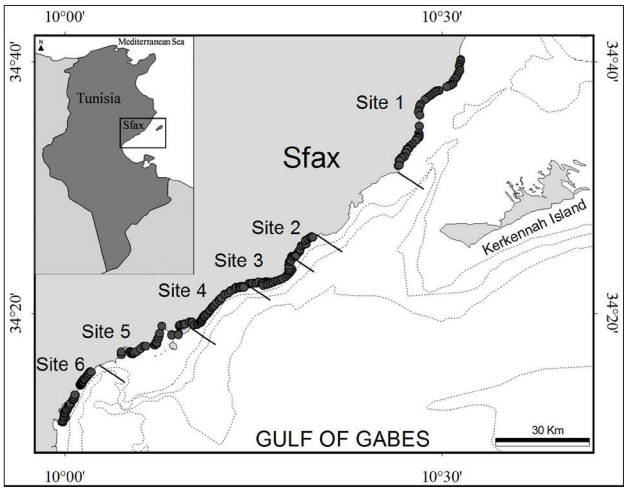

Fig. 1: Geographic position of sampling transects in southern Tunisia.
Sl. 1: Geografski položaj vzorčevalnih transektov v južni Tuniziji.

Seawater temperature and salinity were measured near the seabed immediately after sampling, using a Multi 340i SET multi-parameter kit. To enhance the research on clam distribution patterns, specific interactions between abiotic and biotic factors affecting *P. aureus* spatial distribution were investigated through sediment granulometry. Sediment samples from each site, collected at a depth of 5 cm, were treated with H_2O_2, oven-dried at 40°C, and sieved (2 mm to 63 µm) using AFNOR mesh-type sieves, with grain size classification following Shepard (1954).

Data analysis

In the laboratory, shell length (SL, mm; maximum anteroposterior distance considered as reference length), shell height (SH, mm; maximum hinge-to-ventral margin distance), and shell width (SW, mm; maximum distance between closed valves) were measured with a digital caliper and recorded to the nearest 0.01 mm. Total fresh weight (TW) was determined with a top-loading digital balance (precision of 0.001 g). The dataset was pooled to calculate mean density (ind. m^{-2}) and biomass (g m^{-2}) for each site. Spatial distributions were mapped using ArcGIS 10.8. Stocks were assessed using the Gulland (1969) equation: $Bi = Ni \times Ai/ai \times 1/Xi$, where *Bi* represents total clam biomass, *Ni* is the mean abundance across all quadrat samples per site, *Ai* is site area surface, *ai* is quadrat swept area, and *Xi* is the proportion retained.

Tab. 1: Sediment type recorded in all prospected sites (southern Tunisia).
Tab. 1: Tip sedimenta na raziskovanih lokalitetah (južna Tunizija).

Sites	%Gravel	%Sand	% Silt/clay
Site 1	1.42	97.21	1.37
Site 2	0	98.50	1.50
Site 3	0.25	94.67	5.08
Site 4	0	95.57	4.43
Site 5	0.30	90.31	9.39
Site 6	0.45	99.26	0.29

Statistical analyses included testing data for homogeneity of variance (Levene's test) and normality (Kolmogorov–Smirnov test). The Kruskal–Wallis median test was used to compare densities. Similarities between sites in terms of abundance and biomass were investigated through cluster analysis (group average method). The Spearman correlation coefficient was also applied to identify any significant correlation between clam density and biomass in each site. The results are presented as mean ± standard error (SE), with statistical significance set at $p < 0.05$.

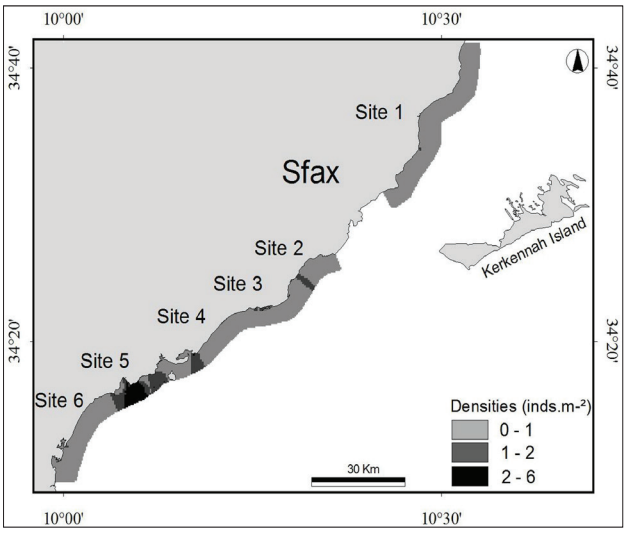

Fig. 2: *Polititapes aureus****: spatial distribution of densities in southern Tunisia.***
Sl. 2: *Polititapes aureus****: prostorska porazdelitev gostote v južni Tuniziji.***

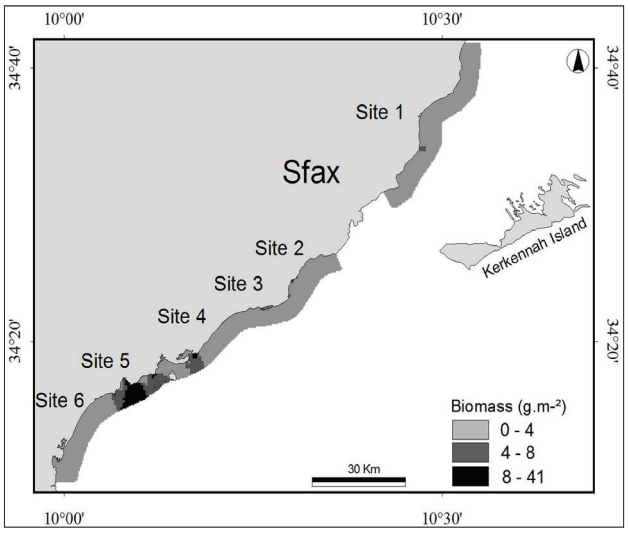

Fig. 3: *Polititapes aureus****: spatial distribution of biomass in southern Tunisia.***
Sl. 3: *Polititapes aureus****: prostorska porazdelitev biomase v južni Tuniziji.***

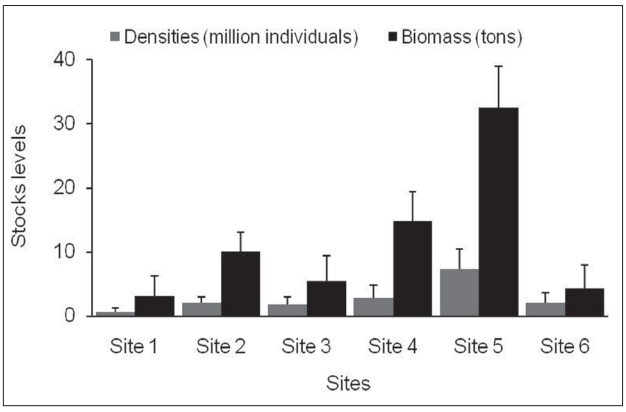

Fig. 4: *Polititapes aureus****: stock levels in the colonized sites and their standard errors (± SE) in southern Tunisia.***
Sl. 4: *Polititapes aureus****: ravni staleža na naseljenih lokacijah in njihove standardne napake (± SE) v južni Tuniziji.***

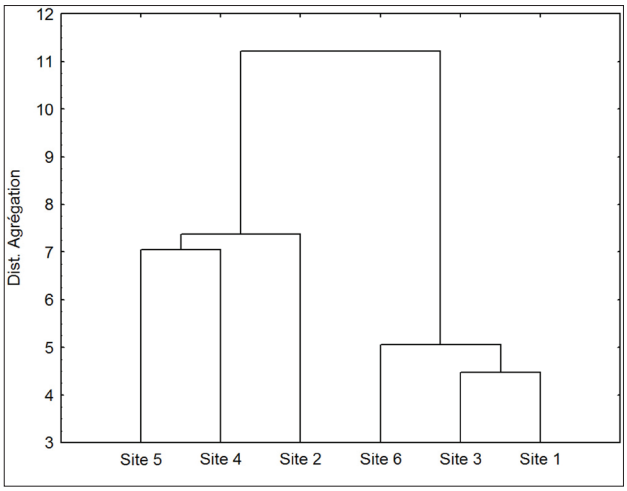

Fig. 5: *Polititapes aureus****: similarity dendrograms for the colonized sites (average group) in southern Tunisia.***
Sl. 5: *Polititapes aureus****: dendrogrami podobnosti za naseljene lokacije (povprečna skupina) v južni Tuniziji.***

RESULTS

Environmental parameters

Sediments across study sites were predominantly silty-sandy, with the exception of Site 5 (Tab. 1). The majority of sampled areas (>50%) were dominated by the seagrasses *C. nodosa* and *N. noltei*. Water temperatures reached maximum values in July (31°C) and minimum values in February (14.9°C). Salinity fluctuated seasonally, ranging from 37 in winter to 47 in summer.

Occurrence and abundance

A total of 184 transects were surveyed, yielding a total of 796 samples and covering a total area of 3,867 ha. The clam *P. aureus* was found at all sampling sites, within a depth range of 0 to 1 m. Across quadrats, density ranged from 0 to 6 ind.m^{-2} and biomass from 0 to 41 g.m^{-2} (Figs. 2 & 3). Densities did not follow a normal distribution pattern (Kolmogorov–Smirnov test, $p < 0.05$) and were not homogeneous (Levene's test, $p < 0.05$). Additionally, pairwise comparisons revealed significant differences in abundance and biomass levels across the six sites (Kruskal–Wallis median test, $p < 0.05$).

Stock assessment

The total stock was estimated at 70.1 ± 15.4 tons (fresh weight), corresponding to 16.58 ± 3.9 million individuals. The average biomass and density estimated from all sampling sites were 1.81 ± 0.4 g.m^{-2} and 0.43 ± 0.1 ind.m^{-2}, respectively. Significant variations in stock levels were documented across the sites (Fig. 4). At Site 5, the results were considerably higher than those observed at other locations ($p < 0.05$). In contrast, no significant differences were found among Sites 1, 3, and 6 ($p > 0.05$). Regarding abundance, biomass levels also exhibited significant variation across all sites, with values at Site 5 higher than those recorded at the remaining sites ($p < 0.05$).

Additionally, a cluster analysis was conducted to assess the similarities among sites, revealing two distinct groups spanning all sampled locations (Fig. 5). Analysis of similarity tests indicated that the first group, comprising Sites 2, 4, and 5, differed significantly from the second group, including the remaining sites (global R greater than 0.8; $p < 0.05$). This differentiation was mainly due to the higher abundance of *P. aureus* stocks in the first group compared to the other sites.

Size structure

The clam population showed a broad size range, with shell lengths (SL) varying from 3 to 32.9 mm (Fig. 6), and a distinct population peak observed at 26 mm SL. The mean shell length was 24.06 ± 1.2 mm SL, with the majority of individuals (79%) falling within the 20–33 mm size classes. The size structure of the clams was analyzed using combined data from all sites within the study area. Size distribution varied significantly across sites, revealing an uneven population structure. Smaller specimens exhibited a heterogeneous distribution across the study area, while larger individuals (11%) were

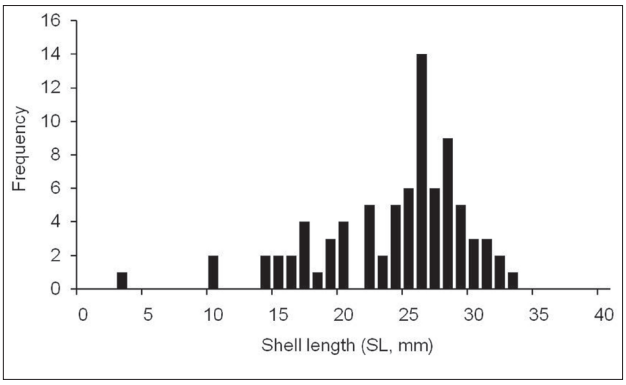

Fig. 6: *Polititapes aureus****: length-frequency distribution in southern Tunisia.***
Sl. 6: *Polititapes aureus****: velikostna porazdelitev v južni Tuniziji.***

geographically restricted to Sites 2, 4, and 5. This spatial pattern could be attributed to natural mortality caused by pollution and increased summer temperatures (31°C).

DISCUSSION

The present study provides a broad informational foundation on the current status of the clam *P. aureus* in the littoral zone of Sfax by investigating stock levels, spatial distribution, and size structure. The species was encountered at depths ranging from 0 to 1 m; however, the density of individuals varied significantly between localities. Based on biomass estimates, the surveyed area supports a total fresh weight stock of 70.1 tons, with population abundance exceeding 16.58 million individuals. The information on *P. aureus* stock levels remains insufficient. Data on the clam stock are limited to preliminary studies conducted exclusively in the southern part of the Sfax region, which have reported a total biomass of approximately 201 tons and notably high relative abundance, exceeding 91 million individuals (Derbali & Jarboui, 2021). A similar pattern can be observed in another clam species, *R. decussatus*, with a total fresh weight of about 115 tons and a high abundance estimated at over 22.4 million individuals in the same study area (Ben Mohamed & Derbali, 2024). The main drivers of stock depletion are climate change and soft seabed characteristics (Gharbi *et al.*, 2023). Indeed, *P. aureus* populations exhibit significant spatial variability both within and between sampling sites, as well as across geographic regions with distinct seabed characteristics, vegetation cover, and physicochemical factors. The bivalve species appears particularly sensitive to strong multi-level environmental interactions (e.g., physicochemical and soft sediment dynamics in the study area) (Derbali & Jarboui, 2021; Ben Mohamed & Derbali, 2024).

The study was carried out in rural zones faced with a range of complex challenges. These include socio-economic issues such as low income from artisanal fishing and farming, as well as illiteracy. In terms of ecology, the area is confronted with issues such as stock depletion, climate change impacts, and a lack of measures to improve the conditions of local communities. The current study revealed significant spatial variability in the distribution of *P. aureus* populations across all sampling sites. Although hydrodynamic conditions were relatively consistent throughout the study area, several key factors affecting the structure of bivalve populations were identified, including soft substrates and climate change (Derbali, 2011; Derbali & Jarboui, 2021; Derbali *et al.*, 2021).

The clam's distribution seems to be inversely related to the proportion of muddy-sandy substrates. There is some evidence suggesting that a high level of gravel may be detrimental. These findings indicate that high densities of clams are likely to be found on muddy-sandy bottoms. Further study involving sediment and clam sampling in each quadrat is required to support this hypothesis. The significant decline in stocks can be attributed to overexploitation in the most shellfish production areas. The authorities have continued to support this sector by establishing a relatively comprehensive institutional framework and launching several development projects.

The clam *P. aureus* appears to be strongly affected by abiotic factors. In this study, hydrodynamic conditions were found to be consisted throughout the sampling area, suggesting that the relative population growth is influenced by other environmental factors, including sediment type, organic matter content, burrowing behavior, and related strategies to counter dislocation and avoid predation (Derbali & Jarboui, 2021).

In fact, several studies have highlighted interesting connections between environmental conditions and bivalve behavior (Derbali *et al.*, 2011; Derbali *et al.* 2021; Ben Mohamed & Derbali, 2024). The clam population appears to be highest in areas covered by the seagrasses *C. nodosa* and *Z. noltii*, which extend over more than 50% of the habitat. Clam distribution showed a significant correlation with that of these two seagrass species. This correlation could be explained by two factors: i) this positive correlation is linked to the detrital organic matter provided by the seagrasses, and ii) their presence reduces bottom scour and allows organic matter to accumulate. Vilela (1950) demonstrated that one of the dominant sources of organic matter in the diet of *R. decussatus* is derived from *C. nodosa*.

The same conclusion was reached by Ben Mohamed & Derbali (2024) for *R. decussatus* in southern Tunisian waters, and by Sarà (2007) for cockles in Italy. In addition to organic sources, other mechanisms structuring clam populations include the nature of the seabed. Notably, a high stock level of *P. aureus* was observed on a silty-sandy bottom (Site 5).

In colonized areas, natural mortality (F) of *P. aureus* (F = 0.82 yr^{-1}) exceeded fishing mortality (M = 0.03 yr^{-1}) (Derbali, 2023). The relatively low mortality rate observed in this study (Z = 0.85 yr^{-1}) can be attributed exclusively to natural causes (predation, pathogens, anthropogenic impacts, and loss of specimens from unstable sediments due to water currents), since there is no *P. aureus* fishery in the Gulf of Gabes. Nevertheless, Aranguren *et al*. (2014) demonstrated that mortality rates in *R. decussatus*, particularly in natural beds, may results from complex synergies between biotic and abiotic factors. Similarly, Robinson & Richardson (1998) established that *Ensis magnus* (Schumacher, 1817) individuals returned to the seabed were slow to rebury and thus highly vulnerable to crab predation. Moreover, habitat degradation and climate change impacts likely represent the primary drivers of natural mortality (M = 0.82 yr^{-1}) in *P. aureus* populations in southern Tunisia.

The elevated water temperatures and salinities observed in the sampling area were significantly higher than those recorded in 2015. Several authors have reported that rising temperature and salinity levels can have a major impact on faunal composition, leading to a decrease in biomass (Fishar, 2000; El-Shabrawy, 2001). These authors have also indicated that elevated seasonal temperatures, particularly summer heat extremes, significantly impact clam populations. Consequently, these unfavorable conditions contribute to mortality in *P. aureus* populations. In this study, the clam population exhibited characteristics similar to those described for other bivalve species. The growth of adult individuals continues to be influenced by mortality rates (Derbali, 2024). According to Ben Mohamed & Derbali (2024), shellfish production areas are influenced by phytoplankton blooms, specifically of diatoms and dinoflagellates. Previous studies have shown that summer blooms of dinoflagellates lead to mass mortalities among bivalve populations (Hamza, 2003; Derbali, 2011), causing them to disappear from large central areas – likely due to anoxia – and to re-colonize these areas again in autumn, once temperatures have cooled (Hamza, 2003).

In conclusion, this study provides crucial information on the current status of *P. aureus*, a potentially valuable commercial species in southern Tunisian waters, by investigating its stock levels, population distribution, and size structure. The findings offer new insights into stock density and the factors contributing to its variability, with distinct assemblages clearly corresponding to major environmental conditions. To support sustainable production, further research should investigate additional biological parameters to enable precise monitoring of clam exploitation. Adopting and implementing regulations, such as size-selective harvest limits, will be essential for protecting this emerging fishery resource, similar to *R. decussatus* wild populations.

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TRENUTNO STANJE VRSTE *POLITITAPES AUREUS* (MOLLUSCA: BIVALVIA) NA OBALNEM OBMOČJU SFAXA V TUNIZIJI (OSREDNJE SREDOZEMLJE)

Abdelkarim DERBALI, Aymen HADJ TAIEB & Wassim KAMMOUN
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

POVZETEK

Školjka Polititapes aureus *je ena najpogostejših vrst školjk v vodah južne Tunizije. Njena potencialna komercialna vrednost v prihodnosti je ključni vir za obrtni ribolov. Ta študija je bila izvedena za oceno staležev in razvoj načrta upravljanja za naravne populacije školjk vzdolž obale Sfaxa. Rezultati kažejo znatna nihanja gostote na območju, ki je bilo razdeljeno na šest glavnih predelov, z gostoto od 0 do 6 os.m^{-2} in vrednostmi biomase med 0 in 41 g.m^{-2}. Skupna biomasa je znašala 70,1 tone, gostota pa je presegla 16,58 milijona osebkov na 3867 hektarih. Primerki so merili od 3 do 32,9 mm. Ugotovljeni so bili ključni okoljski dejavniki, pri čemer je bilo ugotovljeno, da ima več abiotskih parametrov pomemben vpliv na razširjenost vrst školjk. Predlagane so smernice za ohranjanje, da se njeni staleži obnovijo na trajnostne ravni.*

Ključne besede: školjka, *Polititapes aureus*, ocena staleža, razširjenost, velikostna struktura, južna Tunizija

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