

# AM ANNALES

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*Annali di Studi istriani e mediterranee*  
*Annals for Istrian and Mediterranean Studies*  
*Series Historia Naturalis, 32, 2022, 2*





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## VSEBINA / INDICE GENERALE / CONTENTS

BIOTSKA GLOBALIZACIJA  
GLOBALIZZAZIONE BIOTICA  
BIOTIC GLOBALIZATION**Murat BILECENOĞLU & M. Baki YOKEŞ**

New Data on the Occurrence of Two Lessepsian Marine Heterobranchs, *Plocamopherus ocellatus* (Nudibranchia: Polyceridae) and *Lamprohaminoea ovalis* (Cephalaspidea: Haminoeidae), from the Aegean Sea ..... 267  
*Novi podatki o pojavljanju dveh lesepskih morskih polžev zaškrjarjev, Plocamopherus ocellatus (Nudibranchia: Polyceridae) in Lamprohaminoea ovalis (Cephalaspidea: Haminoeidae), iz Egejskega morja*

**Gianni INSACCO, Aniello AMATO, Bruno ZAVA & Maria CORSINI-FOKA**

Additional Capture of *Halosaurus ovenii* (Actinopterygii: Notacanthiformes: Halosauridae) in Italian Waters ..... 273  
*Novi ulov vrste Halosaurus ovenii (Actinopterygii: Notacanthiformes: Halosauridae) v italijanskih vodah*

**Christian CAPAPÉ, Christian REYNAUD & Farid HEMIDA**

First Record of Marbled Stingray, *Dasyatis marmorata* (Chondrichthyes: Dasyatidae) from the Algerian Coast (Southwestern Mediterranean Sea) ..... 281  
*Prvi zapis o pojavljanju marmoriranega morskega biča, Dasyatis marmorata (Chondrichthyes: Dasyatidae) iz alžirske obale (jugozahodno Sredozemsko morje)*

**Maria CORSINI-FOKA & Bruno ZAVA**

Second Occurrence of *Siganus javus* (Siganidae) in the Mediterranean Waters ..... 287  
*Drugi zapis o pojavljanju progastega morskega kunca, Siganus javus (Siganidae), v sredozemskih vodah*

**Daniel GOLANI, Haim SHOHAT & Brenda APPELBAUM-GOLANI**

Colonisation of Exotic Fish Species of the Genera *Pseudotropheus* and *Aulonocara* (Perciformes: Cichlidae) and the Decline of Native Ichthyofauna in Nahal Amal, Israel ..... 293  
*Naseljevanje eksotičnih vrst rib iz rodu Pseudotropheus in Aulonocara (Perciformes: Cichlidae) in upad domorodne ribje favne v reki Nahal Amal, Izrael*

**Panayotis OVALIS & Maria CORSINI-FOKA**

On the Occurrence of *Velolambrus expansus* (Brachyura, Parthenopidae) in Hellenic Waters ..... 301  
*O pojavljanju rakovice vrste Velolambrus expansus (Brachyura, Parthenopidae) v grških vodah*

**Saul CIRIACO, Marco SEGARICH, Vera CIRINÀ & Lovrenc LIPEJ**

First Record of the Long-Jawed Squirrelfish *Holocentrus adscensionis* (Osbeck, 1765) in the Adriatic Sea ..... 309  
*Prvi zapis o pojavljanju vrste veveričjaka Holocentrus adscensionis (Osbeck, 1765) v Jadranskem morju*

**Christian CAPAPÉ, Vienna HAMMOUD, Aola FANDI & Malek ALI**

First Record of Moontail Bullseye *Priacanthus hamrur* (Osteichthyes, Priacanthidae) from the Syrian Coast (Eastern Mediterranean Sea) ..... 317  
*Prvi zapis o pojavljanju lunastorepega velikookega ostriža Priacanthus hamrur (Osteichthyes, Priacanthidae) s sirske obale (vzhodno Sredozemsko morje)*

SREDOZEMSKI MORSKI PSI  
SQUALI MEDITERRANEI  
MEDITERRANEAN SHARKS**Hakan KABASAKAL, Erdi BAYRI & Görkem ALKAN**

Distribution and Status of the Great White Shark, *Carcharodon carcharias*, in Turkish Waters: a Review and New Records ..... 325  
*Status in razširjenost belega morskega volka (Carcharodon carcharias) v turških vodah: pregled in novi zapisi o pojavljanju*

**Alen SOLDI**

200 Years of Records of the Basking Shark, *Cetorhinus maximus*, in the Eastern Adriatic ..... 343  
*Dvesto let opazovanj morskega psa orjaka, Cetorhinus maximus, v vzhodnem Jadranskem morju*

**Hakan KABASAKAL, Ayşe ORUÇ, Cansu LKILINÇ, Efe SEVİM, Ebrucan KALECİK & Nilüfer ARAÇ**

Morphometrics of an Incidentally Captured Little Gulper Shark, *Centrophorus uyato* (Squaliformes: Centrophoridae), from the Gulf of Antalya, with Notes on Its Biology ..... 351  
*Morfometrija naključno ujetega globinskega trneža, Centrophorus uyato (Squaliformes: Centrophoridae), iz Antalijskega zaliva z zapiski o njegovi biologiji*

- Christian CAPAPÉ, Almamy DIABY, Youssof DIATTA, Sihem RAFRAFI-NOUIRA & Christian REYNAUD** Atypical Claspers in Smoothhound, *Mustelus mustelus* (Chondrichthyes: Triakidae) from the Coast of Senegal (Eastern Tropical Atlantic) ..... 359  
*Netipična klasperja navadnega morskega psa, Mustelus mustelus (Chondrichthyes: Triakidae) iz senegalske obale (vzhodni tropski Atlantik)*
- Hakan KABASAKAL, Ayşe ORUÇ, Ebrucan KALECIK, Efe SEVİM, Nilüfer ARAÇ & Cansu ILKILINÇ** Notes on a Newborn Kitefin Shark, *Dalatias licha*: New Evidence on the Nursery of a Rare Deep-Sea Shark in Northeastern Levant (Turkey) ..... 367  
*Zapis o najdbi skotenega klinoplavutega morskega psa, Dalatias licha: novi dokaz o jaslicah redkega globokomorskega morskega psa v severovzhodnem levantu (Turčija)*
- IHTIOLOGIJA  
ITTILOGIA  
ICHTHYOLOGY
- Nadia BOUZZAMMIT, Hammou EL HABOUZ, El hassen AIT-TALBORJT, Zahra OKBA & Hassan EL OUIZGANI** Diet Composition and Feeding Strategy of Atlantic Chub Mackerel *Scomber colias* in the Atlantic Coast of Morocco ..... 377  
*Prehrana in prehranjevalna strategija lokarde (Scomber colias) ob atlantski obali Maroka*
- FLORA  
FLORA  
FLORA
- Amelio PEZZETTA** Le Orchidaceae di Albona (Labin, Croazia) ..... 393  
*Kukavičevke Labina (Hrvaška)*
- FAVNA  
FAVNA  
FAVNA
- Murat BILECENOĞLU & Melih Ertan ÇINAR** The Mauve Stinger, *Pelagia noctiluca*, Has Expanded Its Range to the Sea of Marmara ..... 405  
*Mesečinka (Pelagia noctiluca) je razširila svoj areal do Marmarskega morja*
- Marijana HURE, Davor LUČIĆ, Barbara GANGAI ZOVKO & Ivona ONOFRI** Dynamics of Mesozooplankton Along the Eastern Coast of the South Adriatic Sea ..... 411  
*Dinamika mezozooplanktona vzdolž vzhodne obale južnega Jadrana*
- Abdelkarim DERBALI, Kandeel E. KANDEEL, Aymen HADJ TAIEB & Othman JARBOUTI** Population Dynamics of the Cockle *Cerastoderma glaucum* (Mollusca: Bivalvia) in the Gulf of Gabes (Tunisia) ..... 431  
*Populacijska dinamika navadne srčanke Cerastoderma glaucum (Mollusca: Bivalvia) v Gabeškem zalivu (Tunizija)*
- Vasiliki K. SOKOU, Joan GONZALVO, Ioannis GIOVOS, Cristina BRITO & Dimitrios K. MOUTOPOULOS** Tracing Dolphin-Fishery Interaction in Early Greek Fisheries ..... 443  
*Sledenje interakcij med delfini in ribiči v zgodnjih grških ribiških dejavnostih*
- Pavel JAMNIK, Matija KRŽNAR & Bruno BLAŽINA** Novi najdišči pleistocenske favne pod Kraškimi robom. Smo končno našli tudi jamo *Grotta dell'Orso*? ..... 451  
*Two New Sites of Pleistocene Fauna under Karst Edge. Has a Grotta dell'Orso Cave Been Finally Found?*
- OCENE IN POROČILA  
RECENSIONI E RELAZIONI  
REVIEWS AND REPORTS
- Andreja PALATINUS** Book Review: Plastic Pollution and Marine Conservation. Approaches to Protect Biodiversity and Marine Life ..... 471
- Kazalo k slikam na ovitku ..... 473  
*Index to images on the cover* ..... 473

## POPULATION DYNAMICS OF THE COCKLE *CERASTODERMA GLAUCUM* (MOLLUSCA: BIVALVIA) IN THE GULF OF GABES (TUNISIA)

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### ABSTRACT

*The cockle Cerastoderma glaucum is one of the most abundant shellfish species in the southern Tunisian waters. Its current exploitation status and management are becoming a major concern for fishing industry in Tunisia. This study is the first attempt to investigate its population dynamics including the population structure, growth, mortality, and exploitation status of two populations. Cockles were collected from Sfax (site A) and Gabes (site B) during a one-year period. Length frequency data were analyzed for estimation of population parameters to evaluate the stock. Recruitment was continuous and showed two major pulses in the two sites. The data presented herein are essential for the appropriate fisheries management and conservation for cockles.*

**Key words:** *Cerastoderma glaucum*, population dynamics, mortality, recruitment, south of Tunisia

## DINAMICA DI POPOLAZIONE DEL CUORE DI LAGUNA *CERASTODERMA GLAUCUM* (MOLLUSCA: BIVALVIA) NEL GOLFO DI GABES (TUNISIA)

### SINTESI

*Il cuore di laguna Cerastoderma glaucum è una delle specie di molluschi più abbondanti nelle acque della Tunisia meridionale. Il suo attuale stato di sfruttamento e la sua gestione stanno diventando una delle principali preoccupazioni per l'industria della pesca in Tunisia. Questo studio è il primo tentativo di indagare le dinamiche di popolazione, tra cui la struttura della popolazione, la crescita, la mortalità e lo stato di sfruttamento di due popolazioni. Gli esemplari sono stati raccolti a Sfax (sito A) e a Gabes (sito B) durante il periodo di un anno. I dati sulla frequenza delle lunghezze sono stati analizzati per stimare i parametri della popolazione e valutare lo stock. Il reclutamento è stato continuo e ha mostrato due impulsi principali nei due siti. I dati qui presentati sono essenziali per un'adeguata gestione e conservazione della pesca della specie.*

**Parole chiave:** *Cerastoderma glaucum*, dinamiche di popolazione, mortalità, reclutamento, sud della Tunisia

## INTRODUCTION

*Cerastoderma glaucum* (Poiret, 1789) is a benthic species of bivalve mollusk which is very common in the Mediterranean Sea and southern Europe, preferentially dwells on muddy bottoms of lagoons and estuaries. It has been recorded from the coasts of Tunisia, Egypt, Turkey, Sardinia, Italy, Greece, Portugal, Spain, France, the Netherlands, the British Isles, Denmark, Finland, Norway and in the Wadden Sea, Adriatic Sea, Red Sea, Aegean Sea and Caspian Sea (Derbali, 2011; Malham *et al.*, 2012; Derbali *et al.* 2012, 2014).

The cockle *C. glaucum* lives in a wide range of salinity and thermal characteristics (Rygg, 1970). This makes *C. glaucum* an interesting subject for cultivation and/or reducing the environmental impact of organic loading in estuaries' systems (Trotta & Cordisco, 1998). Cockles have an important role in the nutrient cycle because they establish a connection between trophic levels - feeding on primary producers and being prey of several invertebrates and vertebrates (including humans). Accordingly, *C. glaucum* is important within the macrobenthos that contribute to regulating the benthic fauna ecosystem in its habitat (El-Shabrawy, 2001; Fishar, 2005). In southern Tunisia, cockles represent one of the dominant species of macrozoobenthos (Machreki-Ajmi *et al.*, 2008; Derbali, 2011) and so are important for ecological functioning. Previous findings have shown that the cockle's abundance was highly variable according to location. In southern Tunisian waters, the highest mean density has been estimated as 270 inds.m<sup>-2</sup> (Derbali *et al.*, 2012, 2014). Several studies of *C. glaucum* were also undertaken from other Tunisian sites, e.g., Bougrara Lagoon (Derbali *et al.*, 2009).

Previous surveys have highlighted the high divergence between cockle populations in southern Tunisian waters (Derbali, 2011), that could be related to the environmental and ecological conditions of the Gulf of Gabes. Such studies could be important for investigating the populations' dynamics as a result to their potential adaptations since several environmental characteristics (e.g., climate, temperature, salinity, wave action, available substrate, species composition, species interactions, and food sources) vary considerably.

Despite this species prevalence in the literature, no empirical work has rigorously investigated the cockles' dynamics in the south of Tunisia. The commercial importance of *C. glaucum* increases as a candidate species for Tunisian food, research on its population parameters will be of considerable necessity for future economic valorization and sustainable management of this resource in Tunisian waters. In this context and considering the absence of information on cockles' dynamics, the present study is the first attempt to estimate the population structure, growth, mortality,

exploitation rates and recruitment pattern of *C. glaucum* populations in the Gulf of Gabes.

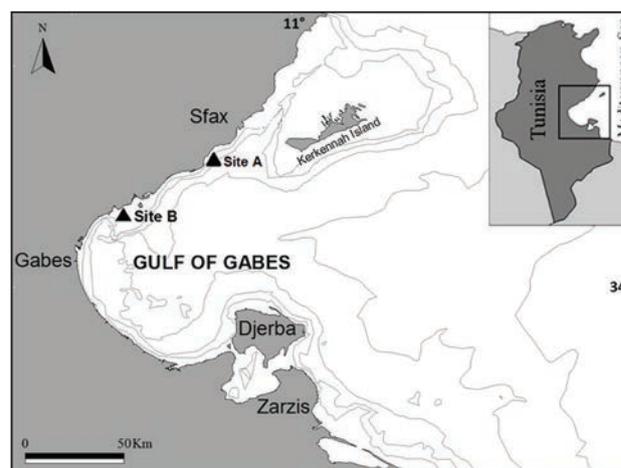
## MATERIAL AND METHODS

## Study area

Sampling sites are located in southern Tunisian waters. Both sites are wide tidal flats. Specimens were sampled from Site A (34°35'17"N, 10°37'00"E) and Site B (34°20'44"N, 10°12'40"E) chosen with respect to environmental conditions and cockle densities (Fig. 1). In the first sector, the substratum is mud and detrital organic matter with high cover of the marine seagrasses *Cymodocea nodosa* (Ascherson, 1870) and *Zostera noltei* (Hornemann, 1832). In contrast, the second sector is characterized by a muddy-sand substratum and the anthropogenic activities resulting from receiving runoff and discharge of pollutants from drainage water (Derbali, 2011).

## Sampling and laboratory procedures

In the two sites, systematic surveys were carried out during one year from January to December 2017. Approximately 200 individuals were collected each month by quadrats (0.25 m<sup>2</sup>) using a shovel (up to 1 m depth). The sediments were washed out carefully in situ through one mm mesh size sieve. Large specimens were collected by hand and the small were taken by the sieve. The materials retained by the sieve were kept in labeled containers filled with 7% formaldehyde-seawater solution. Seawater temperature and salinity were recorded at the same time as the cockle collections.



**Fig. 1: Geographical position of sampling sites of *Cerastoderma glaucum* in the Gulf of Gabes (Tunisia).**

**Sl. 1: Geografski položaj vzorčevalnih postaj za nabiranje navadnih srčank v Gabeškem zalivu (Tunizija).**

In the laboratory, shell length (maximum distance on the anterior-posterior axis, SL) of each cockle was measured to the nearest 0.1 mm using a digital caliper. Length measurements were used to produce length-frequency distribution for each sample collected from the two sites using class intervals of 1 mm size. Total fresh weights (TW) of adult cockles were measured using top-loading digital balance (precision of 0.0001 g).

### Data analysis

#### Length-weight relationships

The relationship between total weight (TW) and anterior-posterior shell length (SL, mm) was described by the following allometric equation:

$$\log TW = \log a + b \log SL$$

where  $\log a$  and  $b$  are intercept (initial growth coefficient) and slope (relative growth rate of variables) of the linear regression line, respectively. The deviation of the  $b$  value of the regression function from the isometric hypothetical value ( $b = 3$ ) was analyzed by means of a Student's  $t$ -test. A significance deviation indicates a negative ( $b < 3$ ) or positive ( $b > 3$ ) allometric relationship. Statistical analyses were carried out using MINITAB software (version 13, 2000). Statistical significance was considered when  $p < 0.05$ .

#### Von Bertalanffy growth parameters

Length-frequency data were analyzed using the FiSAT II software as explained in detail by Gayanilo et al. (2005). The asymptotic shell length ( $L_\infty$ , mm) and the growth coefficient ( $K$ , yr<sup>-1</sup>) of the von Bertalanffy Growth Function (VBGF) were estimated from these data by means of ELEFAN-I (Electronic Length Frequency Analysis; Pauly & David, 1981; Pauly & Morgan, 1987). The VBGF is defined by the equation:

$$L_t = L_\infty [1 - e^{-K(t-t_0)}]$$

where  $L_t$  = mean length at age  $t$ ,  $L_\infty$  = asymptotic shell length,  $K$  = growth coefficient,  $t$  = age, and  $t_0$ , the hypothetical age at which the length is zero (Pauly & David, 1981), here  $t_0 = 0$ .

$L_\infty$  and  $K$  were used to calculate the growth performance index  $\Phi'$  (Pauly & Munro, 1984) using the equation:

$$\Phi' = \log(K) + 2 \log(L_\infty)$$

Growth performance indices are calculated to compare between our two sampling sites and with other populations of *C. glaucum*. The inverse von Bertalanffy

growth equation was used to find the lengths of *C. glaucum* at various ages. The theoretical maximum age ( $T_{max}$ ) was calculated for each population by solving for  $t$  in the von Bertalanffy equation by setting  $L_t = L_\infty$ , using the following equation constructed by Michaelson & Neves (1995):

$$T_{max} = \frac{\ln L_\infty + Kt_0}{K}$$

#### Mortality and exploitation rate

Total mortality ( $Z$ , yr<sup>-1</sup>) was estimated by length-converted catch curve method (Pauly, 1990). FiSAT calculates  $Z$  as well as the 95% confidence intervals surrounding  $Z$  based on the goodness-of-fit of the regression. Natural mortality rate ( $M$ , yr<sup>-1</sup>) was estimated using the empirical relationship of Pauly (1980):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where  $T$  = is the mean annual temperature (°C). Once  $Z$  and  $M$  were obtained, then fishing mortality ( $F$ , yr<sup>-1</sup>) was estimated using the relationship:  $F = Z - M$ . The exploitation rate ( $E$ ) was obtained with the relationship proposed by Gulland (1971):

$$E = F/Z = F / (M+F)$$

#### Recruitment pattern

The routine in FiSAT reconstructs the recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse, using the VBGF parameters (Moreau & Cuende, 1991). Normal distribution of the % of recruits was determined by NORMSEP (Pauly & Caddy, 1985) in FiSAT.

## RESULTS

### Shell length-weight relationships

Relationships between logarithmically transformed data of total weight (TW.) and shell length (SL, mm) of *C. glaucum* collected from site A and site B are shown in Table 1. In site A, isometric growth patterns were recorded for *C. glaucum*. On the other hand, slope values ( $b$ ) significantly deviated from 3 ( $p < 0.05$ ) indicating negative allometric growth patterns for *C. glaucum* at site B.

### Population structure

Overall, 2256 and 2340 individuals of *C. glaucum* were measured and their population structure studied for site A and site B, respectively (Fig. 2). The shell length ranged between 6–31 and 10–35

**Tab. 1: Regression parameters (log a and b) of shell length (SL, mm) and total weight (TW, g.) relationships of *Cerastoderma glaucum* collected from two sites in Tunisia. t: values of Student's t-test; p: level of significance from isometric value of the slope; r2: coefficient of determination; F: variance ratio; N: number of individuals; SD: standard deviation.**

**Tab. 1: Regresijski parametri (log a in b) odnosa med dolžino lupine (totalna dolžina, mm) in maso (g) navadne srčanke iz dveh tunizijskih lokalitet. Legenda: T= vrednost Studentovega testa, p: interval zaupanja izometrične vrednosti naklona; r2: koeficient determinacije; F: delež variance; N: število primerkov; SD: standardna deviacija.**

Length-Weight relationship									
Sites	Log a ± S.D.	b ± S.D.	t	p	r <sup>2</sup>	F	SL range	TW range	N
Site A	-3.34 ± 0.04	2.86 ± 0.03	4.66	p > 0.05	0.937	8189.46	12.0-31.4	0.55-9.532	550
Site B	-3.31 ± 0.05	2.48 ± 0.03	17.33	p < 0.05	0.929	7023.47	12.4-32.4	0.584-9.532	541

mm for the two sites, respectively. Two peaks were observed corresponding to individuals with 20 and 25 mm shell length in site A and with 20 and 26 mm shell length in site B. Large individuals (> 25 mm) represent 31 and 53% of total collected samples from site A and site B, respectively.

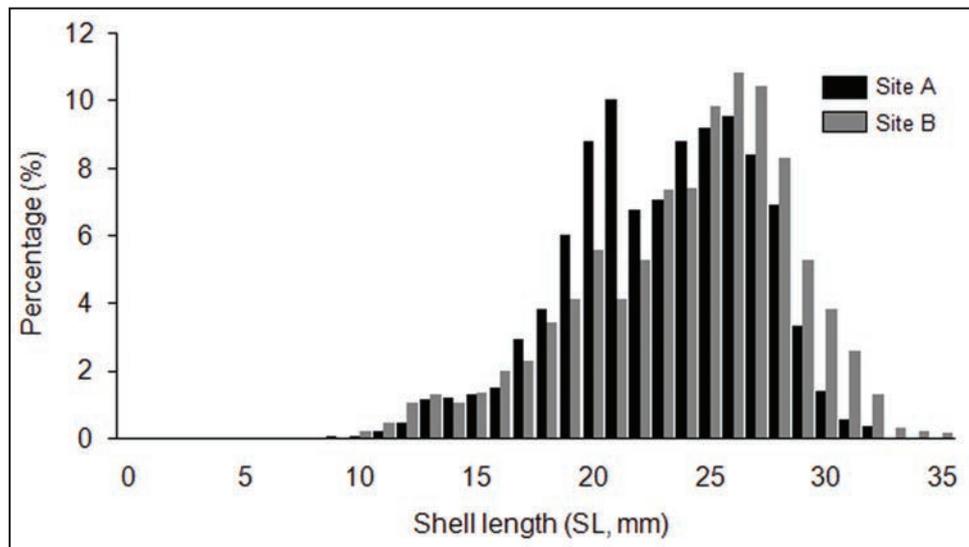
#### Growth and age

Estimated asymptotic length (L<sub>∞</sub>) and growth coefficient (K) of the von Bertalanffy Growth Function (VBGF) by ELEFAN-I were 32.55 mm and 0.48 yr<sup>-1</sup> and 36.75 mm and 0.42 yr<sup>-1</sup> for the cockles collected from site A and site B, respectively. Figure 3

showed length frequency distribution and the superimposed growth curves estimated by ELEFAN-I for *C. glaucum* from the two sites, respectively. Growth performance indices (Φ<sup>3</sup>) were 2.71 and 2.75 in sites A and B, respectively (Tab. 2). Also, the theoretical maximum age (T<sub>max</sub>) was higher in site B (T<sub>max</sub> = 8.58 yr<sup>-1</sup>) than in site A (T<sub>max</sub> = 7.25 yr<sup>-1</sup>).

#### Mortality and exploitation rate

Length-converted catch curve analysis produced total mortality (Z) for *C. glaucum* was 1.25 yr<sup>-1</sup> (confidence interval; CI = -2.13 – 4.63) and 0.90 yr<sup>-1</sup> (CI

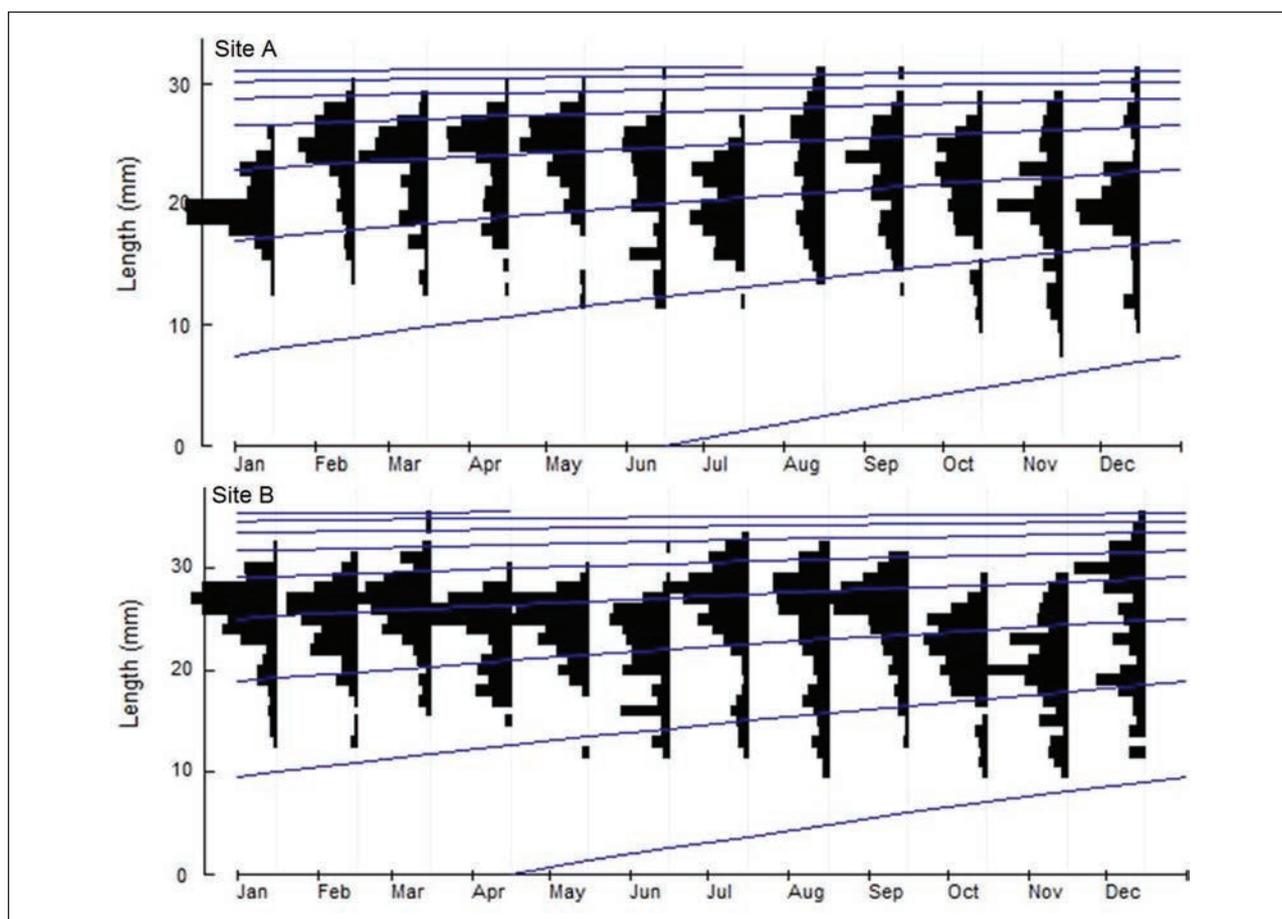


**Fig. 2: Variations in the percentage occurrence of the different size classes of *Cerastoderma glaucum* collected from sites A and B throughout the study period.**

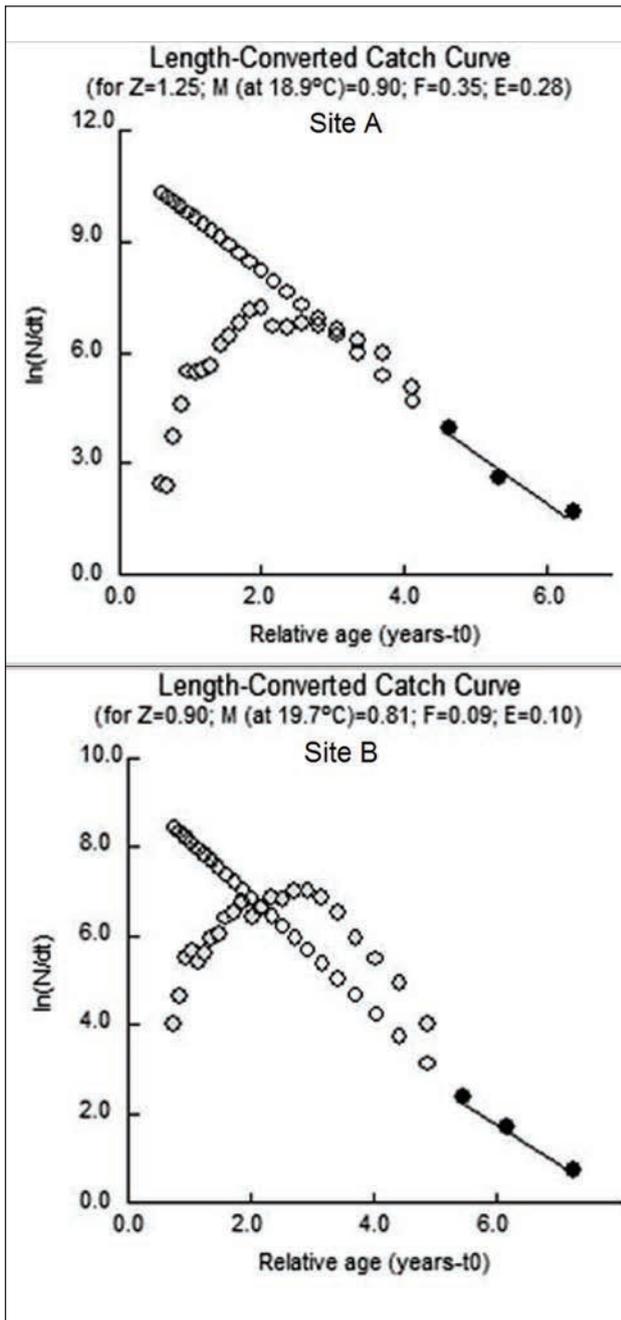
**Sl. 2: Spremembe v deležu pojavljanja posameznih velikostnih razredov primerkov navadne srčanke, pobranih na lokalitetah A in B v obravnavanem obdobju.**

**Tab. 2: Population parameters of *Cerastoderma glaucum* in the south of Tunisia.**  
**Tab. 2: Populacijski parametri navadne srčanke iz juga Tunizije.**

Population parameters	Site A	Site B
Asymptotic length ( $L_{\infty}$ , mm)	32.55	36.75
Growth co-efficient (K) $\text{yr}^{-1}$	0.48	0.42
Growth performance index ( $\Phi$ )	2.71	2.75
The theoretical maximum age ( $T_{\text{max}}$ ) $\text{yr}^{-1}$	7.3	8.6
Natural mortality (M) $\text{yr}^{-1}$	0.90	0.81
Fishing mortality (F) $\text{yr}^{-1}$	0.35	0.09
Total mortality (Z) $\text{yr}^{-1}$	1.25	0.90
Exploitation rate (E)	0.28	0.10
Shell length (SL) range (mm)	6.5 – 31.60	10.00 – 35.00
Sample number (N)	2256	2340

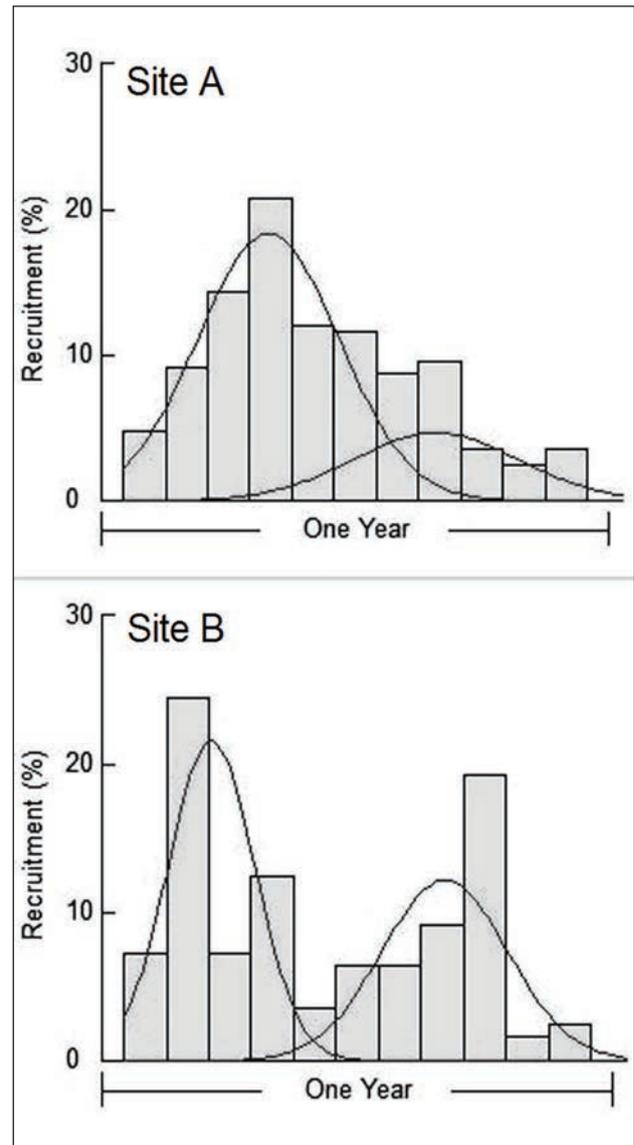


**Fig. 3: Von Bertalanffy growth curves superimposed on length frequency histograms of *Cerastoderma glaucum* at site A ( $L_{\infty} = 32.55$  mm and  $K = 0.48 \text{ yr}^{-1}$ ) and site B ( $L_{\infty} = 36.75$  mm and  $K = 0.42 \text{ yr}^{-1}$ ) using ELEFAN 1.**  
**Sl. 3: Von Bertalanffijeve rastne krivulje in velikostni histogrami primerkov navadne srčanke na lokalitetah A ( $L_{\infty} = 32.55$  mm in  $K = 0.48 \text{ leto}^{-1}$ ) in B ( $L_{\infty} = 36.75$  mm in  $K = 0.42 \text{ leto}^{-1}$ ) z uporabo ELEFAN 1.**



**Fig. 4:** Length converted catch curve of *Cerastoderma glaucum* at sites A and B. Solid dots are those used in calculating the parameters of the straight line, the slope of which is an estimate of Z. Open dots represent cockles not used in mortality estimation.

**Sl. 4:** Krivulja ulova navadne srčanke, preračunane na dolžino, na lokacijah A in B. Polni krogi so tisti, ki so bili uporabljeni pri izračunu parametrov premice, katere naklon je ocenjena Z vrednost. Prazni krogi predstavljajo primerke, ki niso bili upoštevani v oceni smrtnosti.



**Fig. 5:** Recruitment pattern of *Cerastoderma glaucum* at sites A and B showing two major recruitment pulses within a year.

**Sl. 5:** Rekrutacija primerkov navadne srčanke na lokacijah A in B kaže dva letna viška.

= 0.80 – 1.00) for site A and site B, respectively. The catch curves used in the estimation of Z are represented in Figure 4 for the two sites, respectively. The darkened circles represent the points used in calculating Z through least square regression analysis. Estimated value of natural mortality (M) from Pauly's empirical formula is relatively higher (0.90 yr<sup>-1</sup>) in site A than in site B (0.81 yr<sup>-1</sup>). Fishing mortality (F) was estimated to be 0.35 and 0.09 yr<sup>-1</sup> for the two sites, respectively. The rate of exploitation (E) was estimated at 0.28 for site A and 0.10 for site B (Tab. 2).

**Tab. 3: Values of von Bertalanffy growth parameters ( $K$  and  $L_{\infty}$ ) and growth performance indices ( $\phi_r$ ) of *Cerastoderma glaucum* and its congeneric *Cerastoderma edule* in different localities. Legend:  $\phi_r = \log K + 2 \log L_{\infty}$ . \*: Mean value for males and females.**

**Tab. 3: Vrednosti von Bertalanffijevih rastnih parametrov ( $K$  in  $L_{\infty}$ ) in indeks uspešnosti rasti ( $\phi_r$ ) navadne srčanke (*Cerastoderma glaucum*) in njene sorodnice, užitne srčanke (*Cerastoderma edule*) v različnih lokalitetah. Legenda:  $\phi_r = \log K + 2 \log L_{\infty}$ . \*: Srednja vrednost za samce in samice.**

Species	$K$ $\text{yr}^{-1}$	$L_{\infty}$ (mm)	$\phi_r$	Location	Source
<i>C. glaucum</i>	0.48	32.55	2.71	Gargour, Tunisia	Present study
<i>C. glaucum</i>	0.42	36.75	2.75	Akarit, Tunisia	Present study
<i>C. glaucum</i>	0.45	28.35	2.56	Lake Qarun, Fayoum Depression, Egypt	Kandeel <i>et al.</i> (2017)
<i>C. glaucum</i>	0.28	33.60	2.50	Lake Timsah, Suez Canal, Egypt	Kandeel <i>et al.</i> (2017)
<i>C. glaucum</i>	0.22* 0.26*	38.07* 39.31*	2.49 2.59	Lake Timsah, Suez Canal, Egypt	Mohammed <i>et al.</i> (2006)
<i>C. edule</i>	0.600	40.00	2.98	South Bull, Dublin Bay, Irish Sea	West <i>et al.</i> (1979)
<i>C. edule</i>	1.609	26.50	3.05	Rias Atlas, North Spain	Catoria <i>et al.</i> (1984)
<i>C. edule</i>	0.640	34.36	2.88	Bay of Saint-Brieuc, North coast of Britany	Ponsero <i>et al.</i> (2009)
<i>C. edule</i>	0.404	40.00	2.81	Wadden Sea, German	Ramon (2003)
<i>C. edule</i>	0.026	28.27	1.32	Mundaca estuary, north Spain	Iglesias & Navarro (1990)
<i>C. edule</i>	0.180	36.00	2.37	Algeciras Bay, South Spain	Guevara & Niell (1989)
<i>C. edule</i>	0.640	36.00	2.92	Banc d'Arguin, French	Magalhaes <i>et al.</i> (2016)
<i>C. edule</i>	1.300 1.330	31.00 38.00	3.10 3.30	Merja Zerga, Moroccan Atlantic Coast Arcachon Bay, French Atlantic Coast	Gam <i>et al.</i> (2010)

In both sites, the salinity remains almost stable throughout the year, i.e. 28–48 in site A and 36–48 in site B. Temperature of the seawater recorded in the whole study area showed an annual fluctuation between 11°C (winter) and 28°C (summer).

### Recruitment patterns

Relative strength of recruitment pulses generated by FiSAT for *C. glaucum* among the two sites was continuous throughout the year with two major pulses in June and November. For site A, the rela-

tive strength of these pulses was 10.3 and 17.4 % recruitment, respectively. For site B, the relative strength of the pulses was 7.8 and 15.7 % recruitment, respectively. Also, a minor pulse (4.4 and 10.5 % recruitment; respectively) was recorded in August (Fig. 5).

### DISCUSSION

The present study provided new information about the population structure, growth, mortality, and exploitation rates and recruitment pattern of cockles' populations at two different sites in southern Tunisian waters. The strong correlation between

shell length and weight for *C. glaucum* in this study and in earlier studies (Leontarakis et al., 2009; Derbali et al., 2012; Kandeel et al., 2017) is similar to that reported for other bivalves (Gaspar et al., 2001; Zeinalipour et al., 2015).

Previous surveys highlighted several estimations of the growth parameters for *C. glaucum* and its congeneric *C. edule* (Tab. 3). On comparison, our findings were not in agreement with those recorded from Egypt by Mohammed et al. (2006) and later by Kandeel et al. (2017). Saeedi et al. (2010) have suggested several key factors affecting growth at the local scale in bivalves inhabiting the northern Persian Gulf including individual's difference, climate, latitude, and longitude.

Asymptotic shell length ( $L_{\infty}$ ) derived from site A population (32.55 mm) proved to be smaller compared to site B population (36.75 mm) due to the lack of bigger sizes. The negative correlation between asymptotic shell length ( $L_{\infty}$ ) and growth coefficient (K) invalidates comparison based on individual parameters (Pauly & Munro, 1984). As a result, comparison of the growth performance of bivalve populations is better fitted by the growth index phi prime ( $\Phi'$ ). This criterion was used to characterize not only similar species (Pauly & Munro, 1984), but also related species as in the case of scallops (Del Norte, 1988). The value of ( $\Phi'$ ) obtained in the present study (2.75) is consistent with those previously calculated for other studies (Table 3). Values ranged from 2.49 to 2.75 and from 1.32 to 3.05 for *C. glaucum* and *C. edule*, respectively.

Total mortality rate of *C. glaucum* population was significantly higher at site A ( $Z = 1.25 \text{ yr}^{-1}$ ) than at site B ( $Z = 0.90 \text{ yr}^{-1}$ ). Natural mortality ( $M = 0.81 \text{ yr}^{-1}$ ) and total mortality ( $Z = 0.90 \text{ yr}^{-1}$ ) of the cockles in site B have nearly the same value as there is no fishery in the study area (Gayaniilo & Pauly, 1997). A similar observation was recorded for the same species in Lake Qarun, Egypt (Kandeel et al., 2017) and for the clam *Barbatia trapezina* (= *Barbatia decussata*) (Lamarck, 1819) in the northern Persian Gulf, Iran (Zeinalipour et al., 2014). Mortality of *C. glaucum* is generally natural and may occasionally be caused by anthropogenic activities (e.g., habitat modification and habitat degradation). Habitat degradation resulting from receiving runoff and discharge of pollutants from drainage water may be the major reason underlying the relatively high natural mortality ( $0.81 \text{ yr}^{-1}$ ) for *C. glaucum* in site B. However, commercial harvesting of the venerids, *Ruditapes decussatus* (Linnaeus, 1758) causes disturbances and higher mortality for the cockle *C. glaucum* in site A. Thus, fishing mortality of *C. glaucum* in site A

( $0.35 \text{ yr}^{-1}$ ) was much higher than that recorded in site B ( $0.09 \text{ yr}^{-1}$ ). Earlier studies have shown that commercial harvesting can reduce the fitness of bivalves leading to their higher mortality. Robinson & Richardson, 1998 found that undersized *Ensis magnus* (Schumacher, 1817) (= *Ensis arcuatus*) individuals returned to the seabed were slow to re-bury, becoming highly vulnerable to predation by crabs.

Population dynamics of cockles are controlled also by abiotic factors such as salinity, temperature, immersion time, water velocity and sediment dynamics (Malham et al., 2012). Salinity may be the main factor affecting macrobenthos abundance. Rygg (1970) tested the tolerance of *C. glaucum* in a range from 3 to 60 and found that this species lived in a wide range of salinities from 5 to 45. In the present study, we have found that cockles lived in a wide range of salinities between 28 and 48. Boyden (1972) stated that maximum age of the cockle *C. glaucum* is reduced within hypersaline environments. Therefore, salinity increase may interpret the high representation of large sizes (31% and 53%) in populations of site A and site B, respectively. Accordingly, the theoretical maximum age ( $T_{\text{max}}$ ) was lower in site A ( $7.3 \text{ yr}^{-1}$ ) than in site B ( $8.6 \text{ yr}^{-1}$ ).

Reproduction of *C. glaucum* in the two sites occurred throughout the year (Derbali, 2011). Recruitment pattern was continuous during the study period and two major peaks were observed during June and November. Also, one minor peak was recorded in August. This pattern of recruitment is typical for tropical bivalves, which are fast-growing and short-lived species (Del Norte-Campos, 2004).

The cockle *C. glaucum* has a bi-phasic life cycle with a pelagic larva and a benthic postlarval stage which can also be pelagic before settling on the sediment and becoming benthic adults (Malham et al., 2012). Reduction in cockle recruitment success by high predation rates and the presence of high densities of adult macrofauna led to recruitment failures (André & Rosenberg, 1991; Beukema & Dekker, 2005; Flach, 2003). Predation of larval cockles by adult cockles through larviphagy can lead to reductions of up to 40% of the population (Malham et al., 2012). The same sequence of events has been reported for *C. edule* from Sweden (André et al., 1993). Authors stated that survival of settling larvae decreased drastically with increasing adult density and reported that inhalation of settling larvae by populations of resident suspension feeders may cause a significant decrease in settlement on a larger scale.

The present paper is the first report on population structure, growth, mortality, and exploitation status of *C. glaucum* from southern Tunisian

waters. This study will help to accurately monitor the population dynamics of cockles and introduce measures of appropriate fisheries management. The data may help to determine future quantitative changes indicating trends in Tunisian waters that are exposed to various factors of environmental conditions and human activities.

Further work is required to explore the association between spawning and recruitment for *C. glaucum* with environmental variables to accurately monitor its exploitation. The adoption and implementation of rules, such as limiting the size

of cockles, will be required to protect this new exploitable fishery resource similar to *R. decussatus* natural populations.

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POPULACIJSKA DINAMIKA NAVADNE SRČANKE *CERASTODERMA GLAUCUM*  
(MOLLUSCA: BIVALVIA) V GABEŠKEM ZALIVU (TUNIZIJA)

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POVZETEK

*Navadna srčanka (Cerastoderma glaucum) je ena od najštevilčnejših školjk v južnih tunizijskih vodah. Status izkoriščanja in menedžment te vrste v ribištvu v Tuniziji postajata zaskrbljujoča. Ta študija je prvi poskus raziskovanja populacijske dinamike te vrste, upošteva strukturo populacije, rast, smrtnost in status izkoriščenosti dveh populacij. Srčanke so v enoletnem obdobju pobirali v Sfaxu (lokaliteta A) in Gabesu (lokaliteta B). Da bi ocenili populacijske parametre za opredelitev staleža, so analizirali velikostno porazdelitev. Rekrutiranje, ki je bilo kontinuirano, je pokazalo dva glavna viška na obeh lokalitetah. Predstavljeni podatki so ključnega pomena za primeren menedžment navadne srčanke in njeno ohranitev.*

**Ključne besede:** *Cerastoderma glaucum*, populacijska dinamika, smrtnost, rekrutiranje, jug Tunizije

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