# Age structure, growth and shell form of *Cerastoderma glaucum* (Bivalvia: Cardiidae) from El Mellah lagoon, Algeria

Lamia Bensaâd-Bendjedid, Saber Belhaoues, Asma Kerdoussi, Naouel Djebbari, Mardja Tahri, Mourad Bensouilah

Laboratory of Ecobiology for Marine Environment and Coastlines, Faculty of Science, Badji Mokhtar University, Annaba 23000, Algeria. Corresponding author: L. Bensaâd-Benjedid, lamiabendjedid@gmail.com

**Abstract**. *Cerastoderma glaucum* (Poiret, 1789) the lagoon specialist cockle, represents one of the most abundant molluscs in El Mellah coastal lagoon (northeastern Algeria); several morphological and biological characteristics of this species were investigated over a period of 18 months (January 2014 to June 2015). Analysis of allometry and different morphometric indices indicate that this population tends to assume a globular shell shape which becomes elongated as the cockle grows. From length-frequency data examination using software FiSAT II and VONBIT for Excel, age was ranged from the first to the third year old, asymptotic length ($L\infty$) was estimated to 48.061 mm and growth coefficient (K) was 0.71 $yr^{-1}$. The growth performance index ($\Phi'$) and theoretical life span ($t_{max}$) were 3.21 and 4.23 yr respectively, total mortality rate (Z) obtained was 1.94 $yr^{-1}$. Monthly variations in condition index were noticed, two sharp falls due spawning events were observed, the first spawning occurred between March and June and, the second one took place from August to October. The findings of the current study can be utilized to guide future research in various fields as pathology, biomonitoring and environmental management of this species.
**Key Words**: *Cerastoderma glaucum*, shell shape, growth, Condition index, Algeria.

**Introduction**. Bivalve molluscs are frequently dominant in terms of biomass and/or abundance in estuarine and coastal habitats (Norkko & Shumway 2011); they are often key constituents of those environments (Gili & Coma 1998), consequently any changes in their condition, growth rate, abundance, or distribution may have cascading effects on both benthic and pelagic ecosystems (Dahlhoff et al 2002; Newell 2004; Norkko et al 2006).

The brackish water cockle *Cerastoderma glaucum* is an infaunal suspension-feeding bivalve common in the southern Mediterranean, it dominates sandy bottoms in sheltered bays and lagoons, and this species is considered as a key-species of macrobenthic assemblage at temperate latitudes (Sara 2007). In the food chain cockles are a link between primary producers (phytoplankton, phytobenthos) and consumers such as crabs, shrimps, fish and birds (Reise 1985), and several studies validated *C. glaucum* as biomonitor organism (Szefer et al 1999; Machreki-Ajmi & Hamza-Chaffai 2008; Machreki-Ajmi et al 2011; Hamza-Chaffai 2014).

In the Ramsar site El Mellah, the only coastal lagoon in Algeria, *C. glaucum* was first mentioned by Bakalem & Romano (1979) and, according to several authors (Guelorget et al 1989; Draredja 2005) *C. glaucum* is considered as one of the major species of benthic macroinvertebrates of this costal wetland. Despite its ecological importance, research works specifically dedicated to it are very scarce, the main information concerning this population is limited to one study (Melouah et al 2014) dealing principally with its density and recruitment. However there is still a lack of information on this population's basic biology and life history characteristics.

In order to contribute to the baseline data and provide new information about biological parameters of *C. glaucum* from El Mellah lagoon, the present study aims to casting light on: shell form, growth, age, estimating life span and mortality of this species in this area; besides condition index was analyzed as a preliminary indicator of reproductive cycle and spawning periods.

## Material and Method

***Study site.*** The brackish water lagoon El Mellah, is located in the extreme eastern of Algerian coasts (36°54' N – 8°20' E) near the Algerian-Tunisian border (Figure 1). This shallow coastal lagoon (2.7 m of mean depth) classified as a Ramsar site since 2004 and a part of the El Kala UNESCO Biosphere Reserve covers an area of 865 hectares and communicates with the sea by a long and narrow channel of 900 m. Temperature and salinity vary between 11.40 and 30.50°C and 15.90 and 37.10 psu, respectively (Draredja et al 2012).

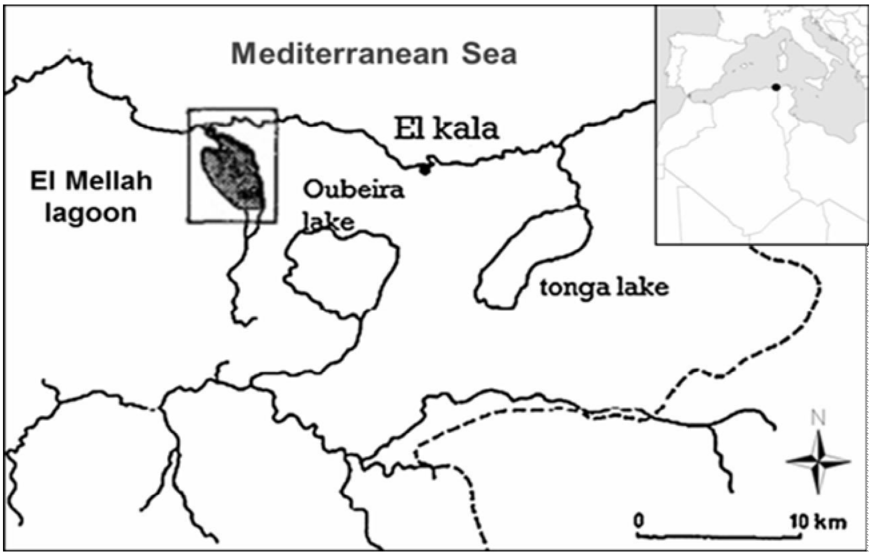

Figure 1. Geographical location of El Mellah lagoon.

***Sampling and laboratory procedure.*** From January 2014 to June 2015, cockles were monthly sampled by hand or using a manual rake, then transferred to the laboratory for processing. Shell length (SL, mm, maximum distance on the anterior-posterior axis considered as reference length), shell height (SH, mm, maximum distance from hinge to ventral margin), shell width (SW, mm, maximum distance between the closed shell valves), were measured with Vernier caliper (±0.01 mm). Total weight (TW, g), shell dry weight (sDW, g) and tissue dry weight (tDW, g) were measured using an analytical balance sensitive to 0.01 g (KERN KB 600-2). Dry weights were obtained by drying the shell and internal tissues at 80°C for 24 h in an oven.

***Relative growth and shell form.*** The morphometric relationships between shell dimensions (SL vs SH, SW; SH vs SW) and SL vs TW were investigated using the allometric equation: $Y = a*X^b$. This equation can be expressed in its linearized form as: Log Y = Log a + b Log X. Where; Y = the dependent variable; X = the independent variable (shell length, SL); a = intercept: initial growth coefficient; b = slope: relative growth rates of size parameters. The allometry coefficient "b" expresses the type of allometry which depends if: the two variables X and Y have the same units of measurement (isometric: b = 1, negative allometric: b < 1, positive allometric: b > 1); or if they have different ones (isometric: b = 3, negative allometric: b < 3, positive allometric: b > 3). The coefficient of determination ($R^2$) was used as an indicator of the quality of the power of relationship between the size parameters and it was obtained with the significance level (0.001). In order to analyze the "b" values obtained in the linear regressions to confirm if they were significantly different from the isometric value (i.e. SL-SH-SW relations: b = 1; SL-TW relation: b = 3), a t-test was applied expressed by the equation (Sokal & Rohlf 1987; Monti et al 1991): $t_s = | b - \beta | / S_b$. Where $t_s$ = t-test value; b = slope; β = isometric value of the slope; $S_b$ = standard deviation of the slope "b". A comparison between the obtained values of t-test and the correspondent tabled critical values allowed for determination of the statistical significance of the "b" values and their inclusion in the isometric range (b = 1 / b = 3), negative allometry (b < 1 / b < 3) or positive allometry ( b > 1 / b > 3). To further optimize shell shape analysis, morphometric indices based on the coupled ratios between the three shell axes and respective linear and ponderal variables (SL, SH, SW and TW), were calculated as follows (Selin 2007; Caill-Milly et al 2012; Vasconcelos et al 2018): Elongation index = SH/SL; Compactness (roundness) index = SW/SL; Convexity index = SW/SH; Density index (or weight ratio) = TW/SL.

***Age and absolute growth**.* In order to determine the age, the Bhattacharya's method (1967) available in the fish-stock assessment tool FiSAT II 1.2.0 (Gayanilo et al 2005) was used, for that purpose cockles were grouped into shell length classes and divided into cohorts at 2 mm intervals.

To estimate L∞ and K, also FiSAT II combined with software VONBIT for Excel (http://www.fao.org/fishery/topic/16078/en) were used. The von Bertalanffy growth function (VBGF) $L_t = L_\infty (1-e^{-K(t-t_o)})$, was applied to describe the growth of cockles, where L∞ is the asymptotic shell length (mm), K the growth coefficient ($year^{-1}$) and $t_0$ is the theoretical age at length zero (year). The length-weight relationship (LWR), $W = a*SL^b$ was used to convert the asymptotic length L∞ to the corresponding asymptotic weight (W∞, g). The growth performance index phi prime (Φ′) of *C. glaucum* from El Mellah lagoon, was determined and compared with values from different sites sampling using the following expressions (Pauly & Munro 1984): $\Phi' = \log10\ K + 2\ \log10\ L_\infty$. The theoretical life span ($t_{max}$) was calculated as: $t_{max} = 3/k$ (Gayanilo & Pauly 1997).

***Mortality**.* The instantaneous annual mortality rate (Z, $year^{-1}$) is an important aspect in the dynamic population of bivalves, indeed total mortality is divided into two components (Z = M + F): natural mortality (M, $year^{-1}$); due to predation, disease, cannibalism, competition, etc., and fisheries mortality (F, $year^{-1}$), due to fishing activities, in cases where there is no fishing pressure on a species as it's the case for *C. glaucum* from El Mellah lagoon; it can be assumed that Z = M (i.e. F = 0). In this study, Mortality (Z) was estimated from the slope of the right descending arm of a length-converted catch curve (Pauly 1983) using FiSAT II which outputs Z as well as the 95% confidence intervals surrounding Z based on the goodness of fit of the regression.

***Condition index**.* During one-year study period, from January 2014 to January 2015, at least 15 individuals ranging from 25 to 35 mm were taken randomly from each monthly sample for the determination of the condition index (CI), which was calculated as: tDW/sDW * 1000 (Walne 1976).

## Results

***Population structure and length frequency**.* A total of 721 cockles were sampled and their population structure was analysed. Shell length range varied between 19.87 and 47.11 mm with a mean value of 33.29 mm, the majority of this population (71.86%) was a part of the size classes included between 28 to 38 mm (Figure 2), the weight ranged between 2.24 and 30.71 g. Data on descriptive statistics size variables of *C. glaucum* from El Mellah lagoon is shown in Table 1.

Table 1

Size parameters and descriptive statistics of *C. glaucum* from El Mellah lagoon

| *Size parameters* | *n* | *Mean±SE* | *Size range* |
|---|---|---|---|
| SL | 721 | 33.29±0.185 | 19.87-47.11 |
| SH | 721 | 28.41±0.148 | 14.8-38.45 |
| SW | 721 | 23.67±0.129 | 13.45-32.85 |
| TW | 721 | 13.82±0.191 | 2.24-30.71 |

n: number of individuals; SE: standard error of mean values.

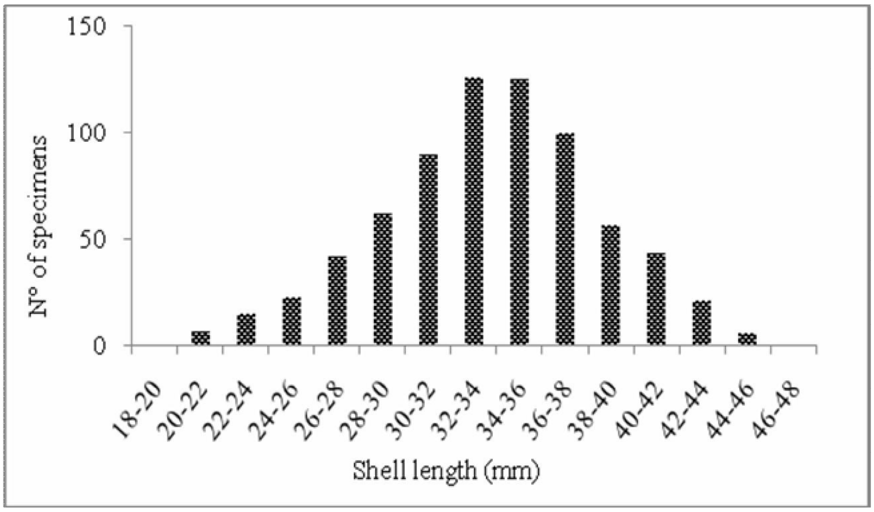

Figure 2. Length-frequency distributions of *C. glaucum* from EL Mellah lagoon.

***Relative growth and shell form***. Data concerning morphometric indices (Table 2) indicated a low TW/SL ratio (< 50%) and high values of the elongation, compactness and convexity (SH, SW were more than 70% of SL and, shell width was equal to 0.83% of height), at the same time, all morphometric relationships were significant ($R^2 \geq 0.85\%$; $p < 0.001$) and reflected negative allometry (SL against SH, SW and TW) (Table 3) with the exception of an isometry recorded in the relationship SH vs SW; this means that, *C. glaucum* from El Mellah is characterized by a heavy, round and globular form but as cockle grows the shell adopts a proportionally elongated and narrow shape.

Table 2

Morphometric indices (elongation, compactness, convexity and density) of *C. glaucum* from El Mellah lagoon

| *Descriptor* | *Equation* | *Mean±SD* | *Minimum* | *Maximum* |
|---|---|---|---|---|
| Elongation index | = SH/SL | 0.86±0.04 | 0.5 | 1.06 |
| Compactness index | = SW/SL | 0.71±0.04 | 0.5 | 0.94 |
| Convexity index | = SW/SH | 0.83±0.05 | 0.63 | 1.43 |
| Density index | = TW/SL | 0.40±0.09 | 0.12 | 0.77 |

SD: standard deviation of mean values.

Table 3

Morphometric relationships and type of growth of *C. glaucum* from El Mellah lagoon

| *Y* | *X* | *n* | *a* | *b* | $R^2$ | *β* | *Type of growth (t-test)* |
|---|---|---|---|---|---|---|---|
| SH | SL | 721 | 1.2542 | 0.8902 | 0.89 | 1 | - A |
| SW | SL | 721 | 0.9748 | 0.9098 | 0.85 | 1 | - A |
| SW | SH | 721 | 0.9148 | 0.9717 | 0.86 | 1 | = I |
| TW | SL | 688 | 0.0025 | 2.4426 | 0.87 | 3 | - A |

n: number of pairs of values; $R^2$: determination coefficient; $p < 0.001$ for all regressions; - A: negative allometry; = I: isometry.

***Age composition, growth parameters and mortality***. The analysis of the length frequency distribution over 18 months suggested the presence of three age groups (Table 4); the second age class was widely dominant in the population (77.25%) while the first was the underrepresented (6.52%). It appears that *C. glaucum* from El Mellah lagoon presents a rapid growth during the first year of life with a data value of 25.95±3.11 mm and then declines during the subsequent two years; moreover the theoretical lifespan ($t_{max}$) was estimated at 4.23 years.

Table 4

Mean length at age of *C. glaucum* from El Mellah lagoon using Bhattacharya's method (FiSAT II 1.2.0)

| *Age (year)* | *M±SD* | *n* | *%* | *Growth rate* |
|---|---|---|---|---|
| 1 | 25.95±3.11 | 47 | 6.52 | 8.31 |
| 2 | 34.26±3.73 | 557 | 77.25 | 9.26 |
| 3 | 43.52±1.42 | 117 | 16.23 | - |

n: number of individuals.

Based on the age-length key, the von Bertalanffy growth parameters obtained were respectively $L\infty$ = 48.061 mm and K = 0.71 (Figures 3 and 4), the growth performance index (Φ') value was equal to 3.21 and asymptotic total weight was $W\infty$ = 32.05 g. Data on results of total weights recorded for each age is shown in Figure 5.

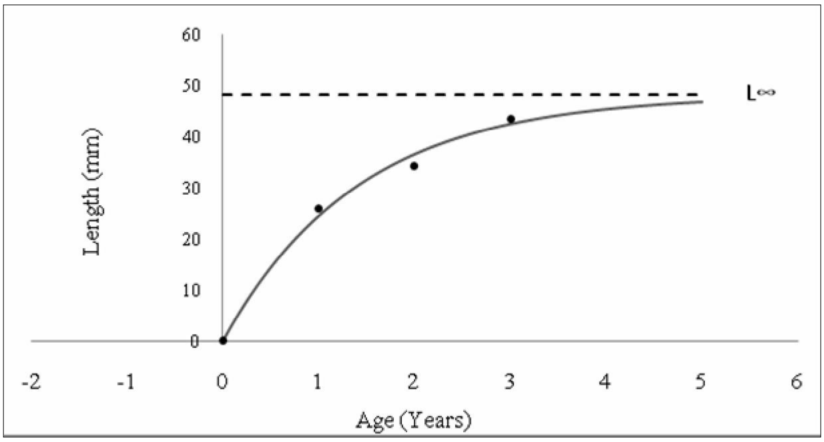


Figure 3. Von Bertalanffy growth curve of *C. glaucum* from El Mellah lagoon.

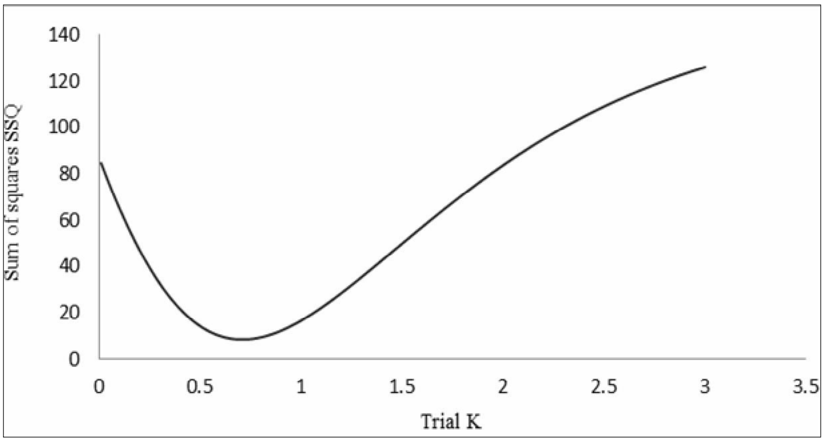


Figure 4. K optimization through minimisation of SSQ of *C. glaucum* from El Mellah lagoon.

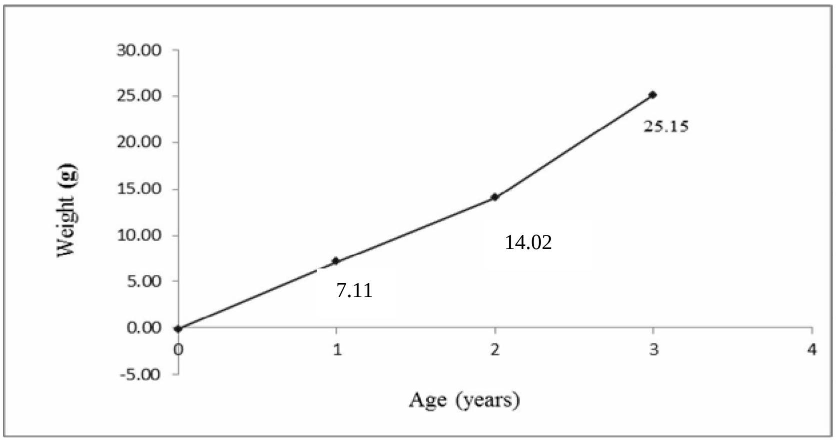


Figure 5. Total weight at each age of *C. glaucum* from El Mellah lagoon.

The length-converted catch curve analysis (Figure 6) based on the mean shell-length distribution over 18 months and the VBGF parameters, showed an annual instantaneous mortality rate (Z) equal to 1.94 $yr^{-1}$ (confidence interval CI = 1.64-2.23).

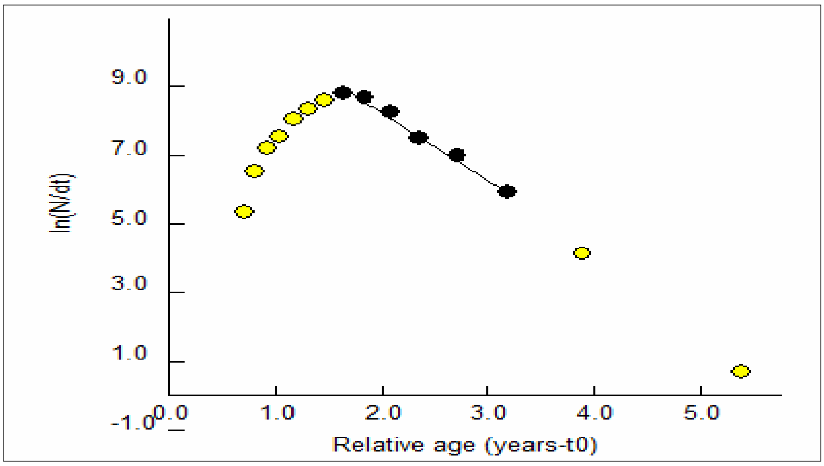


Figure 6. Length converted catch curve of *C. glaucum* from El Mellah lagoon.

***Condition index.*** Condition index exhibited temporal variations (Figure 7); the maximum mean value was observed during August (48.32), while two significant declines were registered, a minor one between March and June and the major was recorded in the period from August to October when CI reaches its minimum value (26.27) with an estimated loss of 45.63%, then a gradual increase in the CI level was noted from November 2014 to January 2015 with a gain about 31.84%.

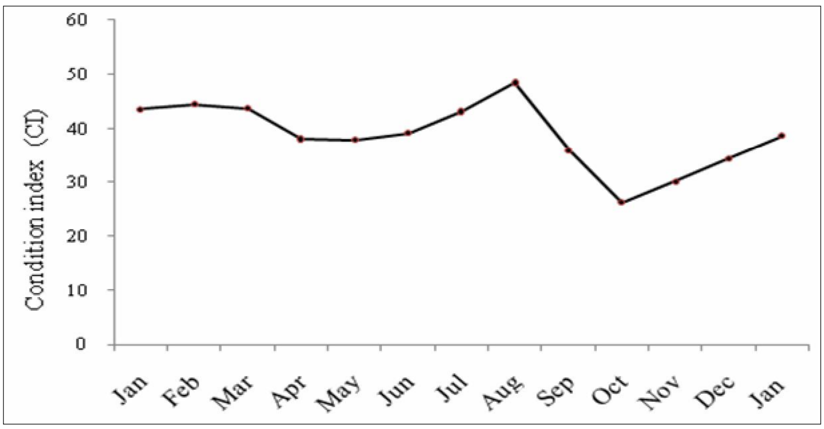


Figure 7. Monthly variations in condition index (CI) of C. *glaucum* from El Mellah lagoon (January 2014 to January 2015).

**Discussion**. In *C. glaucum* from El Mellah lagoon the maximum shell length observed was 47.11 mm. Comparing our data with those of previous studies in various Mediterranean regions, it appears that it is higher to those registered in Tunisia, in the Boughrara Lagoon (29 mm, Derbali et al 2009) and the Gabes coasts (37 mm, Derbali et al 2012) and, in Egypt such as in Lake Qarun and Lake Timsah (27 and 32 mm respectively, Kandeel et al 2017) but this size remains smaller than that observed in northeastern Mediterranean lagoon of Keramoti (53.25 mm, Leontarakis et al 2008). It seems that *C. glaucum* size varied markedly according to environmental factors in different geographical areas. Derbali et al (2012) report that the elevated water temperatures and phytoplankton high levels of the Gulf of Gabes promote rapid growth. On the other hand Tarnowska et al (2009) showed that a low average salinity negatively affects shell growth of *C. glaucum* from the Baltic Sea.

The analysis of the morphometric indices and relationships among the different size parameters suggests that *C. glaucum* from El Mellah lagoon adopts a globular shell shape which becomes elongated as the cockle grows. The elongated form expressed through significant negative allometry was also reported for another bivalve species (*Ruditapes decussatus*) from El Mellah lagoon (Bensaâd-Bendjedid et al 2017) and, for the same species in Eastern and Southern Mediterranean coastal waters (Gontikaki et al 2003; Derbali 2011; Kandeel et al 2017). On the other hand Mariani et al (2002), and Leontarakis et al (2008) described respectively an isometric and positive relative growth in *C. glaucum* from several Mediterranean sites, Atlantic and Baltic coastal habitats. This wide variation in relative growth of the species is surely genotype-driven but also various local-specific environmental factors can strongly influence shell shape variation present in bivalves (Seed 1968). Mariani et al (2002) underlined that the different allometric patterns of *C. glaucum* are functional responses to different habitat typologies. Indeed bivalves are known for their remarkable morphological diversity and the phenotypic plasticity which perceived as a key mechanism for enabling organisms to survive in the face of environmental change (Caill-Milly et al 2014; Muren et al 2015); this especially applies to the *C. glaucum* which has proven its ability to resist to extreme and unstable lagoons environmental conditions, making it a specialist of these ecosystems (Tarnowska et al 2009).

Concerning the absolute growth of species *Cerastoderma* spp., it should be noted that existing literature on the subject concerns mainly *Cerastoderma edule*, this being probably connected with the fact that *C. edule* is extensively exploited throughout its range and has a high economic value, unlike *C. glaucum* which is not commercially fished (Malham et al 2012). However in *C. glaucum* population from El Mellah lagoon, estimating $L\infty$, K and Φ′ were 48.061 mm, 0.71 $y^{-1}$ and 3.21 respectively. These findings are quite higher than what was described in previous studies dealing with this species; so far the best results ($L\infty$ = 46.45 mm, K = 0.15 and Φ′=2.51) being described by Mohammad et al (2006) in *C. glaucum* from Lake Timsah (Suez Canal). Dabouineau & Ponsero (2009) reviewed the main factors influencing the growth of cockles; they noted that the season, the location, water temperature, food availability or population density are key factors affecting the growth of cockles; this allows us to suggest that the good results obtained in present study may be explained by the positive impact of El Mellah environmental conditions on cockles growth. On the other hand, the estimated lifespan ($t_{max}$) was 4.23 years; this value seems to be consistent with results obtained by Boyden (1972) and Mohammad et al (2006) who estimated the maximum age of this species to approximately 5 years in Crouch estuary (England) and Lake Timsah (Egypt) respectively. However longevity has been estimated to be in excess of 6 years for some populations, although with mortality events and poor growth, this can often be reduced to 2-3 years maximum (Jensen 1992; Lindegarth et al 1995).

The mortality rate registered was considered to be from natural causes (M) as there is no *C. glaucum* fishery in El Mellah lagoon. Its value (Z = M = 1.94 $y^{-1}$) was high compared with that of another unexploited bivalve *Ruditapes decussatus* (Z = 0.61 $y^{-1}$) from the same site (Bensaâd-Bendjedid et al 2017). Kandeel et al (2017) attributed the relatively high natural mortality rate of cockles in Lake Qarun (1.06 $yr^{-1}$) to anthropogenic activities (e.g., habitat modification and degradation), other authors attributed it to impact of parasitic infections and high predation rates, as well as the extreme temperatures (Reise 1985; Desclaux et al 2004; Thieltges 2006; Dabouineau & Ponsero 2009). A number of studies of mortality events in *Cerastoderma* spp. show that it is difficult to unequivocally assign a cause to the deaths (Malham et al 2012). According to Burdon et al (2014) cockle mortality can be the result of extrinsic factors, including both physico-chemical and biotic factors, such as competition for food and space, poor environmental quality, or removal by predators; internal physiological factors may also play a part and include the effects of disease, poor body condition and post-spawning mortality.

It is well known that bivalves Condition index is linked to reproductive state, furthermore several authors agree that sharp falls of the CI values correspond to spawning events (Lucas & Beninger 1985; Laruelle et al 1994). Accordingly the analysis of monthly fluctuations of condition index of *C. glaucum* from El Mellah allowed the preliminarily determination of two gamete releases during 2014; one took place between March and June and, the other one during summer/early autumn (August to October). Our results are similar to those obtained in *C. glaucum* populations from Lake Tunis, BouGrara sea and Gulf of Gabes (Zaouali 1980; Derbali et al 2009) while an annual pattern of four spawning was recorded by Kandeel et al (2013) in cockles from Lake Quarun. However in bivalves, it should be emphasized that the number of spawning and the duration of breeding season were often related to temperature as it has a positive effect on those both physiological events (Lubet 1970; Partridge 1977; Laruelle et al 1994).

**Conclusions**. In the present study the good growth performance showed by *C. glaucum* reveals its well adaptation to local conditions, probably mainly related to food availability and favorable environmental conditions offered by El Mellah lagoon. Also our results bring out for the first time baseline data on several morphometric and physiological parameters concerning this species which can facilitate adequate stock management in this area. However it would be advisable that future researches focus on the impact of predation and parasitism widely described in the literature as the major biotic factors influencing cockle population dynamics and which might explain the abnormally high rate of natural mortality or shell morphology pattern observed in *C. glaucum* from El Mellah.

## References


Bakalem A., Romano J. C., 1979 Les peuplements benthiques du lac Mellah. Rapport de la mission sur le lac Mellah, Rapport du Centre de Recherche Océanographique et de la Pêche (CROP) juin 1979, pp. 13-22.

Bensaâd-Bendjedid L., Belhaoues S., Kerdoussi A., Djebbari N., Tahri M., Bensouillah M., 2017 Age, growth, mortality and condition index of an unexploited *Ruditapes decussatus* population from El Mellah lagoon Algeria. International Journal of Biosciences 11(1):436-442.

Bhattacharya C. G., 1967 A sample method of resolution of a distribution into Gaussian components. Biometrics 23(1):115-135.

Boyden C. R., 1972 Relationship of size to age in the cockles *Cerastoderma edule* and *C. glaucum* from the river Crouch estuary, Essex. Journal of Conchology 27:475-489.

Burdon D., Callaway R., Elliott M., Smith T., Wither A., 2014 Mass mortalities in bivalve populations: a review of the edible cockle *Cerastoderma edule* (L.). Estuarine, Coastal and Shelf Science 150:271-280.

Caill-Milly N., Bru N., Mahe K., Borie C., D'Amico F., 2012 Shell shape analysis and spatial allometry patterns of Manila clam (*Ruditapes philippinarum*) in a mesotidal coastal lagoon. Journal of Marine Biology vol. 2012, Article ID 281206, 11 pp.

Caill-Milly N., Bru N., Barranger M., Gallon L., D'Amico F., 2014 Morphological trends of four Manila clam populations (*Venerupis philippinarum*) on the French Atlantic coast: identified spatial patterns and their relationship to environmental variability. Journal of Shellfish Research 33(2):355-372.

Dabouineau L., Ponsero A., 2009 Synthesis on biology of common European cockle *Cerastoderma edule.* Available at: https://hal.archives-ouvertes.fr/hal-00581394. Accessed: March, 2018.
Dahlhoff E. P., Stillman J. H., Menge B. A., 2002 Physiological community ecology: variation in metabolic activity of ecologically important rocky intertidal invertebrates along environmental gradients. Integrative and Comparative Biology 42:862-871.
Derbali A., 2011 Biologie, abondance et cartographie de deux espèces de Bivalves: l'huître perlière *Pinctada radiata* et la coque glauque *Cerastoderma glaucum* dans le golfe de Gabès. PhD thesis, University of Sfax, Tunisia, 169 pp.
Derbali A., Jarboui O., Ghorbel M., Zammouri-Langar N., 2009 Population structure, distribution and relative abundance of *Cerastoderma glaucum* (Mollusca: Bivalvia) from the Bou Ghrara lagoon (Gulf of Gabes, southern Tunisia). Journal of the Marine Biological Association of the United Kingdom 2(2):1-7.
Derbali A., El Hasni K., Jarboui O., Ghorbel M., 2012 Distribution, abundance and biological parameters of *Cerastoderma glaucum* (Mollusca: Bivalvia) along the Gabes coasts (Tunisia, Central Mediterranean). Acta Adriatica 53(3):363-374.
Desclaux C., De Montaudouin X., Bachelet G., 2004 Cockle (*Cerastoderma edule*) population mortality: the role of the digenean parasite *Himasthla quissetensis*. Marine Ecology Progress Series 279:141-150.
Draredja B., 2005 Structure et organisation de la macrofaune benthique de la lagune Mellah (Méditerranée Sud-Occidentale, Algérie). Journal de Recherche Océanographique 30(1-2):24-33.
Draredja B., Melouah K., Beldi H., Benmarce S., 2012 Diversité de la macrofaune benthique de la lagune Mellah (Parc National d'El-Kala, Algérie nord-est). Bulletin de la Société Zoologique de France 137(1-4):73-86.
Gayanilo F. C., Pauly D., 1997 FAO-ICLARM stock assessment tools. (FiSAT). Reference Manual. FAO Computerized Information Series (Fisheries), No. 8, FAO, Rome, 262 pp.
Gayanilo F. C., Sparre P., Pauly D., 2005 FAO-ICLARM stock assessment tools II (FiSAT II). Revised version. User's guide. FAO Computerized Information Series (Fisheries), No 8, revised version, FAO, Rome, 168 pp.
Gili J. M., Coma R., 1998 Benthic suspension feeders: their paramount role in littoral marine food webs. Trends in Ecology and Evolution 13(8):316-321.
Gontikaki E., Antoniadou C., Chintiroglou C. C., 2003 Population structure of *Cerastoderma glaucum* and *Abra ovata* in Vouliagmeni lagoon (Attiki). Journal of the Marine Biological Association of the United Kingdom 83:1095-1097.
Guelorget O., Frisoni G. F., Ximenes M. C., Perthuisot J. P. 1989 Expression biogéologiques du confinement dans une lagune méditerranéenne: le lac Mellah (Algérie). Revue d'Hydrobiologie Tropicale 22(2):87-99.
Hamza-Chaffai A., 2014 Usefulness of bioindicators and biomarkers in pollution biomonitoring. International Journal of Biotechnology for Wellness Industries 3:19-26.
Jensen K. T., 1992 Dynamics and growth of the cockle, *Cerastoderma edule*, on an intertidal mudflat in the Danish Wadden Sea: effects of submersion time and density. Netherlands Journal of Sea Research 28:335-345.
Kandeel K. E., Mohammed S. Z., Mostafa A. M., Abd-Alla M. E., 2013 Reproductive biology of the cockle *Cerastoderma glaucum* (Bivalvia:Cardiidae) from Lake Qarun, Egypt. Egyptian Journal of Aquatic Research 39:249-260.
Kandeel K. E., Mohammed S. Z., Mostafa A. M., Abd-Alla M. E., 2017 Population dynamics of the cockle *Cerastoderma glaucum*: a comparison between Lake Qarun and Lake Timsah, Egypt. Turkish Journal of Fisheries and Aquatic Sciences 17:945-958.
Laruelle F., Guillou J., Paulet Y. M., 1994 Reproductive pattern of the clams, *Ruditapes decussatus* and *R. philippinarum* on intertidal flats in Brittany. Journal of the Marine Biological Association of the United Kingdom 74(2):351-366.

Leontarakis P. K., Xatzianastasiou L. I., Theodorou J. A., 2008 Biological aspects of the lagoon cockle, *Cerastoderma glaucum* (Poiret 1879), in a coastal lagoon in Keramoti, Greece in the northeastern Mediterranean. Journal of Shellfish Research 27(5):1171-1175.

Lindegarth M., Andre C., Jonsson P. R., 1995 Analysis of the spatial variability in abundance and age structure of two infaunal bivalves, *Cerastoderma edule* and *C. lamarcki*, using hierarchical sampling programs. Marine Ecology Progress Series 116:85-97.

Lubet P., 1970 Cycles et rythmes sexuels chez les mollusques pélécypodes. Influence du milieu et étude expérimentale. Ann Institut de biologie marine Michel-Pacha 3:24-50.

Lucas A., Beninger P. G., 1985 The use of physiological condition indices in marine bivalve aquaculture. Aquaculture 44:187-200.

Machreki-Ajmi M., Hamza-Chaffai A., 2008 Assessment of sediment/water contamination by in vivo transplantation of the cockles *Cerastoderma glaucum* from a non-contaminated to a contaminated area by cadmium. Ecotoxicology 17:802-810.

Machreki-Ajmi M., Rebai T., Hamza-Chaffai A., 2011 Variation of metallothionein-like protein and metal concentrations during the reproductive cycle of the cockle *Cerastoderma glaucum* from an uncontaminated site: a 1-year study in the Gulf of Gabès area (Tunisia). Marine Biology Research 7:261-271.

Malham S. K., Hutchinson T. H., Longshaw M., 2012 A review of the biology of European cockle (*Cerastoderma* spp.). Journal of the Marine Biological Association of the United Kingdom 92:1563-1577.

Mariani S., Piccari F., De Matthaeis E., 2002 Shell morphology in *Cerastoderma* spp. (Bivalvia: Cardiidae) and its significance for adaptation to tidal and non-tidal coastal habitats. Journal of the Marine Biological Association of the United Kingdom 82(3):483-490.

Melouah K., Draredja B., Beldi H., 2014 Dynamique de la coque *Cerastoderma glaucum* (Mollusca, Bivalvia) dans la lagune Mellah (Algérie Nord-Est). Revue des Sciences et de la Technologie. Synthèse 28:34-45.

Mohammad S. H., Mohallal M. E., Mohammed S. Z., Attia M. N., 2006 Age and growth of the cockles *Cerastoderma glaucum* and *Papyridea papyracea* in Lake Timsah, Suez Canal. Catrina 1(1):25-32.

Monti D., Frenkiel L., Moueza M., 1991 Demography and growth of *Anomalocardia brasiliana* (Gmelin) (Bivalvia: Veneridae) in a mangrove, in Guadeloupe (French West Indies). Journal of Molluscan Studies 57:249-257.

Murren C. J., Auld J. R., Callahan H., Ghalambor C. K., Handelsman C. A., Heskel M. A., Kingsolver J. G., MacLean H. J., Masel J., Maughan H., Pfennig D. W., Relyea R. A., Seiter S., Snell-Rood E., Steiner U. K., Schlichting C. D., 2015 Constraints on the evolution of phenotypic plasticity: limits and costs of phenotype and plasticity. Heredity 115:293-301.

Newell R. I. E., 2004 Ecosystem influences of natural and cultivated populations of suspension-feeding bivalve molluscs: a review. Journal of Shellfish Research 23:51-61.

Norkko A., Hewitt J. E., Thrush S. E., Funnell G. A., 2006 Conditional outcomes of facilitation by a habitat-modifying subtidal bivalve. Ecology 87:226-234.

Norkko J., Shumway S. E., 2011 Bivalves as bioturbators and bioirrigators. In: Shellfish aquaculture and the environment. Shumway S. E. (ed), John Wiley & Sons, Inc., pp. 297-317.

Partridge J. K., 1977 Studies on *Tapes decussatus* in Ireland. Natural populations, artificial propagation and mariculture potential. PhD Thesis, University College of Galway, Ireland, 336 pp.

Pauly D., 1983 Length-converted catch curves: a powerful tool for fisheries research in the tropics (part I). Fishbyte 1(2):9-13.

Pauly D., Munro J. L., 1984 Once more on the comparison of growth in fish and invertebrate. Fishbyte 2(1):21.

Reise K., 1985 Tidal flat ecology - an experimental approach to species interactions. Springer Verlag, Berlin-Heidelberg-New York-Tokyo, 194 pp.
Sara G., 2007 Sedimentary and particulate organic matter: mixed sources for cockle *Cerastoderma glaucum* in a shallow pond, Western Mediterranean. Aquatic Living Resources 20:271-277.
Seed R., 1968 Factors influencing shell shape in the mussel *Mytilus edulis*. Journal of the Marine Biological Association of the United Kingdom 48:561-584.
Selin N. I., 2007 Shell form, growth and life span of *Astarte arctica* and *A. borealis* (Mollusca: Bivalvia) from the subtidal zone of northeastern Sakhalin. Russian Journal of Marine Biology 33(4):232-237.
Sokal R. R., Rohlf F. J., 1987 Introduction to biostatistics. 2nd edition, W. H. Freeman and Co., New York, 363 pp.
Szefer P., Wolowicz M., Kusak A., Deslous-Paoli J. M., Czarnowski W., Frelek K., Belzunce M. J., 1999 Distribution of mercury and other trace metals in the cockle *Cerastoderma glaucum* from the Mediterranean Lagoon Etang de Thau. Archives of Environmental Contamination and Toxicology 36(1):56-63.
Tarnowska K., Wołowicz M., Chenuil A., Féral J. P., 2009 Comparative study on the morphometry and physiology of the European populations of the lagoon specialist *Cerastoderma glaucum* (Bivalvia). Oceanologia 51(3):437-458.
Thieltges D. W., 2006 Parasite induced summer mortality in the cockle *Cerastoderma edule* by the trematode *Gymnophallus choledocus*. Hydrobiologia 559:455-461.
Vasconcelos P., Moura P., Pereira F., Pereira A. M., Gaspar M. B., 2018 Morphometric relationships and relative growth of 20 uncommon bivalve species from the Algarve coast (southern Portugal). Journal of the Marine Biological Association of the United Kingdom 98(3):1-12.
Walne P. R., 1976 Experiments on the culture in the sea of the butterfish *Venerupis decussata* L. Aquaculture 8:371-381.
Zaouali J., 1980 [Sexual cycle of *Cerastoderma glaucum* Poiret, 1798 (Bivalvia, Eulamellibranchia, Cardiidae) in Lake Tunis and in the Bou Grara sea (Tunisia)]. Archives de l'Institut Pasteur de Tunis 57:281-295. [in French]

Received: 13 March 2018. Accepted: 31 May 2018. Published online: 26 June 2018.
Authors:
Lamia Bensaâd-Bendjedid, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: lamiabendjedid@gmail.com
Saber Belhaoues, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: belhaoues.saber@yahoo.fr
Asma Kerdoussi, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: asma_kerd@yahoo.fr
Naouel Djebbari, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: bionawel@hotmail.com
Mardja Tahri, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: mardja.tahri@yahoo.fr
Mourad Bensouilah, Laboratory of Ecobiology for Marine Environments and Coastlines, Faculty of Science, Badji Mokhtar University-Annaba, 23000 Annaba, Algeria, e-mail: bensouilah_mourad@yahoo.fr

How to cite this article:
Bensaâd-Bendjedid L., Belhaoues S., Kerdoussi A., Djebbari N., Tahri M., Bensouilah M., 2018 Age structure, growth and shell form of *Cerastoderma glaucum* (Bivalvia: Cardiidae) from El Mellah lagoon, Algeria. AACL Bioflux 11(3):894-904.