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Age and growth of *Carcinus aestuarii* Nardo, 1847 (Portunidae) and *Maja squinado* Herbst, 1788 (Majidae) in the Gulf of Gabes, Southeastern Tunisia, Central Mediterranean

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Abstract: The Mediterranean green crab, *Carcinus aestuarii* Nardo, 1847 (Crustacea, Brachyura, Portunidae), and the spider crab *Maja squinado* Herbst, 1788 (Crustacea, Brachura, Majidae) are common inhabitant of the shallow waters in the Gulf of Gabes (southern Tunisia, central Mediterranean).

The Von Bertalanffy growth parameters CW∞/CL∞, k and t0 were estimated on the basis of size-frequency modal progression analysis method. The values of CW∞ (mm), K (year-1) and t0 (year) would be, respectively, 95.61, 0.84 and -0.104 for males; 73.92, 1.11 and -0.149 for females in *Carcinus aestuarii* and, CL∞ (mm), K (year-1) and t0 (year) would be, respectively, 172.46, 0.68 and -0.147 for males; 147.05, 0.6 and -0.175 for females in *Maja squinado*.

These results were obtained, as the first attempt to study age and growth of these two crustaceans which will be of a great use for their eventual stock assessment studies.

Keywords: Carcinus aestuarii; Maja squinado; Age; Growth; Crab Fisheries; Introduced species; Gulf of Gabes; Central Mediterranean.

1. Introduction

Carcinus aestuarii belongs to the family of Portunidae and has an extensive distribution around the Mediterranean Sea to a depth of 26 m (Abello et al. 1988). Until the end of the 20th century, this species was only known to live in estuarine and lagoon waters of the Mediterranean and Black Seas (Mori et al. 1990, Behrens Yamada and Hauck 2001), but there have also been some recent records from Japan (Sakai 1986, Furta et al. 1999). In the last two centuries, specimens of *Carcinus aestuarii* have been accidentally

introduced into several regions outside their native range as a result of maritime commerce and ballast transport to the Canaries (Almaça 1961), and Tokyo Bay, Japan (Sakai 1986, Ikeda 1989, Chen et al. 2004).

The spider crab *Maja squinado* (Herbst, 1788) inhabits the Northeast Atlantic from the British Isles to Guinea and the Mediterranean Sea (Kergariou, 1984; Latrouite and Le Foll, 1989; Le Foll, 1993) and it is subject to an intense fishery. As for other species of the Majidae, the post larval life history of *Maja squinado* consists of two main phases, growth and reproduction, which are separated by a terminal molt (Hartnoll, 1963, 1978; Edwards, 1980; Meyer, 1993; Gonzalez-Gurriaran et al., 1995).

In Tunisia, crab *Carcinus aestuarii* Nardo, 1847 has no very important commercial interest and has not been thoroughly studied beforehand, it is small in size with little flesh in the claws and so rarely consumed. The fishing of this species is most often accidental. Indeed, it is generally observed in the discards of benthic trawling and nets (gillnet and trammel). The captured crabs are discarded at sea or rarely conserved for use as bait for octopus vulgaris by means of traps.

Few studies on *C. aestuarii* and *M. squinado* were carried out in Tunisian waters and are related only to some biological and genetic aspects (Deli et al. 2014, 2015, 2016; Baklouti et al. 2013 a et b, 2015). This work was carried out, as the first attempt to study age and growth of these two crustaceans which will be of a great use for their eventual stock assessment studies.

2. Materials and Methods

The study is focused on the Gulf of Gabes coasts, which is located in the southeastern part of Tunisia with the town of Chebba in the north and the Tunisian-Libyan border in the south. It occupies a wide continental shelf area and represents approximately 33% of the Tunisian coastal waters and more than 50% of the 700 km long Tunisian coastline (Bejaoui et al, 2020).

The age and growth of *C. aestuarii* and *M. squinado* were determined on the basis of the length frequency distributions (lfds), which have been shown to be useful in crustacean studies.

Data on carapace width (mm) for *C. aestuarii* (CW) and carapace length (mm) for *M. squinado* (CL), as respective reference lengths, were obtained monthly from trawling catches of these two crabs in the gulf of Gabes (southeastern Tunisia, central Mediterranean), in depths ranging from 30 to 65 m. The lfds of monthly samples were grouped and then analyzed. Size frequency data were analyzed using the software package FiSAT II (FAO/ICLARM Stock Assessment Tools). All specimen collected were kept in the fridge at -18°C and then transported to the lab, where sexed; and therefore, sexes were analyzed separately. Monthly lfds were constructed in 5 mm classes, as this scale was the most useful for the detection of modes according to data's preliminary analyses using 1 mm, 5 mm and 10 mm classes. The number of individuals sampled monthly for each species is shown in Table 1. During all months, there were no moulting individuals observed in the samples.

Table 1: Number of individuals sampled monthly for *Carcinus aestuarii* and *Maja squinado* in the gulf of Gabes

Species	*C. aestuarii*		*M. squinado*	
	F	M	F	M
January	70	43	13	89
February	136	160	15	39
March	42	110	2	5
April	42	52	34	46
May	68	39	9	15
June	112	161	71	86
July	81	101	40	50
August	175	33	7	7
September	84	45	13	13
October	66	45	19	26
November	173	111	14	11
December	332	170	11	8
TOTAL	1381	1070	248	395

The multinomial distribution (Haddon, 2001) was employed in order to separate the modes for each cohort present in lfds. Once the mean and standard deviations are calculated for the lfds of all months, the Von Bertalanffy growth formula is fit.

$$Lt = L_{\infty}\,(1- e^{-K(t-t_0)})$$

Where

L∞: Asymptotic length (CW∞ for *C. aestuarii* and CL∞ for *M. squinado*)

K: Curvature parameter

t0: Theoretical age at length zero

t: Age

The parameters of the previous equation were fit through least squares employing as objective function (Gallucci et al., 1996).

$$\Delta L = L_{t+\Delta t} - L_t = (L_{\infty} - L_t)\left(1 - e^{-K\Delta t}\right)$$

Where ΔL is the difference observed in length for a given cohort in time interval Δt. Since there is a subjective component in the identification of two distributions estimated over different times, as pertaining to the same cohort, only the modes between contiguous months were included, as the probability of committing an error in identification of the cohort was judged to be minor. Thus, if one mode was not evident in the sample of the following month, this datum was not considered, even if it was not considered; even it was evident in the second following month.

ΔL was calculated without considering the year in which the sample was taken, in order to favour obtaining a greater contrast of information on sizes and to include the entire range of sizes present in the catches. The basic assumption here was that the pattern of growth was the same, regardless of the year.

In order to evaluate the reliability of the parameters estimated for *C. aestuarii* and *M. squinado* in the gulf of Gabes, they were compared with those estimated for other species of same genus, following the criteria of Pauly and Munro (1984) and Pauly (1991), who reported that a species-specific relation exists, at the genus level, between log (L∞) and log (K) such that the relation between these parameters remained constant, independently of their values and this allows to estimate the pertinence of the values of the growth parameters (L∞) and (K), since ϕ' does not change independently of these values. In such a way, an evaluation can be made to whether the estimates of two parameters are valid or incorrect, as they become more distant from the value of ϕ' reported for species of the same genus (Sparre and Venema, 1995) allowing for the establishment for interspecific comparisons (Pauly, 1991).

3. Results and discussion

During a one-year period between January and December 2012, 2 571 green crabs (1 088 males and 1 483 females) and 670 spider crabs (417 males and 253 females) were collected. Figures 1 and 2 reproduce the length class frequency distributions for the two species. For *C. aestuarii*, mean CW varied from 40.7 during autumn to 45.5 mm during winter in males and, from 37 mm during autumn to 40 mm during spring in females (Table 2). In males, small crabs (less than 20 mm CW) occurred in April.

Their sizes increase to about 25 mm CW in June-July and 35 mm CW in October. In November and December, larger males formed 2 groups with modes of 38-40 mm and 47-50 mm CW. In females, small crabs were observed during June and larger one (> 50 mm CW) in February, April and November-December.

During the sampling period, the mean carapace length of *M. Squinado* ranged between 60.5 and 64.4 mm in males and 59.7 and 62.4 mm in females (table 1). Larger spider crabs (>75 mm CL) were observed mainly in June and July for males and only in January for females; while smaller one (<30 mm CL) were collected in July and March respectively for the tow sexes

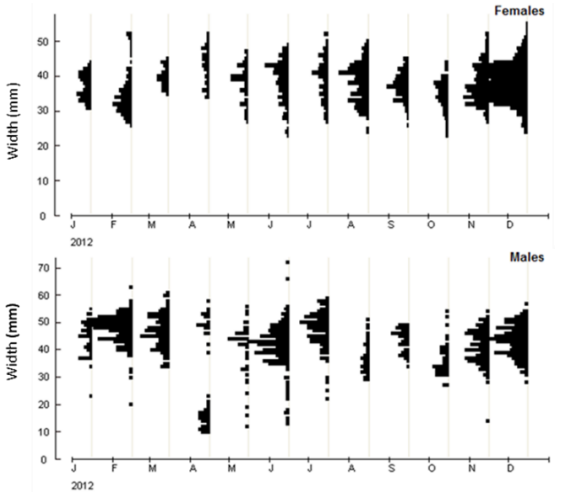


Figure 1. Length frequency distributions in *Carcinus aestuarii*.

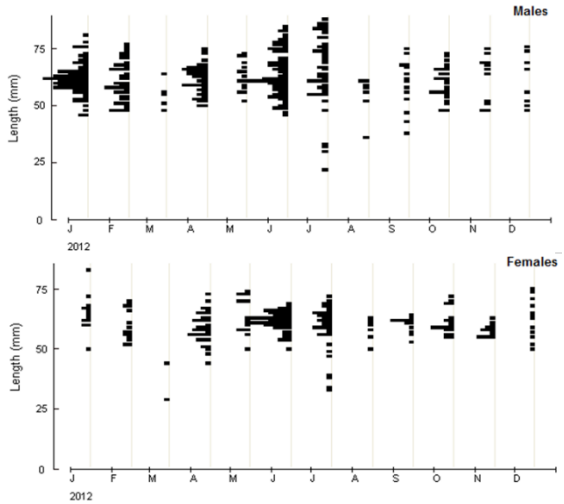


Figure 2. Length frequency distributions in *Maja squinado*.

Table 2. Seasonal mean lengths for *Carcinus aestuarii* and *Maja squinado* in the gulf of Gabes (L = CW for *C. aestuarii* and CL for *M. squinado*).

Species	***C. aestuarii***		***M. squinado***	
Sex	M	F	M	F
Winter	45.4	37.3	61.6	62.4
Spring	40.7	40.0	61.6	59.7
Summer	43.1	38.6	64.5	60.6
Autumn	40.7	37.0	60.5	59.9

For *Carcinus aestuarii* collected in the area, the size ranges between 10 and 72 mm for males and between 20 and 59 mm for females. The number of cohorts obtained from the sample analysis using Normsep's method was 42 for males and 23 for females. The IS between different modes was >2 in all cases, which satisfied the requirement for a minimum distance between the distributions.For males, mean values for the different identified cohorts ranged between 10.97 and 61.17 mm. For females, modes identified by the analysis method ranged between 14.21 and 49.5 mm. In both sexes, the relation between size and monthly increase in length has high variability (Fig. 3).

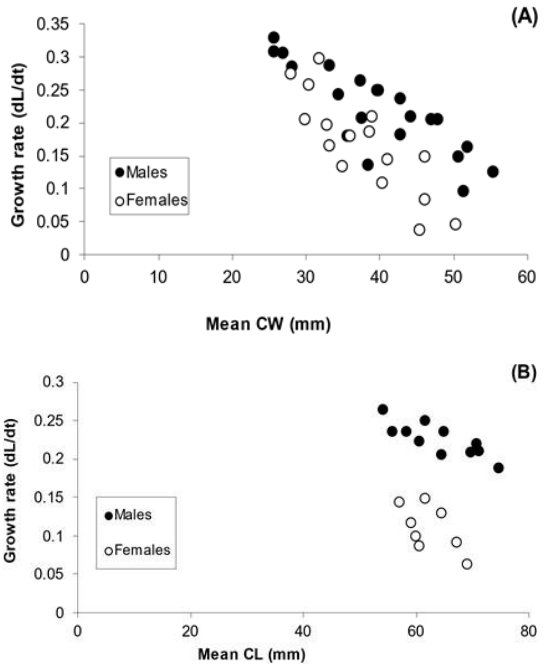


Figure 3. Monthly length increases as a function of size in *Carcinus aestuarii* (A) and *Maja squinado* (B)

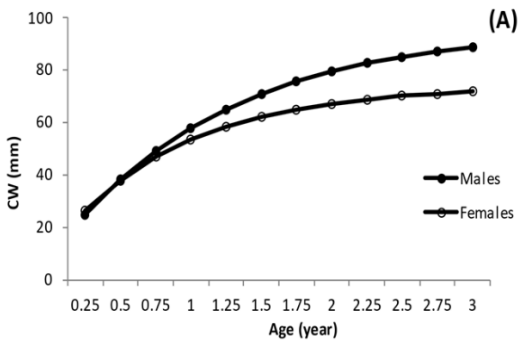
For *Maja squinado*, sample' sizes ranged between 22 and 88 mm. The total number of identified cohorts identified by Normsep's method was 55 (36 for males and 19 for females). Means values of the different modes varied between 28 and 84.16 for males and 28.03 and 77.52 for females. In the spider crab, a negative relation between size and monthly increase in length with great variations was observed (Fig. 3).

For *Carcinus aestuarii and Maja squinado* in the gulf of Gabes, the Von Bertalanffy growth equations obtained by the Normsep's method are represented in the table 3 and the figure 4.

Table 3. Parameters of the Von Bertalanffy growth model estimated for *Carcinus aestuarii* and *Maja squinado* in the gulf of Gabes

Species		***C. aestuarii***		***M. squinado***	
Sexes		**M**	**F**	**M**	**F**
$L\infty_1$	value	95.61	73.92	172.5	147.05
	SE	1.94	6.84	32.18	26.67
K	value	0.84	1.11	0.68	0.6
	SE	0.037	0.139	0.195	0.171
t_0	value	-0.104	-0.149	-0.15	-0.175

[1] L∞ = CW∞ for *C. aestuarii* and CL∞ for *M. squinado*



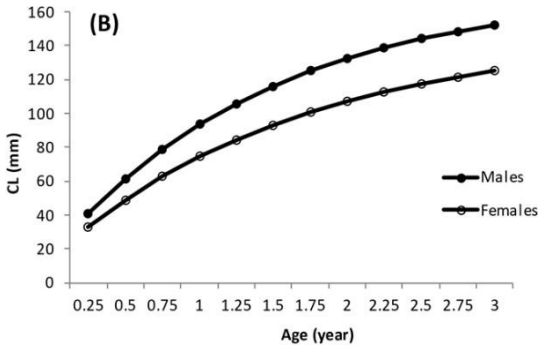


Figure 4. Growth curves fitted males and females of *Carcinus aestuarii* (A) and *Maja squinado* (B)

The value of ϕ ' was similar between sexes, obtaining 1.880 for males and 1.783 for females in *Carcinus aestuarii* and 2.306 for males and 2.113 for females calculated in *Maja squinado*.

4. Discussion

Almost all the spider crab *M. squinado* sampled in winter and spring were mature measuring more than 52 mm in CL, as the CL50 was estimated to 52.17 mm and 54.31 mm, respectively, for females and males (Baklouti et al., 2015). Indeed, during the sampling period, the mean carapace length of *M. Squinado* ranged between 60.5 and 64.4 mm in males and 59.7 and 62.4 mm in females (table 2). In the coastal habits of Galicia (Northwestern Spain), Sampedro et al. (2003) found that the specimen, of *M. Squinado* caught in winter and spring were immature, measuring less than 110 mm in length. The authors noted that this size increased until June with the appearance of the first adult animals.

For *C. aestuarii*, mean CW varied from 40.7 during autumn to 45.5 mm during winter in males and, from 37 mm during autumn to 40 mm during spring in females. In this species, the percentage of mature individuals (CW> 43.93 mm in males and 34.56 in females (Baklouti et al., 2013a) is most important during spring season. The size distribution data showed that, in the Gulf of Gabes, most crabs typically recruit before April, and then grow large enough during the summer to participate in

breeding season which occurs, in the study area, during autumn-winter (Baklouti et al., 2013b). New recruits were not collected in March, but the presence of small crabs in April and May suggests that the crabs begin recruiting at the end of March. These results are quite similar to those signaled by Furota et al. (1999) in Tokyo bay in Japan, who noted that, early in the breeding season (November-December), ovigerous females were found among larger crabs, which may be once or twice overwintered individuals that had recruited during the previous one or two years; or may be the recruits of the earliest recruits from the current spring.

The estimation of age and growth in crustaceans is hampered by the absence of hard structures with periodic marks, due to the loss of the tegument in succeeding moults which also makes impossibly the application of marking methods (Rajyalakshmi, 1966; Hartnoll 1982). So, the application of the length frequency distribution (lfds) methods to obtain the growth curve may be of great interest in population studies of those animals.

For *C. aestuarii* and *M. squinado* in the gulf of Gabes, the Von Bertalanffy growth parameters showed that males grow faster than females. In fact, in the green crab, males present a high asymptotic length ($L\infty$) with a smaller K. However, in the spider crab, higher values of and K were obtained for males. The value of ϕ' was similar between sexes, obtaining 2.773 for males and 2.706 for females in *Carcinus aestuarii* and 2.721 for males and 2.762 for females calculated in *Maja squinado*.

In *C. aestuarii* and *Maja squinado* of the Gulf of Gabes, males exhibit faster growth rates than females which is consistent with the larger male sizes observed in the catches. Sexual dimorphism exists in *Carcinus* species (Leignel et al. 2014). Adult males are always larger than females in both (Koçak et al. 2011; Matozzo et al. 2013). During the first two years, males of green crab reached a CW of 57-80 mm while females reached a CW ranging between 53 and 68 mm. Otherwise, *M. Squinado* reached a CL of 93-133 mm for males and a CL of 74-108 mm for females at 1-2 years age. Males of *C. aestuarii* appeared to grow faster than females in the first and second year of the life cycle (Glamuzina et al., 2017). According to the growth parameter estimates, male crabs grew slightly faster than females and also reached a larger asymptotic size hence exhibited a greater growth performance (Tıraşın et al., 2020). The estimated index of growth performance (ϕ') presents similar values among sexes of each species, which indicated similar growth pattern among them and, that the estimations are correct (Sparre & Venema, 1995).

Finally, we must point out that the growth parameters obtained in this study for *C. aestuarii* and *M. Squinado* present the first results related to the age and growth aspect of these crustaceans in the Gulf of Gabes and in Tunisian waters. These estimations will be useful for the stock assessments of these two crab species, since they become among the commercialized crustaceans in the local Tunisian markets. However, comparison of growth *C. aestuarii* and *M. Squinado* with that of other species belonging to the same genus, is very difficult, firstly due to the rare number of quantitative nature articles available in the literature and secondly due to heterogeneity of methods applied.

5. Conclusion

The growth parameters obtained in this study for *C. aestuarii* and *M. Squinado* present the first results related to the age and growth aspect of these crustaceans in the Gulf of Gabes and in Tunisian waters. These estimations will be useful for the stock assessments of these two crab species, since they become among the commercialized crustaceans in the local Tunisian markets. However, comparison of

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