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ORIGINAL ARTICLE

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Dimorphic growth in male and female cuttlefish *Sepia orbignyana* (Cephalopoda: Sepiidae) from the Adriatic Sea

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Abstract The relationships between mantle length and number of cuttlebone chambers (or septa), and between weight and number of cuttlebone chambers were studied in *Sepia orbignyana* collected in the south-western Adriatic Sea. Weight-at-chamber count and mantle length-at-chamber count were statistically higher in females than in males. As the available literature suggests that the rate of cuttlebone septum formation is the same in both sexes of *Sepia* species, it follows that in *S. orbignyana* females have higher growth rates than males.

Keywords Growth · Sexual dimorphism · Cephalopoda · *Sepia* · Adriatic Sea

Introduction

Sepia orbignyana Férussac, 1826 (Cephalopoda: Sepiidae) is a small cuttlefish that lives in the Mediterranean Sea and the eastern Atlantic Ocean, on muddy and sandy grounds at depths of 50–450 m (Mangold and Boletzky 1987). Little is known about growth rates of this species. According to Mangold-Wirz (1963) females grow faster than males. Ragonese and Jereb (1991) used the modal analysis method to find that the mean growth rate of mantle length is about 2.9 mm/ month in males and about 3.0 mm/month in females. Considering that females are statistically heavier than males at any mantle length (Bello 1988), it follows that weight increases faster in females. However, according to Arkhipkin (1991) the indirect methods for assessing the age of cephalopods, such as the one used by Ragonese and Jereb (1991), are useful only in cases where well-defined and short-term spawning events take place with no changes in population structure due to migration. This is not the case with *S. orbignyana*. Incidentally, it is known that the study of statolith structure does not allow ageing in cuttlefishes (Clarke 1993).

Several attempts have been made to age cuttlefish by counting the septa of the sepion (Choe 1963; Richard 1967, 1969). It has been shown that chamber counts cannot be used readily to age these cephalopods, as the rate of septum formation depends on temperature and is faster as temperature increases (Richard 1967, 1969). Nevertheless, it was shown in *Sepia* spp. that at constant temperature and when food is not in short supply, the septa are formed at a constant rate in both sexes (Mangold 1966; Richard 1969; Boletzky 1988; Natsukari et al. 1991). Moreover, no sex-related differences were reported by Le Goff et al. (1998) in the rate of septum formation in *Sepia officinalis* from a coastal area with variable temperature.

The purpose of the present study is to investigate the relative growth in males and females of *S. orbignyana* from the south-western Adriatic Sea by means of cuttlebone chamber counts. The study is based on the assumption that septum formation rate is the same in both sexes at constant temperature (about 13°C throughout the year in the present case); therefore, the number of cuttlebone chambers represents a relative age index. This assumption is supported by the available literature cited above.

Materials and methods

The cuttlefish were sampled by bottom trawls in depths ranging from 120 to 170 m in the south-western Adriatic Sea, in a restricted area off Mola di Bari, from late April to early June 1991. Specimens collected in a restricted area and within a restricted period of time are supposedly free from bias in biological parameters due to geographical, depth (Mangold 1982) and seasonal differences (Dawe 1988).

The collected cuttlefish consisted of 52 males (mantle length range=1.76–8.10 cm, weight range=1.2–49.2 g) and 71 females (mantle length range=2.51–9.25 cm, weight range=2.5–70.3 g).

Because of fishing operations, several cuttlefish had their cuttlebone broken in a way that made it impossible to count their

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chambers with accuracy. Therefore, only 46 males and 69 females were useful for the present study.

The following measurements and counts were taken:

ML dorsal mantle length, to 0.01 cm.

W body wet weight less stomach contents wet weight, to 0.1 g. The weight of stomach contents was subtracted from the total body weight in order to eliminate this possible source of bias.

CN number of cuttlebone chambers or loculi. The number of chambers is the same as the number of septa or lamellae, provided that the last deposited septum, i.e. the one that is completely visible in the ventral cuttlebone surface, is counted. All chambers, including the embryonic ones, were counted on the whole cuttlebone; some bones were cut at the posterior end to test count precision as in large specimens the inner cone may mask the innermost embryonic chambers.

Following log-transformation (natural logarithms) of data, predictive regression equations correlating ln *ML* to ln *CN*, and ln *W* to ln *CN*, were calculated for each sex, with ln *CN* being the independent variable. Ricker (1973) recommends the use of geometric or functional regressions when correlating morphometric parameters, such as body measures and chamber counts; see also Sokal and Rohlf (1981) about the preferability of this type of regressions when correlating continuous variables distributed according to the bivariate normal distribution. However, in the present case *CN* was used as an index of time and, therefore, properly represents the independent variable; hence the predictive regression model was used.

Outliers were detected by the analysis of standardised residuals (Sokal and Rohlf 1981), and were rejected.

The regression equations for males were compared to those for females by Student's *t*-test (Mayrat 1959).

Results

A few cuttlebones bore scars of healed wounds in the posterior half. In most of them, a few chambers were appressed to each other in the scar region; cuttlefish affected by this phenomenon presented higher chamber counts than expected with respect to their body size according to the regression equations. Outlier analysis showed that four ln *W*–ln *CN* points (1 male and 3 females) and six ln *ML*–ln *CN* points (3 males and 3 females) pertaining to scarred cuttlefish were indeed outliers.

The points for mantle length against chamber number (*ML*–*CN*) (Fig. 1a) and weight against chamber number (*W*–*CN*) (Fig. 2a) are distributed according to curves that can be described by power equations. The distributions of the same points following log-transformation and their respective regression lines are shown in Figs. 1b and 2b.

The regression equations for the ln *ML*–ln *CN* and ln *W*–ln *CN* correlations for each sex, and the results of the

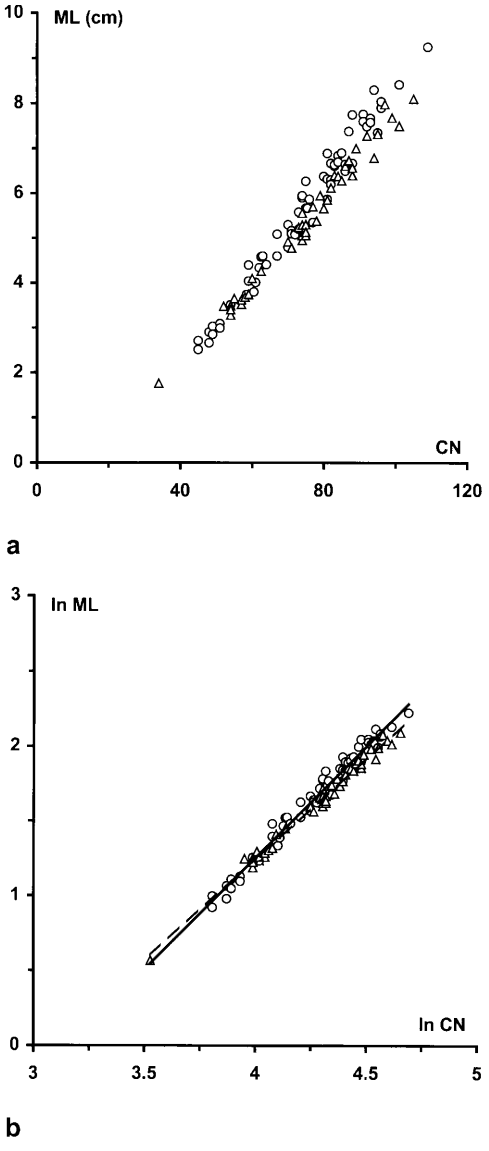

Fig. 1a, b Relationship between mantle length (*ML*) and cuttlebone chamber count (*CN*) for males and females of *Sepia orbignyana*. **a** Raw data. **b** Log-transformed data with regression lines. △ and *broken line* Males; ○ and *continuous line* females

Table 1 Analysis of the correlations between mantle length (*ML*) and cuttlebone chamber number (*CN*), and between weight (*W*) and cuttlebone chamber number (*CN*) for males (*M*) and females (*F*) of *Sepia orbignyana*; *n* sample size, *r* correlation coefficient, s_b standard error of regression coefficient, *t*=Student's *t*, *df* degree of freedom, *P* significance level of Student's *t*

Sex	Regression equation	*n*	*r*	s_b	*t*	*df*	*P*
M	ln *ML*=–4.180+1.355 ln *CN*	43	0.993	0.0250			
					3.572	105	<0.001
F	ln *ML*=–4.712+1.491 ln *CN*	66	0.988	0.0286			
M	ln *W*=–11.762+3.359 ln *CN*	45	0.992	0.0654			
					5.236	107	$<10^{-6}$
F	ln *W*=–13.755+3.870 ln *CN*	66	0.989	0.0724			

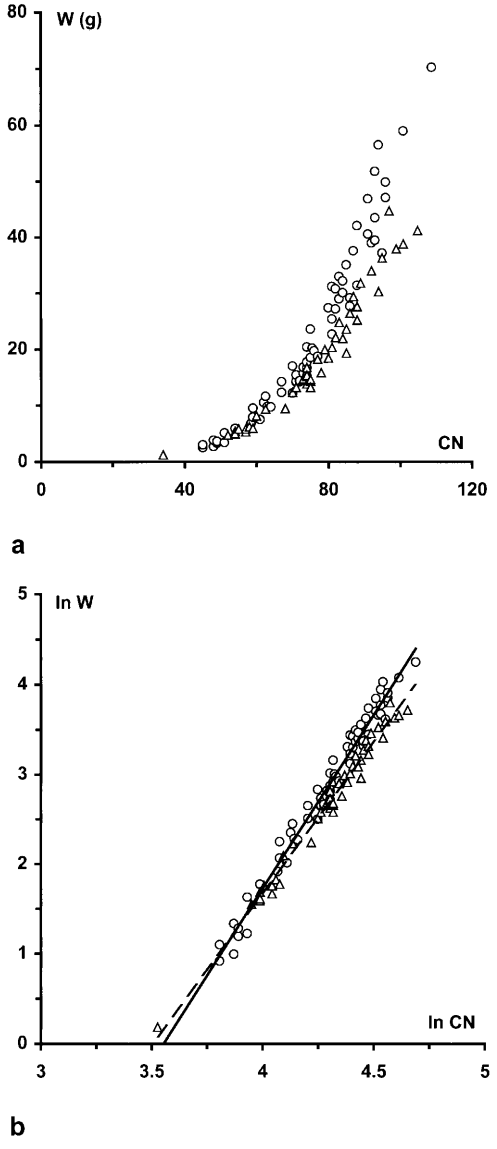

Fig. 2a, b Relationship between weight (*W*) and cuttlebone chamber count (*CN*) for males and females of *Sepia orbignyana*. **a** Raw data. **b** Log-transformed data with regression lines. △ and *broken line* Males; ○ and *continuous line* females

t-test applied to pairs of equations are given in Table 1. In both correlations, the differences in slope, *b*, between the equations of males and females were found to be statistically significant. (The *t*-test applied to differences in elevation was not performed because of its redundancy.) Accordingly, females have a statistically higher mantle length-at-chamber count and a statistically higher weight-at-chamber count than males.

Discussion

The assumption that the number of cuttlebone chambers represents a relative age index may be expressed, regardless of sex, by the equation:

$$(t_2\text{-}t_1) = k\,(CN_2\text{-}CN_1) \quad (1)$$

Growth in weight is $G_m = \frac{dW_m}{dt}$ in males and $G_f = \frac{dW_f}{dt}$ in females. In the lapse of time (t_2–t_1) during which the same number of lamellae is formed in specimens of both sexes, growth will be $G_{m(2-1)} = \frac{W_{m_2} - W_{m_1}}{t_2 - t_1}$ in males and $G_{f(2-1)} = \frac{W_{f_2} - W_{f_1}}{t_2 - t_1}$ in females; or, taking into account equation [1], $G_{m(2-1)} = \frac{W_{m_2} - W_{m_1}}{k(CN_2 - CN_1)}$ males and $G_{f(2-1)} = \frac{W_{f_2} - W_{f_1}}{k(CN_2 - CN_1)}$ in females. Since weight-at-chamber count is statistically higher in females than in males, it follows that $W_{f_2} - W_{f_1} > W_{m_2} - W_{m_1}$. Hence $G_f > G_m$, i.e. growth in weight is faster in females. The same demonstration may be applied to increase in mantle length.

The present results corroborate Mangold-Wirz's (1963) hypothesis and Ragonese and Jereb's (1991) results, that is to say, in *S. orbignyana*, growth rates of females are higher than those of males. In addition, females are wider than males (Bello 1988). Both sexual dimorphic features enhance fecundity in this large-egged species (egg diameter=7–9 mm; Mangold-Wirz 1963).

Bello and Piscitelli (2000) showed that females of *S. orbignyana* have longer tentacular clubs than males and ingest larger quantities of food than males at any given size, and hypothesised the existence of a cause–effect relationship between sex-related club size and growth.

Higher growth rates in females have been demonstrated in a number of cephalopods, e.g. *Berryteuthis magister* (Oegopsida: Gonatidae) (Natsukari et al. 1993), *Illex coindetii* (Oegopsida: Ommastrephidae) (Arkhipkin 1996), and *Loliolus noctiluca* (Myopsida: Loliginidae) (Dimmlich and Hoedt 1998). Moreover, in several species females reach a much larger size than males, which is indirect evidence of faster growth in females, e.g. in *Rossia macrosoma* (Sepiolioidea: Sepiolidae), *Eledone cirrhosa* (Octopoda: Octopodidae), and *Ocythoe tuberculata* (Octopoda: Ocythoidae).

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