Berliner Paläobiol. Abh.	03	013-018	Berlin 2003

SCAR-BEARING CUTTLEBONES IN WILD-COLLECTED *SEPIA ORBIGNYANA* (CEPHALOPODA: SEPIIDAE) AND THE EFFECTS OF SCAR OCCURRENCE ON MORPHOMETRIC RELATIONSHIPS

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ABSTRACT

The examination of a sample of wild-collected *Sepia orbignyana* showed that 22 out of 115 cuttlebones (= 19.13%) were affected by scars. In two cases, scars were interpreted as fish teeth-marks. The actual nature of traumas recorded in most other cuttlebones in the form of a few dark-coloured closely spaced septa was not established; however, this pattern looks very much like that brought about by experimental shell implosion in *S. orbignyana*. Three scar-bearing cuttlebones were asymmetrical with respect to the sagittal plane. The analysis of the standardized residuals of the regressions 'ln weight – ln chamber number' and 'ln mantle length – ln chamber number' showed that the set of cuttlefish with scarred shells had average values of weight- and mantle length-at-chamber number lower than cuttlefish with normal shells, thus pointing out that the growth of specimens affected by traumas had been slowed down for a while after the wounding event; this feature is also revealed by the crowding of septa in connection with the trauma. Moreover the analysis showed that the proportions between body size and chamber number were abnormally low in two males and two females with scarred cuttlebones, which indicates that their growth had been significantly stunted with respect to the other cuttlefish. The stunted growth in the period of recovery is supposedly due to either energetic investment to repairing damages to body tissues and shell or temporary impaired feeding capabilities, or both.

INTRODUCTION

Cephalopods, like other molluscs, are capable of repairing and regenerating parts of their body following traumatic events. Occurrences of repairs of hard structures, such as the calcified external or internal shell, are well known in fossil and living cephalopods (Meenakshi *et al.* 1974, Keupp 2000); usually the signs of post-traumatic repairs are evident as scars. For the genus *Sepia* (Sepiida: Sepiidae), there are many reports dealing with single cases of anomalous cuttlebones, *i.e.* the calcified internal shell, discovered by chance (Battiato 1983). An exception is the paper by Boletzky and Overath (1991) that describes comprehensively several scarred cuttlebones of *Sepia officinalis* Linnaeus, 1758.

The subject of the present study is the occurrence of scars on cuttlebones of wild-collected *Sepia orbignyana* Férussac, 1826. This cephalopod is a comparatively deep-living species, known from 50 to 450 m of depth (Mangold & Boletzky 1987), inhabiting the Mediterranean and the eastern Atlantic Ocean. The occurrence of scar-bearing shells was discovered while analysing the correlations between body dimensions (mantle length and body weight) and number of cuttlebone chambers or loculi in *S. orbignyana*; this analysis included the rejection of outliers (Bello 2001). The outlying specimens were found to have an anomalous cuttlebone. A closer inspection of all available cuttlebones revealed a fairly high incidence of scars, and this observation prompted the present work.

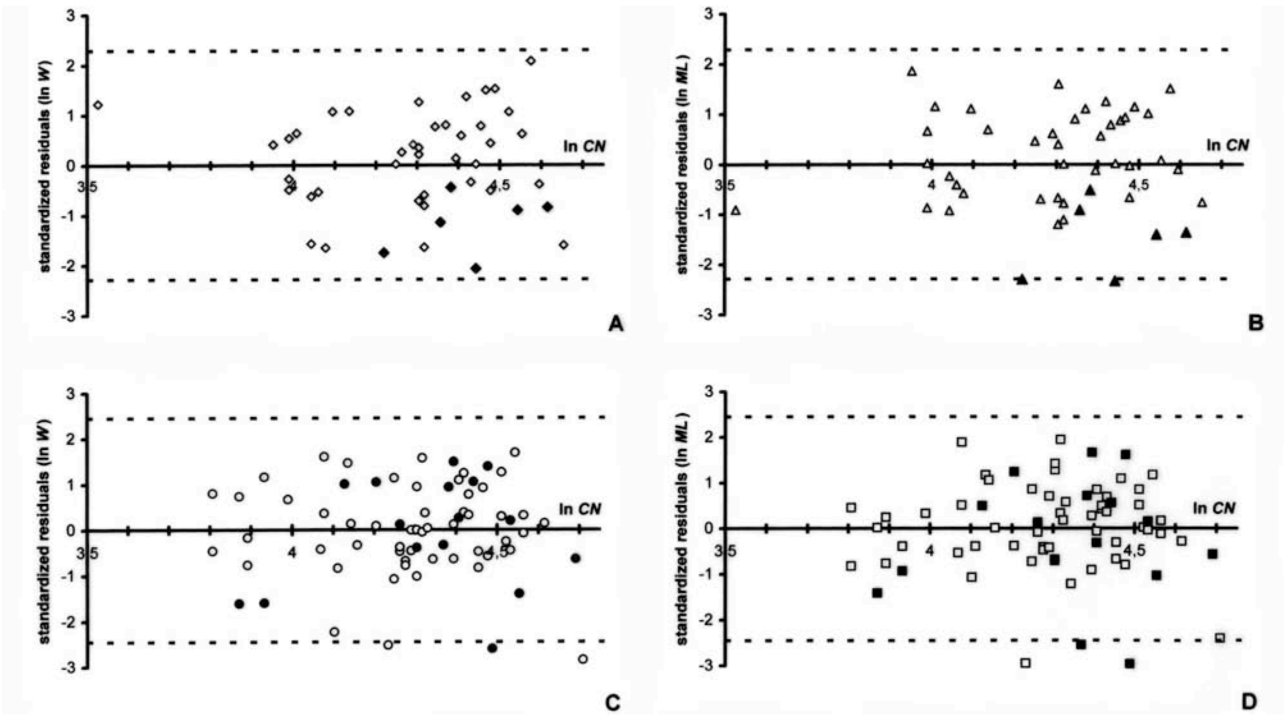

Fig. 1 Distribution of standardized residuals of 'ln *W* – ln *CN*' and 'ln *ML* – ln *CN*' regressions for males (A and B) and females (C and D) of *Sepia orbignyana*. Broken lines: limits comprising (n-1) members of the standardized residual population; filled symbols: residuals of cuttlefish with scarred cuttlebones; empty symbols: residuals of cuttlefish with normal cuttlebones

In this paper we deal with the scarred cuttlebones of *S. orbignyana* mainly from the statistical standpoint in order to investigate the effects of traumatic events on somatic growth. To the best of our knowledge this is the first description of anomalous shells in this species and the first attempt to approach the phenomenon statistically in a wild population of the genus *Sepia*.

MATERIALS AND METHODS

The cuttlebones came from a sample of 123 *Sepia orbignyana*, 52 males and 71 females, collected by bottom trawls in depths ranging from 120 to 170 m in the south-western Adriatic Sea, off Mola di Bari, from late April to early June 1991. After discarding a few cuttlefish badly damaged by the fishing operations, the following set of measurements and counts was taken on 46 males and 69 females:

ML = dorsal mantle length, to 0.01 cm;

W = body wet weight less stomach contents wet weight, to 0.1 g;

CN = number of cuttlebone chambers, including the embryonic ones.

For further details refer to Bello (2001).

Several years later, the dry-stored cuttlebones were re-examined and the following additional counts were taken on scarred shells:

chambers-at-scar, back-counted number of cuttlebone chambers at the occurrence of trauma;

scar width, number of chambers involved in the scar.

The correlations between the pairs of morphometric variables *ML-CN* and *W-CN*, separately for males and females (*S. orbignyana* is sexually dimorphic in this respect), were analysed in Bello (2001). They are re-discussed here with respect to the scar-bearing cuttlebones. The analysis of standardised residuals (Sokal & Rohlf 1981) was carried out to detect outliers, *i.e.* specimens affected by anomalous proportions between the body dimensions (*ML* and/or *W*) and the number of cuttlebone chambers (*CN*). According to the probabilistic criterion chosen in the present analysis, outliers are characterized by residuals that exceed the limits comprising n-1 members of the standardized residual population.

RESULTS

A comparatively high proportion of cuttlebones of *Sepia orbignyana*, *i.e.* 22 (= 19.13%), bore some sort of scars, from barely visible to very evident ones. Five

Table 1 Means of standardized residuals for scarred and normal cuttlebones in the 'ln *W* – ln *CN*' and 'ln *ML* – ln *CN*' regressions, and significance level, $P_{(t)}$, of the Student's-*t* test for differences between means

	ln *W* – ln *CN*		ln *ML* – ln *CN*	
	scarred	normal	scarred	normal
Males	−1.196	+0.188	−1.470	+0.223
	$P_{(t)} < 0.001$		$P_{(t)} < 0.0005$	
Females	−0.043	+0.010	−0.209	+0.059
	$P_{(t)}$ = n.s.		$P_{(t)}$ = n.s.	

specimens bore two scars each. In most cases scars appeared as a disruption of the smoothness of the dorsal cuttlebone surface; in the corresponding zone of the siphuncular stripes (ventral surface), the septa were dark-coloured and more closely spaced than the average, thus showing that growth had slowed down soon after the wounding event. The number of septa affected by stunted growth ranged from 1 to 6. Three scar-bearing cuttlebones had lost their symmetry with respect to the sagittal plane, one of them to a great extent; conversely, no normal cuttlebone was asymmetrical. The nature of most traumas was not established; the scars of two cuttlebones were interpreted as fish teeth-marks.

The incidence of scars according to sex is 13.04% in males and 23.19% in females; however no significant difference was found between the two sexes ($\chi^2 = 1.61$; $P = 0.21$, n.s.).

The analysis of the standardised residuals of the regressions 'ln *ML* – ln *CN*' and 'ln *W* – ln *CN*' proved that two males and two females with scarred cuttlebones presented outlying values of *ML*-at-*CN* (all four specimens) and *W*-at-*CN* (only one female) (Fig. 1). In all cases, these values were abnormally low. Such a feature indicates that growth was significantly stunted in these specimens compared to the other cuttlefish.

Apart from these extreme cases, the set of cuttlefish with scarred shells displayed average values of residuals lower than cuttlefish with normal shells, in all four correlations – although differences between means were statistically significant only in the male regressions – (Table 1), thus showing that specimens affected by traumas had average values of *ML*-at-*CN* and *W*-at-*CN* lower than normal and, in turn, that their

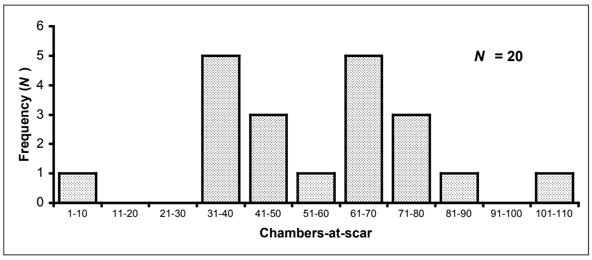

Fig. 2 Frequency distribution of chambers-at-scar values for female *Sepia orbignyana*. The distribution includes 12 chamber counts for single-scarred cuttlebones and 8 chamber counts for 4 double-scarred cuttlebones

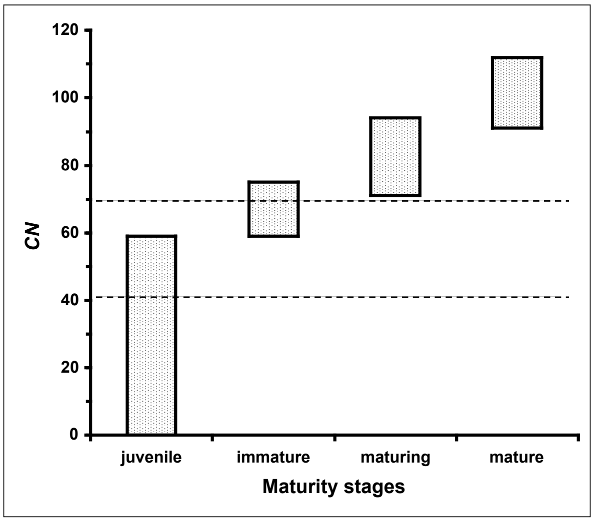

Fig. 3 Distribution of cuttlebone chamber numbers (*CN*) according to maturity stages of female *Sepia orbignyana*. The broken lines correspond to the two peaks of chambers-at-scar frequency distribution, 40.3 and 69.4 chambers respectively (see Fig. 2)

growth both in length and weight was somewhat slowed down.

The frequency distribution of the female chambers-at-scar values is bimodal (Fig. 2) (male chambers-at-scar values are too few to analyze their distribution), which suggests that most traumatic events recorded on the cuttlebones were not distributed evenly throughout the whole life of cuttlefish, being rather concentrated in two distinct periods of the biological cycle. The first peak (40.3 chambers) corresponds to the juvenile phase and the second peak (69.4 chambers) roughly corresponds to the onset of the maturation processes (Fig. 3).

The scars of two cuttlebones may be reliably interpreted as fish teeth-marks (Pl. 1/1 and 2); predatory attacks may also be the cause of scars in two other shells. The nature of traumas recorded in most cuttlebones in the form of a few dark-coloured closely spaced septa was not established.

DISCUSSION

The dominant type of scars on cuttlebones of wild-caught *Sepia orbignyana*, *i.e.* a few dark-coloured closely spaced septa, looks very much like that brought about by experimental shell implosion in the same species resulting from disintegration of the pillars between the chamber septa (Ward & Boletzky 1984). Such a similarity is particularly evident in the cuttlebone shown in Pl. 1/3, with the very last chamber affected by a recent trauma (compare Pl. 1/3 of this paper to Fig. 2 (E) in Ward & Boletzky 1984).

The implosions described by Ward and Boletzky (1984) were experimentally caused by lowering live cuttlefish to depths of 600 m and deeper, which are below the natural depth limits for *S. orbignyana*. It seems unlikely that cuttlefish, *i.e.* cephalopods well equipped for controlling floatation (Denton & Gilpin-Brown 1973), may become victims of accidental descent beyond their usual depth levels. Hence the hypothesis that this type of scars may have been caused by traumatic events other than the accidental descent to overly deep levels. The correct interpretation of shell anomalies may contribute to the understanding of cuttlefish interactions with physical environmental conditions and other living creatures (Keupp & Riedel 1995). In this respect, scars in cuttlebones may be the only readily accessible record left on the cuttlefish by certain traumatic events because of their regenerating capabilities (Féral 1978). In fact no evident anomalies were detected on the body surface of any cuttlefish during their examination and measurement (which included the inspection of their reproductive system and removal of their stomach).

Whatever the actual cause of cuttlebone scars, their comparatively high incidence (19.13%) in wild-caught *S. orbignyana* shows that these animals possess good capabilities of overcoming certain traumas. This fact endorses the supposition by Ward and Boletzky (1984) that the minor shell implosions, which produce little shell damage, can be readily survived by this species.

The wounding events recorded as scars in the cuttlebone disturbed chamber deposition and somatic growth for some time. This phenomenon is evidenced by the close spacing of septa in connection with the traumatic event as well as by the lower than average weight- and mantle length-at-chamber in the scar-affected specimens. The crowding of septa is usually ascribed to deceleration of shell growth (Keupp & Riedel 1995). The stunted growth in the period of recovery is supposedly due to either energetic investment for repairing damages of body tissues and shell or temporary impaired feeding capabilities (Boletzky 1974 showed that underfed cuttlefish deposit more narrowly spaced septa), or both.

ACKNOWLEDGEMENTS

We are grateful to Dr. Sigurd von Boletzky for making us aware of the experimental effects of shell implosion in cuttlefish and for the very useful discussion. The information provided by Prof. Helmut Keupp on anomalies in fossil cephalopod shells is also acknowledged. Finally, special thanks to Dr. Kerstin Warnke for her hospitality during the 2002 Coleoid Symposium in Berlin.

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Received: 13 January 2003 / Accepted: 16 June 2003

Plate 1

Scar-bearing cuttlebones of *Sepia orbignyana*.

1 Cuttlebone with supposed fish teeth-mark (mature female, *ML* = 9.3 cm, *CN* = 109)

2 Cuttlebone with supposed fish teeth-mark (maturing female, *ML* = 5.9 cm, *CN* = 82)

3 Cuttlebone with the last few chambers affected by a scar pattern similar to that brought about by experimental shell implosion (maturing female, *ML* = 6.9 cm, *CN* = 78)

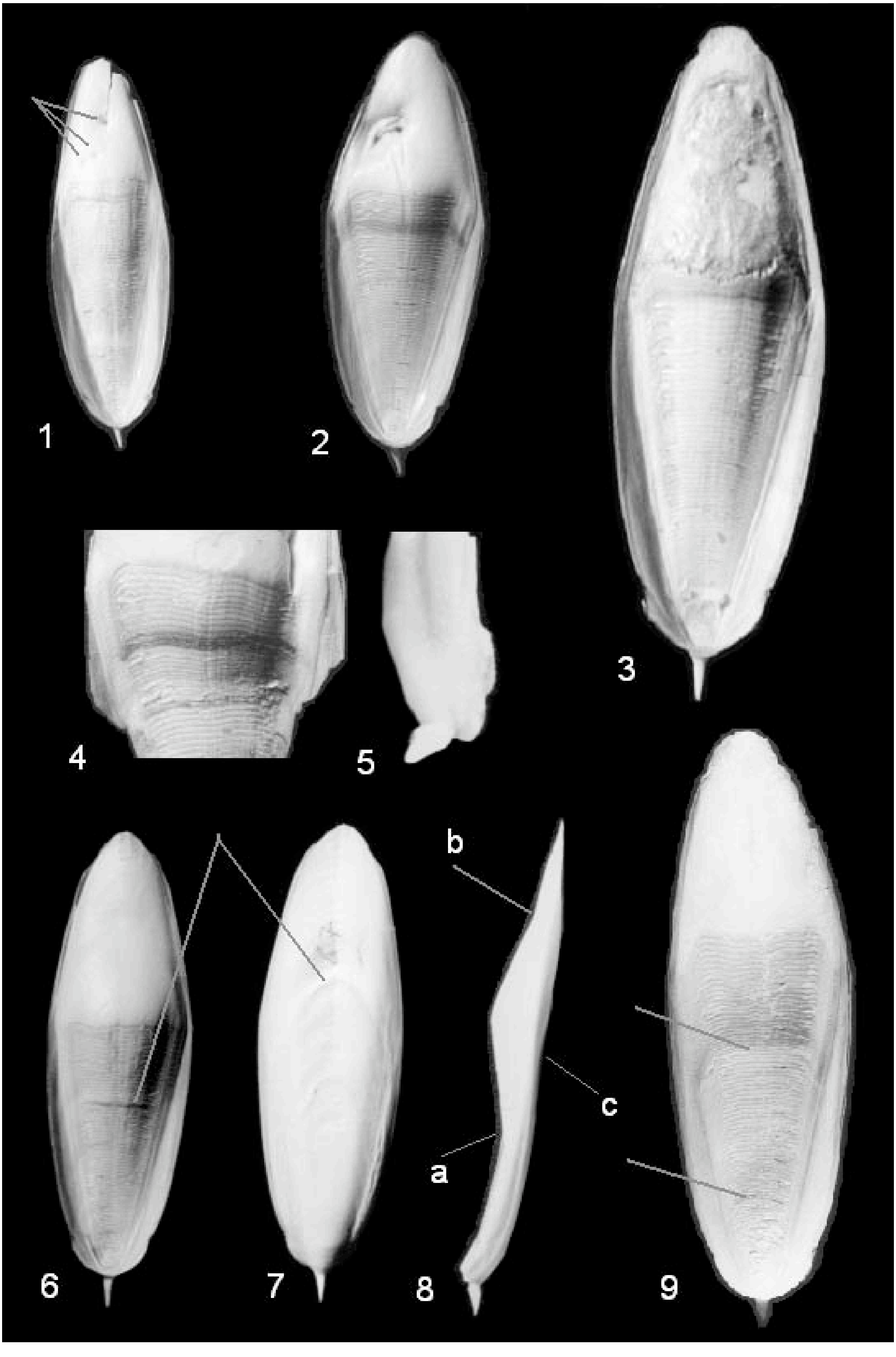
4 Siphuncular zone of the most abnormal cuttlebone, which shows the effects of at least two traumatic events, namely dark-coloured closely spaced septa, and asymmetry with respect to the sagittal plane (maturing female, *ML* = 5.3 cm, *CN* = 79)

5 Posterior spine of same specimen as in **4**. The spine is directed dorsally at an abnormal angle with respect to the longitudinal axis of the shell (compare with the normal spine in **8**) and shows signs of an earlier fracture

6-7 Ventral and dorsal views of scarred cuttlebone (maturing female, *ML* = 6.9 cm, *CN* = 86). The pointers indicate the same pathologic septa in ventral and dorsal views

8 Same specimen as **6-7**, in lateral view. The pointers indicate the effects of a traumatic event visible as altered curvature in the siphuncular zone (a), in the ventral surface of septa (b), and in the dorsal surface of the shell (c)

9 Double-scarred cuttlebone; the shell became slightly asymmetrical with respect to the sagittal plane after the second traumatic event (mature male, *ML* = 7.5 cm, *CN* = 111)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