Age determined from the daily deposition of concentric rings on common octopus (*Octopus vulgaris*) beaks

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The common octopus (*Octopus vulgaris* Cuvier, 1797) is an Atlantic and Mediterranean species (Guerra, 1992; Mangold, 1998). It is one of the most important target species of the Northwest African fisheries (Hernández and Bas, 1993; Foucher et al., 1998). The common octopus catch reported for this area in 1994 was 137,844 t, representing 47.17% of the total world octopus catch. In 1996 it was 156,300 t, representing 50.03% of the total world octopus catch (FAO, 1998).

Octopus age and growth have been determined by laboratory rearing studies (Itami et al., 1963; Nixon, 1969; Mangold and Boletzky, 1973; Smale and Buchan, 1981; Villanueva, 1995) and by field studies (Guerra, 1979; Hatanaka 1979; Pereiro and Bravo de Laguna, 1979). Growth rates can be calculated for animals maintained in the laboratory, but comparison with growth under natural conditions is questionable (Mangold, 1983). In field studies, growth and age can be correlated when there is clear evidence that a single year class from a stable population is under consideration, but where the spawning season is very long as in the common octopus (Mangold, 1983; Guerra, 1992), identifying year classes is difficult (Guerra, 1979, Hatanaka, 1979).

Cephalopod age has been determined by several methods: Guerra (1979), Pereiro and Bravo de Laguna (1979), and others have reported growth and age correlations by following a single year class from a stable population. Concentric rings on statoliths (Young, 1960), the internal shell, and eye lenses (Gonçalves, 1993) of *Octopus vulgaris* have been reported. Raya and Hernández-González (1998) observed marks on the internal rostral area of beaks from common octopus, possibly related to daily growth.

None of these methods has been validated for known-age *Octopus vulgaris*. Furthermore, all require fairly complex methods for preparing structures prior to observation under the microscope (polishing, embedding in resin, and sectioning with a diamond, etc.) which hinders their application to field studies. This paper provides an easy new method of determining *Octopus vulgaris* age based on the upper beak microstructure, validated for the paralarval period.

Material and methods

The study was carried out on 275 common octopus (164 males and 111 females) collected between January 1998 and May 1999, from catches of the small-scale fishery off the island of Gran Canaria (The Canary Islands, central-east Atlantic).

An additional sample of 27 *Octopus vulgaris* paralarvae was obtained from spawning females that deposited and incubated egg bunches in plastic burrows inside a 12,000-L tank. The embryonic development took between 25–30 days at a temperature range of 19–22°C. Once hatched, the paralarvae were transferred to transparent 12-L containers with open seawater flow, in July 1997 and June and July 1999, and reared in the laboratory at 19–22°C water temperature and natural photoperiod. The dates of hatching and death of each paralarva were recorded. The bottom was siphoned daily to remove dead individuals. During rearing, paralarvae were fed with recently hatched crab zoeae (see Hernández-García et al., 2000).

Ventral mantle length (VML) was measured in both benthic octopus and paralarvae to the nearest 0.1 mm. We used VML as the body measurement because we consider it to be more accurate than dorsal mantle length. Total body weight (TW) of benthic octopus was recorded to the nearest 0.01 g (to the nearest 0.0001 g in paralarvae). With the exception of the paralarvae, all the specimens were sexed.

The beak of each animal, including paralarvae, was removed and stored in 70% ethyl alcohol. Lower and upper beaks were sagittally sectioned with scissors to obtain two symmetrical half beaks (Fig. 1). The half beaks were cleaned with water and the mucus covering the inner part of the lateral walls was removed by rubbing it softly with the fingers (obviously, this operation was not necessary in the case of the paralarvae beaks).

By using a stereoscopic microscope, the concentric rings in the lateral wall of each beak were counted from the rostral tip area to the opposite end of the lateral wall. Because of the lack of pigmentation in paralarvae beaks, the concentric rings in their lateral wall were more easily counted with a microscope. Rings of each beak were

Manuscript accepted 10 April 2001.
Fish. Bull. 99:679–684 (2001).

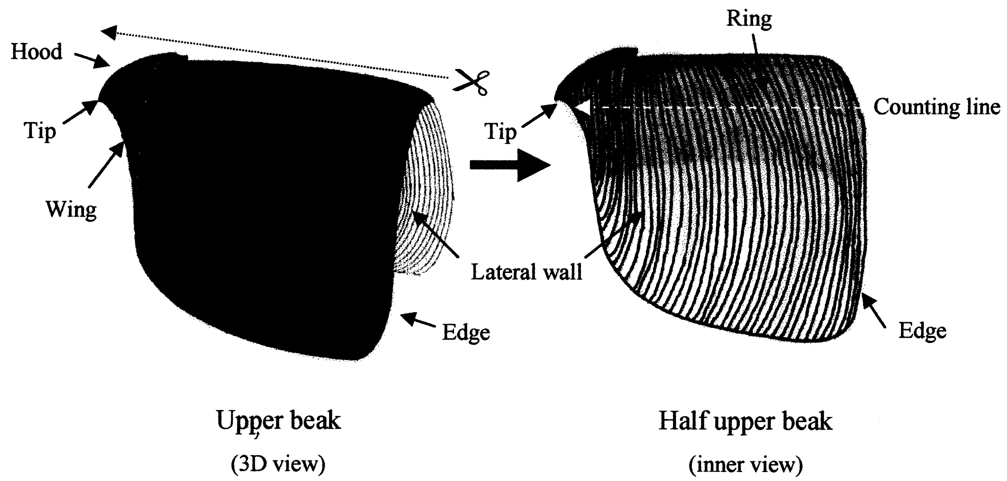

Figure 1

Diagram of upper beak of *Octopus vulgaris* and lateral wall showing growth bands, rostral tip area, the distal posterior beak end, and counting line.

counted at least three times by the same person, and those with less than two identical counts were rejected from analysis.

The number of rings in beaks of paralarvae was compared with the number of days each one lived.

Results

Octopus obtained from the small-scale fishery ranged in size from 4.8 to 165 mm VML, and weighed between 0.38 and 3926 g. Females ranged from 60 to 165 mm VML and weighed from 215 to 3926 g. Males ranged from 58 to 160 mm VML and from 200 to 3167 g in weight. We were unable to sex two individuals (4.8 mm VML, 0.38 g and 8.1 mm VML, 0.60 g). Paralarvae ranged from 1.0 to 2.7 mm VML and from 0.001 to 0.005 g in weight.

The internal lateral walls of upper beaks from 302 individuals (27 paralarvae and 275 individuals in benthic stages of *Octopus vulgaris*) revealed a pattern of concentric bands deposited from the rostral tip of the beak to the opposite margin of the lateral wall, parallel to the beak edges. Both halves of the upper beaks showed similar spatial and density patterns of microstructures. Lower beaks showed no regularity in the pattern of bands along the lateral walls and were discarded. On the upper beaks the distance from the rostral tip to the distal end of the lateral wall showed a positive correlation with the VML (Pearson's correlation: r=0.825; P<0.001) (Fig. 2).

Ring counts were more difficult near the rostral tip where rings were frequently discontinuous. Counts were easier to make near the edges of the lateral wall which was less highly pigmented.

Paralarvae survived in tanks from 3 to 26 days. For 48.1% of paralarvae, the concentric ring count in the lateral wall of the upper beak equaled the number of days that they lived. Otherwise, in 22.2% and 29.6% of paralarvae the number of rings counted were one more or one less, respectively, than the number of days of age. These data (Fig. 3) indicate that daily deposition of a growth increment in the lateral wall of the upper beak begins on day one after hatching. The weight-age and VML-age relationships of paralarvae (Fig. 4, A and B) were similar to those found by Villanueva (1995), with differences attributable to rearing conditions. Given the correlation between increment counts and age of paralarvae, we applied the upper beak ring count method for age determination of 272 common octopus, ranging from 4.8 to 165 mm VML. Results should be taken with caution for the benthic stages of octopus pending the validation of growth of adults and the frequency of rings deposition.

Increments counted on beaks from octopus collected in the wild ranged from 53 to 398 corresponding to individuals of 0.38 and 3926 g body weight, respectively (4.8 and 165 mm VML). Males and females had no difference in the number of rings counted in the lateral walls of upper beaks (ANOVA, F=0.0006, P=0.98). The age of males ranged between 3.2 and 12.3 months (95–369 rings), and females ranged between 3.1 and 13.3 months (93–398 rings), see Figure 5 (A and B) for weight-age and MVL-age relationships for benthic octopus.

Discussion

In *Octopus vulgaris* and other shallow-water cephalopods, regular patterns of activity and evidence of endogenous rhythms induced by the light–dark cycles have been reported in both field and laboratory animals (Cobb et al., 1995). These endogenous rhythms may be reflected in a

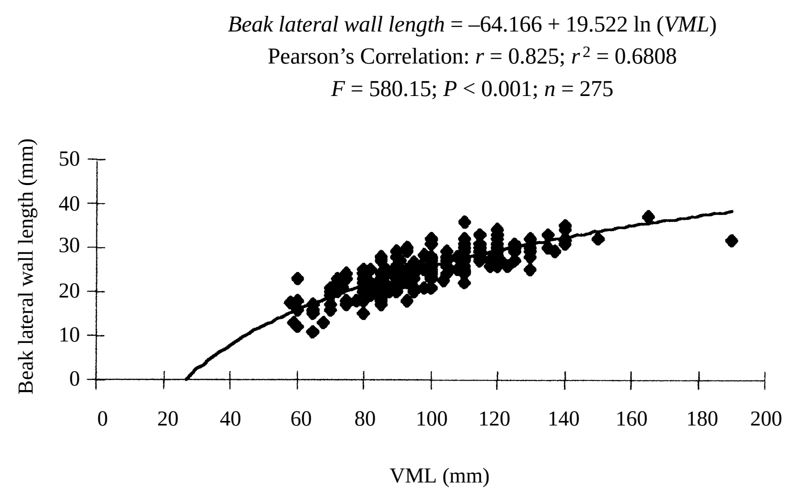

Figure 2

Relationship of beak lateral wall length to ventral mantle length (VML) of benthic *Octopus vulgaris*.

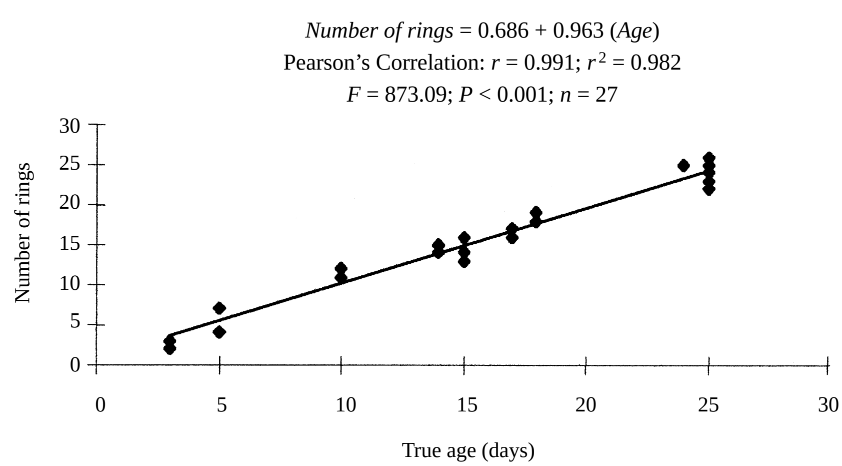

Figure 3

Lateral wall ring counts versus real age in 27 paralarvae from 3 to 26 days old.

chitinous structure such as the beaks (Raya and Hernández-González, 1998) or in calcium deposits in statoliths. Statoliths are the hard structures most commonly used for cephalopod age estimation (Lipinski, 1986, 1993; Arkhipkin, 1993), although the presence of concentric rings in the internal shell, beaks, and eye lenses have also been used (Clarke, 1965; Gonçalves, 1993; Raya and Hernández-González, 1998). When beaks are used, erosion of the rostral area during the life of the animal may bias age determination toward underestimation (some of the first rings may be eroded and therefore not counted). We found evidence of incomplete increments on the edge of the lateral wall, near the rostral tip area; therefore, ages we provide for benthic adults are to be considered minimum estimates.

If rings on the lateral walls of the upper beaks are laid down daily and can be accurately counted even in the oldest specimens (as indicated by the pattern in paralarvae), then our results are consistent with a lifespan of 12–13 months in the Canary Island waters. Raya and Hernández-González (1998) gave a lifespan of 10–12 months for octopus caught off the coast of northwest Africa (21–26°N)

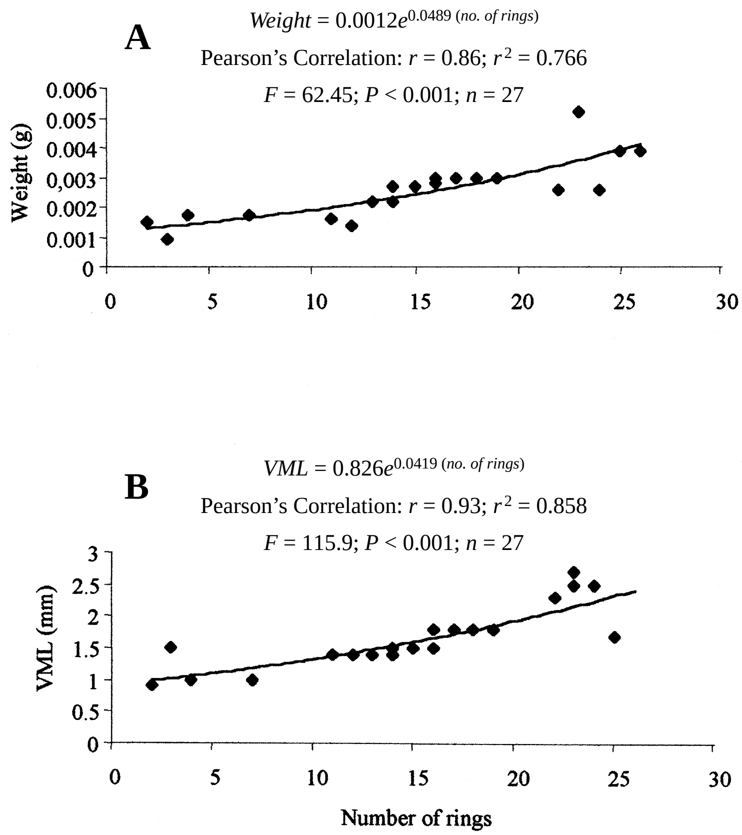

Figure 4

Plot of the number of rings counted on the lateral walls of the upper beak against (**A**) body weight and (**B**) ventral mantle length (VML) of paralarvae of *Octopus vulgaris*.

although they reported some heavier but younger specimens than we found. This difference could be due to discrepancies in the aging methods or, as in the case of Mangold (1983), areas off the coast may have different growth patterns and lifespans. Thus, Smale and Buchan (1981) proposed a lifespan of 9–12 months in females and 12–15 in males *Octopus vulgaris* from the South African coast.

Several authors have noted that size (and probably weight) may not reliably indicate age in field-caught cephalopods (Mangold and Boletzky, 1973; Hixon, 1980) because it may vary greatly depending upon factors such as food and temperature (Van Heukelem, 1979; Mangold, 1983). Cephalopods reveal great morphological variability with latitude attributed to environmental influences on development (Hernández-García and Castro, 1998), and probably on lifespan. The length and weight ranges of octopus caught off the Canary Islands are within the ranges reported for this species off East Africa, are the limits of range (upper and lower) off South Africa (Smale and Buchan, 1981) and in the western Mediterranean Sea (Mangold, 1983), although the range recorded in our study (Canary Islands) is closer to that reported for the Mediterranean Sea.

The smallest octopi that we examined from fishery catches were 4.8 and 8.1 mm VML (0.38 and 0.60 g TW, respectively), well outside the minimum commercial length (90–100 mm VML). Their estimated ages were 51 and 91 days old. In the English Channel, the planktonic phase for common octopus has been estimated at 3 months (Rees, 1950; Rees and Lumby, 1954); and average weight of 0.2 g at settling may be normal regardless of temperature (Mangold, 1983). *Octopus* typically spend the first 5–12 weeks of life as an active predator on plankton (Mangold, 1983); they change gradually from a planktonic to benthic life style (Boletzky, 1977) in some way dependent upon temperature (Mangold 1983). We did not observe marked differences in ring pattern spacing indicative of the transition between planktonic and benthic life styles. However, the distance between rings does change during the benthic phase of life—a feature that seems related to water temperature—the rings being larger than average during winter and smaller during summer.

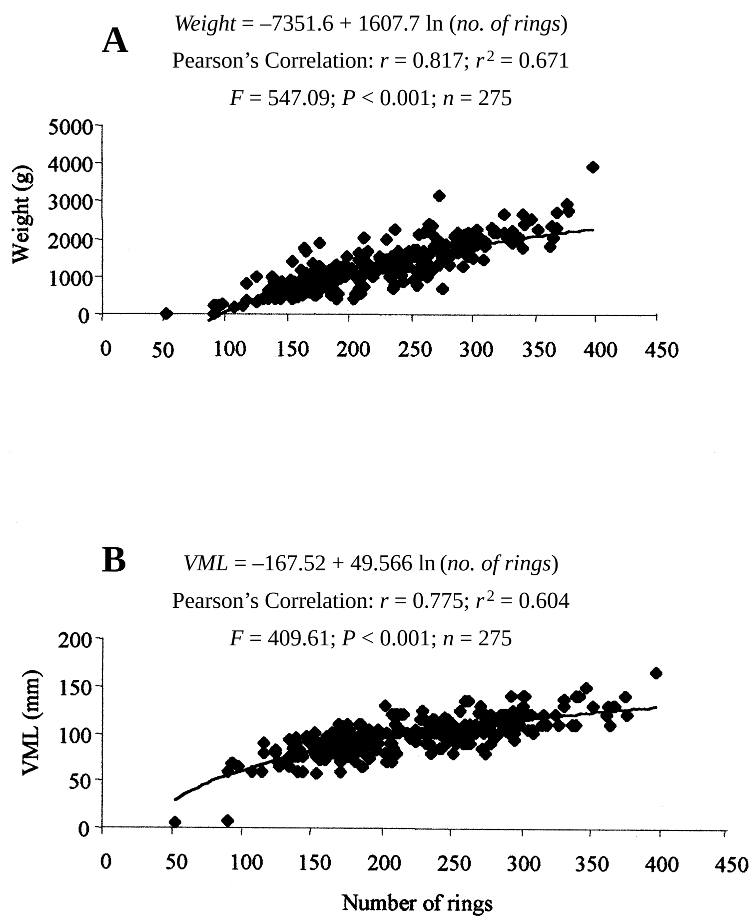

Figure 5

Plot of the number of rings counted on the lateral walls of the upper beak against (**A**) body weight and (**B**) ventral mantle length (VML) of benthic *Octopus vulgaris*.

Acknowledgments

We thank Ana Y. Martín-Gutiérrez for her assistance in data collection. This study was funded by the Secretariat for Fishing of the Autonomous Government of the Canary Islands (Spain).

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