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SIZE AND AGE AT FIRST SEXUAL MATURITY OF THE EDIBLE GIANT SNAIL *ADELOMELON BECKII* (NEOGASTROPODA: VOLUTIDAE) FROM MAR DEL PLATA, ARGENTINA

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INTRODUCTION

The giant volutid *Adelomelon beckii* (Broderip, 1836) inhabits coastal areas of the western South Atlantic and is distributed from Espíritu Santo, Brazil, to Tierra del Fuego, Argentina, on sandy bottoms between 40 and 70 m (Weaver & Dupont, 1970). This species is one of the top benthic predators found within the studied area (Arrighetti, 2009) and has low population densities (Carranza et al., 2008). The Argentinean populations used to be harvested as part of the bycatch by fishing trawlers, but recently this species has been used for consumption and its large, attractive shell (up to 40 cm SL) sold as an ornament. Despite its impressive size and its increasing significance as a fishery resource, surprisingly little is known about the biology of *A. beckii* and its role in the ecosystem, except for some aspects of reproduction (Giménez et al., 2009; Arrighetti, 2009; Arrighetti & Giménez, 2010). Sexes are separate, with males having copulatory organs and the females laying egg capsules; each capsule contains 7–9 embryos and is attached to an empty bivalve shell (Penchaszadeh et al., 1999). *Adelomelon beckii* off Mar del Plata reproduces in spring and autumn (Arrighetti & Penchaszadeh, 2010) and is one of the species of gastropods with highest longevity thus far studied, reaching 29 years old (Arrighetti, 2009).

The objective of this study is to describe size and age at first sexual maturity of *Adelomelon beckii* in the fishing area off Mar del Plata using gonadal maturation studied by histology. These results will then be used to determine minimum catching size in order to establish a future management of this resource.

MATERIAL AND METHODS

Samples were collected monthly during two consecutive reproductive periods: from September 2004 to April 2005 (season 2004) and from August 2005 to April 2006 (season 2005) (Arrighetti & Penchaszadeh, 2010), so all mature specimens had mature gametes. The study was carried out by bottom trawling in the Mar del Plata area (38°20'S, 57°37'W) at a depth of 40–70 m. A total of 8–20 snails per month, ranging from 16 to 39 cm total shell length (SL) were studied. In the laboratory, each snail shell length was measured with a vernier caliper to the nearest 0.1 cm, and shell free wet mass (SFWM) was weighed to the nearest 1 g. Sex was identified by the presence or absence of a penis. The testis and the ovary in *Adelomelon beckii* cannot be clearly separated from the digestive gland, so no gonadosomatic index could be calculated. Sexual maturity was established using histological criteria. For both sexes, after removal from the shell, a small piece of the gonad and seminal vesicle was removed and fixed in Bouin's solution for 3 h at room temperature and subsequently transferred to 70% alcohol for storage. Tissues were dehydrated using an ascending series of ethanol dilutions and then embedded in resin (Leica Historesin). Sections were cut at 5 µm thickness with an electronic microtome (Leica), stained with hematoxylin-eosin, and observed under a light microscope (Zeiss Axioimage Z. 1). Females were considered mature when oocytes undergoing vitellogenesis were present and males when spermatozoa were present in the spermatic tubules and in the seminal vesicle.

Statistical difference between SL distributions between the two reproductive seasons was

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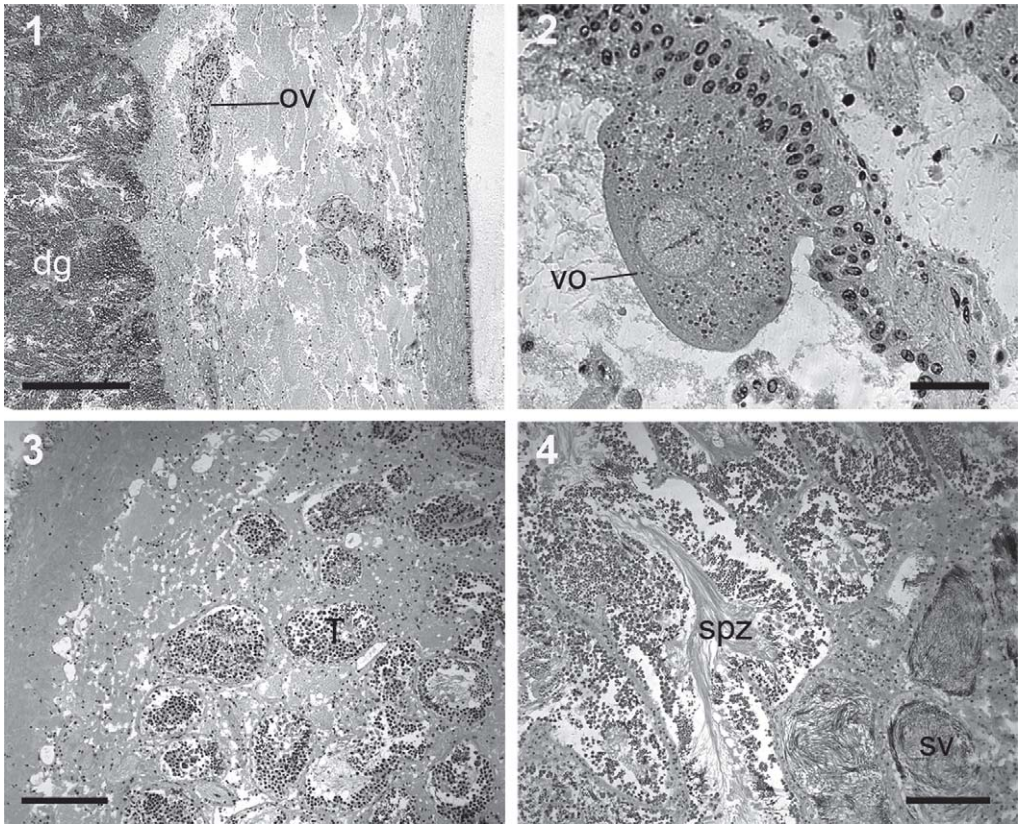
TABLE 1. *Adelomelon beckii* shell length (SL in cm) comparison between sexes in Mar del Plata populations, effects are significant at $p < 0.05$.

Variable	SL Mean 2004	SL Mean 2005	*t*-Value	df	*p*
SL_{males}	27.50	27.47	0.03	103	0.978
$SL_{females}$	31.12	30.96	0.12	125	0.904

established. For both sexes, the percentages of mature individuals were plotted against SL and SFWM. In order to estimate the size at 50% first sexual maturity, logistic regressions using nonlinear regression by least square (Statsoft, version 6.0) of SL-maturity and SFWM-maturity were used. The size and weight at which 50% of the studied population exhibit mature gonads were used as an indicator of the length at which 50% of the population became mature. Differences in SL and SFWM at maturation between sexes were tested by an analysis of covariance (ANCOVA).



FIGS. 1–4. *Adelomelon beckii*. Histological sections showing immature and mature gonads. FIG. 1: Immature gonad from a 23 cm shell length female. Digestive gland (dg), ovary (ov); FIG. 2: Mature gonad from a 29 cm shell length female, note the presence of a vitellogenic oocyte (vo); FIG. 3: Immature gonad from a 19.5 cm shell length male. Testis (T); FIG. 4: Mature gonad from a 33 cm shell length male, note the presence of spermatozoa (spz) and the seminal vesicle (sv) full of spermatozoa. Scale bars: FIG. 1 = 25 µm; FIG. 2 = 50 µm; FIG. 3 = 200 µm; FIG. 4 = 100 µm.

Considering that sexual maturation in snails produces a change in the relationship between SL and SFWM (deMaintenon, 2001), these variables were plotted. The intersection point for the pair of straight lines that best fit the data was considered the SL at which 50% of the population became mature (Somerton, 1980).

The age of first sexual maturity was calculated from the specialised von Bertalanffy growth model as described by Arrighetti (2009): $SL = 405.43 * (1 - e^{-0.098 * (t - 0.733)})$

RESULTS

No significant differences were found in SL distribution between the two reproductive seasons (2004–2005), so all data were pooled together (Table 1).

The histological analysis showed that females of *Adelomelon beckii* begin sexual maturation at 24.2 cm SL, vitellogenic oocytes in specimens less than this size were not observed (Fig. 1). SL versus maturity showed that 50%

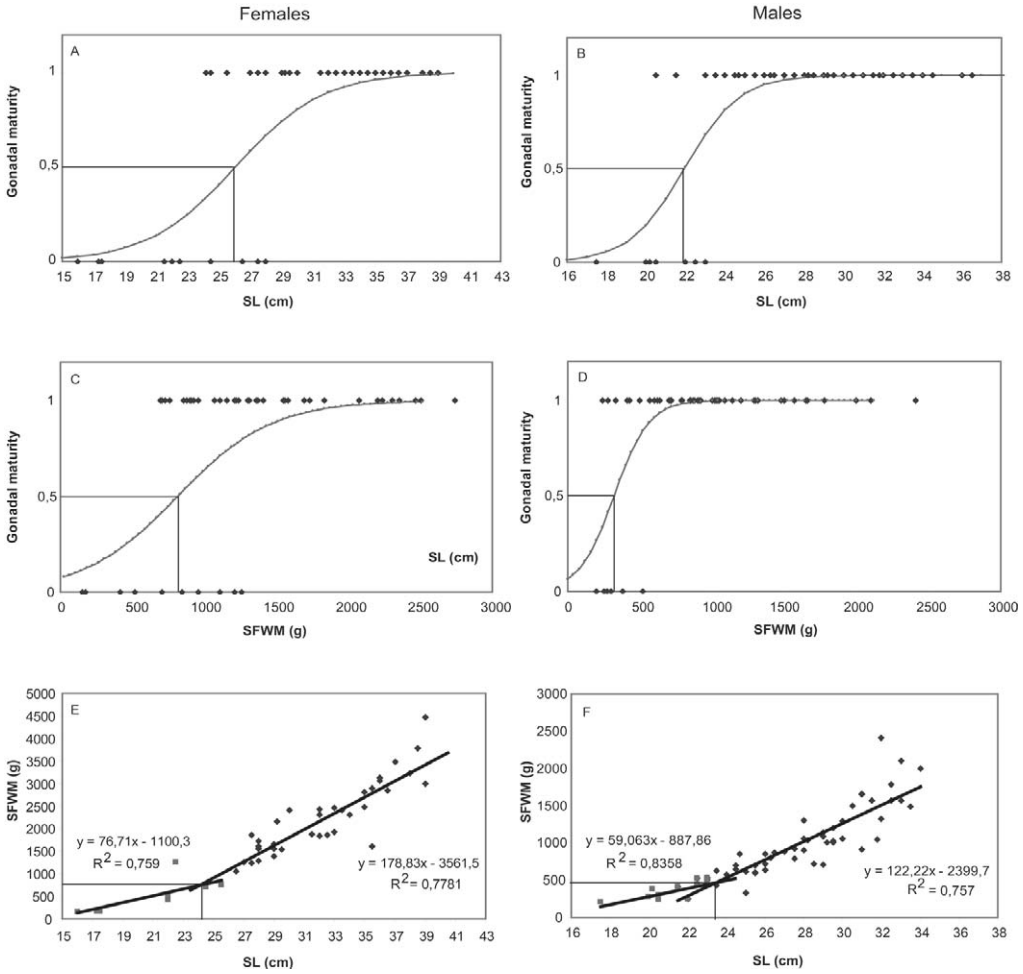


FIG. 5. *Adelomelon beckii*. Logistic regression of gonadal maturity according to histological criteria plotted against shell length (SL) for (A) females; (B) males and against shell free wet mass (SFWM) for (C) females; (D) males. 0, immature; 1, mature. SL plotted against SFWM for (E) females, (F) males, intersection between two regressions showed SL at which 50% of population became mature.

of females are mature at 25.6 cm SL (Fig. 5A). At sizes > 28 cm SL, all females were sexually mature (Fig. 2). Males did not show signs of maturation until 20.5 cm SL (Fig. 3), and below this size no spermatozoa were found in the spermatic tubules. The size at which 50% of the male population showed a mature gonad was 21.9 cm SL (Fig. 5 B). All males contained mature spermatozoa at 23 cm SL (Fig. 4). Logistic regression of SL versus maturity of gonad (according to histological criteria) follows these formulae:

$$\text{Gonadal maturity}_{female} = 1/(1+\exp^{(12.16-0.46*SL)})$$

$$\text{Gonadal maturity}_{male} = 1/(1+\exp^{(15.87-0.72*SL)})$$

ANCOVA of female and male size at maturation was significant $P < 0.05$.

When we analysed gonadal maturity against SFWM, the maturation process began at 690 g SFWM and 240 g SFWM for females (Fig. 5C) and males (Fig. 5D) respectively. Size at which 50% of population reaches first sexual maturity was 806.6 g SFWM for females and 321 g SFWM for males. All females were mature at > 1250 g SFWM and males at > 520 g SFWM. The following formulae were used:

$$\text{Gonadal maturity}_{female} = 1/(1+\exp^{(2.48-3.08*SL)})$$

$$\text{Gonadal maturity}_{male} = 1/(1+\exp^{(2.67-8.32*SL)})$$

ANCOVA of female and male SFWM at maturation was significant $P < 0.05$.

The relationship SFWM-SL showed an intersection point at 24 cm SL for females (Fig. 5D) and 23.5 cm SL for males (Fig. 5E).

Using the specialised von Bertalanffy growth model, females reach first sexual maturity at approximately 14 years, whereas males achieve this at 11 years.

DISCUSION

According to the histological criteria, females of *Adelomelon beckii*, in the sampled population, reached first sexual maturity at 25.6 cm SL, while males matured at 21.9 cm SL. Very similar results have been reported in populations of other neogastropod species, with female maturation taking place at a larger size than in males (*Buccinum cyaneum* – Miloslavich & Dufresne, 1994; *Zidona dufresnei* – Giménez & Penchaszadeh, 2003; *Adelomelon brasiliana* – Cledón et al., 2008). The later maturity of females is probably connected with their greater (compared to males) energy and materials investment during reproduction (production of egg capsules and intracapsular fluid containing proteins, carbohydrates and free amino acids (de Mahieu et al., 1974; Penchaszadeh et al., 1999). For example, in *Buccinum undatum* females invest 6 to 16 times more in reproduction than males (Brokordt et al., 2003).

When we analysed SFWM against gonadal maturity we found that 50% of the population is mature at 806.6 g SFWM for females and 321 g SFWM for males, which corresponds to 24.3 cm SL and 23 cm SL for females and males respectively. These results are similar to those found in the SL against gonadal maturity in logistic regression. The change in weight during sexual maturation is reflected in the inflexion point found in the relation of SL and SFWM, 24 cm SL for females and 23.5 cm SL for males. Our results for *A. beckii* are only applicable to the Mar del Plata population, because other studies demonstrate that size at first maturity can differ among populations from different locations (Martel et al., 1986; Kideys et al., 1993).

The age of sexual maturity is around 14 years for females and 11 years for males. This seems to be rather late if we compared other large commercial gastropods, for example, *Haliotis rubra*, six to seven years (Prince et al., 1988); *Buccinum undatum*, six to seven years (Gendron, 1992); *Zidona dufresnei*, eight years (Giménez & Penchaszadeh, 2003; Giménez et al., 2004); *Adelomelon brasiliana*, seven years (Cledón et al., 2008). Potential lifespan of *A. beckii* in Mar del Plata region is 29 years (Arrighetti, 2009), being one of the most long-lived gastropods studied to date.

Adelomelon beckii exhibits a slow growth rate (Arrighetti, 2009). This together with the lack of a planktonic opportunity for dispersal, renders this species very vulnerable to exploitation. Since the Argentinean population is currently fished, it is necessary to apply certain controls to ensure the sustainability of the stock. Considering all the analysed parameters we can conclude that 50% of female population is mature between 24 and 25.6 cm SL and 50% of male population is mature between 21.9 and 23.5 cm SL. We propose a minimum catching size of 28 cm SL for both sexes, allowing each female to spawn over at least two reproductive seasons (Arrighetti & Penchaszadeh, 2010).

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