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High energetic cost of oviposition in an edible marine gastropod

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ABSTRACT

The edible neogastropod *Buccinanops cochlidium* from Patagonia, Argentina, reproduces by means of egg capsules attached by the female to its own shell. Gravid females lay an outstanding mean of 500,000 eggs that nurse around 800 embryos, which hatch as crawling juveniles (4 mm in shell length) after four months of intracapsular development. This reproductive investment could be expressed as the energy content (EC) estimated for the production of a complete egg mass (33.94 ± 12.85 KJ), representing a conservative estimation of the total EC needed for an adult female to spawn, which is in average ~12% of the total EC in gravid females. This high maternal investment allows a considerable offspring size, which confers them high survival chances. A translocation of energy stored in the foot during the oviposition season is shown in a relative decrease of ~10% in the foot EC in respect of the total EC (61.8% in non-gravid females vs. 51.3% in gravid females). Gravid females showed significantly higher body wet mass/shell length index and higher total EC than non-gravid females (266.0 ± 66.4 KJ vs. 184.3 ± 69.6 KJ), suggesting that a body condition threshold is required for females to reproduce. These values represent an energetic surplus of over 40% of the total EC per individual when compared to non-gravid females. Protecting gravid females from fisheries would ensure the sustainability of the resource and must be taken into account when establishing fisheries policies.

1. Introduction

Marine gastropod reproductive modalities vary from the production of many small eggs evacuated to the water column with a reduced success rate to the spawn of a reduced number of larger eggs/embryos that receive protection during their development to potentiate their chances of success (Pianka, 1970). Those species that present encapsulated embryonic development invest great amounts of energy in reproduction. This investment is mainly represented by eggs (including nurse eggs), intracapsular liquid (including nutritive substances), egg capsule production and oviposition (Perron, 1981; Kideys et al., 1993; Miloslavich, 1996) and, in some cases, maternal care of the egg capsules (Penchaszadeh, 1971; Brown, 1982; Chaparro et al., 1999; Averbuj and Penchaszadeh, 2010). Male contribution, including sperm formation and copulation, appears irrelevant in terms of energetic comparisons in most animal groups, in particular in marine gastropods (Riechert, 1988). The energetic cost of reproduction in the marine gastropod *Buccinum undatum*, studied by means of a calorimetric analysis of the gonad (Kideys et al., 1993), showed a seasonal variability in its

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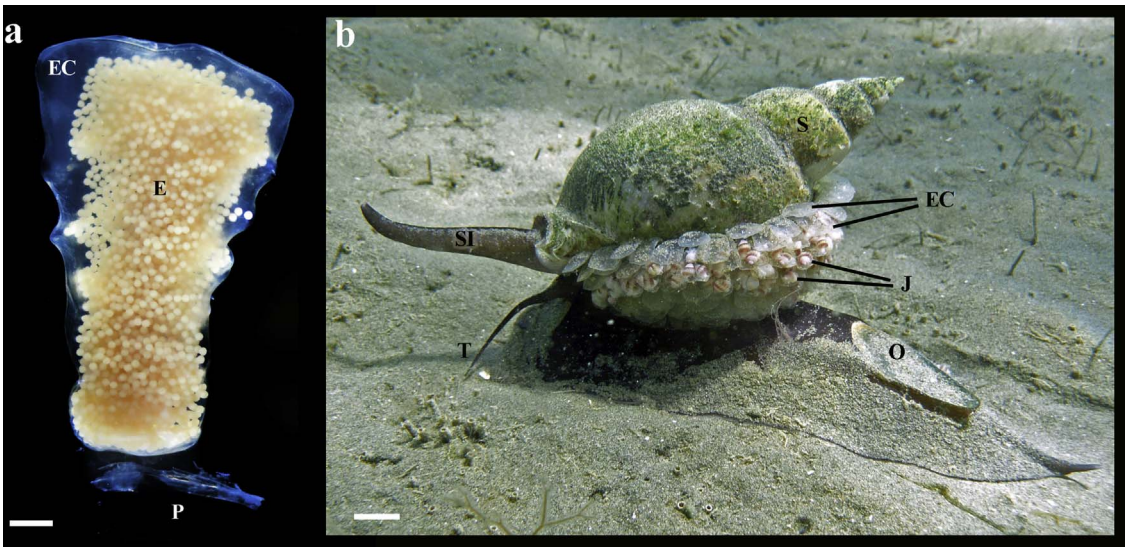

Fig. 1. *Buccinanops cochlidium* spawn. a-Egg capsule of *B. cochlidium* in early developmental stage. Note the abundance of eggs inside, b-Female of *B. cochlidium* carrying egg capsules in late developmental stage. Abbreviations: E: eggs, EC: egg capsule, F: foot, J: hatching juveniles, O: operculum, P: peduncle, S: shell, SI: siphon, T: tentacle. Scale Bars: (a) 1 mm, (b) 1 cm.

reproductive behaviour accompanied by a variation in the energy content, with differences between males and females. The energetic budget needed by the female to afford reproduction includes not only egg production, but also oviposition. Perron (1981) determined that egg capsule and ova production costs in marine gastropods of the genus *Conus* were approximately partitioned into 50–50%, although not considering capsule modelling and care. Meanwhile, Chaparro et al. (1999) determined that 90% of the reproductive cost in *Crepidula dilatata* corresponded to egg production, probably because modelling and care of the very thin capsule was reduced due to incubation. Marine gastropod females may invest a large amount of energy in egg capsule formation, which is explained by their protective role conferred to the offspring, resulting in higher survival rates (Perron, 1981).

Buccinanops cochlidium (Dillwyn, 1817) is a common gastropod that inhabits marine sandy bottoms from Argentine Patagonia (Averbuj and Penchaszadeh, 2010). It is the species of the genus *Buccinanops* that shows the largest spawn in terms of number of egg capsules, eggs and hatchlings per female (Penchaszadeh, 1973; Averbuj and Penchaszadeh, 2016), with an outstanding mean of 500,000 eggs per female, from which around 800 are embryos and the rest nurse eggs (Fig. 1). The hatchlings emerge as fully developed crawling juveniles after 4 months of maternal care (Averbuj and Penchaszadeh, 2010).

In northern Atlantic Patagonia, *B. cochlidium* shows reproductive seasonality: mating occurs from March to October, followed by oviposition, that begins in July and peaks in October (few females spawn until December); then, intracapsular development takes place and, finally, hatchlings emerge in February (Averbuj et al., 2010; Averbuj and Penchaszadeh, 2010).

In Argentina, artisanal fisheries of *B. cochlidium* are being developed in northern Patagonic gulfs and although no massive captures are reported, the product is commercialized into the local and Asian markets (Bigatti et al., 2015); however, no official capture records are available. Although the regulation of this resource is absent until present, it appears as a potential complement to artisanal bivalve fisheries in the region (FAO, 2002; Bigatti and Ciocco, 2008; Bigatti et al., 2015). In this respect, previous studies raised an alert about its fragility and risk of stock depletion if a massive fishery is established. This alert was related to *B. cochlidium* low embryonic dispersion, long reproductive periods with high extraembryonic nutrition (nurse eggs) investment and a feeding dependence of juveniles from adults in early life stages, that affects growth at initial sizes (Averbuj et al., 2010; Averbuj and Penchaszadeh, 2010; Averbuj et al., 2012; Averbuj and Penchaszadeh, 2016).

A complete understanding of the reproductive process is essential to the management of marine invertebrate fisheries (Barber and Blake, 2006). Studies on the reproductive biology of marine gastropods usually focus on reproductive modalities or seasonality patterns (Underwood, 1974; Giese and Pearse, 1977; McKillup and Butler, 1979). However, there are still no available studies on the energy content and cost of oviposition of any gastropod species from the Argentine Sea. The aim of this study is to estimate the energetic cost of reproduction in the edible gastropod *B. cochlidium* from San José Gulf, Argentina. This information will be useful to understand the utilization of energetic resources during reproduction that may influence fisheries management decisions.

2. Materials and methods

2.1. Sampling

Thirty two individuals [11 males, 10 non-gravid females and 11 gravid females (carrying egg capsules attached to their shells)] were collected by scuba diving on sandy bottoms at 5–15 m depth in Playa Villarino, San José Gulf (42°25′S, 64°31′W), Patagonia, Argentina, in October 2010. Samples were collected within a week period to avoid temporal variations. Gastropods were taken alive