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Short Communication

Pearls in the ribbed mussel *Aulacomya atra* caused by polydorin polychaetes (Spionidae) infestation

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ABSTRACT

Aulacomya atra populations of the San Jose gulf, Northern Patagonia, Southwestern Atlantic Ocean, are infested by two polydorin species, *Polydora rickettsi* and *Dipolydora* cf. *giardi*. The infestation by these boring polychaetes causes the formation of pearls which is evidenced by the presence of capsules containing polydorin tissue debris and the elemental composition of organic material inside the pearls. Moreover, a positive relationship between the abundance of perforations of polydorin polychaetes and abundance of pearls was found by applying generalized lineal model analysis. These results constitute the first evidence of pearls formation due to infestation by polychaete.

1. Introduction

The infestation by polydorin polychaetes is a serious concern for mollusc fisheries and aquaculture (e.g., Simon et al., 2006). The infestation may cause serious damage such as retarded body growth, gonad reduction, shell damage and the death of the mollusc (e.g., Bergman et al., 1982; Sato-Okoshi et al., 2008). Up to date, the most severe damage reported by polydorin is the mud blister or tumor-like formations affecting the quality of product for the shellfishery (e.g. Cremonte, 2011; Diez et al., 2013; Silina, 2006).

In Northern Argentine Patagonia, two polydorin species were reported: *Polydora rickettsi* Woodwick, 1961, boring all the exploited molluscs except the mussel *Mytilus edulis,* and *Dipolydora* cf. *giardi* (Mesnil, 1896) affecting only the ribbed mussel *Aulacomya atra* (Diez et al., 2011, 2016). In this region, *A. atra* is exploited by artisanal fishermen (Orensanz et al., 2006), who reported their concern about the presence of pearls, making this resource not suitable for the commercial market. Therefore, the aim of the present study was to establish the cause of the pearl formation in *A. atra* populations. We also investigate several variables (sampling site, shell length, condition index and abundance of polydorin perforations) affect the abundance of pearls using generalized linear model analysis.

2. Materials and methods

Ribbed mussels of commercial size were collected in Punta Gales (42°25′S 64°20′W) (n = 80) and in Fracasso beach (42°25′S 64°07′W) (n = 100), San José gulf, Argentine, during October 2013 and March 2014. The specimens were collected by scuba diving at about 15 m depth and transported to the laboratory. The maximum shell length of each specimen was measured. Soft parts were removed and weighed separately to the shells to calculate the condition index [(soft part weight/shell weight) ∗ 100] (Lucas and Benninger, 1985) and then were fixed in 10% formalin and transferred to 70% ethanol. Digital images of the inner shell surface (n = 49 from Punta Gales and n = 84 from Fracasso beach) were taken under stereoscopic microscope and processed using Image J software, determining the number of pearls and polydorin perforations. Shells from a subsample (n = 62 from Punta Gales, n = 90 from Fracasso beach) were used to calculate the prevalence (percentage of infested shells). Shells were broken into small fragments; polydorins were removed and identified under light microscope and the intensity of infestation (number of polydorins per shell) was determined. The microstructure of the pearls was studied through 0.3 mm sections under a light microscopy (Leica DM 2500) and by a scanning electron microscope (Philips XL 30) (SEM). An Energy Dispersive X-ray Analysis (EDAX) was used to describe elementary composition of the different stages of pearl formation. Fixed mantle tissue containing pearls was decalcified with acetic acid. Histological sections of decalcified tissues were

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Table 1
Prevalence (P) and intensity (I) (mean followed by range in parenthesis) of polychaeta polydorins, and pearls in the ribbed mussel, *Aulacomya atra*, from Northern Patagonian coast, Southern Atlantic Ocean. The number of ribbed mussels examined to determine each value is indicated in parentheses. The category "pearls" includes only those attached to the inner shell surface.

Sampling site	Shell length Mean (range)	*Polydora rickettsi* (n = 62; 90)		*Dipolydora* cf. *giardi* (n = 62; 90)		Pearl (n = 49; 84)	
		P (%)	I	P (%)	I	P (%)	I
Punta Gales (n = 80)	95 (62–132)	32	9 (1–22)	89	25 (1–117)	8	2 (1–40)
Fracasso Beach (n = 100)	84 (54–124)	30	7 (1–16)	75	15 (1–46)	24	3 (1–40)

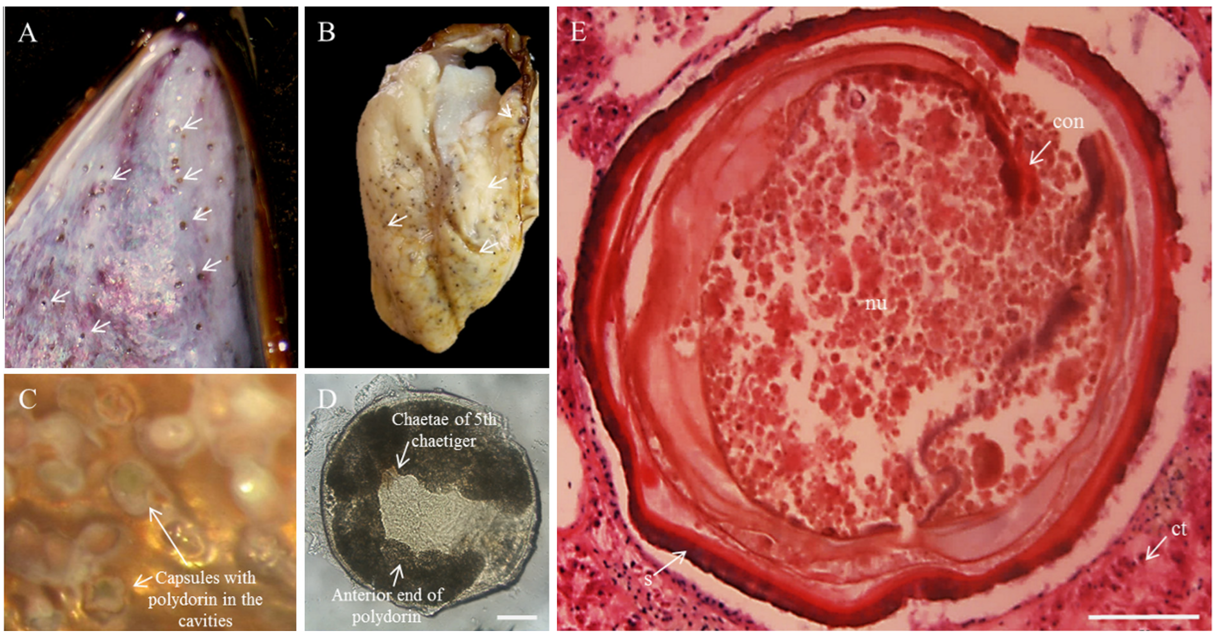

Fig. 1. Capsules and pearls caused by borer polychaetes in the ribbed mussel, *Aulacomya atra*. (A) Pearls (arrows) attached to the inner shell and (B) embedded in the mantle tissue (C) Detail of capsules in the cavities and (D) detail of a capsule with polydorin tissue debris with associated chaetae. (E) Transverse histological section of the pearl embedded in the mantle tissue, nu: nucleus of pearl, s: epithelium pearl sac, con: conchiolin basis of pearl, ct: connective tissue. Scale bars: A, 0.5 cm; B, 1 cm; C, 150 µm; D and E, 50 µm.

stained with hematoxylin-eosin and examined under a light microscope.

Abundance of pearls was evaluated by a Generalized Linear Model (GLM) with quasi-Poisson distribution and a log link function (Agresti, 2007). A set of models was used to test this variable with regard to the following predictor variables: sampling site, shell length, condition index and abundance of polydorin perforations. The Akaike information criterion (AIC) was used to determine the best model for the analyzed dataset. Model selection was performed with an Information Theoretic (IT) approach using the AIC and model averaging (Grueber et al., 2011). The AIC values and the AIC for small samples (AICc) (Hurvich and Tsai, 1989) were calculated for each model. Because of the over-dispersed data, we calculated an AIC modified by the principle of quasi-likelihood, or QAIC, and a version of QAIC for small sample sizes QAICc (Burnham and Anderson, 2002). From the AICc differences (Di), where Di = AICCi − AICCmin, Akaike weights (wi) (Akaike, 1978) were obtained for all candidate models. Akaike weights (wi) were obtained for all candidate models, which were ranked by their wi values for each dataset. The model with the highest wi was considered the one with the best supporting data. The top model set was averaged using a zero method (Symonds and Moussalli, 2011). The predictor variables in the top models were reported with their relative importance weights, model-averaged parameter estimates, unconditional standard error and 95% confidence intervals. Results were expressed in terms of odds ratios, calculated as the exponential of the coefficient of each parameter corresponding to the averaging model. All statistical analyses were performed in R (R Development Core Team, 2011).

3. Results

Two species of polydorins were identified under light microscope in *Aulacomya atra*: *Polydora rickettsi* and *Dipolydora* cf. *giardi*. The polydorin perforations have the typical 8-shaped: two holes very close to each other; from one of them the palps projecting out of one of the tubes, and in the other the posterior end of polydorin is found (see Fig. 2). Broking the shell, it was possible to observe the borrows with the worm inside. Data of prevalence and intensity of infestation by these two species and pearls from the two sampling sites are presented in Table 1.

The cavities, capsules and pearls were identified in the shell and in the mantle tissue (Fig. 1). The pearls were observed covering the entire inner shell surface and less frequently embedded in the mantle tissue (Fig. 1A and B). Two stages of the pearl formation were identified. In an initial stage, capsules containing polydorin debris with chaetae in their interior located in shallow cup-like cavities were observed in the inner shell surface (Fig. 1C and D). In an advanced stage, the pearl is already formed, which is variable in size (40 mm) and mostly black in color, although often white or purple. The smallest pearls, elliptical and light gloss, were found