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Seasonal changes in physiological responses and evaluation of "well-being" in the Venus clam *Chamelea gallina* from the Northern Adriatic Sea

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Abstract

Chamelea gallina is an infaunal bivalve, widespread in sandy bottoms along Mediterranean coasts. It is an important economic resource for fisheries in the Adriatic, although in recent years over-fishing, and other concurrent factors, have dramatically decreased clam harvesting. In this context, it is of great interest to gain information on seasonal variations in the physiological performance of clams, for an overall evaluation of their well-being. In this study, laboratory experiments were performed to define allometric relationships and effects of temperature on clearance and respiration rates of *C. gallina*. The mean values of *b* coefficients were calculated and used to correlate physiological measurements to 'standard' body mass, when seasonally collected clams were analysed. The highest clearance rate (0.42 L h^{-1}) was measured in clams collected in July 2000; the highest respiration rate (12.22 μmol O_2 h^{-1}) was observed in July 2001, leading to a negative scope for growth (−2.8 J h^{-1}). The influence of environmental and endogenous factors, mostly reproduction, was discussed. Survival in air and condition indices, showing higher stress conditions in December 2000 and July 2001, were in good agreement with the other physiological measurements. The physiological responses examined in this study appear to be suitable for providing detailed indications on the well-being of *C. gallina* and may be useful for future studies aimed at eco-sustainable management of the resource.

Keywords: Adriatic Sea; Bivalves; *Chamelea gallina*; Clearance rate; Condition index; Respiration rate; Scope for growth; Survival in air

1. Introduction

The infaunal venerid bivalve *Chamelea gallina* is a filter-feeder, widespread on well-sorted fine sand in shallow waters, at depths between 1 and 10 m. This clam species is distributed throughout the Mediterranean and the Black Sea. It is also present in a few localities of the Atlantic, mostly along the Portuguese coast of Algarve (Backeljiau et al., 1994). The optimal habitat for *C. gallina* shows limited variations in environmental parameters such as temperature and salinity, and sediments having peculiar conditions in grain size, mostly littoral sands with scarce biogenic remains and over 95% in weight of particles from 2.000 to 0.063 mm diameter, good oxygenation and redox potential greater than 300 mV (Stella and Rodinò, 1986; Brooks et al., 1991). *C. gallina* has considerable economic importance, being commercially exploited in the Mediterranean, particularly in the inshore waters of Italy, Spain, Turkey and Morocco (Ramón and Richardson, 1992). In the western Adriatic Sea, landing of *C. gallina* increased greatly during the 1980s, due to the introduction of hydraulic dredges and to uncontrolled fishing: it was estimated that up to 100,000 tons of clams per year were harvested (Froglia, 1989). However, during the last few years a clear-cut decrease in clam population density has been observed, associated with a reduction in the number of clams over 25 mm long, the minimum legal marketable size, although the maximum length recorded for this species is about 50 mm (Froglia, 1989). The decline in clam biomass was also enhanced by the occurrence of several irregular mortality events, and failure in recruitment (Del Piero and Fornaroli, 1998; Del Piero et al., 1998; Froglia, 2000).

The main objective of the present work was to study some physiological responses of the Venus clam *C. gallina* from the north-western Adriatic and consequently to evaluate clam well-

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being in this area. In this regard, knowledge is limited to information about cellular biomarkers such as immunological and cytochemical responses (Ballarin et al., 2003; Viarengo et al., 1998), growth rates and biological behaviour (Keller et al., 2002). Therefore, physiological responses such as scope for growth (SFG), survival in air and two condition indices (volumetric and gravimetric) were evaluated seasonally in order to highlight variations, mostly related to the reproductive cycle and changes in environmental conditions. A series of laboratory experiments was also performed, to determine the allometric relationship between the physiological parameters measured for SFG calculation (i.e., clearance and respiration rates) and clam body size. All the above physiological responses are considered as general stress indices which represent a non-specific response to the sum of various stimuli, including natural and/or anthropogenic stressors, thus giving information about the overall impact of environmental changes (Widdows and Donkin, 1992). These parameters also integrate many cellular and biochemical processes, being evaluated on the entire organism.

SFG reflects the balance between processes of energy acquisition, such as feeding and digestion, and energy expenditure, such as respiration and excretion, providing an instantaneous measure of the energy state of an organism (Smaal and Widdows, 1994). SFG ranges from maximum positive values in optimal environmental conditions, decreasing to negative values when an animal is severally stressed and is using its body reserves. Seasonal variations in the physiological energy budget of bivalves are usually related to intrinsic factors like body size and reproductive conditions, and to extrinsic factors like temperature and food availability (Bayne and Newell, 1983; Widdows, 1985). SFG has been evaluated in several bivalve species for environmental quality assessment in a number of coastal areas in the USA and Northern Europe (Nelson, 1990; Widdows et al., 1990, 1995a,b, 2002). In the North Adriatic, some studies have been performed on *Mytilus galloprovincialis* and *Tapes philippinarum* from the Lagoon of Venice (Widdows et al., 1997; Da Ros et al., 1998; Marin et al., 2001).

"Survival in air" is a stress response that exploits the natural ability of bivalves to survive periods of aerial exposure (Eertman et al., 1993). This physiological index is considered to be a rapid, simple and low-budget method for examining whether environmental parameters may have perturbing effects leading to reduced fitness of individuals (Eertman and de Zwaan, 1994; de Zwaan and Eertman, 1996). The usefulness of this test has been studied in both field and laboratory conditions (Veldhuizen-Tsoerkan et al., 1991a,b; Viarengo et al., 1995; Marin et al., 2001).

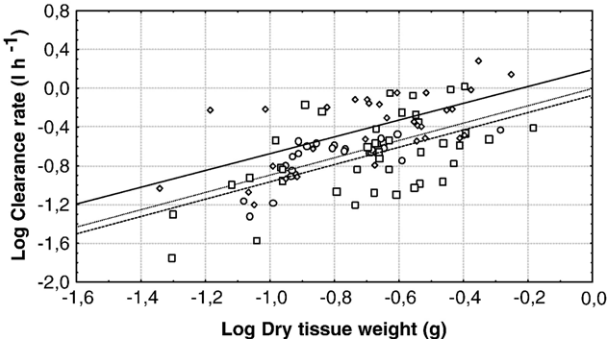

Fig. 1. Linear regression relating clearance rate of *Chamelea gallina* to dry weight at three temperatures tested. Covariance Analysis-Parallelism test: no statistical differences detected among slopes.

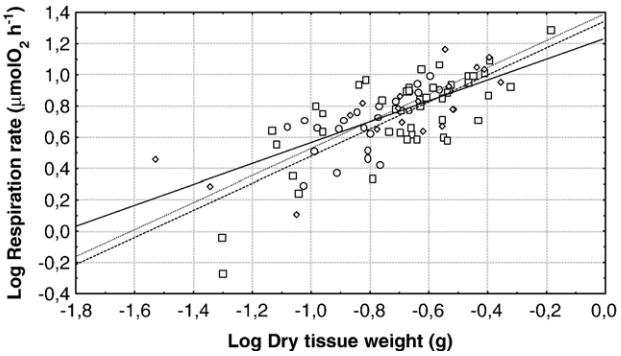

Fig. 2. Linear regression relating respiration rate of *Chamelea gallina* to dry weight at three temperatures tested. Covariance Analysis-Parallelism test: no statistical differences detected among slopes.

Lastly, condition indices are generally considered useful tools to determine the nutritive status of bivalves. They have been used to follow seasonal changes in gross nutrient reserves and/or in bivalve aquaculture, both to designate the quality of marketed products and to characterise the apparent "health" of cultured stocks (Lucas and Beninger, 1985; Crosby and Gale, 1990). The pattern of condition indices has also been used to reveal the optimum period for the sales of mussels (*Mytilus edulis*, *M. galloprovincialis*) and clams (*T. philippinarum*) (Zandee et al., 1980; Bressan and Marin, 1985; Marin et al., 2003).

2. Materials and methods

2.1. Laboratory study

The influence of body size and temperature on clearance and respiration rates was studied by a series of measurements of clams of differing size ranging from about 0.05 g to 0.50 g dry weight at three temperatures: 8, 16 and 24 °C, related to winter, spring-autumn and summer conditions, respectively. Clams, dredged along the north-western Adriatic coast, were kept in the laboratory for 6 days before any measurements at the experimental temperatures and at salinity of 35±0.5 PSU, and fed with *Isochrysis galbana*. Clearance and respiration rates were measured on individual clams.

Clearance rate (CR), expressed as volume of water cleared of suspended particles per unit of time, was determined using a static approach: each animal was placed in a glass beaker containing 1l of 0.45-µm filtered seawater and 15000 cell mL^{-1} of *I. galbana*, this concentration never causing pseudofaeces production. Seawater was kept gently aerated during the experiment and one beaker without a clam acted as a control. Microalgae concentration was measured on four 20-mL aliquots collected from each beaker every 30 min over a period of 2 h, by a Coulter Counter (Model Z2). The CR (L h^{-1}) was calculated