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The effect of salinity on clearance rate in the suspension-feeding estuarine gastropod *Crepipatella dilatata* under natural and controlled conditions

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Abstract

The suspension-feeding gastropod *Crepipatella dilatata* occurs in estuaries in southern Chile that experience considerable fluctuations in salinity, driven by tidal and atmospheric forces. In the Quempillén estuary salinities as low as 9 psu may occur after severe rainstorms, and persist for several hours. In this study salinity was the major factor influencing the clearance rate of *C. dilatata*. At salinities below 20 psu, filtration ceased, whereas at high salinities (>22 psu) mean clearance rate was 0.24 l h^{-1} standard animal^{-1} (S.D. 0.18) for actively filtering individuals. This was confirmed by laboratory experiments under controlled conditions. Endoscopic observations were consistent with measurements of clearance rate, and showed that at salinity 25–30 psu the rate of transport along the gill filaments of particulate material embedded in mucus was 759 μm s^{-1} (S.D. 480), but particle transport ceased at and below salinity 20 psu. Complete or partial isolation of the mantle cavity from the environment may be a mechanism to protect soft tissues and/or incubated egg capsules from osmotic stress.

Keywords: clearance rate; salinity; *Crepipatella*; estuary; suspension-feeding; filtration

1. Introduction

Many environmental variables can influence clearance rate (CR) and the feeding process in suspension-feeders, among them seston quality and quantity (Stenton-Dozey and Brown, 1992; Wong and Cheung, 2001; Gardner, 2002), seston volume (Hawkins et al., 2001), chlorophyll *a* (Hawkins et al., 2001; James et al., 2001), particle concentration and size (Stenton-Dozey and Brown, 1992, 1994), temperature (Wong and Cheung, 2003), and salinity (Navarro, 1988; Hutchinson and Hawkins, 1992; Navarro and Gonzalez, 1998; Spicer and Strömberg, 2003). Most of these investigations were carried out in the laboratory, allowing control of environmental conditions, but some were field studies in which short-term changes in the food supply were demonstrated. However, few attempts have been made to investigate the effects of other potentially important variables on suspension-feeding on short time scales (e.g. phaeopigments, energy content of seston, biochemical composition of seston, feeding indices). In this context estuaries are particularly interesting, owing to the combined effects of tidal cycles and freshwater input (Riaux, 1981; Huang et al., 2003) and their impact on physiological rate functions of estuarine organisms, especially those that determine energy balance (Navarro, 1988).

The estuary may experience rapid and profound changes in the physical, chemical and biological environment in the water column associated with tidal forces, wind stress and heavy rainfall (Toro and Winter, 1983; Chaparro et al., 2008). These events also impact the bottom, especially in shallow estuaries,

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such as Quempillén, southern Chile (Chaparro et al., 2008), leading to resuspension of bottom sediments. The result is a dynamic environment in which the food source for suspension-feeders often varies on short time scales. An important feature of an estuary is the changing salinity that results from the influx and efflux of sea water, which is diluted by the input of fresh water from the river. Salinity has been termed by Kinne (1966) an ''ecological master factor'' in estuaries, and is an important regulator of many behavioural and physiological processes in estuarine organisms (Navarro, 1988; Hutchinson and Hawkins, 1992; Navarro and Gonzalez, 1998; Kim et al., 2001; Spicer and Strömberg, 2003; Marsden, 2004).

The gastropod *Crepipatella dilatata* is common in the estuaries of southern Chile (Gallardo, 1979), including Quempillén, where there is a large population. The females of *Crepipatella* spp., which are all sessile, feed by removing particles from suspension (Newell and Kofoed, 1977a,b; Chaparro et al., 2002). The suspension-feeding mechanism in *Crepipatella fecunda* has been described by Chaparro et al. (2002). Suspended particles are entrained on a unilamellar gill which is covered by short dorsal and ventral cilia and also possesses long lateral cilia. The particles are trapped in a mucous sheet which covers the surface of the lamella and is moved to the distal region of the branchial filaments, where it forms a mucous string. This particle-laden string is transferred to a muscular canal in the neck, where it forms a compact mucous cord which is moved anteriorly towards the buccal region, where it is seized by the radula and ingested. In a companion paper (Chaparro et al., 2008) we deal with short-term (tidal cycle) and long-term (seasonal) environmental changes in the physical and biochemical characteristics of the Quempillén estuary, which we found to be very susceptible to wind and rain storms. The purpose of the present study was to investigate the effects of environmental factors on the CR of *C. dilatata*, specifically how CR responds to short-term changes in the properties of the water column, particularly salinity, during the tidal cycle at different times of the year.

2. Materials and methods

2.1. Water sampling and seston analysis

The study was undertaken in the Quempillén estuary, Chiloé Island, southern Chile (41°52′S; 73°46′W). In each season of the year, 2 or 3 tidal cycles of 12 h were investigated. Water was pumped continuously into the laboratory and the following variables measured: temperature, salinity, particle numbers, total particle volume, total particulate matter, particulate organic matter, particulate inorganic matter, chlorophyll *a*, total phaeopigments, and particulate lipid, protein, carbohydrate and energy. Salinity (practical salinity scale) was monitored continuously with a temperature/conductivity meter (YSI 300). For details of water sampling and methods for measuring environmental variables and properties of seston, see Chaparro et al (2008).

2.2. Clearance rate in estuary water

Sessile females (shell length 23–33 mm, mean: 27.9 mm) of *Crepipatella dilatata* were collected from the subtidal zone in the Quempillén estuary. The individuals in each stack were separated from one another and only those attached directly to the rocky substrate were retained. These were returned to the estuary, where they remained for at least 2–3 months before being used for measurements of CR.

A few days before each set of measurements began, specimens were taken to the laboratory, cleaned of epibionts and placed in 100 L tanks supplied with flowing unfiltered water directly from the estuary 25 m away i.e. under ambient conditions. The limpets were then transferred to the CR measurement apparatus, which consisted of a series of 8 plastic chambers (250 ml) individually supplied with ambient seawater by gravity from a constant head device (Navarro and Thompson, 1995). Six chambers contained individuals of *Crepipatella dilatata* (one per chamber), whereas 2 chambers contained only flowing water and served as controls. The inflow line to each chamber was fitted with a flow restrictor (a plastic plug drilled lengthwise to produce a hole of the required diameter). The constant head tank was continuously supplied with water pumped from the estuary, the inlet being placed as close as possible to the bottom without removing sediment. The flow through the chambers was adjusted to provide a detectable difference (25–30%) in particle concentration between inflow and outflow. Limpets were left overnight in flowing ambient seawater in the chambers before CR measurements were made.

For each measurement of CR, the outflow from each chamber was collected over a measured time period, permitting the calculation of flow rate. Particle numbers were determined with a particle counter (Beckman Coulter Z2) fitted with a 100 μm orifice tube. The size range of the particles counted was nominally 2–40 μm equivalent spherical diameter, which comprised over 95% of the particles in the estuary (Chaparro et al., 2008). Replicate counts were made for each sample. Clearance rate was calculated as $CR = FR(N_i - N_o)/N_i$ where FR = flow rate ($l\ h^{-1}$), N_i = particles ml^{-1} in inflow (mean of 2 control chambers), N_o = particles ml^{-1} in outflow from experimental chamber. Measurements were made hourly for 12 h during tidal cycles in November 2002 and January, May, August and November 2003. A fresh set of limpets (6–12 individuals) was used for each series of measurements (for details see Chaparro et al., 2008).

The soft tissues of each limpet used were excised, dried to constant mass at 90 °C and weighed. CR values were adjusted for a limpet of standard body mass 0.33 g (the mean value for the individuals used).

2.3. Clearance rate under controlled conditions

Data from limpets kept in water from the estuary suggested that CR was inhibited at salinities below 20 psu (see Section 3). We therefore carried out a controlled laboratory experiment in August 2004 to investigate this further.