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Clearance rates of *Cerastoderma edule* under increasing current velocity

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Abstract

Estimates of clearance rates (CR) of *Cerastoderma edule* (300 ind. m^{-2}) as a function of free-stream current velocity (U) (from 5 to 40 cm s^{-1}) were compared between a small annular (60 l) and a large racetrack (8850 l) flume with different hydrodynamic conditions. Results showed that the flumes differ considerably in their hydrodynamic characteristics. The relationship between CR and U is different in the two flume tanks, however there appears to be a straightforward unimodal trend between CR and shear velocity (U_*). It was found that the cockles themselves influence the benthic boundary layer (BBL) characteristics, by causing steeper velocity gradients and increasing the mixing over the cockle bed compared to bare sediment. This provides new evidence on how endobenthic organisms can affect the BBL. However, the influence of CR on U_* could not be quantified because these parameters have interactive effects that cannot be dissociated.

Keywords: Benthic boundary layer; *Cerastoderma edule*; Clearance rates; Annular and racetrack flumes; Shear velocity

1. Introduction

The clearance rate (CR) of bivalves has a known impact on the phytoplankton concentrations in aquatic ecosystems (Kamermans, 1993). It is also an important process in sediment dynamics. Filter feeders can enhance the direct transfer of suspended particles from the water column to the bed. The accurate establishment of bivalve CR has been, and still is, the subject of extensive research and discussion (Riisgård, 2001). Many authors have observed that CR increase with quantity and quality of suspended matter up to a threshold, after which clearance and absorption efficiency is influenced negatively by increasing quantity (Navarro and Widdows, 1997) and quality (Iglesias et al., 1996; Hawkins et al., 1998; Ibarrola et al., 2000).

Other works focus upon the effects of changes in current velocity on bivalve CR (Wildish and Miyares, 1990; Ackerman, 1999; Sobral and Widdows, 2000; Newell et al., 2001; Widdows et al., 2002). These studies show that low current velocities have a positive effect on CR but as velocity increases, CR are reduced with unimodal responses to current velocity.

Whilst current velocity can influence bivalve CR, the inverse is also true: the bivalves can influence

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local hydrodynamics. This has been shown particularly for epibenthic species (Butman et al., 1994; Green et al., 1998; Nikora et al., 2002) whose presence is related to regions of increased drag coefficients together with a greater level of turbulence and, consequently, reduced flow speed. The increase in turbulence is often related to increased roughness effects, produced by the shells protruding into the benthic boundary layer (BBL), and the interaction of the exhalent jets with the overlying flow (Monismith et al., 1990; O'Riordan et al., 1995). The effects of endobenthic bivalves, where low impacts on the surface roughness, the BBL, and on current velocities from clearance activities would be expected, have not been studied.

The cockle *Cerastoderma edule* is a widely distributed bivalve from European coasts that occurs in densities of up to 1750 ind. m^{-2} in the Schelde estuary, Netherlands (Ysebaert and Herman, 2002). It is an endobenthic suspension feeder that feeds on phytoplankton and resuspended microphytobenthos (Sauriau and Kang, 2000; Rossi et al., 2004), and in the process changes the gradient and composition of suspended matter passing over the cockle beds (Smaal and Haas, 1997). According to Ysebaert et al. (2002), *C. edule* occurs in environments subject to flow velocities of up to 80 cm s^{-1}, having a maximum probability of 0.35 of occurring at flow velocities around 35 cm s^{-1}. Kamermans (1993) and Lenihan et al. (1996) found that cockles show increased growth with increasing flow velocities (0–7 cm s^{-1}) under laboratory conditions and, more clearly, in the field.

The reason why bivalve clearance activity is influenced by water flow is twofold: firstly, the flow determines the rate at which food particles are transported towards the animals; and secondly, the water exerts a force on the bed and hence on the feeding apparatus of the animals. It is therefore not only the flow velocity that is important, but also the structure of the boundary layer and the shear stresses caused by the velocity gradient. Experimental research into flow effects on bivalve feeding activities is carried out normally in flume tanks. The boundary layer structure is related to flume design (straight, racetrack, annular, and with several dimensions). This can lead to difficulties in comparison (or even misinterpretation) of results obtained in different laboratory devices. This was observed recently by Amos et al. (2004) in a comparative study on sediment stability measurements in different flumes (see also Widdows et al., 2007).

Some larger flumes, with a straight working section, provide hydrodynamic conditions that closely resemble the boundary layer in the field. However, the large volume of water relative to a small area of cockle bed can introduce large errors in estimates of CR. Small annular flumes have the advantage of being easier to operate. There are no entrance and exit conditions to consider, and the relatively small surface-to-volume ratio of the test section makes it easy to detect reductions in algal concentrations. However, the curvature of the flume walls produces a centrifugal force that generates secondary flows and radial variability in bed stress (Amos et al., 1992; Yang et al., 2000), producing a boundary layer structure different to that found in the field. Cross-channel variation in bed stress variability is also reported for long straight flumes, but it is considered to be less than the stress gradients encountered in annular flume designs (Black and Cramp, 1995).

In this work, we compare the effect of current velocity on the CR of *C. edule* in two different flumes: a small annular (60 l) and a large racetrack (8850 l) flume. We also analyse the effect of *C. edule* on the boundary layer characteristics, by comparing it with the hydrodynamic characteristics over a bare sediment and over a smooth surface.

2. Materials and methods

2.1. Collection of organisms, experimental set-up, and procedures

The experiments took place in November–December 2002 at the Instituto do Mar, Universidade Nova de Lisboa (IMAR-FCT/UNL), and at the Netherlands Institute of Ecology (NIOO) in June–July 2003. Organisms were collected, brought to the laboratory and allowed to acclimatise for a minimum of 5 days. They were stored in seawater aquaria under continuous aeration, and with temperature and salinity similar to the experimental conditions (see Tables 1a and b) until used.

In the IMAR flume, fine sand (<250 μm) was used as an experimental substrate. Observations at that time revealed that the resuspension of very fine grains interfered with cell counts and produced errors in clearance rate estimates. For this reason coarser sand (average grain diameter 750 μm) was used in the NIOO flume.

For both flumes, each group of organisms (see Table 1a) was introduced into the flume and left