Journal of Experimental Marine Biology and Ecology 343 (2007) 44–51
Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY
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# Influence of current speed on clearance rate, algal cell depletion in the water column and resuspension of biodeposits of cockles (*Cerastoderma edule*)

J. Widdows [a,*], J.M. Navarro [b]

[a] *Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, PL1 3DH, England, United Kingdom*
[b] *Instituto de Biologia Marina, Universidad Austral de Chile, Casilla 567, Valdivia, Chile*

Received 20 September 2006; received in revised form 14 November 2006; accepted 16 November 2006

**Abstract**

The main objectives of this study were: 1) to determine the influence of water currents on the suspension feeding rate of cockles (*Cerastoderma edule*); 2) to quantify the interaction between cockle feeding and flow on algal cell depletion in the overlying water column, and 3) to measure the effect of flow on resuspension of their pseudofaeces and faeces. Flume experiments demonstrated that suspension feeding rate (i.e. clearance rate) of *C. edule* was not significantly affected by increasing current speed, at least between 5 and 35 cm $s^{-1}$. Measurement of vertical profiles in algal cell concentrations within the water column showed a marked depletion above the bed, and the size of this was inversely related to currents' speeds below 5 cm $s^{-1}$. At 2 cm $s^{-1}$ the algal cell depletion was maximum immediately above the bed. However, below currents of 1 cm $s^{-1}$ the maximum depletion was at 10 cm above the bed. This was a result of the exhalent jet of the cockle pumping filtered water (i.e. algal free) vertically into the water column and above the intake level of the inhalant siphon. Such stratification of the water column would appear to be beneficial to the cockle because it reduces the degree of re-filtration of algal cell depleted water at times of low flow, when there is poor mixing and thus poor replenishment of phytoplankton to the boundary layer. Critical erosion thresholds for cockle biodeposits, produced from a diet of silt and unicellular algae, were recorded at current velocities of 15 and 25 cm $s^{-1}$, or shear velocities of 0.6 and 1.0 cm $s^{-1}$, for pseudofaeces and faeces respectively.


*Keywords:* Biodeposits; *Cerastoderma edule*; Clearance rate; Cockles; Current velocity erosion threshold; Faeces; Pseudofaeces

## 1. Introduction

There have been relatively few studies investigating the impact of water currents on bivalve feeding rates and what limited information is available appears to be somewhat contradictory. Previous studies have shown that some populations of mussels (*Mytilus edulis*) are relatively sensitive to currents and reduce their suspension feeding rates with increasing flow rates between 5 and 25 cm $s^{-1}$ (Wildish and Miyares, 1990), whereas others have shown that *M. edulis* maintains high feeding rates independent of currents up to at least 80 cm $s^{-1}$ (Widdows et al., 2002). In another study, Sobral and Widdows (2000) recorded a linear decline in the feeding rate of the clam (*Ruditapes decussatus*) between 3 and 36 cm $s^{-1}$, but there was the confounding factor of increased sediment resuspension at higher current speeds. Suspension feeding can also cause near-bed algal cell

* Corresponding author.
*E-mail address:* j.widdows@pml.ac.uk (J. Widdows).

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doi:10.1016/j.jembe.2006.11.011

depletion at low current speeds and thus alter the vertical and horizontal distribution of algal cells in the water column above a bed of bivalves (Fréchette et al., 1989; Muschenheim and Newell, 1992; Jonsson et al., 2005). There have also been several hydrodynamic studies of the effects of bivalve pumping activity on boundary layer structure, examining interactions between horizontal flows and exhalent jets from siphons of living bivalves (Ertman and Jumars, 1988; Van Duren et al., 2006) as well as beds of artificial siphons (Monismith et al., 1990; O'Riordan et al., 1993, 1995). However, the impact of bivalve filtration activity on the food depletion in the boundary layer still needs to be more clearly defined. There is also need for improved understanding of the current speeds and bed shear stresses required to resuspend biodeposits produced by bivalves, and to distinguish between the resupension of pseudofaeces (mucus bound particles rejected by the gills and labial palps) and faecal pellets. This aspect is recognised as important in relation to environmental problems associated with the accumulation of biodeposits connected with bivalve culture in low energy environments. There is a dearth of quantitative information on the strength of currents necessary to resuspend and transport biodeposits away for the culture area. Relatively few studies have quantified the critical erosion thresholds for biodeposits (Minoura and Osaka, 1992; Widdows et al., 1998b; Austen et al., 1999; Giles and Pilditch, 2004).

The main objectives of this study were: 1) to determine the influence of water currents on the suspension feeding rate of cockles (*Cerastoderma edule*); 2) to quantify the interaction between cockle feeding and flow on algal cell depletion in the overlying water column, and 3) to measure the effect of flow on resuspension of their pseudofaeces and faeces. The cockle is a commercially important infaunal, suspension feeding bivalve which lives buried in the top few cm of the sediment. When open and pumping both the inhalent and exhalent siphons are usually the only visible parts of the cockle ~5 mm above the bed. Consequently they are adapted to life in the benthic boundary layer and are dependent on the near-bed flows to deliver suspended food particles and remove biodeposits (faeces and pseudofaeces).

## 2. Materials and methods

### 2.1. Collection of cockles and sediment

Cockles (*C. edule*) were collected from Lympstone on the Exe estuary (Devon, England). The cockle population occurred at a density of 43 individuals m$^{-2}$ and individuals of a similar size were collected for the flume experiments (mean shell length = 2.75 cm ± 0.05 SE; mean dry tissue weight = 270 mg ± 16.8 SE). Sandy sediment was collected from the intertidal zone at Exmouth. Following transportation to the laboratory, the sediment was washed in freshwater and sieved through a 1 mm sieve to remove the finer grains that are more easily resuspended by water currents. Cockles were cleaned, added to the sandy sediment, and allowed to acclimatize to laboratory conditions (temperature of 15 °C; salinity 33; diet of *Isochrysis galbana*) for at least 14 days prior to the flume experiments.

### 2.2. Description of annular flume

A detailed description of the annular flume and the operating procedures has been provided by Widdows et al. (1998a, 2000). In summary, the flume represents a smaller, modified version of the design described by Fukada and Lick (1980). The annular flume is constructed of acrylic material with a 64 cm (outer) and 44 cm (inner) diameter, resulting in a 10 cm channel width with a total bed area of 0.17 m$^2$, a maximum water depth of 38 cm, and a maximum volume of 60 L. The flume is microprocessor controlled and data is logged. Water flow, ranging from 0.01 to 0.50 m s$^{-1}$, is generated by a rotating drive plate connected to a motor and gearbox. The current speed was measured using an electro-magnetic current meter (Valeport model 800–175). Smooth turbulent flow is generated over smooth beds of fine sediment in both the annular flume and the field (Pope et al., 2006). The following equation describes the relationship between current speed and bed shear stress under these conditions:

$$\text{Bed shear stress (Pa)} = 4.768U^3 - 1.260U^2 + 0.426U \quad r^2 = 0.99 \tag{1}$$

where $U$ is current speed in m s$^{-1}$ at 10 cm above the bed. This is equivalent to the depth averaged or free stream velocity because there is a compressed boundary layer in the annular flume and the current speeds are relatively constant between 1 and 20 cm above the bed (Pope et al., 2006). The above relationship was established in the flume and the field using a Sontek micro-Acoustic Doppler Velocimeter (ADV) for measuring near-bed currents and bed shear stress (Turbulent Kinetic Energy method — Pope et al., 2006).

Washed and sieved sediment (> 1 mm) was added to the flume to provide an even surface. A sheet of 'bubble wrap' the size and shape of the annulus was carefully placed on the sediment surface and fully oxygenated seawater gently pumped onto the sheet, which then gradually floated off