

COMMENT

Bivalve clearance rates: inaccurate measurements or inaccurate reviews and misrepresentation?

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The issue of clearance rate measurements, and the range of techniques and their accuracy, has been raised by Riisgård (2001) in his review: 'On measurement of filtration rates in bivalves—the stony road to reliable data: review and interpretation'. His main conclusion is that a large proportion of published studies have used methods that are flawed and that only those studies that show maximum filtration rates measured under optimal laboratory conditions (Table 1; Riisgård 2001) are valid. He either ignores or dismisses the majority of the world literature on bivalve feeding rates.

Riisgård's conclusions appear to be largely based on incorrect interpretation and inaccurate statements concerning the literature. The criticisms of the flow-through chamber method (i.e. avoidance of water recirculation, geometry of chamber, flow rates and the appropriate equations) formulated by Riisgård (2001) were all recognised more than 20 yr ago and were outlined in the procedures described by Widdows (1985a). While it should not come as a surprise to readers that today's techniques and understanding are better than 30 to 40 yr ago, the arguments put forward by Riisgård (2001) do not apply to the majority of studies performed in the last 20 yr. His conclusions are largely based on inaccuracies concerning the literature. For example, he states that 'following the recommendation by Widdows (1985a), Smaal & Twisk (1997) used a constant flow-through rate of 50 ml min⁻¹ in a filtration study with *M. edulis*'. However, Widdows (1985a) recommended flow rate >150 ml min⁻¹ for the 'flow-through chamber method', whereas 50 ml min⁻¹ together with adequate mixing was the flow rate suggested for the method of Hildreth & Crisp (1976), referred to by Riisgård as the 'steady-state method'. Furthermore, Widdows (1985a) compared the 'flow-through chamber' and 'steady-state method', together

with the 'closed chamber or indirect method', and found no significant differences in the measured clearance rates.

The most important research question and environmental issue is: 'Why are suspension feeders not performing at their maximum clearance rate?' This is due to a range on environmental factors, including natural variables such as food quality and quantity (Hawkins et al. 2001), temperature (Bayne et al. 1977), salinity (Widdows 1985b), as well as pollution (Widdows & Donkin 1992, Widdows et al. 1995a). However, these and the majority of other bivalve feeding studies conducted world-wide have been dismissed and ignored by Riisgård (2001), simply because the animals are not feeding at their maximal rate. Research has clearly demonstrated that there are several reasons why bivalves are not feeding at their maximal rate: (1) there are regulatory responses to changes in the quality/quantity of suspended particles (Hawkins et al. 2001); (2) salinity and temperature conditions may be beyond the range of complete acclimation for the population/species (Bayne et al. 1977, Widdows 1985b); and (3) pollutants in the water and accumulated in the body tissues are inducing an inhibitory effect on feeding activity (Widdows & Donkin 1992, Widdows et al. 1995a).

I am only focussing on the third aspect here as this work has been rejected by Riisgård (2001). The overwhelming evidence from laboratory, mesocosm and field studies is that environmentally realistic concentrations of toxicants induce an inhibitory effect on suspension feeding rate (reviewed by Widdows & Donkin 1992, Widdows et al. 1995a). Despite measuring bivalve feeding rate under near optimal conditions (of temperature, salinity, food quality/quantity and high water quality, as stated in the methods of Widdows 1985a, 1993), mussels collected from the majority of coastal and estuarine sites in the UK and elsewhere (Widdows & Johnson 1988, Widdows et al. 1990, 1995a) do not filter feed at their maximum potential due to the

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presence of pollutants in their body tissues. The maximal feeding rates recorded by Møhlenberg & Riisgård (1979) and included in Table 1 of Riisgård (2001) probably reflect the origin of the animals, which were collected from the northern part of the Øresund in Denmark. However, the 'optimal' environmental conditions at this site are probably atypical and relatively few animals living in the coastal waters of densely populated and industrialised Europe are feeding and growing under 'optimal' conditions. The majority of mussel populations studied along the North Sea coastline (Widdows et al. 1995a) and more recently the Irish Sea coastline (Widdows et al. in press) have depressed clearance rates (i.e. significantly below maximum rates), primarily due to pollution and reduced water quality (i.e. effects of food, temperature and salinity are removed). High feeding rates (ca $7 \text{ l g}^{-1} \text{ h}^{-1}$), comparable to the bivalves in the Øresund, have been consistently recorded in mussels originating from pristine North Atlantic coastal sites, such as the Shetlands (Widdows et al. 1995a,b) and the west coast of Scotland (Widdows et al. in press), and far removed from urban/industrial developments. Mussels from a total of 64 coastal sites were measured at the Plymouth Marine Laboratory under standardised 'near optimal' laboratory conditions using clean offshore seawater designed to maximise the clearance rates. Maximal rates were only recorded in ca 20% of the mussel populations.

Once again Riisgård (2001) makes the assumption that the 'filtration rates are wrongly determined' in the North Sea mussels study and chooses to selectively mis-quote and mis-interpret the detailed findings presented in Widdows et al. (1995a). Riisgård chooses to use such terms as 'allegedly due to different degrees of pollution', but only highlighting the presence of the 'unexplained component' and not the 'explained component'. The fact that given the nature and scale of the survey there is consistency in the data and the reduction in clearance rate and SFG (scope for growth) can be explained by quantitative toxicological interpretation of tissue residue data (i.e. measured contaminants) in more than half of the sites is selectively ignored by Riisgård (2001). The fact that we identify an 'unexplained component' to the reduced scope for growth at many sites does not reflect the inaccurate measurement of clearance rate, but rather the presence and influence of unidentified contaminants. This finding is not surprising, and is now widely acknowledged, because routine chemical analyses of contaminants in the aquatic environment only quantify a small percentage of the total pollutant load. Furthermore, the spatial changes in water quality and the presence of unidentified toxicants, recorded in the North Sea mussels study, have subsequently been confirmed by other pol-

lution studies using different techniques, specifically modified to improve sensitivity and detection limits (Kirby et al. 1998).

Riisgård (2001) also comments that 'it is difficult to see the advantages of the SFG technique in field monitoring programmes' in comparison to 'the precise measurement of actual growth of mussels in bags', again adding 'particularly not if the filtration rates are wrongly determined'. However, the advantages of SFG over actual growth measurement have been stated by Widdows & Donkin (1992), Widdows (1993) and Widdows et al. (1995a). The 2 major advantages are firstly, that when measured under standardised conditions (with food availability, temperature, salinity and dissolved oxygen held constant) the SFG reflects the underlying toxic effects of pollutants accumulated in the body tissues. Furthermore, the effects on SFG can be interpreted in relation to pollution through a quantitative toxicological interpretation of tissue residue chemistry. Secondly, given the considerable variability in growth due to spatial and temporal variability in food quality and quantity, it is difficult to interpret any measured changes in actual growth because it is not possible to separate and distinguish between 'nutritional effects' and 'toxicant effects'. The ability to carry out precise measurements of actual growth will not advance our understanding or provide an interpretation of the causes of reduced growth.

Finally, it is not clear why Riisgård chose to use the metaphor of a 'stony road' in the title of his review. However, anyone travelling along a 'stony road' (perceived or otherwise) should look and check carefully because they may trip up, or be going up a 'blind alley'.

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