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Density-dependent effects on seston dynamics and rates of filtering and biodeposition of the suspension-cultured scallop *Chlamys farreri* in a eutrophic bay (northern China): An experimental study in semi-in situ flow-through systems

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Abstract

Effects of stocking density on seston dynamics and filtering and biodeposition by the suspension-cultured Zhikong scallop *Chlamys farreri* Jones et Preston in a eutrophic bay (Sishili Bay, northern China), were determined in a 3-month semi-field experiment with continuous flow-through seawater from the bay. Results showed that the presence of the scallops could strongly decrease seston and chlorophyll *a* concentrations in the water column. Moreover, in a limited water column, increasing scallop density could cause seston depletion due to scallop's filtering and biodeposition process, and impair scallop growth. Both filtration rate and biodeposition rate of *C. farreri* showed significant negative correlation with their density and positive relationship with seston concentration. Calculation predicts that the daily removal of suspended matter from water column by the scallops in Sishili Bay ecosystem can be as high as 45% of the total suspended matter; and the daily production of biodeposits by the scallops in early summer in farming zone may amount to 7.78 g m^{-2}, with daily C, N and P biodeposition rates of 3.06×10^{-1}, 3.86×10^{-2} and 9.80×10^{-3} g m^{-2}, respectively. The filtering and biodeposition by suspension-cultured scallops could substantially enhance the deposition of total suspended particulate material, suppress accumulation of particulate organic matter in water column, and increase the flux of C, N and P to benthos, strongly enhancing pelagic–benthic coupling. It was suggested that the filtering-biodeposition process by intensively suspension-cultured bivalve filter-feeders could exert strong top-down control on phytoplankton biomass and other suspended particulate material in coastal ecosystems. This study also indicated that commercially suspension-cultured bivalves may simultaneously and potentially aid in mitigating eutrophication pressures on coastal ecosystems subject to anthropogenic N and P loadings, serving as a eutrophic-environment bioremediator. The ecological services (e.g. filtering capacity, top-down control, and benthic–pelagic coupling) functioned by extractive bivalve aquaculture should be emphasized in coastal ecosystems.

Keywords: Filtering; Biodeposition; Bivalve; *Chlamys farreri*; Suspension aquaculture; Seston; Top-down control; Pelagic–benthic coupling; Eutrophication; Bioremediation; Sishili Bay (northern China)

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1. Introduction

In shallow coastal and estuarine waters, filter-feeding bivalves often dominate the benthos in numbers as well as biomass. They are essential to the ecological systems as well as to the economic potential of the waters. Previous studies have demonstrated that when high densities of filter-feeding bivalves occur in shallow waters, they can play a significant role in coupling pelagic and benthic organic matter flow as well as control material recycling (Jordan and Valiela, 1982; Doering et al., 1986; Kautsky and Evans, 1987; Loo and Rosenberg, 1989; Dame et al., 1991; Hily, 1991; Ahn, 1993; Asmus et al., 1995; Chiantore et al., 1998; Gibbs et al., 2005). Filter-feeding bivalves possess highly efficient filtering mechanisms that enable them to concentrate particles from the pelagic system and reject undigested organic and inorganic material as faeces and pseudofaeces (collectively termed biodeposits), that finally reach the bottom (a process defined as biodeposition; Haven and Morales-Almo, 1966). Since faeces and pseudofaeces are voided from the animal body as mucus-bound aggregates, they have a faster sinking velocity than nonaggregated particles and settle at rates up to 40 times that of nonaggregated particles (Kautsky and Evans, 1987; Widdows et al., 1998). Accordingly, the biodeposition by filter-feeding bivalves has been recognized as an important process enhancing deposition of suspended materials from the water column to sea bottom (Haven and Morales-Almo, 1966, 1972; Kautsky and Evans, 1987; Graf and Rosenberg, 1997; Norkko et al., 2001; Newell, 2004; Zhou et al., in press-a). Increased organic deposition would enhance nutrient regeneration, and thereby refuel pelagic activity (Kelly and Nixon, 1984; Prins et al., 1998; Asmus and Asmus, 1991; Newell, 2004). Therefore, dense filter-feeding bivalve populations can act as a conduit for nutrients to benthos (Kautsky and Evans, 1987; Peterson and Heck, 1999). In fact, it is argued that dense assemblages of bivalves are more important as agents of sedimentation and nutrient cycling than as components of energy flow (Kuenzler, 1961; Dame et al., 1984; Kautsky and Evans, 1987; Dame et al., 1991).

Filter-feeding bivalves often act as functional group or as keystone species in coastal healthy ecosystems (Dame, 1996). Filter-feeding bivalves are well known for their terrific filtering capacity. They are important phytoplankton consumers in coastal waters and as such dense assemblages could remove a large amount of phytoplankton and other suspended particulate matter from the water column and thus participate in a natural cleansing process (Nakamura and Kerciku, 2000; Yamamuro et al., 2000). Through filtering and biodeposition, natural populations of bivalves are known to reduce total suspended particulate matter and induce a top-down control on phytoplankton biomass (Cloern, 1982; Officer et al., 1982; Dame, 1996; Haamer, 1996; Soto and Mena, 1999; Nakamura and Kerciku, 2000; Riisgård et al., 2004; Cerrato et al., 2004; Zhou et al., in press-a). Since pre-industrial time, coastal waters has been input by nearly doubled nitrogen due to urban and coastal development, and excess eutrophication has been caused worldwide (Cloern, 2001). Increased land-derived N loads may markedly increase phytoplankton biomass, and thereby increase shell and soft tissue growth in filter-feeding bivalves (Kirby and Miller, 2005), and increase bivalve soft-tissue N content (e.g. Carmichael et al., 2004). Filter-feeding bivalves are suggested to be potentially used for mitigating eutrophication pressures on coastal ecosystems by restoring or increasing them through aquaculture (Ulanowicz and Tuttle, 1992; Gottlieb and Schweighofer, 1996; Haamer, 1996; Edebo et al., 2000; Rice, 2000; Nelson et al., 2004; Gifford et al., 2004, 2005; Lindahl et al., 2005).

Cultivated bivalves can also play a key role in many coastal ecosystems due to their high filtration capacity and culture density (Newell, 2004). They also contribute to enhanced sedimentatixon proximal to the culture sites (Jaramillo et al., 1992; Hatcher et al., 1994). Kaspar et al. (1985) envisioned mussel farm as a large filter that creates fast sedimenting pellets from suspended particulate particles. The mariculture of bivalve shellfish is widely distributed, and potentially one of the most sustainable forms of mariculture, requiring no artificial food input, since the animals obtain all their nutrition from phytoplankton, microphytobenthos and other organic detritus (e.g. Grant, 1999; Hawkins et al., 2001; Nunes et al., 2003). Nevertheless, rapid growth of the industry has inevitably raised the problems of carrying capacity and sustainability (e.g. Grant, 1999). As more biomass is accumulated, the proportion of primary production available to further growth of bivalve biomass declines (Dame and Prins, 1998), and biodeposition at very high bivalve density may be so intense that the stimulated microbial respiration results in anoxic condition in underlying sediments (Dahlbäck and Gunnarsson, 1981; Bartoli et al., 2001; Stenton-Dozey et al., 2001; Newell, 2004). In recent years, assessing the environmental impacts of shellfish aquaculture has become increasingly important as the aquaculture industry grows (Dahlbäck and Gunnarsson, 1981; Kaspar et al., 1985; Mojica and Nelson, 1993;