AQUACULTURE update

96 Editor: C. M. Pearce April 2006
Pacific Biological Station

Biological Feasibility of Suspended Pacific Oyster and California Sea-Cucumber Polyculture

Debbie Paltzat[1,3], Chris Pearce[1,*], Penny Barnes[2], Scott McKinley[3]

[1] Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, Canada V9T 6N7
[2] Centre for Shellfish Research, Malaspina University-College, 900 Fifth Street, Nanaimo, British Columbia, Canada V9R 5S5
[3] Centre for Aquaculture and Environmental Research, The University of British Columbia / Fisheries and Oceans Canada, 4160 Marine Drive, West Vancouver, British Columbia, Canada V7V 1N6

*Author for correspondence
Tel: (250) 756-3352
E-mail: pearcec@pac.dfo-mpo.gc.ca

Introduction

Dense assemblages of filter-feeding bivalves enhance the vertical flux (i.e. flow) of organic matter towards the benthic environment. Bivalves, to a large extent, remove small suspended particles from the water column and release larger particles known as biodeposits [i.e. pseudofaeces (particles rejected prior to ingestion) and faeces]. Although there is no net addition of organic matter, the concentrated biodeposits are a potential energy source (e.g. carbon and nitrogen) for micro-organisms, both in the water column and in the benthos, and for benthic macro-invertebrates such as deposit-feeding sea cucumbers, in the vicinity of oyster farms.

The California sea cucumber (*Parastichopus californicus*) has become the focus of a limited commercial dive fishery in British Columbia, Washington, and Alaska. This species of sea cucumber is highly valued for import and re-export in Hong Kong. Like many other commercially important sea-cucumber species, it has previously been fished extensively to meet the increased demand for bêche-de-mer, the market name for the dried product from the body wall of holothurians, in Southeast Asia.

An integrated system of marine aquaculture has the potential to increase the efficiency and productivity of intensive mono-culture systems while reducing waste loadings and potential environmental impacts. Polyculture has been applied to sea-cucumber production in China where sea cucumbers reduce particulate organic matter produced by co-cultured species. For example, *Stichopus japonicus* (a temperate species in the western Pacific) has been successfully grown without supplemental feeding on artificial reefs placed in shrimp ponds. However, in other parts of the world, suitable culture methods for commercially fished species of sea cucumber have not yet been developed or are in the experimental stage.

Study Objectives

In the present study, the feasibility of rearing California sea cucumbers on oyster raft culture systems was investigated. The primary objectives of the research program were to: (1) study the potential for enhanced sea-cucumber growth and production when grown in polyculture with suspended Pacific oysters (*Crassostrea gigas*) and (2) study the potential for this form of polyculture to reduce the rate of biodeposition at oyster culture facilities. A 12-month field study was undertaken at two established oyster culture sites to examine: (1) growth (i.e. changes in muscle and skin wet weights) and survivorship of sea cucumbers grown under oyster culture rafts and (2) organic content of oyster biodeposits and assimilation of these biodeposits by sea cucumbers.

Experimental Design

Naturally settled sub-adult sea cucumbers (contracted length: 8–13 cm) were collected from oyster strings at farms in Village Bay (*VB*), Quadra Island and Gorge Harbour (*GH*), Cortes Island, British Columbia, Canada.

High-Flow™ oyster grow-out trays (L × W × H: 56.2 × 56.2 × 21.2 cm) were used as the experimental units. The trays were modified as follows: the bottoms were lined with a solid PVC insert (thickness: 0.156 cm) to prevent loss of biodeposits, the sides were reinforced with a wire panel (mesh size: 0.625 cm), and the tops were covered with wire panel of the same mesh size to prevent the sea cucumbers from escaping. Modifications to 30 trays cost approximately $450.

In January 2004 the trays were deployed 2.5 m below the oyster strings and were randomly positioned towards the center of each of the rafts to capture maximal deposition. Three rafts per site were used in the study and these rafts had oysters that were about 1-year old. Approximately 15 dozen oysters are typically cultured on each string and the rafts usually contain ~250 strings (i.e. ~45,000 oysters per raft). Field observations and sampling were carried out three times over the course of 10 months in VB. The oysters used at this site reached commercial size in November 2004 and had to be harvested, thus the field study was terminated after 10 months. Field observations and sampling in GH were carried out for 12 months to obtain data throughout an annual growth cycle.

At both study sites, sediment traps (each trap consisting of a double array of canisters; 10 cm inner diameter, 50 cm high) were deployed under the culture rafts. One trap was placed at the same water depth as the experimental trays (*shallow*) and another trap was located below the experimental trays at a minimum of 2 m above the sediment surface at low tide (*deep*) (Fig. 1). Hence, a total of six sediment traps were deployed (two for each of the three experimental rafts) at both sites for 3 d during each sampling period. Organic matter collected in the traps was used to calculate sedimentation rates of particulate organic matter (POM), which was analysed to calculate sedimentation rates of particulate organic carbon (POC) and particulate organic nitrogen (PON).

In the laboratory, sub-adult sea cucumbers (contracted length: 6–10 cm) collected from oyster strings at the VB farm were offered faeces/pseudofaeces from oysters as well as sediments with different organic matter composition to identify the rates of sediment processing and organic matter uptake. Sea cucumbers were placed in each of three rectangular Plexiglas containers (L × W × H: 52 × 35 × 9 cm), divided into four equal compartments. Each compartment housed one of the following treatments: sterilized/sieved sediment with added oyster biodeposits, sterilized/sieved sediment without biodeposits, natural sediment (not sterilized/sieved) without biodeposits, and no sediment. Twelve sea cucumbers were randomly selected, measured, and placed singly in each compartment. Four replicate trials over time were conducted. Each trial continued for 3 h following the production of the first faecal pellet by the experimental animals. At the end of the trials, the faecal pellets were collected, counted, and weighed. The sea cucumbers were subsequently dissected and the foregut and hindgut contents removed. The uptake rate, or quantity of organic matter removed by the animals, was calculated by multiplying the proportion of that material removed during the passage of sediment through their digestive tracts (sediment – faeces) by the rate of faecal production.

Study Results

In this study, *Parastichopus californicus* grown in trays showed a mean wet weight increase of 22.3 g and 28.1 g in VB and GH, respectively, in approximately 10 months (Fig. 2). After 12 months, the mean wet weight increase of sea cucumbers in GH was 42.9 g. Growth rates ranged from 0.061 to 0.082 g d^{-1} in VB and 0.084 to 0.158 g d^{-1} in GH, with an overall average of 0.08 g d^{-1} and 0.12 g d^{-1}, respectively, during the respective 10 and 12 month growth periods. On average, muscle and skin wet weights of sea cucumbers in VB increased 5.89 g and 13.86 g, whereas those of animals in GH increased 9.04 g and 18.53 g, respectively, in 10 months. The muscle and skin wet weights of *P. californicus* in GH increased an average of 5.63 g and 27.45 g, respectively, after 12 months of growth in the trays. During the respective growth periods, the muscle increment of sea cucumbers in VB and GH averaged 0.021 g d^{-1} and 0.016 g d^{-1}, and the skin increment averaged 0.050 g d^{-1} and 0.078 g d^{-1}, respectively. The differences in growth between VB and GH may be related to the hydrographic differences between the two sites and the availability of phytoplankton to the cultured oysters. When food concentration is increased, larger amounts of biodeposits are produced, which amounts to more organic matter available to the sea cucumbers feeding on this material.

Sedimentation rates of POM in shallow traps at VB ranged from a low of 42.0 ± 13.5 g (dry weight, mean ± SD) m^{-2} d^{-1} in January to a high of 93.6 ± 47.4 g m^{-2} d^{-1} in July while POM sedimentation rates in deep traps at VB ranged from a low of 35.1 ± 14.5 g m^{-2} d^{-1} in January to a high of 75.5 ± 9.48 g m^{-2} d^{-1} in April. Sedimentation rates of POM in shallow traps at GH ranged from a low of 22.5 ± 3.43 g m^{-2} d^{-1} in January to a high of 93.6 ± 8.95 g m^{-2} d^{-1} in July while POM sedimentation rates in deep traps at GH ranged from a low of 27.2 ± 6.95 g m^{-2} d^{-1} in January to a high of 80.4 ± 40.8 g m^{-2} d^{-1} in July.

Seasonal, site, and depth differences in POC levels are shown in Fig. 3. Sedimentation rates of POC in shallow traps at VB ranged from a low of 1211.4 ± 423.0 mg (dry weight, mean ± SD) m^{-2} d^{-1} in January to a high of 3122.8 ± 503.6 mg m^{-2} d^{-1} in July while POC sedimentation rates in deep traps at VB ranged from a low of 951.7 ± 181.5 mg m^{-2} d^{-1} in January to a high of 2945.3 ± 769.6 mg m^{-2} d^{-1} in November. Sedimentation rates of POC in shallow traps at GH ranged from a low of 602.4 ± 128.5 mg m^{-2} d^{-1} in January to a high of 4150.3 ± 1810.2 mg m^{-2} d^{-1} in July while POC sedimentation rates in deep traps at GH ranged from a low of 784.3 ± 2.11 mg m^{-2} d^{-1} in January to a high of 2486.9 ± 629.1 mg m^{-2} d^{-1} in April.

Feeding activities of *P. californicus* were examined in laboratory experiments designed to assess the rates of sediment ingestion and uptake of POM. Sea cucumbers that were fed natural marine bottom sediment ingested this sediment at an average rate of 9.17 g (dry wt) d^{-1} and removed POM at an average rate of 6.53 mg (dry wt) d^{-1}. From these rates, and assuming that these rates of sediment processing are representative of those in the field, it was determined that approximately 5 sea cucumbers m^{-2} would be required in VB and 4 sea cucumbers m^{-2} in GH to remove the POC produced by cultured oysters.

Feasibility of Commercial-Scale Pacific Oyster and California Sea-Cucumber Polyculture

The successful utilization of the naturally available biodeposits from cultured oysters and the significant population of sea cucumbers at the oyster farms indicate the potential for culture of *P. californicus* in a co-culture system with oysters. Polyculture of sea cucumbers with oysters resulted in significant sea-cucumber growth, which was directly related to the biodeposition of pseudofaeces/faeces below the culture rafts and the high nutritional value of this settling material. Growth rates and the assimilation efficiency for the utilization of this organic matter indicated that the biodeposits (and the associated micro-organisms) were a good food source for *P. californicus*.

With polyculture, two or more compatible aquatic species are cultured together with the objective of maximizing overall production and environmental sustainability using organisms that make use of various feeding trophic levels and niches. Integrated coastal aquaculture includes elements that may increase the utilization efficiency of food and energy sources, reduce waste nutrients among the culture components, assist in utilizing nutrients efficiently, and increase stability of the systems by reducing potential environmental impacts and producing multiple market products.

Culturing sea cucumbers with oysters could increase the efficiency in utilization of POM at the farm site with a concomitant reduction in the amount of organic carbon reaching the local benthic environment. Uptake of POM by the sea cucumbers may increase the environmental sustainability of oyster farms and co-rearing of this commercially important sea-cucumber species would increase and diversify the crop production. Growing sea cucumbers in polyculture with oysters will require little adjustment to current animal production strategies and could provide enhanced revenues resulting in improved business viability, which will not only increase the supply of sea-cucumber exports to southeast Asia, but also increase export revenues in BC.

However, no published studies have reported on the potential effects of sea-cucumber diet on meat quality, including flavour. Research will be required to determine the palatability of sea cucumbers reared on oyster biodeposits and to optimize sea-cucumber market condition. Due to the relatively long production cycle (≥3 years) for sea cucumbers and the cost of modified trays for culture, a more feasible and economical method of grow-out may be on the seafloor, directly below the oyster farms. However, basic information is required on the effects of stocking density and inter-specific competition on growth rates and survivorship of sea cucumbers corralled on the ocean floor.

Acknowledgements

This research was funded by the Aquaculture Collaborative Research and Development Program (ACRDP) of Fisheries and Oceans Canada and the Industrial Research Assistance Program (IRAP) of the National Research Council (NRC).

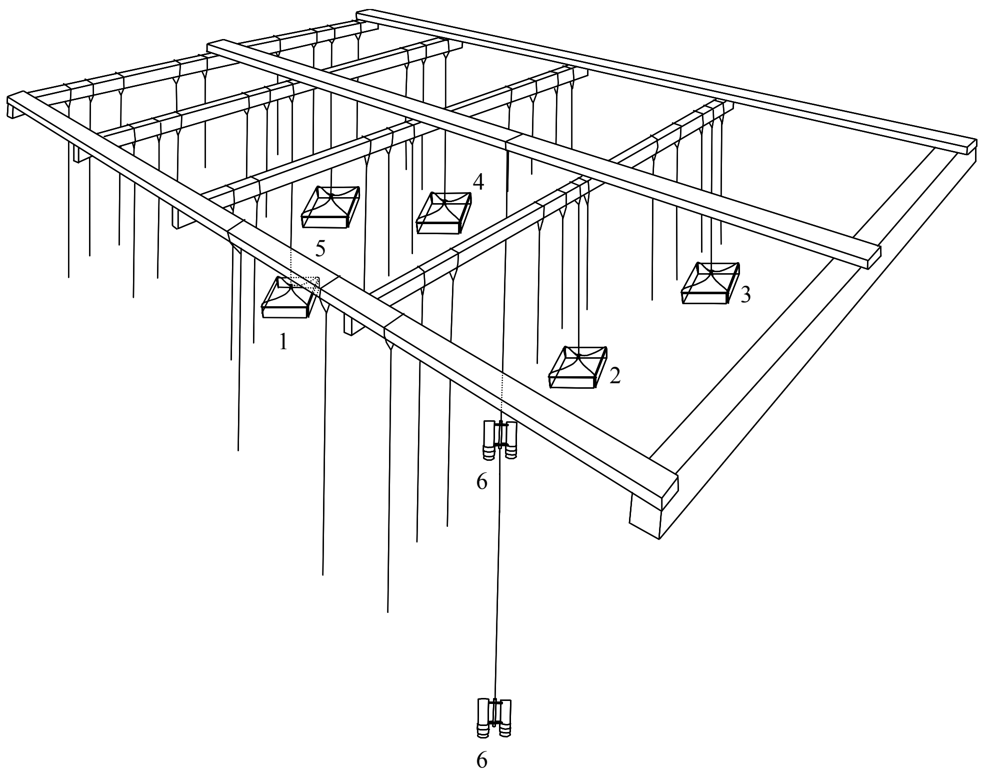

Fig. 1 Diagrammatic representation of experimental and control tray arrangement below the culture rafts. **1-4** Experimental trays; **5** Control tray; **6** Sediment traps.

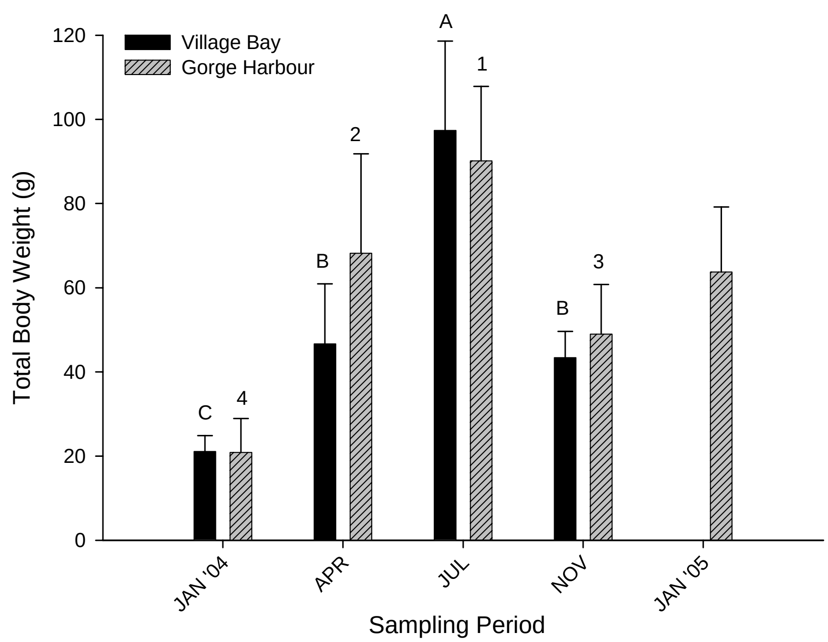

Fig. 2 Mean total body wet weights for sea cucumbers grown in trays in Village Bay (VB) and Gorge Harbour (GH) from January 2004 to January 2005. Data are combined tray means [VB (*n* = 18); GH (*n* = 18 Jan. to July 2004; *n* = 19 Nov. 2004; *n* = 17 Jan 2005)] for each sampling period and error bars indicate SD. Different letters or numbers above bars indicate significant differences among times at VB and GH, respectively.

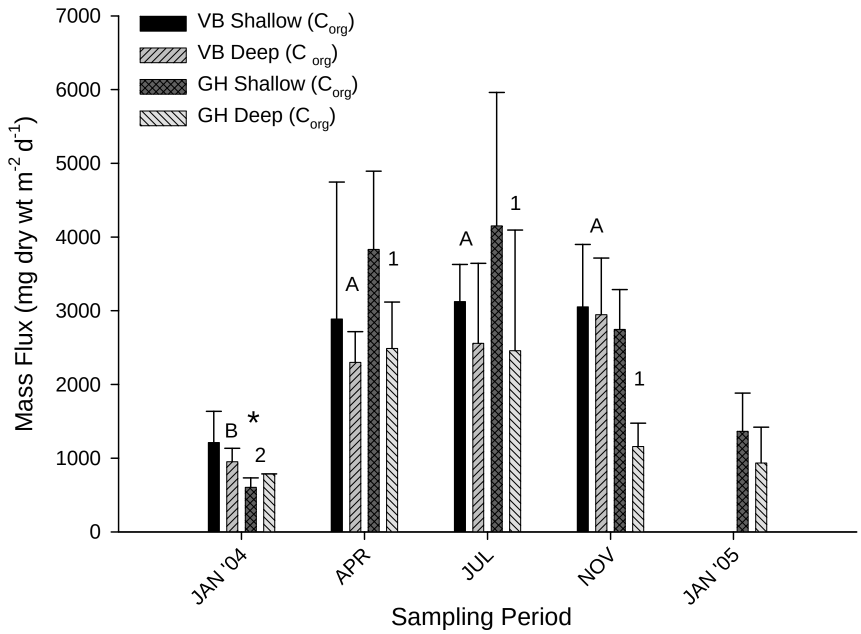

Fig. 3 Particulate organic carbon (C_{org}) flux in shallow and deep sediment traps deployed under oyster culture rafts in Village Bay (VB) and Gorge Harbour (GH) from January 2004 to January 2005. Data are means (n = 6) for both shallow and deep traps in each sampling period at both sites and error bars indicate SD. * indicates a significant site effect. Different letters or numbers above bars indicate significant differences among times at VB and GH, respectively.