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Survivorship and growth of the sea cucumber *Australostichopus (Stichopus) mollis* (Hutton 1872) in polyculture trials with green-lipped mussel farms

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Abstract

The suitability of the common New Zealand sea cucumber *Australostichopus mollis* to polyculture with green-lipped mussels was investigated in a six-month field study. Sea cucumbers were caged at three densities (2.5, 5 and 15 ind m^{-2}) on the seabed beneath an operating mussel farm and survivorship and growth (weight change) monitored on a monthly basis. The sea cucumbers transplanted to below an operating farm showed excellent survivorship (91.7% overall) over the period of the study and exhibited growth at densities exceeding observed natural densities. Growth was density-dependent and at the highest densities appeared to be constrained by food limitation. *A. mollis* held at 2.5 and 5 ind m^{-2} gained 15.37%±5.33 (mean±SE) and 13.16%±3.42 of their pre-caged body weight, respectively, while those caged at a density of 15 ind m^{-2} showed a 0.21%±2.12 weight loss over the six-month trial. In addition, the acceptability of mussel farm-impacted sediment as a food source was investigated in tank-based feeding experiments with wild-collected *A. mollis*. Adult *A. mollis* readily consumed mussel farm-impacted sediment in laboratory feeding experiments, consuming 6.70 g±1.59 (mean±SE) wet weight mussel sediment d^{-1}. These results clearly indicate that *A. mollis* is an ideal candidate for polyculture with green-lipped mussel farms.
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Keywords: *Stichopus mollis*; Polyculture; Sediments; Mussel farms; Sea cucumber; Waste conversion

1. Introduction

Mussel farming causes large scale biodeposition as a result of mussel feeding. This deposition causes a suite of profound changes to the sedimentation regime and characteristics, in particular alteration of the sediment chemistry below the farm (Dahlbäck and Gunnarsson, 1981; Kaspar et al., 1985; Hatcher et al., 1994; Grant et al., 1995; Christensen et al., 2003). This alters the conditions experienced by benthic organisms and can lead to significant shifts in the composition of associated benthic communities (Kaspar et al., 1985; Grant et al., 1995; Hartstein and Rowden, 2004). These impacts are of concern as they represent degradation of large areas of coastal habitat and such concerns have stimulated interest in finding methods of reducing the impact of farming activities. One potential ecological solution is the polyculture of another species with mussel farms in order to reprocess or remove some of the waste produced. The environmental benefits of successful polyculture are decreased nutrient and waste output and

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reduced feeding requirements within aquaculture systems (Neori et al., 1998; Lutz, 2003). Bivalve culture can improve water quality and reduce nutrient loads in both marine and freshwater finfish pond culture (Swingle, 1968; Shpigel and Blaylock, 1991). Zhou et al. (2006) also reported small reductions in organic content and nutrient concentrations in scallop lantern net waste in polyculture with *Apostichopus japonicus*.

There has been increasing interest in the potential of polyculturing deposit-feeding sea cucumbers that have the capability of consuming sediments impacted by aquaculture activities, thereby reducing the associated impact on the benthos and potentially producing a valuable secondary product. These organisms have previously been suggested as suitable candidates for polyculture with filter-feeding bivalves and finfish (Inui et al., 1991; Wu, 1995). They process large amounts of sediments and represent a high value food crop. There are several examples of successful polyculture trials involving sea cucumbers. Ahlgren (1998) reported increased growth of sea cucumbers in polyculture with salmon and consumption of salmon waste and fouling on cages. Kang et al. (2003) showed that *A. japonicus* grows well in polyculture with the charm abalone *Haliotis discus hannai*, while Zhou et al. (2006) reported that *A. japonicus* grows well and reduces organic waste indicators when polycultured with scallops in lantern nets. *A. japonicus* is also grown in polyculture on a commercial scale with shrimp in land-based ponds in China, although there is no information available regarding the ecological benefits of this practise (Yaqing et al., 2000).

The common New Zealand sea cucumber *Australostichopus mollis* is relatively abundant around the New Zealand coast in a range of habitats from shallow rocky reef to mud seafloor at depths exceeding 100 m (Pawson, 1970). The species has recently been reclassified in the new genus *Australostichopus* on the basis of biochemical and morphological differences to other members of the genus *Stichopus* (Moraes et al., 2004). This species also feeds on organic-rich sediments and is a valuable food and food extract crop. *A. mollis* is included in the New Zealand fisheries quota management system (QMS) with a total allowable commercial catch of 22 tonnes for the entire fishery. Small scale export fisheries for *A. mollis* existed in Fiordland and Marlborough in New Zealand's South Island, and a "cottage" fishery exists to supply the small domestic market in New Zealand. The species can yield returns of up to US$12/kg greenweight if appropriately processed. Sea cucumbers are a valuable food item and dietary supplement in the People's Republic of China, Hong Kong, Taiwan, Singapore and Korea (Conand, 2000). The high value of sea cucumber in the international fish trade – up to US$60/kg at market for the premium species – ensures that fisheries are heavily exploited as part of the traditional and commercial fisheries which exist in many coastal nations. The species which are commercially fished show rapid depletion, species are generally fished out in descending order of value (Toral-Granda and Martínez, 2000; Uthicke, 2000). In the light of the promised financial rewards of harvesting, the current low exploitation of *A. mollis* appears unlikely to continue. It is the combination of factors such as commercial value and ability to feed on enriched sediments that make *A. mollis* an ideal candidate for a pilot polyculture system with green-lipped mussels.

As green-lipped mussel culture exclusively uses longline methods, any polyculture undertaking will involve maintaining the sea cucumbers directly on the seafloor below the farm. Consequently, polycultured animals will be exposed to enhanced sedimentation, altered nutrient availability, altered inorganic nutrient fluxes and possibly anoxia (Hatcher et al., 1994; Christensen et al., 2003; Hartstein, 2003). It is unknown how these conditions will affect the survival and growth of *A. mollis*.

This study investigated the potential of a novel polyculture system combining *A. mollis* and green-lipped mussels. The primary aim of the research was to investigate the initial potential of sea cucumber farming techniques for reducing or limiting the benthic impacts caused by mussel farms in New Zealand while producing an additional crop at low cost. Experimental work focussed directly on two aspects critical to any polyculture undertaking: 1) examining the survivorship and growth of *A. mollis* in the conditions beneath operating mussel farms, and 2) investigating suitable stocking densities at farm sites, as compared to observations of natural densities.

2. Materials and methods

2.1. Study area

Experiments were carried out in Kennedy Bay (S 36°40′ E 175°34′), Coromandel Peninsula, northeastern New Zealand. The bay has an area of approximately 3.9 km^2 and opens to the east through a 0.9-km mouth. The bay is relatively sheltered in all but direct Easterly weather conditions and has a low current regime (Gribben et al., 2004; Kelly et al., 2004). Situated at the northern end of the bay is a green-lipped mussel (*Perna canaliculus*), farm consisting of 5 farm blocks covering a total of 0.19 km^2 (19 ha). Two caging sites were established within the bay, an experimental caging site located in the centre of the green-lipped mussel farm and a control caging site situated

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