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Original Article

Improving inland culture performance of juvenile sea cucumbers, *Holothuria scabra*, by co-culture with red tilapia

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Abstract

Holothuria scabra are tropical sea cucumbers that are widely distributed in the Indo-Pacific Ocean and are considered to be a delicacy in China, Japan, Korea, Hong Kong, and Taiwan. Since they can be easily harvested in the wild, populations in sea beds around Thailand have been decreasing. This problem has led to the construction of hatcheries and growout facilities in order to effectively culture these high-priced species. However, there is a disadvantage in farm-grown production of these species due to its slow growth as it usually takes two years from hatching to marketable size. To increase its growth rate, we have tried co-culturing *H. scabra* with red tilapia under 30 ppt seawater. We found that growth and survival of the sea cucumbers was significantly higher when being co-cultured than when being cultured alone, while the growth rates of red tilapia showed no change or showed an increase. This co-culture would be a strategy to improve inland culture performance of *H. scabra*, during which income from growing red tilapia is achieved.

Keywords: *Holothuria scabra*, sea cucumber, red tilapia, co-culture, biodeposit

1. Introduction

The sea cucumber *Holothuria scabra*, or sandfish, is distributed naturally in the seabeds of several tropical countries, including the Gulf of Thailand and Andaman Sea. This high-priced species is consumed widely in China, Japan, Korea, Hong Kong, and Taiwan (Conand, 1990; Akamine, 2004), and has been caught from the wild, dried (known as *beche-de-mer*), and exported to these countries for many years. This unfortunate practice has led to a scarcity of *H. scabra* in the seabeds around these countries. The alarming rate of sandfish depletion in the seawater around these areas has lead to the construction of hatcheries designed to produce *H. scabra* seeds so that they can be placed in natural seawater to help replenish those that have been caught. With this purpose in mind, hatchery-produced larvae of *H. scabra* are raised to 30-40 g juveniles, a size that can be safely stocked in growout ponds or sea pens (Purcell and Simutoga, 2008). Since the growth rate of *H. scabra* is naturally slow, we hoped to enhance the growth rates of sandfish by co-culturing *H. scabra* juveniles with red tilapia juveniles. Red tilapia is another economic species that have already been cultured for commercial purposes in Thailand and in many countries; these fish are a special strain of red tilapia that grows well in 30ppt seawater [Charoen Pokphand Foods (Public) Company]. A favorable result of this co-culturing is reported herein.

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2. Materials and Methods

A round plastic pond having a diameter of 12 m and a depth of 1 m of seawater was used in this experiment. The pond was laid with a sand substrate having a depth of 10 cm and was aerated using sand-immersed air stones placed at the center (circular-air system). Additionally, airlifts were placed at the periphery of the pond (air-lift system). It was divided into 8 compartments that were separated by net cages made of 3mm mesh (Figure 1). Within each 5.4-m^2 compartment, *H. scabra* and red tilapia juveniles were stocked as shown in Table 1.

H. scabra juveniles were produced from a hatchery located in the Shrimp Genetic Improvement Center (SGIC), Chaiya District, Surat Thani, Thailand, and were raised from larvae to juveniles using techniques previously described (Battaglene *et al.*, 2002; Pitt and Duy, 2004; Agudo, 2006). The sandfish were stocked at 3.7 individuals/m^2 and their body weight (BW) varied from 12 to 20 g.

Red tilapia juveniles (*Oreochromis niloticus* x *O. mossambicus*) were obtained from Charoen Pokphand Foods (Public) Company. The experiments were divided into three trials; in the first trial, the BW of the fish was approximately 100 g, while in the second and third trials, it was 30-40 g. The red tilapia juveniles were fed with commercial pellets at the rate of 4% biomass per day, evenly divided into three meals as recommended (Cruz and Ridha, 1991). In groups 2, 3 and 5 (Table 1) that stocked *H. scabra*, shrimp feed No.1 [Charoen Pokphand Foods (Public) Company] was also provided for the sea cucumber at the rate of 2% biomass per day. Water quality was monitored bi-weekly using test kits [Charoen Pokphand Foods (Public) Company] to ensure optimum conditions (dissolved oxygen 5.0-5.5 ppm, pH 7.5-8.0, alkalinity 140-160 ppm, total ammonia nitrogen < 0.5 ppm, total nitrite <0.2 ppm, and salinity at 28-30 ppt) for one-month. The experiments were completed in three trials with a two-week interval occurring between trials, and were performed on different sets of red tilapia and sea cucumber.

At the end of experiment, the final BW of each replicate in the three trials, of red tilapia and *H. scabra*, were compared with their respective initial BW. Additional focus was on *H. scabra* performance by calculating survival, average daily growth (ADG), coefficient of variation of the final BW (CV) and biomass increase. The ADG was calculated as: (final BW-initial BW)/30 and expressed as g/d. The biomass increase was calculated as: (final biomass – initial biomass)/initial biomass.

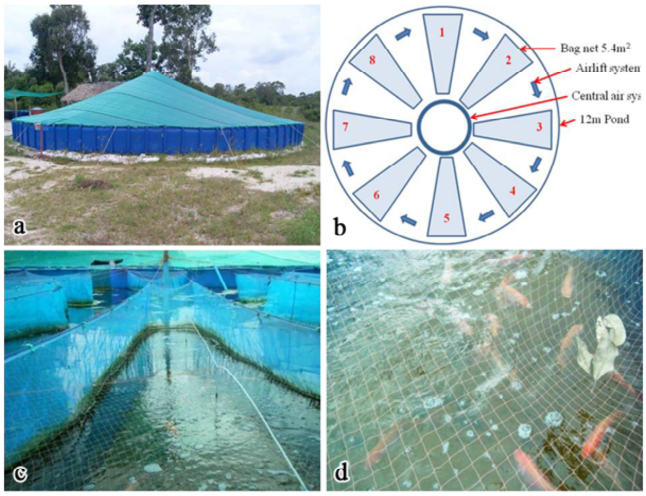

Figure 1. A round plastic pond with 12m diameter and 1m water depth used in the co-culture of sea cucumber *Holothuria scabra* and juvenile red tilapia (a). The animals were stocked, either alone or together in separate bag nets (b, diagram; c & d, pictures). The water was aerated with air stones, arranged as central-air and air-lift systems.

Quantitative data are presented as mean ± SD (standard deviation). Data were analyzed by one-way ANOVA and differences between the means were accessed by Duncan's new multiple range test. Probability values of $P<0.05$ were considered statistically significant.

3. Results and Discussion

The BW and survival of red tilapia and sea cucumber in the co-culture of the three trials is shown in Figure 2. In all trials, the initial BW of red tilapia and sea cucumber in all groups were not statistically different. At the end of the experiment the fish in all groups and all trials had a 100% survival rate. One replicate of fish in group 4 (stocking at 4.6 ind/m^2 and co-cultured with sea cucumber) in trials 1 and 3 had significantly ($P<0.0001$) higher BWs than those in other

Table 1. Grouping of sea cucumber *Holothuria scabra* and red tilapia, stocked in a 12m round plastic pond. f, fish; N, number of animals; Rep, replication number; sc, sea cucumber

Group	Stocking	N x Rep
1	Only red tilapia, at 2.3 ind/m^2	10 x 1
2	Only red tilapia, at 4.6 ind/m^2	20 x 1
3	Sea cucumber, at 3.7 ind/m^2 + red tilapia, at 2.3 ind/m^2	(16 sc + 10 f) x 2
4	Sea cucumber, at 3.7 ind/m^2 + red tilapia, at 4.6 ind/m^2	(16 sc + 20 f) x 2
5	Only sea cucumber, at 3.7 ind/m^2	16 x 2

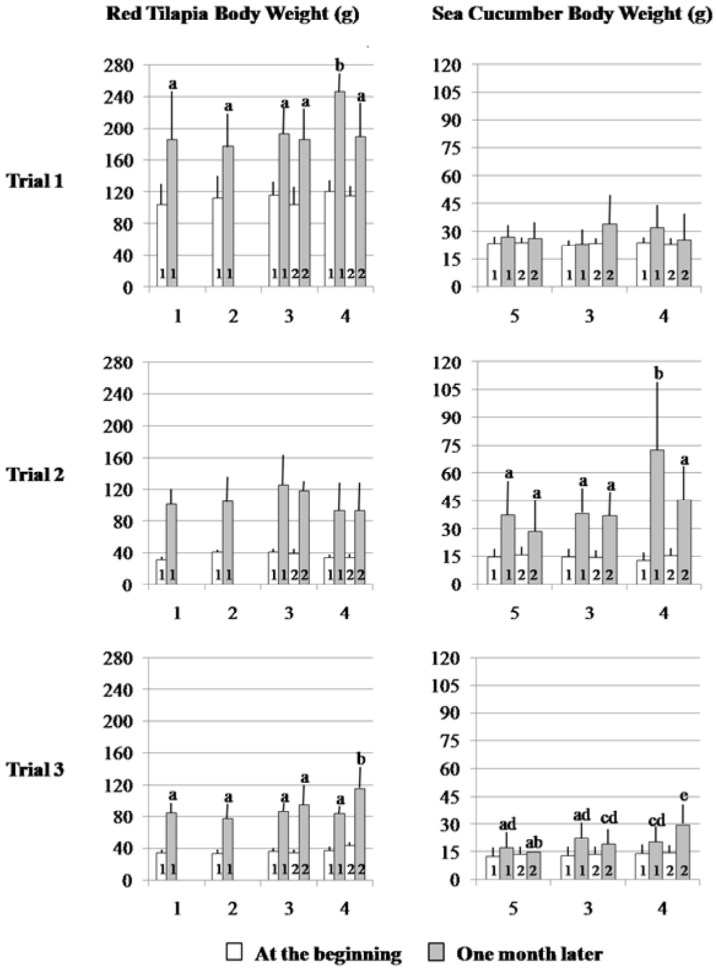

Figure 2. Body weights of red tilapia and sea cucumber *Holothuria scabra* in mono- or co-culture. The numbers of the X-axis are the following groups in culture:
1, only red tilapia, at 2.3 ind/m^2; one replicate
2, only red tilapia, at 4.6 ind/m^2; one replicate
3, sea cucumber, at 3.7 ind/m^2 + red tilapia, at 2.3 ind/m^2; two replicates
4, sea cucumber, at 3.7 ind/m^2 + red tilapia, at 4.6 ind/m^2; two replicates
5, only sea cucumber, at 3.7 ind/m^2; two replicates
Number 1 and 2 in the bar graphs are replicate number. Different superscripts indicate statistical significance ($P<0.0001$).

groups, while the BWs of other groups, that were either cultured alone or were co-cultured with sea cucumbers, did not differ statistically. These findings suggest that red tilapia grew at either equal or at a higher rate when being co-cultured with sea cucumbers when compared to those being mono-cultured.

The sea cucumber replicates in group 4 (being co-cultured with red tilapia at 4.6 ind/m^2) in trials 2 and 3 had significantly ($P<0.0001$) higher BWs than those that were cultured alone (Figure 2). One replicate in group 3 (being co-cultured with red tilapia at 2.3 ind/m^2) in trial 3 also had significantly ($P<0.0001$) higher BW than one replicate of sea cucumber in mono-culture. In trial 2, the BW of the sea cucumber seemed to be higher than that in 1 and 3 but we made no attempt to compare them statistically as it was not meaningful scientifically. The overall survival of the sea cucumber in all trials was comparable, therefore the higher BW in trial 2 cannot be explained by the survival (as low survival or low stocking density usually results in high growth rate). It is possible that different batches of *H. scabra* and different period of stocking (under different environment) might result in different growth rates. Table 2 shows values (means ± S.D.) of survival, ADG, CV of the body weights and biomass increase in *H. scabra* being cultured alone or with red tilapia. Data from the three trials were combined since the initial body weights of the sea cucumber from the three trials were comparable. Survival of *H. scabra* co-cultured with red tilapia was significantly ($P<0.05$) higher than that of *H. scabra* when cultured alone. Increasing survival rates and BWs of the sea cucumber co-cultured with red tilapia

Table 2. Survival, average daily growth (ADG), coefficient of variation (CV) in the body weights, and increase in biomass of *Holothuria scabra* being mono-cultured or co-cultured with red tilapia. Biomass increase is calculated as: (final biomass-initial biomass)/initial biomass. Values = means ± S.D., calculated from three trials combined. Different superscripts in the percentage of survival indicate statistical significance (P<0.05).

	Stocking alone	Stocking with red tilapia	
		at 2.3 fish/sq.m.	at 4.6 fish/sq.m.
Survival (%)	75.0 ± 20.2^{a}	95.8 ± 7.6^{b}	94.8 ± 6.1^{b}
ADG (g/d)	0.27 ± 0.28	0.40 ± 0.31	0.68 ± 0.72
CV (%)	35.25 ± 14.56	38.28 ± 5.72	42.04 ± 8.90
Biomass increase	0.17 ± 0.70	0.75 ± 0.70	1.29 ± 1.59

resulted in an increase in biomass which was about 7.6 times that of *H. scabra* when cultured alone. Due to high variations in BWs of the sea cucumber, as evidenced from the high CV of the BWs, the biomass increases did not differ statistically. High variation in BWs of the sea cucumber is possibly due to the amount of sand being ingested and water accumulation in the respiratory tree of the individual animals (Sewell, 1987, cited by Slater and Carton, 2007). The ADG observed also revealed an approximately 2-3 times faster growth rate, although the values did not differ statistically. The ADG of the control group (mono-culture) was similar to that reported elsewhere (Battaglene *et al.*, 1999; Pitt and Duy, 2004).

The reason the sea cucumber grew and survived better when being co-cultured with red tilapia could be the bio-deposition in the sand bed. It is less likely due to any difference in water qualities since the animals were in the same pond, and the water flowed freely among the cages. This bio-deposition could be from fish excretion, left-over fish feed, or changes in the sediment chemistry. These results appear to be consistent with reports on sea cucumbers co-cultured with other aquatic species, including salmon (Ahlgren, 1998), abalone (Kang *et al.*, 2003), scallops (Zhou *et al.*, 2006), marine shrimp (Purcell *et al.*, 2006), mussels (Slater and Carton, 2007), and oysters (Palzat *et al.*, 2008). When bio-deposit sediments occur from green-lipped mussel, sea cucumbers *Australostichopus mollis* grew faster despite having a higher stocking density than is found under natural conditions in sea beds (Slater and Carton, 2007). This suggests that co-culture with selective species could allow higher stocking density of sea cucumbers than previously suggested (Agudo, 2006), without compensation for its growth rate. Sea cucumbers were found to feed on bio-deposits from bivalves in lab-scale experiment as well (Zhou *et al.*, 2006: Slater and Carton, 2007).

Co-culturing of *H. scabra* and red tilapia juveniles has another practical significance. Red tilapias require good nursery care from 0.35g fry to 100 g size as mortality is usually high at this stage (Withyachumnarnkul, pers. observation). After 100 g size, the fish can be stocked in growout facilities without much problem. At nursery stage, it is important that the fish should be reared in a relatively good environment, and being co-cultured with *H. scabra* that feed on bio-deposits from the fish will improve the water quality to a certain extent. These studies revealed that both *H. scabra* and red tilapia have mutual benefits when being co-cultured.

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