The influence of commercial diets on growth and survival in the commercially important sea cucumber *Holothuria scabra* var. *versicolor* (Conand, 1986) (Echinodermata: Holothuroidea)

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Abstract

There has been enormous commercial interest in culturing tropical sea cucumbers in countries where sea cucumber populations have been overexploited. The production of sea cucumber juveniles in the hatchery requires suitable feeds to maximize survival rates and promote somatic growth. However, so far no research has evaluated the relative efficacy of commercially available feeds for promoting somatic growth and survival for the commercially important sea cucumber *Holothuria scabra* var. *versicolor*. Therefore, several experiments were conducted in the hatchery to evaluate somatic growth of newly settled six-week-old *H. scabra* var. *versicolor* juveniles.

Four commercially available feeds (Algamac 2000, Algamac protein plus, *Spirulina* and *Dunaliella* gold) were used to feed six-week-old juveniles, which averaged 1.7 mm in length at the beginning of the experiments. Juveniles were fed once a day at 3% of their initial body weight. Total body length and survival rates were measured at the end of every week. Significant differences in growth and survival were noticed among juveniles in the four feeding treatments. While Algamac protein plus induced good growth rates in golden sandfish as an individual feed, a mixed feed (Algamac 2000 and Algamac protein plus at 1:1 ratio) produced greater growth rates and survival.

Introduction

Sea cucumbers are harvested worldwide for their body wall (beche-de-mer), with the majority of product being exported to Asia. The rising demand for beche-de-mer product in Asian markets has created mounting harvest pressure on natural populations of sea cucumbers, which has led to severe overfishing throughout the world (Hamel et al. 2001; Conand 2004; Lovatelli et al. 2004; Uthicke 2004). In recent years, there has been a significant decline in natural sea cucumber populations in almost all countries that harvest them (Conand 2004).

Depletion of highly commercial natural stocks has encouraged aquaculture programmes for tropical holothurians (Battaglene et al. 1999; Conand 2004; Lovatelli et al. 2004; Pitt and Duy 2004; Giraspy and Ivy 2005; Ivy and Giraspy 2006; Agudo 2006). Stock enhancement of sea cucumbers, through the release of hatchery reared juveniles, has been suggested as a good solution to restore depleted populations (YSFRI 1991; Yanagisawa 1996; Battaglene and Seymour 1998).

The tropical sea cucumber *Holothuria scabra* var. *versicolor* (market name: golden sandfish) (Fig. 1), a holothurian believed to have aphrodisiac and medical properties, is an economically important species in Asian markets (Conand 1990, 1997; Conand and Byrne 1993). This species has long

Figure 1. *Holothuria scabra* var. *versicolor* – three color morphs (Image: D.A.B. Giraspy)

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been exploited as an important fishery resource in Australia and Pacific nations (Conand 1990, 1997, 2004). High-quality, golden sandfish beche-de-mer fetch more than USD175/kg on the Singapore market.

Economically feasible methods for mass producing *H.scabra* var. *versicolor* have been developed for the first time at Bluefin Sea Cucumber Hatchery (Ivy and Giraspy 2006). Successful production of *H. scabra* var. *versicolor* juveniles during 2005 facilitated the commercial culture of this species in Australia (Ivy and Giraspy 2006).

A major determinant of the viability of sea cucumber grow-out operations in the hatchery is the use of suitable feed for enhancing somatic growth and survival of juveniles in nurseries before releasing them into grow-out ponds or sea ranching. One of the problems encountered in this culture method is that there is no specific diet for small juveniles.

Several studies on nutrition and artificial diets have focused on larvae and juveniles of the temperate species *Stichopus japonicus* (Sui et al. 1986; Sui 1988, 1989). A few studies have also investigated artificial feeds for growing juvenile of other tropical sea cucumbers (Battaglene et al. 1999; Rasolofonirina and Jangoux 2004; Purcell 2005; Asha and Muthiah 2007), but no research has examined the most effective feed to promote growth and survival in *H. scabra* var. *versicolor* juveniles.

As part of commercially growing these golden sandfish juveniles to a size suitable for release into sea ranching areas, several experiments were carried out to promote the growth of settled juveniles. This study is part of an ongoing investigation to promote the somatic growth and survival rates of sea cucumber juveniles using artificial diets, and to identify the specific diet suitable for different species of sea cucumbers cultured in the hatchery. The present study examined the effect of four different commercial feeds on the growth and survival of juvenile *H. scabra* var. *versicolor.*

Materials and methods

The proximate compositions (i.e. total protein, lipid and carbohydrate) of four commercial feeds used in this study are shown in Table 1.

Experiment 1: Effect of food type on the growth and survival of sea cucumber juveniles

To determine the effect of commercial feeds on the survival and growth of early juveniles, twelve 44-L plastic containers were stocked with randomly selected six-week-old *H. scabra* var. *versicolor* juveniles. Dietary treatment setup consisted of 720 randomly selected juveniles from the same batch divided equally among the 12 containers. Sea cucumber juveniles were fed at 3 % of their initial body weight in triplicate containers. The mean length of juveniles stocked was 1.7 mm at the start of the experiment in each of the containers.

The lengths of a sub-sample of 15 juveniles from each diet treatment were measured at the start of the experiment and at the end of every week during the experiment. The survival rates in different treatments were also determined at the end of each week and the percentage calculated.

Experiment 2: Effect of stocking density on growth and survival of sea cucumber juveniles

The effect of *H. scabra versicolor* juvenile stocking density on survival and growth was determined by stocking randomly selected six-week-old (mean length of 1.7 mm) golden sandfish juveniles at different densities. The three stocking densities used were 60, 90 and 120 juveniles in each 44-L container. The feeding regime was Algamac protein plus and

Table 1. Composition of commercial feeds.

Feed	Ingredient	Composition (%)				
		Protein	Fat	Carbo-hydrate	Minerals (ash)	Moisture
Algamac 2000	Spray dried cells of Schizochytrium algae	39.0	32.0	13.0	12.0	3.0
Algamac Protein plus	Heterotrophic and phototrophically produced algae, fungi and yeast cells.	42.9	21.0	-	12.4	6.0
Spirulina powder	Highly nutritious blue-green algae	57.0	8.0	24.0	6.2	2.1
Dunaliella gold	Nutrient-dense edible soft wall marine microalgae	7.4	7.0	29.7	49.0	3.0

Algamac 2000 (1:1 ratio) at 3% initial body weight each day. All treatments were made in triplicate and the feeding rate was maintained the same throughout the experiment.

Juvenile rearing conditions

Rearing conditions were similar in all experimental containers and were not artificially controlled. The seawater used in the experiment was one micron filtered and UV sterilized. A 50% water exchange was conducted every day and containers were cleaned weekly with minimal disturbance to the animals. Aeration was provided continuously and the oxygen level was always maintained above 5.5 mg L^{-1}. Seawater temperatures ranged between 24 ºC and 27 ºC, and salinity fluctuated between 34 ppt to 35.5 ppt during the experiments. The pH value was constant throughout the experiment and the photoperiod was maintained at 14 L:10 D.

Results

Juvenile growth

At the start of the experiments, there were no differences in body lengths of test sea cucumber juveniles among diet treatments (Table 2). However, at the end of the experiments, final body lengths of test animals in different treatments varied considerably (Figs. 2 and 3). Mortality rates of juveniles were high during the first three weeks in all the four treatments.

In single diet treatments, juvenile growth rates were greatest in containers fed with Algamac protein plus, with juveniles reaching a mean length of 46.8 ± 3.6 mm (Fig. 2). Juveniles fed with Algamac 2000 and *Dunaliella* gold reached 34.7 ± 2.6 and 33 ± 4.1, mm respectively. Juveniles fed with *Spirulina* grew to a mean length of 18.6 ± 2.9 mm (Table 2).

Daily growth rates of test sea cucumbers varied with different diet treatments and showed a descending order of diet: Algamac protein plus > Algamac 2000 > *Dunaliella* gold > *Spirulina* powder. Juvenile growth rates on Algamac protein plus was 0.65 mm per day, while it was 0.24 mm per day with *Spirulina*.

Stocking density

The effect of stocking density on the growth and survival of golden sandfish juveniles was quite noticeable in this experiment. Juveniles stocked at a lower density grew to 41.7 mm ± 4.2 in two months time.

This is 12.6 mm more than those juveniles stocked at medium density, and 23.1 mm than those stocked at higher density in eight weeks (Fig. 4). Juveniles stocked at a lower density showed an increase of 0.71 mm per day, while juveniles stocked at medium and high densities grew 0.49 mm and 0.30 mm per day, respectively (Fig. 5)

Table 2. Initial and final growth data for golden sandfish, *H. scabra* var. *versicolor*, early juveniles fed with four different commercial diets.

Feed type	Replicate no.	Total length	
		Start (mean ± s.e)	End (mean ± s.e)
Algamac 2000	3	1.7 ± 0.4	34.7 ± 2.6
Algamac protein plus	3	1.7 ± 0.3	46.8 ± 3.6
Spirulina powder	3	1.7 ± 0.3	18.3 ± 2.9
Dunaliella gold	3	1.7 ± 0.4	33.0 ± 4.1

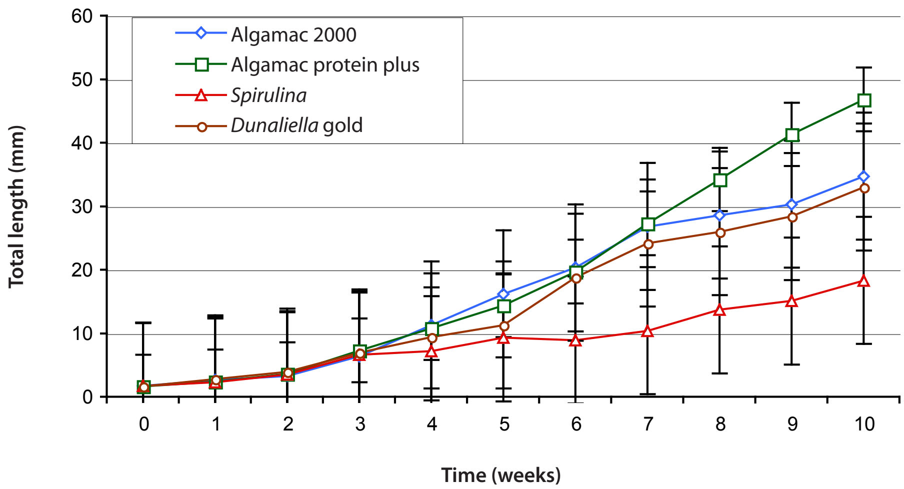

Figure 2. Mean growth of juvenile golden sandfish, *H. scabra* var. *versicolor* fed with commercial feeds.

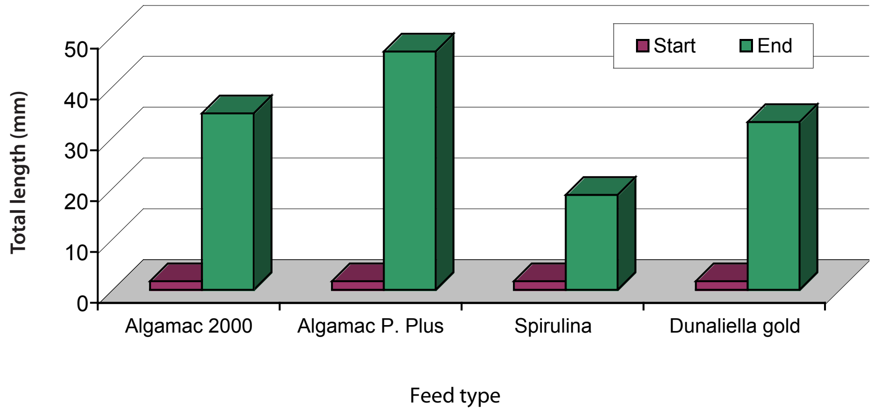

Figure 3. Initial and final body lengths of juvenile golden sandfish *H. scabra versicolor* fed with commercial feeds.

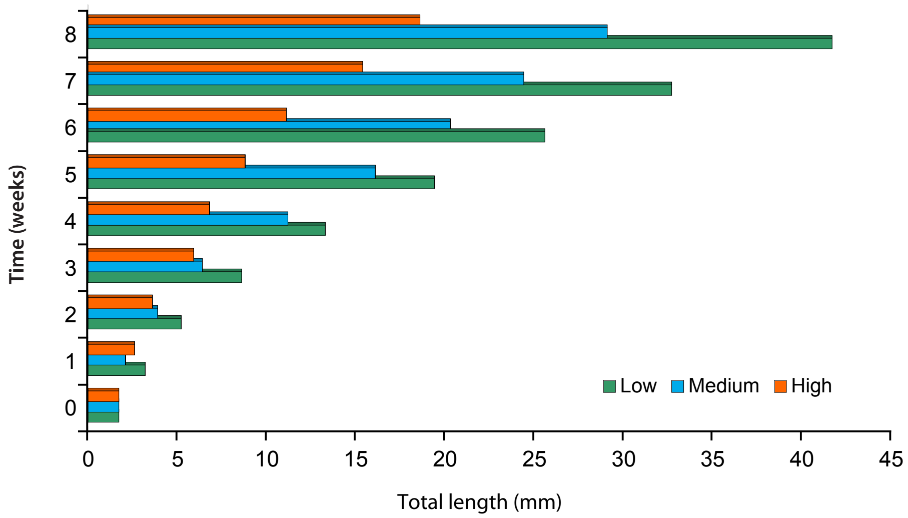

Figure 4. Mean growth of juvenile golden sandfish, *H. scabra* var *versicolor* maintained at different densities.

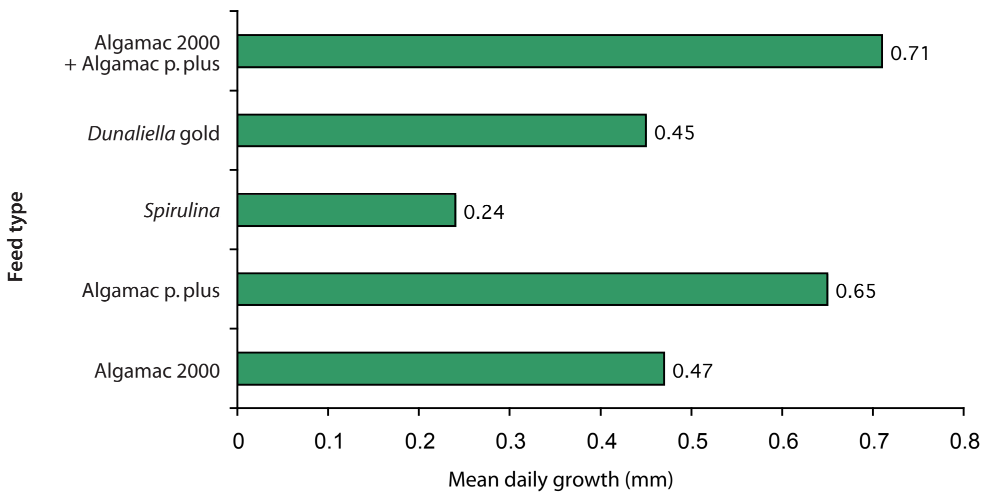

Figure 5. Daily growth rate of juvenile golden sandfish, *H. scabra* var. *versicolor* fed with five different types of feed.

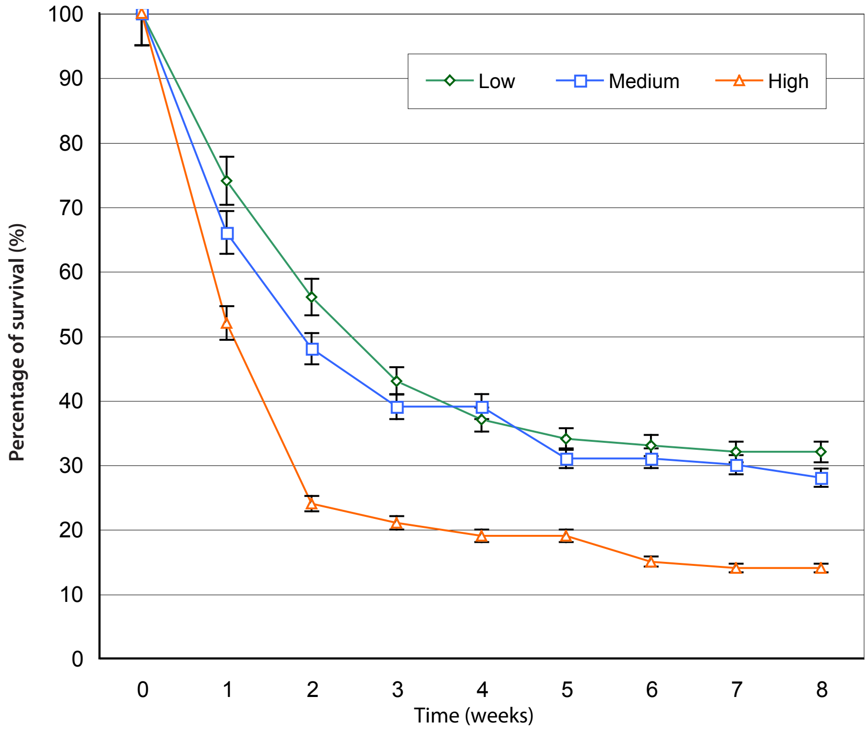

Figure 6. Survival rates (%) of *H. scabra* var *versicolor* juveniles. Juveniles were reared in three different densities: low, medium and high.

The mean percentage survival of *H. scabra versicolor* juveniles varied greatly at low, medium and high densities (Fig. 6). At the end of the experiment, the percentage of survival at low density was 32%, and was 28% and 18% at medium and high densities, respectively. More than 50% of juvenile mortality occurred during the first three weeks of the experimental period. Juveniles in all treatments showed differential growth, irrespective of the density and feed type (Fig. 7).

Discussion

Early juvenile rearing is fundamentally important to commercial hatcheries that rear sea cucumbers, because juveniles are more susceptible (Ramofafia et al. 1997; Battaglene et al. 1999). Commercially available feeds used in the present investigation showed that certain commercially available microalgal feeds are effective in promoting growth and survival rates in *H. scabra versicolor* in the nursery stage. Artificial feeds investigated in this study were selected on the basis of suitability for nursery rearing based on the commercial availability. Previous usage in the hatchery has shown better growth and survival with *H. scabra*. (Giraspy and Ivy 2005; Ivy and Giraspy 2006)

Figure 7. Differential growth observed in *H. scabra* var. *versicolor* juveniles.

Size is an important factor in survival when sea cucumber juveniles are transferred between different rearing systems, and survival rates of larger juveniles are relatively high compared to smaller individuals (Battaglene et al 1999; Purcell, 2005). In all treatments, mortality was higher during the first three weeks of the trials compared to the following weeks. The higher mortality rates in the earlier part of the experiment may be due to the smaller size (1.7 mm) of juveniles selected for the study. The survival rate of *Stichopus japonicus* — stocked at a mean length above 4 mm — was more than 60% for over 30 days (Ito 1995). Battaglene et al. (1999) in their studies observed higher mortalities of *H. scabra* juveniles mainly in the first two weeks of the experiment when stocked at a mean length of 1.5 mm.

Since the late 1980s, powdered algae have been used in the hatchery production of sea cucumber juveniles in China, Japan and India (Sui 1988; James et al. 1994; Battaglene et al. 1999). Battaglene et al. (1999) noted that *H. scabra* juveniles fed with Livic grew to a significantly greater length than those fed Algamac after four weeks. However, they did not find any significant differences in survival, total length or weight between diets at the end of the experiment. Most deposit-feeding holothurians have little cellulose activity in their gut and did not appear to assimilate macroalgae before it was decomposed by bacteria and fungi (Yingst 1976).

The present investigation clearly shows the growth differences among juveniles under different treatments. Battaglene et al. (1999) suggested that an addition of powdered algae was beneficial at high densities. Survival rates of newly settled *Stichopus japonicus* are related to stocking density and food availability (Ito 1995; Hatanaka 1996; Yanagisawa 1996; Ito and Kitamura 1997). James et al. (1994) argued that the survival of newly settled *H. scabra* might be improved by reducing competing organisms by filtration and also by providing food by conditioning plates.

The mean percentage survival of golden sandfish juveniles varied considerably in the density trial experiments. Survival rate also improved as they increase in size and age. The sea cucumber *S. japonicus* grew to a mean size of 4.3 mm up to 27.0 mm, depending on initial stocking density and culture conditions and the overall average length was 11 mm after three months (Ito 1995). In the present investigation, *H. scabra versicolor* juveniles grew faster than *S. japonicus*, to a mean length of 46.8 mm in 70 days (Table 2). *H. scabra* juveniles stocked at lower density grew significantly faster than those held at higher density (Battaglene et al. 1999). Higher survival rates (61.1 to 72.8%) were also recorded in *S. japonicus* stocked at mean lengths of 4.3–4.7 mm over 30 days (Ito 1995). Battaglene et al. (1999) found that *H. scabra* juveniles stocked at 20–31 mm in length grew 0.2–0.8 mm day per day with an overall average of 0.5 mm per day. Muliani (1993) recorded growth rates of 0.4 g day for larger *H. scabra* juveniles at initial stocking densities of 134–186 g m^{-2}, in enclosures without addition of food.

Conclusion

The present investigation has, for the first time, compared the efficacy of commercial diets in promoting growth and survival for the large-scale application in the hatchery. Results of this study validate the use of suitable commercial feeds as food for *H. scabra* var. *versicolor* juveniles in the nursery phase. Juveniles fed with a mixed diet comprising Algamac 2000 and Algamac protein plus grew more than animals fed with individual diets, indicating that this composition would be better for intensive cultivation of *H. scabra* var. *versicolor* juveniles in the nursery. The use of these artificial feeds, either full or partial (i.e. in conjunction with seagrass or seaweed extract), should be considered in order to reduce commercial production costs and to improve the survival and growth rates of juvenile sea cucumbers.

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