HATCHERY CULTURE OF *TROCHUS NILOTICUS* AND *TECTUS PYRAMIS* (GASTROPODA: PROSOBRANCHIA: TROCHIDAE) IN PHUKET, THAILAND

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ABSTRACT

Broodstocks of *Trochus niloticus* and *Tectus pyramis* were induced to spawn by the static water method. The hatchery reared juveniles were stocked at different densities in relation to surface area of algae. The growth rate of *T. niloticus* was 2.5 times higher at a stocking density of 10 juveniles m^{-2} compared to 500 juveniles m^{-2}. Survival rates of *T. pyramis* ranged from 8.7 % at a stocking density of 700 juveniles m^{-2} to 57 % at a stocking density of 10 m^{-2} after 5 months. At high stocking densities only less palatable species of algae could colonise the panels. High grazing rates caused rapid changes in algae composition and declining growth rates of juveniles. Stock assessment of both species around Phuket Island showed very low population sizes with the highest density of 31 *T. niloticus* and 25 *T. pyramis* $hectare^{-1}$, indicating that reseeding using hatchery cultured juveniles should be included in the management strategy of these species.

INTRODUCTION

The natural distribution of *Trochus niloticus* (Linnaeus, 1767) extends from Sri Lanka in the west to the Samoa Islands in the east, and from Australia in the south to Ryukyu Islands in the north (Gillett 1986; Smith 1987). The reefs of many remote Pacific islands have the basic requirements of *T. niloticus* habitats, but the surrounding ocean constitutes a dispersal barrier because larvae of *T. niloticus* are lecithotrophic with a relatively short pelagic period (Heslinga 1981a). Very little has been published about *Tectus pyramis* (Born, 1778). There has been some taxonomic dispute, regarding the taxonomic status of *T. pyramis*, but recently both traditional taxonomic methods and genetic analysis have shown that *T. niloticus* and *T. pyramis* should be placed in separate genera within the family Trochidae (Borsa & Benzie 1993). According to Cernohorsky (1972) *T. niloticus* and *T. pyramis* have similar distributions. Both species are often found sympatric in shallow water on reef flats consisting of live corals, dead coral rubble and rocks; especially where there is a good growth of algae (Parkinson 1984). *T. niloticus* grows to a maximum size of 15 cm in shell diameter (Hahn 1989) whereas *T. pyramis* grows to a maximum size of 7 cm (Cernohorsky 1972). However, slightly larger *T. pyramis* were recorded during the present survey.

Commercial fisheries for *Trochus niloticus* exist in most areas within its natural distribution in the tropical Indo-West Pacific (Appukuittan 1977; Heslinga *et al.* 1984; Zoutendyk 1989), where it is considered as the economically most important gastropod (Gillett 1986; Fagolimul & Price 1987; Smith 1987). Along the Thai coast of the Andaman Sea both *T. niloticus* and *T. pyramis* are harvested commercially, but the annual catches have decreased considerably during recent years (pers. comm. Mr. Somneuk). Further out in the Andaman Sea, close to the Andaman and Nicobar Islands, *T. niloticus* has also been over-harvested to near extinction (Daniel & Rajagopal 1969; Krishnamurthy 1996).

The aragonite shells of *T. niloticus*, primary raw material for mother-of-pearl buttons, are mainly exported to Asia and Europe. Health and shipping constraints associated with perishable products do not affect the *T. niloticus* industry due to the fact that only the dry shells are exported. This makes *T.*

niloticus an ideal resource for utilisation in remote areas. *Tectus pyramis* is also harvested for the shell (Ueng *et al.* 1984).

Because *T. niloticus* depletion has increased due to unregulated or poorly regulated harvesting in the Indo-West Pacific, resource management has been adopted. Measures have been application of restricted harvest seasons, size limits and the establishment of sanctuaries (Heslinga *et al.* 1984). If the stocks are close to extinction, restocking seems to be the only way to re-establish the populations (Heslinga 1980). Numerous studies on *T. niloticus* have examined their biology (Moorhouse 1960), distribution (Smith 1987), exploitation (Setna 1932; Carleton 1984), management (Yamaguchi 1988), and transplantation (Gillett 1986), but only a few papers have been published on the culture of *T. niloticus* and reseeding using juveniles (Heslinga & Hillmann 1981; Hoffschir 1990). The main problem concerning mass culture of the herbivorous *T. niloticus* seems to be the balance between the production of algae and the increasing food requirements of the juveniles (Hahn 1989; Heslinga & Hillman 1981). If food limitation is the main problem then the stocking density of juveniles must be a key factor, therefore the intentions of this study were to develop hatchery techniques for mass production of both *T. pyramis* and *T. niloticus*, with emphasis on optimal stocking density. To enable an evaluation of the optimal management strategy, this paper also includes stock assessments of natural populations of the two species around Phuket Island.

MATERIALS AND METHODS

In February 1996 a culture facility was constructed with seven 500 litre polyethylene tanks and four 1,000 litre fibre glass tanks with running unfiltered sea water and aeration to each tank at Phuket Marine Biological Center. The tanks were fitted with corrugated fibre glass plates (0.6 x 0.6 m), referred to as algae panels, to enhance the surface area for algae growth. The total surface was increased by adding 10 m^2 algae panels in each 500 litre tank and 20 m^2 in each 1,000 litre tank.

To produce algae the system was left for three weeks with running sea water and aeration until the sides of the tanks and algae panels were covered by a layer of mainly filamentous green algae and diatoms. During that period a broodstock of 25 adult *T. niloticus* and 30 *T. pyramis* were collected from Koh Phuket and around Koh Maiton, Koh Yao Yai, Koh Khai Nok, Koh Khai Nai, Koh Racha Yai and Koh Hi. Stock assessments of *T. niloticus* and *T. pyramis* were made at each island by searching the bottom along a transect line while SCUBA diving. The transect line was anchored to the bottom in a suitable habitat and all topshells were counted in a 4 m wide area along the transect line covering an area of 400 m^2. The transect search was repeated 4 times at each station covering an area of 1,600 m^2.

The broodstocks were kept separate in two 1,000 litre tanks and spawning was induced by the static water method (Okabe 1982). Heslinga & Hillmann (1981) found that *T. niloticus* most frequently spawned in darkness around new moon. Therefore, induction of spawning was performed in that period. During the night before new moon the broodstock of both species were kept without aeration and flowing sea water throughout the night. If spawning had not occurred during the night, the water in the spawning tanks was changed at once, and they were left with aeration and running sea water until sunset when the water flow and aeration was stopped again.

T. niloticus spawned after two days with repeated spawning induction yielding approximately 120,000 eggs. *T. pyramis* spawned after one induction yielding 140,000 eggs, estimated by counting the number of eggs in 20 subsamples of 0.25 litre. After spawning, the broodstocks were transferred to a 60 m^2 enclosure constructed on the sea bottom to preserve the algae layer in the rear-

Table 1. Parameters of water quality measured in all tanks at different depths and time of day.

	Temp. (°C)	Ph (units)	Salinity (‰)	DO (mg/l)
Average±s.d.	28.38±0.16	8.27±0.13	32.30±0.06	6.20±0.24

ing tanks. Two days after spawning, stocking densities from 100-7000 veligers m^{-2} algae covered surface was obtained by transferring known volumes of water from the spawning tanks to the nursery tanks after vigorous aeration. Because of limited tank capacity *T. pyramis* juveniles were stocked at 8 different densities whereas *T. niloticus* juveniles only were stocked at 3 different densities. Settling occurred in both species between day 3 and 5 after hatching. Stocking densities of newly settled juveniles in each tank were estimated by calculating the average number of juveniles within 20 frames of 10 x 10 cm. Growth was estimated monthly by measuring the largest shell diameter of 20 randomly chosen juveniles in each tank using Vernier callipers. After 50 days, 100 juvenile *T. niloticus* and 100 *T. pyramis* were randomly chosen from two tanks with a stocking density of approximately 500 juveniles m^{-2}, and transferred to a stocking density of 10 juveniles m^{-2} and food in excess.

Estimates of survival rates were influenced by clumping and nocturnal behaviour of the snails. Total counts of snails in two tanks showed that the estimated values based on frame-counting were slightly higher than the actual number. Both live and dead snails in these two tanks were counted to get an estimate of survival from egg.

During grow-out all tanks were cleaned frequently by the use of a siphon, and the composition of algae was recorded and analysed when major changes in composition occurred. Temperature, pH, salinity and dissolved oxygen were measured on two occasions, using a CTD in the morning and afternoon at different levels in all tanks.

RESULTS

Water quality

The parameters of water quality did not reveal any significant differences (*t*-test) between the different tanks or depths on each sampling occasion (Tab. 1). The temperature increased approximately 1 °C during the day with a water flow of 150 litres h^{-1} to each tank.

Stock assessment

Stocks were assessed around the islands where both species were most common. The densities of adult specimens are shown in Tab. 2.

Growth rates and survival

Growth rates of *T. pyramis* and *T. niloticus* were only significantly different (*t*-test) from day 48 to day 80 after hatching (Fig. 1). The survival rate of *T. niloticus* from eggs to 5

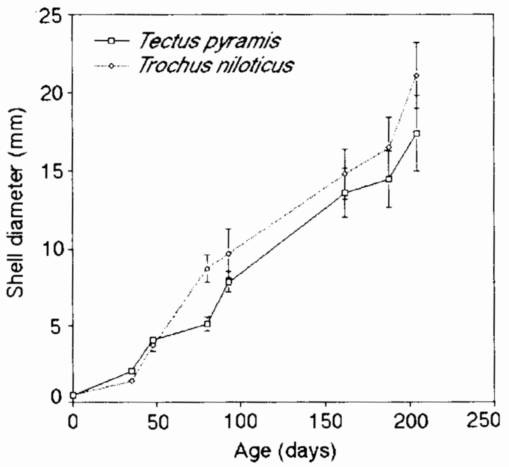

Figure 1. Growth rates of *T. pyramis* and *T. niloticus* in the hatchery at a stocking density of 10 juveniles m^{-2} during 200 days.

Table 2. Density of adult topshells at different islands based on transect sampling.

	T. niloticus/ hec±s.d.	*T. pyramis*/ hec±s.d.
Koh Maiton	6.3±12.5	18.8±23.9
Koh Kaï Nai	12.5±14.4	0
Koh Kai Nok	0	25.0±20.4
Koh Yao Yai	31.3±31.4	6.3±12.5
Koh Racha Yai	0	0
Koh Phuket, Nai Harn	0	12.5±14.4
Koh Hi	6.3±12.5	6.3±12.5

month old juveniles was 10 % at the highest density of 120 eggs litre^{-1} (or 5,000 eggs m^{-2} algae covered surface) yielding a stocking density of approximately 500 juveniles m^{-2}. The highest mortality occurred from larvae to newly settled juveniles. Based on total counts a survival rate of approximately 15 % was found for *T. niloticus* at a stocking density of 94 juveniles m^{-2}. Stocking density was negatively correlated with both survival and growth rates for both species (Figs. 3). Survival rates of *T. pyramis* ranged from 8.7 % at a stocking density of 700 juveniles m^{-2} algae covered surface to 57 % at a stocking density of 10 m^{-2} after 5 months. Optimal stocking density with respect to production of juveniles was obtained at a stocking density of approximately 530 juveniles m^{-2} with a survival rate of 15 % and a growth rate of 2.6 mm month^{-1}.

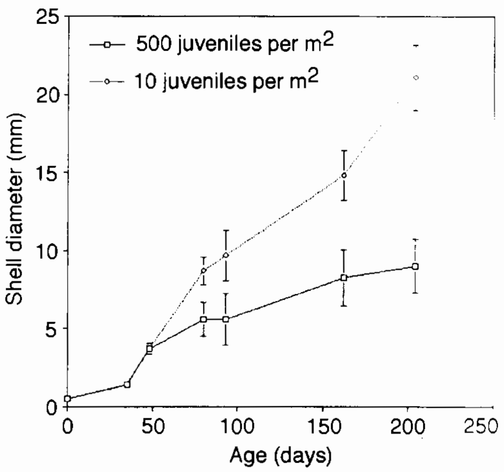

Figure 2. Growth of the same batch of juvenile *T. niloticus* cultured at a stocking density of 500 m^{-2} and transferred to 10 m^{-2} after 48 days.

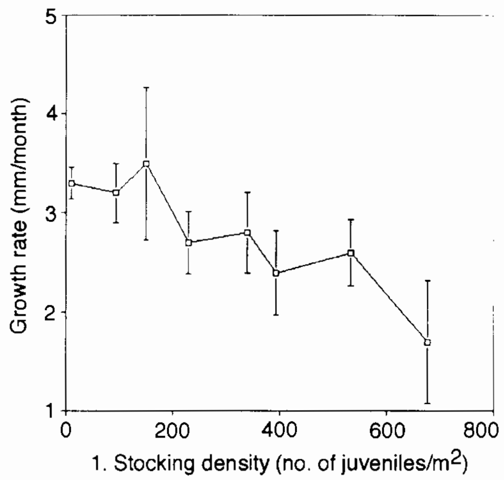

Figure 3. Growth rates of *T. pyramis* in relation to different stocking densities.

Food and feeding

During grow-out of the snails, the algae cover changed in species composition on several occasions. The algae panels were dominated by filamentous green algae, mainly (*Enteromorpha* spp.) and pennate diatoms, mainly *Navicula* spp., during the first three months after introducing the snails. Siphonate green algae were present in the tanks and were only eaten to a limited extent, because they were free floating. The first changes in algae composition occurred in the two tanks with the highest density of juveniles. A change from domination of filamentous green algae and diatoms to total domination of blue green algae (*Lyngbya* spp.) occurred in less than a week. With increasing size of juveniles these shifts occurred in all tanks after five months. This domination of *Lyngbya* spp. shifted again to tougher species of green algae (*Chladophora* spp.) and red algae (*Gracilaria* spp.) in a relatively short time during the sixth month.

DISCUSSION

I found that both *T. niloticus* and *T. pyramis* were triggered to spawn by the same method, they had a similar duration of larval phase, and mode of larval development. Stock assessment around Phuket Island showed a very low population size of both species with the highest density of 31 *T. niloticus* and 25 *T. pyramis* hectare^{-1}. In this survey, all snails were found in the upper 6 meters either on rocks or on dead corals, probably because the algae on which they feed are found in this zone. In the Pacific *T. niloticus* was rarely found in water below 10 m (McGovan 1958), and stock assessments showed considerably higher figures. Bour & Hoffshir (1985) found 176 *T. niloticus* hectare^{-1} on average at 312 surveyed sites around New Caledonia, and Sims (1985) found from 100 to 2,500 *T. niloticus* hectare^{-1} at the Cook Islands.

Hatchery culture of juvenile *T. niloticus* for reseeding has been attempted in the Pacific region with variable success (Heslinga 1979; Heslinga & Hillmann 1981). *T. pyramis* has also been produced in hatchery, but the results was unfortunately only published in Japanese (Kudo *et al.* 1994). The small population size and the limited dispersal of the larvae of *T. niloticus* and *T. pyramis* around Phuket Island make hatchery culture of juveniles for reseeding, in combination with the establishment of sanctuaries, the only reliable method to re-establish the populations. Introduction of size limitations, restricted harvest seasons, or a total ban on harvest will probably not be respected in this area due to the high demand caused by the increasing tourism.

The growth rates of *T. pyramis* and *T. niloticus* in this experiment were not significantly different, except from day 48 to day 80, but a tendency towards faster growth of *T. niloticus* was noted (Fig. 1). The growth rates were closely related to stocking densities, therefore caution should be applied when rates from different experiments are compared. Heslinga & Hillmann (1981) produced 7,000 juvenile *T. niloticus* of an average size of 7.8 mm in a 5,000 litre tank in 4 months, which equals a stocking density of around 400 juveniles m^{-2} and a growth rate of 1.95 mm month^{-1} which is similar to growth rates obtained in the present study. At a stocking density of only 10 juveniles m^{-2} the growth rate was 3.0 mm month^{-1} and the snails measured 22 mm in average shell diameter after 200 days whereas they only measured 8 mm at a density of 500 m^{-2} (Fig. 2). When *T. niloticus* was transferred from a stocking density of 500 m^{-2} to a density of 10 m^{-2}, the growth rate increased rapidly. A significant difference in average size was obtained in less than a month indicating that either food is the limiting factor or that high densities may cause stress. When the snails were exposed to food limitation for several months the growth ceased, but the mortality remained very low indicating that all energy was used to maintain themselves. After transplantation to low density and food in excess the growth rate increased rapidly. *T. pyramis* responded to increasing stocking densities similar to *T. niloticus*. In this experiment *T. pyramis* was reared at eight different stocking densities for five months after hatching to investigate the effect on growth (Fig. 3) and survival. As it could be expected, the growth rate of *T. pyramis* was highest at the lowest densities, but not significantly different at densities between 92 and 530 juveniles m^{-2}. After five months the growth rates at high densities decreased to near stagnation, indicating that food was the limiting factor. According to this experiment a stocking density of maximum 500 juveniles m^{-2} algae covered surface is recommended until five months of age. The most practical method to obtain this density is by transferring the appropriate number of pelagic veligers considering a survival rate of approximately 15 % from veliger to juvenile.

According to the measurements of the water quality there were no differences between the tanks. The nutrient level was most probably similar in the tanks since the whole system was cleaned regularly, and the same source of sea-water was used in all tanks.
The most probable cause of changes in algae composition was the food preference of the juveniles. During one year, Thapanand & Chunhabundit (1995) investigated the stomach contents of *Trochus maculatus* (Linnaeus, 1758) in Thai waters and found that *Enteromorpha* spp. was the most frequent macroalgae and that *Navicula* spp. was the preferred diatom. The surface area is the limiting factor for the filamentous algae, and if green algae, as found by Thapanand & Chunhabundit (1995), were preferred to blue green algae, then colonisation of empty space and domination would be facilitated for less preferred species of algae. When the optimal stocking density was exceeded, the production of algae could not sustain the increasing food demand of the juveniles, and less palatable species of algae could colonise the panels.
The growth of *T. niloticus* is exponential and most often fitted to the von Bertalanffy growth function (Hahn 1989; Nash 1993). Heslinga (1981b) cultured T. *niloticus* for 12 months in an *ad libitum* feeding regime. The relative increment in size peaked after six months. This is an important aspect for the selection of release size, because the investment in terms of food in juveniles increases considerably compared to the previous months in culture. After five months *T. niloticus* and *T. pyramis* will require a relatively larger amount of food, and this will reduce the optimal stocking density in the culture facility.

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