PREDATION AND MORTALITY IN A RESTOCKING PROGRAMME WITH *TRIDACNA SQUAMOSA* LAMARCK, 1918

Jens Hagelskjaer[1] & Jintana Nugranad[2]
[1] *Department of Aquatic Ecology, University of Aarhus, Denmark; e-mail: jens.hagelskjaer@get2net.dk*
[2] *Prachuap Khiri Khan Coastal Aquaculture Development Center, Coastal Aquaculture Division, Department of Fisheries, Klong Wan, Prachuap Khiri Khan 77000, Thailand*

ABSTRACT

Tridacna squamosa were cultured at the Prachuap Khiri Khan Coastal Aquaculture Development Center (CADC) and transplanted to Koh Tao, the Gulf of Thailand to study mortality during two months. Predators were identified using traps, video camera, photography and direct observation. The main predators were fish, which crushed the clams placed in cages as well as on longlines. Survival rates increased with size. Camouflage and placement of the clams were important factors for the survival.

INTRODUCTION

The uniqueness of the giant clams, which many people find amazing, is because of their size and the beautiful colours of their mantle. These colours come from both the iridophores, also called the eyes of the clam, and from the zooxanthellae. The zooxanthellae, *Symbiodinium microadriaticum*, are dinoflagellates in a symbiotic relationship with the clams and live within the blood lacunae in their mantle tissue (Svane 1996; Fankboner & Reid 1990). The giant clams are able to obtain more than 50 % of their metabolic carbon from their symbionts (Mingoa 1988), mainly as glucose from photosynthesis. However, Reid *et al.* (1984 from Fankboner & Reid 1990) have noted that if adequate levels of plankton are available for filter feeding, *T. squamosa* can survive in the absence of zooxanthellae. Simultaneous hermaphroditism is another special characteristic of tridacnids. They spawn sperm followed by eggs within a short interval to hinder inbreeding, though viable larvae can occur through inbreeding (Murakoshi & Hirata 1993).

In Thailand only three species of giant clams were commonly found: *T. maxima* (Röding, 1798), *T. crocea* Lamarck, 1819, and *T. squamosa* Lamarck, 1819 (Chantrapornsyl *et al.* 1996). Because of over exploitation by fishermen and collectors of souvenirs *T. squamosa* has been driven to near extinction. This has triggered restocking programmes where biologists have succeeded in breeding *T. squamosa* through aquaculture (Nugranad *et al.* 1997). A major obstacle is the high mortality after release into their natural environment (Munro 1993; Heslinga *et al.* 1984; Svane 1996). The aim of this project was to identify the main predators and the way they killed the tridacnids. When the predators are known, future reseeding programmes can be better protected from major mortality due to predation. This implied investigation of the size of *T. squamosa* suitable for release.

MATERIALS AND METHODS

The site for the study of predation was located 250 m offshore from the building of the Fishery Patrol on the island of Koh Tao, the Gulf of Thailand. Totally 686 juveniles of *T. squamosa* from Prachuap Khiri Khan Coastal Aquaculture Development Center (CADC) were used in the experiment. All clams were 32 months old and varied in shell length from 3.6 to 14.8 cm.

Two groups of juvenile giant clams were

tagged with numbers photocopied on transparent plastic and subsequently attached on to the shells by a layer of epoxy glue. One group was numbered from 1 to 300 and the second group from 301 to 686. In addition, the second group was provided with loops of monofilament fishing line with a carrying strength of 7.5 kg. The loops were attached to the epoxy glue together with the numbers. The loops were used to tether the clams to the longlines according to the method used by Bech (1995).

Clams numbered 1-300 acted as the control group. The mean size was 5.4 ± 0.7 cm (S.D.). They were placed in metal-framed nylon net cages. One hundred clams were put in each cage and placed at three different locations in the field. The iron frames measured 50 x 70 cm at the bottom and 40 x 60 cm at the top.

Clams numbered 301 to 600 (shell length 5.2 ± 0.6 cm) and number 601-630 (10.5 ± 0.2 cm) were put out on longlines made of monofilament fishing line. Each longline measured 9 m and was stretched out between two or more iron poles. Clams were tethered with a 20 cm monofilament line from the longline to the loop on the clam. On each of the longlines, 30 clams were placed at intervals of 30 cm. The sea bed consisted of coral rubble to which the clams attached by byssus. In addition, clams numbered 631-668 (9.3 ± 0.9 cm) were put on longlines after having stayed in the field for 4 months prior to the experiment. They had thicker shells compared to the those taken directly from the hatchery.

The clams were observed several times using SCUBA in the days following their release. Empty shells and fragments were collected and brought back to CADC for further studies. Survivors were recorded. Animals behaving as predators as well as potential predators (but passive at the time of observation) were noted.

To detect which predators had eaten the *T. squamosa* at the longlines three fishing/crab-traps with *T. squamosa* as bait were used to catch the predators. The construction of the traps resembled the kind used by Thai fishermen, but made of iron (see Fig. 1). The traps were placed at different locations and they were checked for predators with short intervals both night and day.

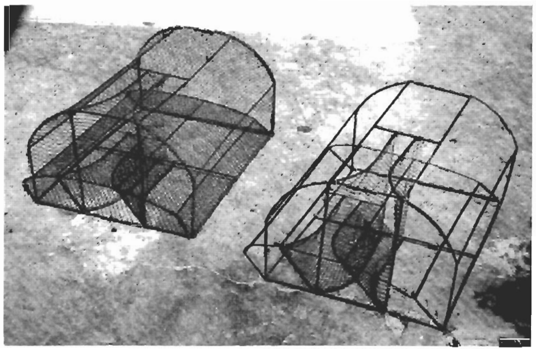

Figure 1. Traps for catching predators.

The method of predation was observed at the field site and if possible confirmed in a fibreglass pool at the CADC. Remaining shell parts from observed attacks were studied, and photos taken of predators to help identification. An underwater video camera was set up in front of a longline to record predators and their feeding behaviour. Clams numbered 669 to 686 (4.0 to 10.4 cm shell length) were tethered to this longline to test if the predators were selective regarding prey size. The video camera recorded for 90 minutes without any people in the area.

Clams found dead with their shells intact within the first 24 hours after release were assumed dead due to transportation and not included in the calculations.

Data was tested in NCSS 97 statistics program for Windows 97.

RESULTS

Clams placed in cages

In cage 1 the mortality was remarkably higher than in the other two cages after two weeks (Table 1). Sand and coral rubble next to and under the cage were dug away, and crushed shells matching the numbers from that cage were found outside. Coral rubble was replaced and all of the cages were supplied with bigger pieces of corals next to the bottom frame of the cage.

Clams placed on longlines

The mortality rate of the 298 clams (two died during transportation), in group 1 (mean size 5.2 ± 0.6 cm) was 100 % after 72 hours. Group 2 (mean size 10.57 ± 0.23 cm) and group 3 (mean size 9.3 ± 0.9 cm) had a higher survival rate (Fig. 2 and Table 1).

Table 1. Survival frequency of giant clams in cages (1, 2 & 3) and on long-lines (group 1, 2 & 3) during one month

Cage or group	Survival frequency (%)		
	3 days	2 weeks	4 weeks
Cage:			
1	100	72	69
2	100	95	87
3	100	91.8	85.7
Group:			
1	0	0	0
2	17	3.3	0
3	50	10.5	10.5

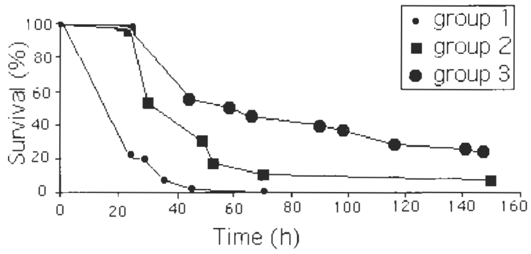

Figure 2. Survival frequency in the three different groups of giant clams on longlines during the first week after the release.

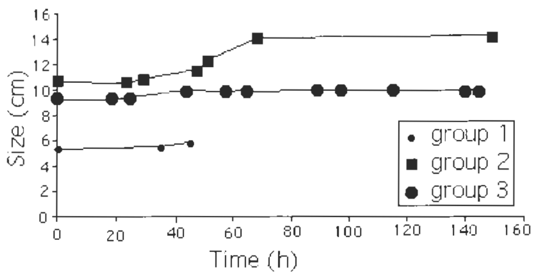

Figure 3. Mean size of surviving giant clams in the three different groups on longlines during the first week.

The mean size of surviving clams increased over time among the three groups put out on the longlines. The smaller size was eaten first. Though this was only significantly shown by group 2 (Fig. 3).

Predation on the clams

A giant triggerfish, *Balistoides viridescens* attacked the clams in several cases. The triggerfish was only seen splitting the shells of the clams from the ventral side (Fig. 4),

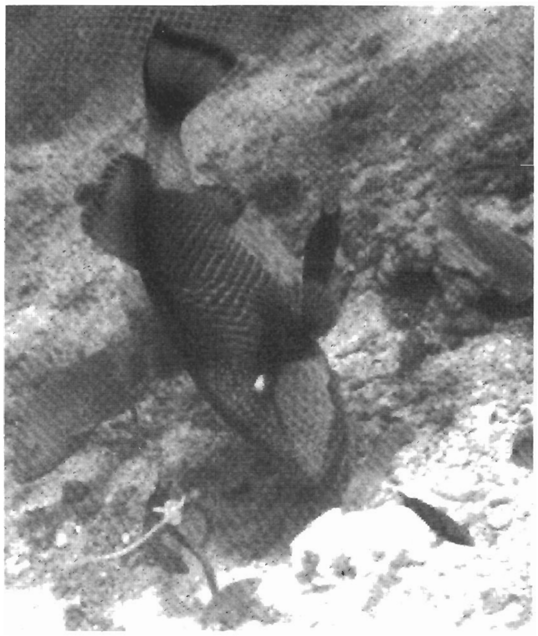

Figure 4. After the byssus of the clam had been torn off the coral, the triggerfish split the valves apart from the ventral side.

and was never observed eating clams smaller than approximately 8 cm. The triggerfish spent approximately 10 minutes splitting the two valves. This was often done without crushing the shells, but by tearing the hinge of the shell apart. The shell margins often showed signs of the rough treatment (Fig. 5). After the mantle was laid bare, the flesh was easily consumed within a few minutes by the triggerfish and the scavenger moon wrasses, which quickly arrived on the scene. If the triggerfish had problems getting to the flesh it broke off

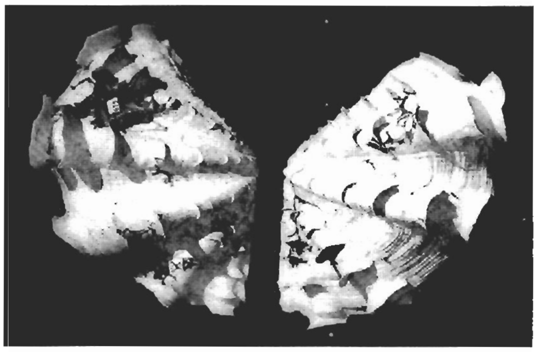

Figure 5. Missing scutes and damaged appearance on the shell margins are characteristic of clams attacked by the triggerfish.

Figure 7. Shell remains after a crab had eaten the soft body. The valves were not crushed and the hinge was still intact.

Figure 6. One of the valves has been crushed by triggerfish. This was often done after the fish had opened the valves to reach the flesh.

Figure 8. A tripletail wrasse. This fish could take a whole clam (from group 1) into its mouth and crush the shell completely.

pieces of one of the valves. These remaining shell parts are very characteristic of shells attacked by the triggerfish (Fig. 6). The shells of clams bigger than 13 cm seemed to be very troublesome for a triggerfish to split apart. Only one time we observed a successful attack on a clam from group 3 and it took two days of effort before the prey was overcome.

Some clams were eaten by the tripletail wrasse, *Cheilinus trilobatus*, and the redbreasted wrasse, *Cheilinus fasciatus*. Records by the video camera showed *C. fasciatus* preying on one clam (4 cm). *C. trilobatus* and *C. fasciatus* ate the clams by crushing the shells. *C. trilobatus* could often get the whole clam in its mouth (Fig. 8) and crushed the shells completely, whereas *C. fasciatus* mostly crushed one valve only. Tooth marks were typically appearing on the unbroken valve, either as a hole in the shell or as cracks on the inner side of the shell (Fig. 9a-b). The scavenger moon wrasse, *Thalassoma lunare* harmed the clams by picking and eating of the mantle margin.

Groupers and parrotfish were often seen in the area, but never observed preying on the clams. Both are known as predators of molluscs (Barker *et al.* 1988). The parrotfish usually occurred in schools of juveniles grazing on algae next to the clams without attacking them.

One clam (8.7 cm) was eaten by a crab. The monofilament line was cut and the crab was eating the clam under a leather coral. The crab was not identified and was not seen attacking the clam. The hinge of the shells was still intact and the shells were not crushed but one shell part had been peeled (Fig. 7).

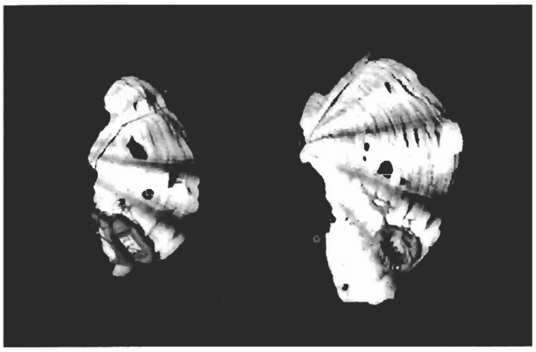

Figure 9a. Tooth marks in the valves made by the redbreasted wrasse.

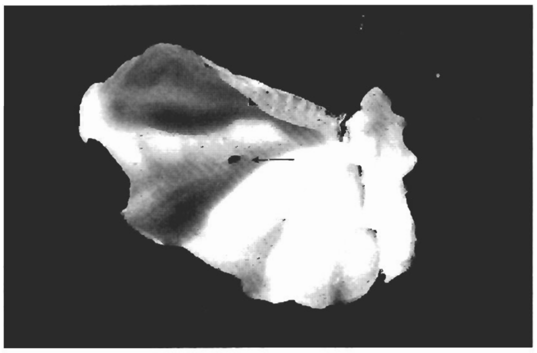

Figure 9b. On the inner side of the valve the marbled surface was cracked due to the pressure from the crushing.

DISCUSSION

Use of cages

The survival rate of the clams in cages was much higher than the survival rate of the same size clams put out on longlines, even though predators had also eaten clams from at least one of the cages. Substrata other than sand and coral rubble to be placed in the cages would be preferable. Many detritus feeders such as goatfish, sea cucumbers *etc.* dig the sand away, making it easier for the predators to get to the clams. Even the tripletail wrasses were seen removing sand and entering the cages. Big cement plates in the bottom of the cages would not only keep out the predators, but also make the clam's attachment more secure. This could reduce mortality in seasons with big wave action.

Normal nursery techniques used by CADC, because of the reasons mentioned above, often include the box-like plastic cages with fixed bottoms supplied with coral rubble. A dilemma is that these cages exclude predators but during the monsoon some cages get tossed around, resulting in total mortality. In some cases the cover of cages may just flip and the remaining clams left back has a chance to survive.

Use of longlines

All clams on the longlines, except one taken by a crab, were presumed eaten by fish. No intact shells, or shells with bore-holes indicating attack by gastropods (Patterson *et al.* 1992), were found. The crab was not observed during the attack, so it is possible that the crab was scavenging on a dead clam.

The clams from group 1 were unquestionably too small to be released at the present site without cages. The tripletail wrasse and the redbreasted wrasse were very abundant in the area and they were feeding on this group of clams.

The clams, which had been in a cage at the field site for four months prior to being tethered (group 3), had the best survival frequency even though they were not the largest. The explanation seems to be the camouflage they obtained by the algae, *etc.*, which grew on the shells. A low survival rate was found for clams of similar size but with shiny shells, which made them easily seen from a distance. We observed that the first clams to be eaten were the shiny clams from group 2 exposed on the bleached coral rubble. The habitat of the single clams was of utmost importance for the survival. The clams should be protected and match in with their surroundings. When clams were placed next to live corals or stones with massive growth of algae, the approach seemed to be to difficult for the triggerfish. The fish would then search for a new prey. The giant triggerfish was not able to attack clams from the dorsal side if the clam exceeded 10 cm in shell length. However, this depended on the condition of the scutes on the clam. Many of the hatchery clams suffered from lack of scutes due to the transportation. The scutes of the clams probably function as protection. Not only do scutes increase the size of the clam, but they are also very sharp, which may annoy a crushing predator.

We conclude that the major reason for mortality at this field site was observed to be the predators. Cages could not completely prevent predation and further effort must be taken to develop combinations of cages and substrate to minimise this kind of mortality A higher survival rate than the one obtained from this experiment must be desirable when clams are released for restocking. A lower density would probably mean better survival rates.

ACKNOWLEDGEMENTS

We wish to thank Dr Jorgen Hylleberg and Dr Tomas Cedhagen at the Department of Marine Ecology, University of Aarhus, Denmark. A great thank is due to Miss Tipaporn Traithong and the staff at Prachuap Khiri Khan Coastal Aquaculture Development Center for their help in the field. Furthermore we wish to thank the Fisheries Patrol providing transportation to the field-site.

REFERENCES

Barker, J.R., Crawford, C.M., Shelley, C.C., Braley, R.D., Lucas, J.S., Nash, W.J. & Lindsay, S. 1988. Ocean-nursery technology and production data for the giant clam *Tridacna gigas*. Pages 225-228 *in* J. W. Copeland & J. S. Lucas (eds.). Giant Clams in Asia and the Pacific. - ACIAR Monograph No. 9. ACIAR Canberra.

Bech, M. 1995. Predation on juvenile *Chicoreus ramosus* (L., 1758); effects of body size and habitat complexity. - Phuket Marine Biological Center Special Publication **15**: 175-180

Chantrapornsyl, S., Kittiwattanawong K. & Adulyanukosol, K. 1996. Distribution and abundance of giant clam around Lee-Pae Island, The Andaman Sea, Thailand. Phuket Marine Biological Center Special Publication **16**: 195-200.

Fankboner, P.V. & Reid, R.G.B. 1990. Nutrition in giant clams (Tridacnidae). Pages 195-209 *in* Brian Morton (eds.). The Bivalvia - Proceedings of a Memorial Symposium in Honour of Sir Charles Maurice Young, Edinburgh, 1986. Hong Kong University Press, Hong Kong, 1990.

Heslinga, G.A., Perron, F.E. & Orak, O. 1984. Mass culture of giant clams (F. Tridacnidae) in Palau. - Aquaculture **39**: 197-215.

Mingoa, S.S.M. 1988. Photoadaptation in juvenile *Tridacna gigas*. Pages 145-160 *in* J. W. Copeland & J. S. Lucas (eds.). Giant Clams in Asia and the Pacific. - ACIAR Monograph No. 9. ACIAR Canberra.

Munro, J.L. 1993. Giant clams. Pages 431-450 *in* Wright, A. & Hill, L (eds.).Nearshore Marine Resources of the South Pacific

Murakoshi, M. & Hirata, H. 1993. Self-fertilisation in four species of giant clam. - Bulletin of the Japanese Society of Scientific Fisheries **59**(4): 581-587.

Nugranad, J., Traithong, T., Poomtong, T. & Sahavacharin, S. 1997. Hatchery seed production of the fluted giant clam (*Tridacna squamosa* Lamarck, 1819) and ocean nursery of the juveniles for restocking in Koh Tao, Thailand. Phuket Marine Biological Center Special Publication **17**: 101-107.

Patterson, E.J.K., Xavier Ramesh, M. & Ayyakkannu, K. 1992. Comparative study of holes in bivalves, chipped and bored by the muricid gastropods *Chicoreus ramosus*, *Chicoreus virgineus* and *Murex tribulus*. Phuket Marine Biological Center Special Publication **11**: 106-110.

Svane, I. 1996. Some recent advances in studies on the biology of giant clams (Tridacnidae). - Phuket Marine Biological Center Special Publication **16**: 221-241.