Preliminary Studies on Locomotion and Burrowing by Juvenile Boring Clam, *Tridacna crocea*

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Abstract

Preliminary experiments in Okinawa, Japan, revealed that survival of juvenile *Tridacna crocea* depends on the size of the pit in which it is placed and its locomotory behavior. Juvenile *T. crocea*, less than 20 mm in shell length (SL), are relatively active. Greater locomotion was observed in darkness. However, their locomotory capacity was lost with increase in size. This corresponded with increased burrowing behavior. Individuals greater than 20 mm in SL did not move by their foot, owing to the increased weight of their shell valves. The burrowing habit was closely connected with the size of the byssal orifice. The ratio of the length to the width of the byssal orifice was variable early in life, but stabilized after reaching 20 mm in SL.

Introduction

Giant clams (family Tridacnidae) are common bivalves living on coral reefs in the Indo-Pacific region. *Tridacna crocea* is the smallest of the family and the only species which can completely burrow into coral reef substrates. It has a large pedal aperture on the ventral side of the shell and it attaches itself to the substrate tightly by the byssus. The white anterior mantle extends over the burrow from the opening and erodes the substrate with acid (Hedley 1921; Yonge 1980; Kawaguti 1983). The size of this opening increases rapidly with the growth of the clam indicating that the burrowing habit is more important for adult clams than juveniles (Hedley 1921). *T. crocea* attains its adult form and begins to bore when the shell length (SL) reaches at least 4 mm (Kawaguti 1983).

T. crocea is an important shellfish for food in Okinawa, Japan and commands high prices. Overexploitation of the natural resource, however, has resulted in declining production. *T. crocea* has been propagated artificially since 1979 and planting of juvenile clams (about 8 mm SL) has been carried out on some reefs (Murakoshi 1986). It is important to understand the locomotion, burrowing habits and survival of juvenile clams for this endeavor. As a result, preliminary studies have been undertaken in the field and in laboratories.

Materials and Methods

Survival of Cultured Juveniles in the Field

An experiment to study survival of cultured juvenile *T. crocea* of 6-13 mm in SL was carried out on the reef flat at Cape Zampa, Yomitan, Okinawa, Japan. Observations were made on a coral rock substrata of 5 × 3 m at a depth of about 3 m.

Juvenile *T. crocea* individuals were set into three types of pits, at least two weeks after attachment by their byssus: a large pit (long axis 10-15 mm, short axis 6 mm, depth 6-8 mm) for individuals of 6-8 mm SL; a tight fitting pit (long axis 7-15 mm, short axis 4.8-6 mm, depth 4-8 mm) for individuals of 6-13 mm in SL, and a shallow pit (long axis 10-15 mm, short axis 6 mm, depth 2-3 mm) for individuals of 8-13 mm in SL. A drill press bored pits in the dead skeletons of the coral *Porites* sp. On 13 June 1996, a total of 177 juvenile clams (53, 37 and 87 individuals for the large, tight fitting and shallow pits, respectively) were placed into *Porites* substrates, which were then attached to a natural boulder with underwater cement. The surviving individuals were counted and recorded for 16 days using underwater photography.

Survival of Wild Clams in the Field

Survival of 60 wild *T. crocea* specimens (7-74 mm SL) was observed at the same site as above, from

10 June to 13 October 1996. Observations were made at two coral rock substrata (5 × 3 m, and 3 × 2 m) at a depth of about 3 m. Tags made of rubber hosing were nailed near the clams for identification.

Laboratory Studies

The *T. crocea* individuals maneuver their foot in a vertical position in order to move. This locomotion was recorded by time-series photographs. Two or four individual clams were placed inside a plastic container (242 × 351 × 155 mm) with scotched glass on the bottom containing 5-1 seawater (34%) at 28 ± 2°C. The clams were kept under light with aeration for three hours prior to being photographed.

Experiments were conducted overnight from 1800 to 0600 h. In the first experiment (light-dark-light), the clams were kept for 2 hours in light (1500 lux), 8 hours in darkness and 2 hours in light. Ten cultured *T. crocea* individuals (4.5-16.8 mm SL), and

four wild from Cape Zampa (9.1-32.1 mm) were used. The 9.1 mm SL clam was not buried.

The second experiment was conducted under constant illumination (1500 lux) for 12 hours. Eleven cultured *T. crocea* (4.0-16.6 mm SL) and one wild individual (9.1 mm SL) were used for the experiment.

Locomotory capacity was calculated on the basis of clam size using a locomotion index (LI), where:

LI = distance traveled for twelve hours / shell length.

Subsequently, the relationship between foot size and locomotory capacity in *T. crocea* was examined. Clams were fixed in 5% or 10% formalin depending on size. The foot was removed from the body (Goreau et al. 1992) and measured to the nearest 0.001 mm using a micrometer. The SL and shell width were measured to the nearest 0.1 mm using vernier calipers. Shell weight was determined to the nearest 0.01 g.

The length and width of the pedal opening in the shell were

measured for 164 individuals. Specimens obtained from the local market in Naha were examined to determine whether the opening size increased allometrically with increase in the SL.

Results

Survival of Cultured Juveniles in the Field

The number of juvenile *T. crocea* in shallow pits decreased rapidly during the first two days. Only 22.9% of clams were present by the second day, 1.1% on the sixth day and none remained after two weeks (Fig. 1). The survival of those in the tight fitting pits was approximately 90% by the second day and 30% on the sixth day. In the case of the large pits, survival of the juveniles was less than the rate in the tight fitting pits but greater than that in the shallow pits. It was evident from the increase in percentage survival in large pits from the second to the fifth day (Fig. 1), and from view-
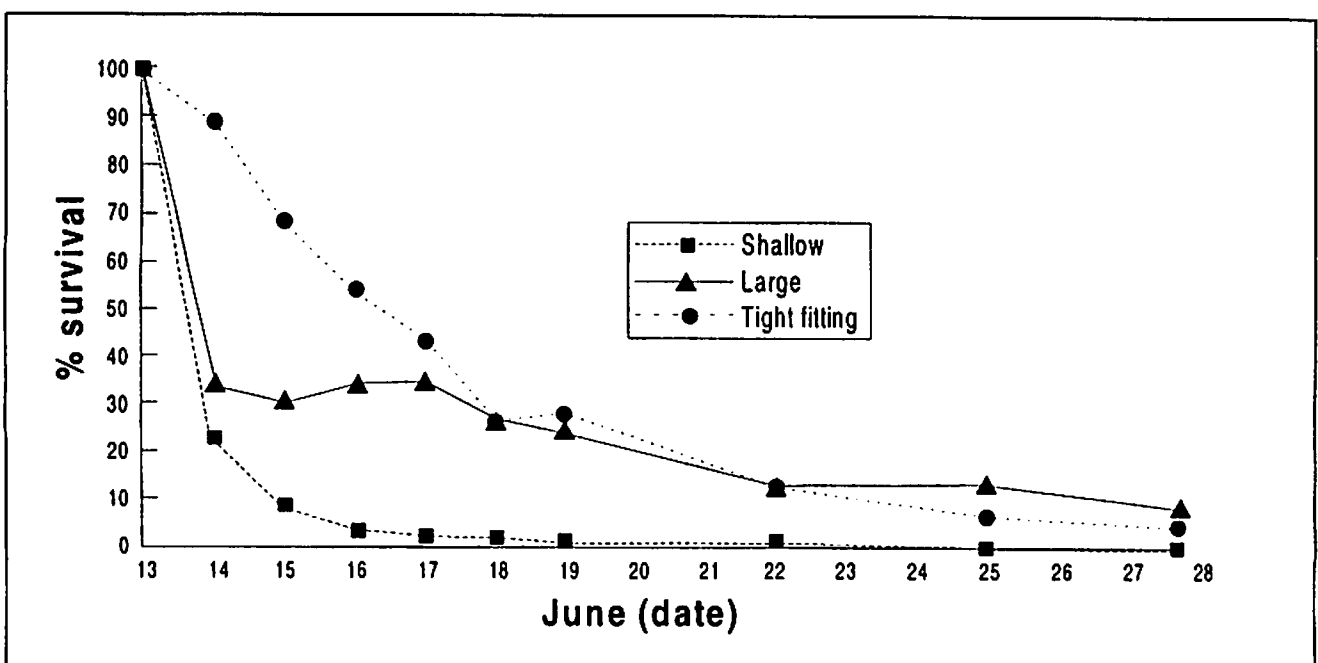

Fig. 1. Survival of cultured juvenile T. crocea set into three types of pits.

ing the photographs of the site, that the juvenile clams did not necessarily die but may have moved from the pits to other holes by detaching themselves.

Dead juvenile shells were not observed during the fifteen days of this experiment. However, predation of juvenile clams by a wrasse *Thalassoma lutescens* was observed on the second day.

Survival of Wild Clams in the Field

Disappearance of the wild *T. crocea* presented itself in three ways: dead intact shells within burrows, broken shells in burrows, and empty burrows. The burrows were shorter where dead intact shells were found (average 27.8 mm), than where there were broken shells or empty burrows (average 53.9 mm). No clams were observed leaving their burrows. The number of clams surviving and dying in different ways is presented in Fig. 2. Overall, 82% of tagged clams survived for 4 months.

Laboratory Observations

In the light-dark-light experiment, clams became active and started moving more than two hours after the onset of darkness. They were particularly active from 2200 to 0200 h (Fig. 3a). Under conditions of constant light, locomotion activity was fairly constant throughout the 12 hour period (Fig. 3b).

There was an obvious relationship between SL and locomotion in *T. crocea* less than 20 mm SL. Clams greater than 20 mm SL were also observed to move, but not by maneuvering the foot in a vertical position. They moved by sudden closure of the shell valves to expel sea-
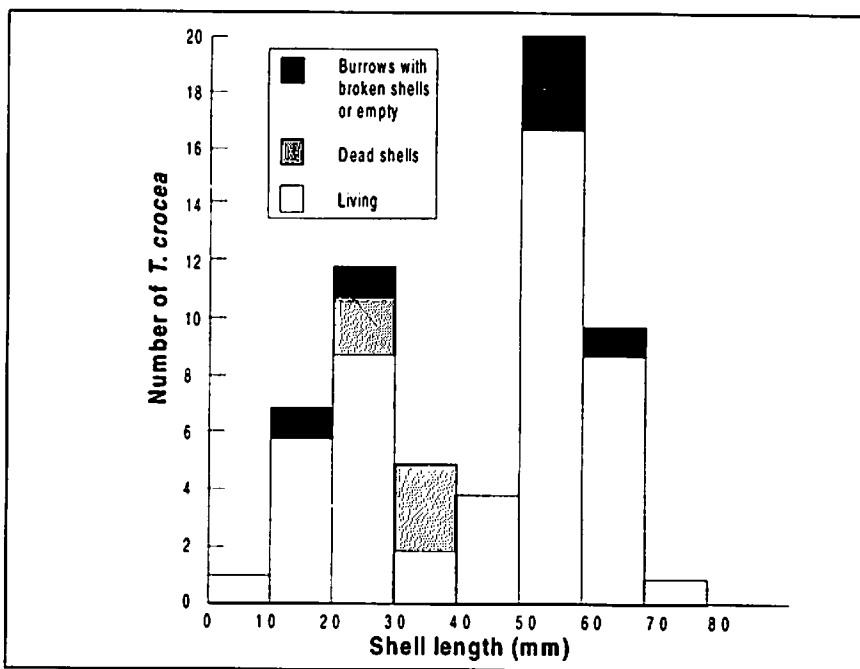

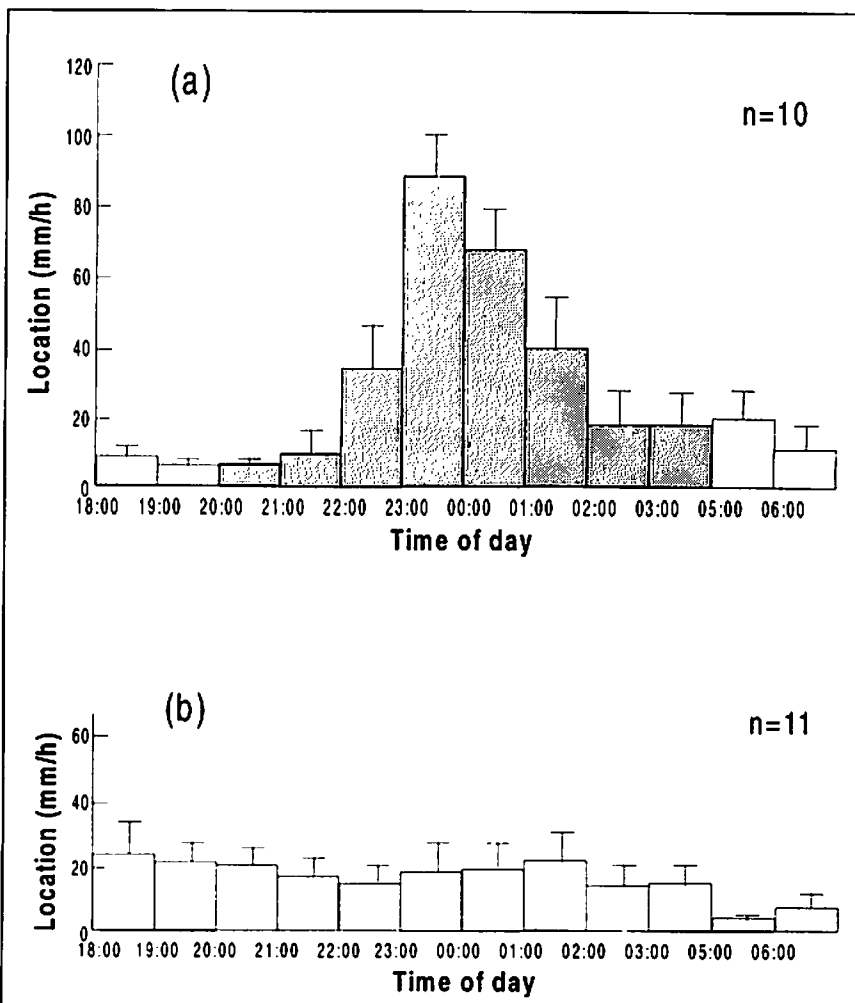Fig. 2. Survival of T. crocea depending on shell length on the reef flat at Cape Zampa.

Fig. 3. Mean (and SE) locomotion of T. crocea under two different light-dark regimes: (a) The first two hours in light, followed by eight hours of darkness (shaded) and two hours of light periods. (b) Under constant illumination.
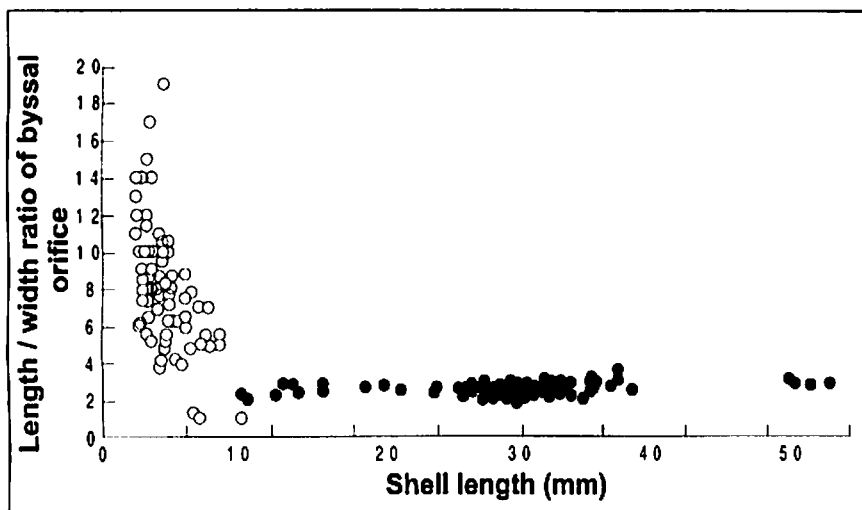
Fig 4. *Ratio of length to width of byssal orifice and shell length in* T. crocea. *Open marks represent data of cultured specimens and closed marks represent those of wild specimens.*
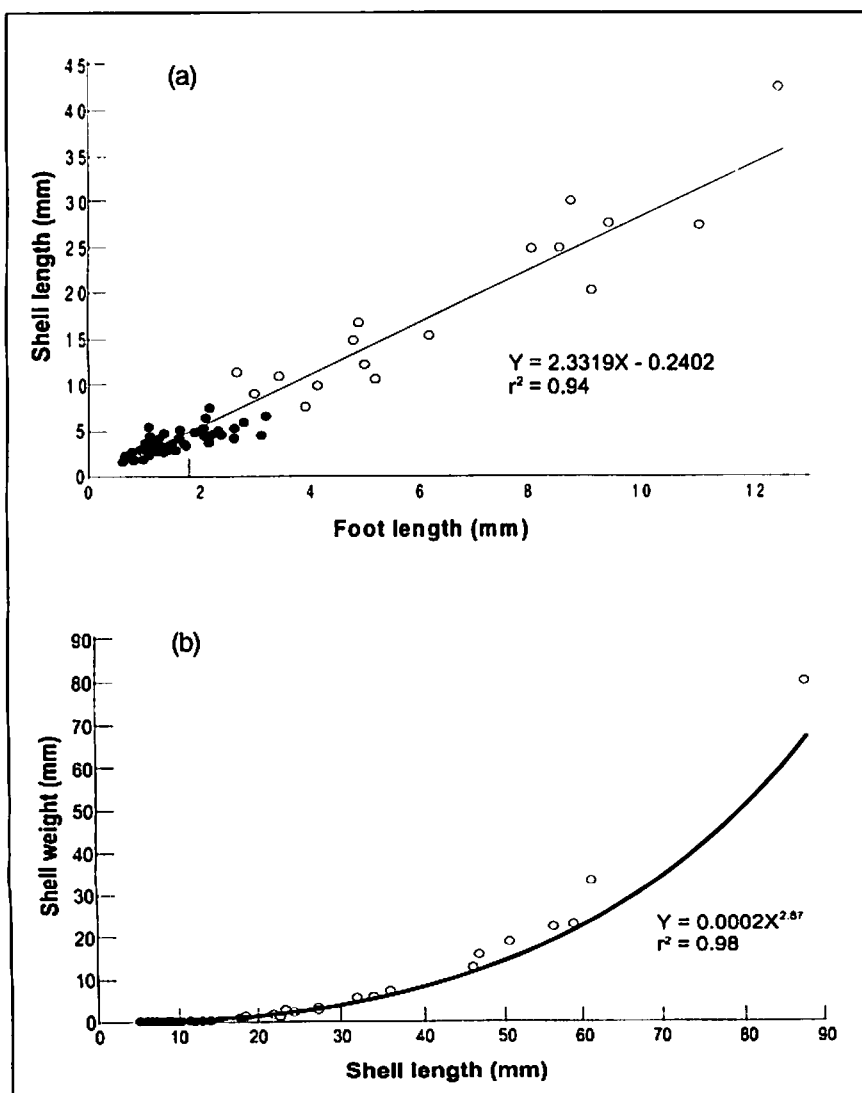

$Y = 2.3319X - 0.2402$
$r^2 = 0.94$

$Y = 0.0002X^{2.87}$
$r^2 = 0.98$

Fig. 5. *Relationships between foot length and shell width (a) and between shell length and shell weight (b) in* T. crocea. *Open marks represent data of wild specimens and closed marks represent those of cultured specimens.*

water or by ejecting water through the exhalant siphon.

Morphometrics

Shell width increased faster than the foot length and the shell weight increased logarithmically once it reached 20 mm in shell length. The ratio of the length to the width of the byssal orifice was variable early in life, but stabilized after reaching 20 mm SL (Fig. 4).

Discussion

Juvenile *T. crocea* artificially set into tight fitting pits showed a higher retention/survival rate than those in shallow or large pits. This was presumably due to predation and movement of the clams: *T. lutescens* was observed to prey on clams in shallow pits, and it was easy for juvenile *T. crocea* in shallow pits to leave the holes.

Juvenile clams less than 10 mm SL were difficult to collect in the field. Those found were in large, deep holes, or in crevices on coral boulders. This may indicate that the juvenile clams were using the holes and crevices as shelter from predators. *T. crocea* has a relatively large posterior mantle early in life (Griffiths and Klumpp 1996) which presumably aids photosynthesis by zooxanthellae and the removal of sediment in the deep holes.

The three types of losses of the wild clams were characteristic of different sizes of clams (Fig. 2). This indicates that distinct predators attacked clams of a particular size group. For example, large size clams appeared to be preyed upon by large crustaceans and medium size clams by carnivorous gastropods. Further investigations are needed to confirm this.

The ability for locomotion in juvenile *T. crocea* appears to become lost as the clams increase in size. It was shown that individuals greater than 20 mm SL did not use their foot. After reaching 20 mm in SL, the foot could not extend sufficiently (Fig. 5a), and clams could not sit upright owing to their increased weight (Fig. 5b). This is in contrast to other sessile bivalves, such as *Mytilus* sp., which have primary and secondary settlement in the post-larval stage (0.25-3.00 mm). In *Mytilus* sp., the post-larvae are transported by water currents with their mucus threads, crawl using their foot, and repeatedly attach and detach themselves (Bayne 1964; Cáceres-Martínez et al. 1994).

It is not clear what benefit locomotion is to the small *T. crocea*. Reid and King (1988) suggested the ability to pedal feed when the feeding mode is changed after metamorphosis. If this is true, it may also apply to other tridacnid clams since they also have pedal openings and move using their foot in early life (Rosewater 1965). In this regard, it is interesting to note that the clams became active in the dark (Fig.3a), when there were fewer predators with visual ability.

There seems to be a connection between the width of the byssal orifice and burrowing habit in *T. crocea*. In juvenile *T. crocea* the size at which burrowing begins varies (Yonge 1936). The change in the width of the byssal orifice is different for each individual (Fig. 4) and burrowing starts when the width of the byssal orifice opens wide enough to burrow. Under suitable conditions, juveniles appear to start burrowing at a size of 20 mm in SL. Burrowing protects the vulnerable byssal orifice of *T. crocea* from predators.

The planting of *T. crocea* at about 8 mm SL for fishery enhancement should take into consideration the locomotion of juvenile clams. After planting, clams should be protected with mesh until they start to burrow. Suitable pit sizes and periods of protection with mesh remain to be determined.

Acknowledgments

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