

## PREDATION ON JUVENILE *CHICOREUS RAMOSUS* (L., 1758): EFFECTS OF BODY SIZE AND HABITAT COMPLEXITY

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### ABSTRACT

Predation on *Chicoreus ramosus* was investigated during 9 months by tethering 30 *C. ramosus* with monofilament line *in situ*. The snails were recorded weekly, and dead individuals replaced. Crabs were the main predators, fish occasional predators. Predation by carnivorous gastropods was impossible to evaluate because no marks were left on the empty shells. Predation frequency was higher with decreasing *in situ* sediment depth because burying is the main defence. Size dependent mortality by predation was further investigated by using enclosures. Predation on *C. ramosus* decreased significantly when they attained a total length of more than 4.5 cm.

### INTRODUCTION

The muricid *Chicoreus ramosus* has been chosen as target species in the Tropical Marine Mollusc Programme (TMMP) because of its commercial importance in Southeast Asia. Predation on commercial molluscs during field grow-out remains one of the major hurdles to successful culture in many areas of the world (Jory *et al.* 1984). The number of predator species decreases with increasing size of the prey. Therefore, it is essential to find both the optimum size to release in relation to predation and to find a habitat where predation is minimized, before a restocking programme of this species is implemented (Bech 1994). Predation is a major factor shaping aquatic community structure (Smith & Herrnkind 1992; Chilton & Bull 1984; Russ 1980). Field experiments on mobile marine invertebrate prey generally require limiting an animal's range of movement using enclosures (Hoffman 1980; Chilton & Bull 1984; Jory & Iversen 1983), tethering (Ray & Stoner 1994; Smith & Herrnkind 1992; Eggleston *et al.* 1990; Stoner & Davis 1994) or laboratory studies (Vermeij 1982; Bertness & Cunningham 1981). Such techniques are effective for comparing predation levels, although they cannot measure absolute predation because of the artificial constraints on either the prey or the predator. Physical structure of the habitat can strongly mediate predator-prey interactions, affecting not only total predation rates, but also modifying selectivity for different prey species or size classes (Eggleston *et al.* 1990). Hence, the effect of habitat structure can potentially interact

with that of body size. To distinguish between the influence of these two factors, it is necessary to eliminate either the differences in size or habitat in the experimental set-up. Therefore, this investigation makes use of two experiments: one on the influence of the habitat on predation using prey of the same size, and one on the size dependent predation using different size classes of prey in equal habitats.

Gastropods were put in cages to determine predation on them. Cages exclude benthic predators, such as carnivorous gastropods, whereas tethering does not. Therefore, tethering was used to investigate the influence of shelter in this experiment and size dependent mortality by predation was studied by the use of cages. The aims of this study is to find the optimum size and habitat for sea-farming to avoid heavy predation on the juveniles and to identify the predators.

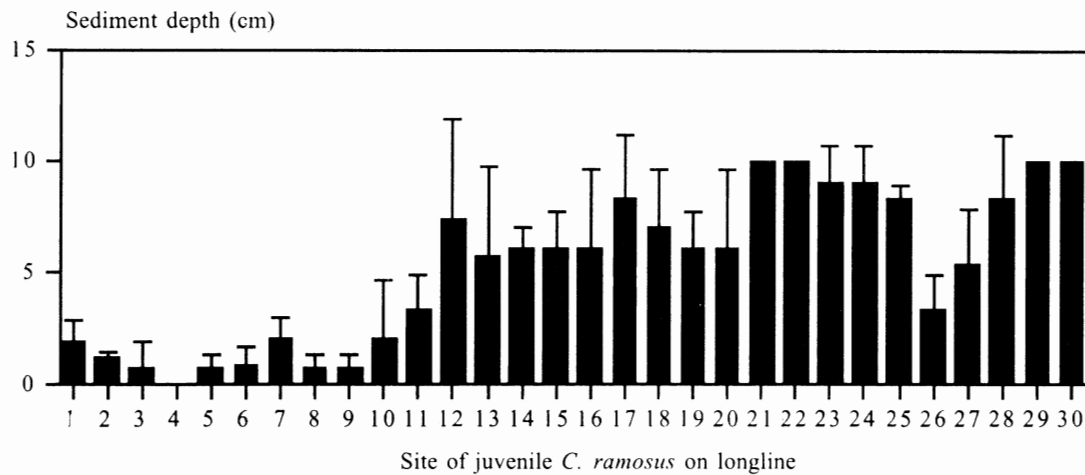
### MATERIAL AND METHODS

The study site was located 200 m offshore from Phuket Marine Biological Center, Thailand. The juvenile *C. ramosus* used in these experiments were reared from eggs at Prachuap Khiri Khan Coastal Aquaculture Center, Thailand.

**Tethering.** The 9 months tethering experiment was made in the period from October 1993 to June 1994 and designed as a longline used for fishing, with a main line of 45 m nylon rope fastened to the bottom with iron poles. Thirty pieces of monofilament line (carrying strength > 5 kg) each 0.56 m long were tied to the

main line at 1.5 m intervals. The 30 juvenile *C. ramosus*, 4.0-6.0 cm in total length, were tied to each of the 30 monofilaments. This allowed the juveniles to move freely, hide or bury, if possible, within an area of 1 m<sup>2</sup>. Each monofilament was tied around the juveniles and became embedded in shell material as they grew, indicating that only their range of mobility was restrained.

The longline was placed on a slope with hard bottom and coral rubble in the shallow end at 4 m depth and soft sand bottom in the deepest end at 6 m depth. Approximately half the longline was placed on coral rubble and half on soft sand bottom. Average sediment depth was measured using an iron pole with a scale thrust 5 times randomly into the sediment at each of the 30 sites (Fig. 1).



**Figure 1.** Average sediment depth with standard deviation within the area of mobility of each juvenile along the longline. Maximum depth measured was 10 cm.

The longline was observed weekly during nine months using SCUBA. At each observation the total length of the juveniles was measured and all dead, chipped or missing juveniles were recorded and replaced by new snails. All empty shells and fragments of shells were collected and studied at the PMBC. From these empty shells and fragments a preliminary identification of predators could be made. In general, a shell may be broken either by crushing or by peeling. By crushing, the shell as a whole is compressed between two opposing surfaces, such as the jaws of a fish. By peeling, the columella is left intact, the apex seldom broken, and mainly the larger whorls are broken away. The size of juveniles used in this experiment (4-6 cm in total length) makes it fairly safe to assume that crushing is mainly done by fish. Shell fragments from gastropods predated by fish are easy to distinguish from fragments from gastropods predated by crustaceans (Bertness *et al.* 1981). Vermeij (1982) found that crushing was the main technique used by fish to eat gastropods whereas crabs used the peeling technique. The

crushing technique could only be used by very large crabs, but none were seen in the area or caught in gill net.

To facilitate identification of predators, shell fragments from the longline were compared with shell fragments of juvenile *C. ramosus* eaten by crabs, *Scylla serrata*, and the carnivorous gastropod *Fasciolaria trapezium* held in concrete tanks.

**Enclosures.** To study the effect of hiding, 12 cages were designed to investigate size dependent predation. The cages had a bottom of tile plate 0.7 x 0.7 m. The sides were made of 10 cm high metal mesh (1 cm mesh size). The top of the mesh-edges was bent inward, to prevent the juveniles from leaving. This design proved satisfactory as 25 juvenile *C. ramosus* in concrete tanks did not escape during a period of a week.

On the outside of the cages 4 pieces of tile plate, 70 x 15 cm, were placed as ramps to enable benthic predators to enter the cages.

The cages were placed on the sea bottom in the same area as the longline and anchored to the bottom. The

juvenile *C. ramosus* were divided into six different size classes, with 50 in each class. 25 were placed in each cage, with one replicate for each size class. The six size classes were 20-25; 25-30; 30-35; 35-40; 40-45, and 45-50 mm. Predation in the cages was recorded daily by counting the remaining juveniles in each cage for ten days using SCUBA. Shell fragments from the cages were collected and analyzed.

**RESULTS**

**Tethering experiment.**

The size range of 4-6 cm in total length was chosen, because the enclosure experiment showed that juveniles larger than 4.5 cm are of optimum size for restocking projects. The overall predation on juveniles in that size range was fairly low. On an average, one juvenile was preyed upon every fourth day during nine months. From the empty shells and fragments of shells the following predator groups were identified:

**Table 1.** Predation frequency of major groups of predators on juvenile *C. ramosus*, based on the remains of 62 devoured juveniles.

Predation by:	Frequency (%)
Crabs	47
Fish	26
Gastropods/unexplained	27

A total of 27 % juveniles were possibly preyed upon by carnivorous gastropods lacking boring organs (Ta-

ble 1). Such mortality could not be distinguished from other causes of death like stress or starvation. *Fasciolaria trapezium* kept in aquaria was observed to insert its proboscis in the gap between the operculum and aperture of the prey, killing the juvenile without leaving a mark on the shell. Since the death causes for the remaining 73 % of the juveniles were identified, this group was used to establish the importance of hiding as a defence against predation.

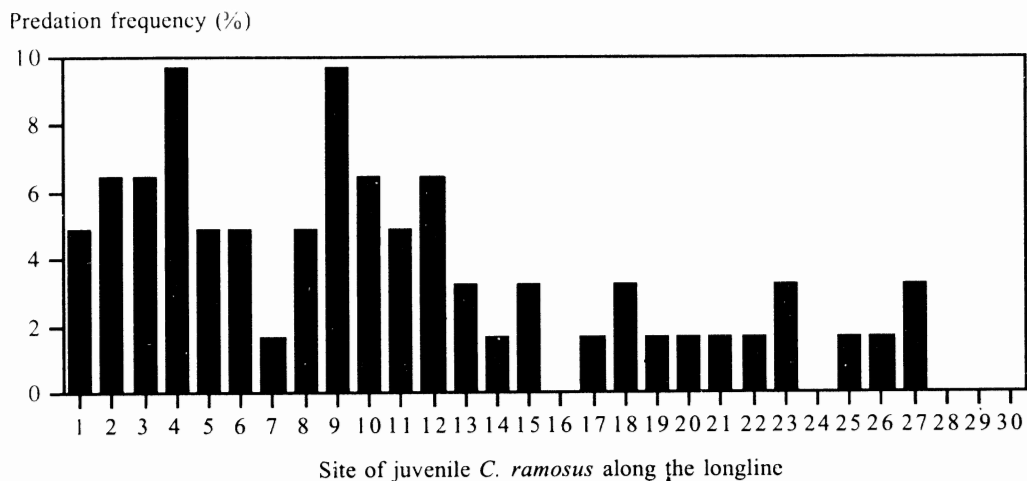
Predation frequency at each of the 30 sites along the longline was compared to average sediment depth at the site, to test the importance of burying (Figs. 1 & 2).

The regression line for predation frequency as a function of sediment depth is negatively correlated ( $P < 0.01$ ) for crabs (Fig. 3), and ( $P < 0.05$ ) fish (Sokal & Rohlf 1981). Juvenile *C. ramosus* without the possibility to bury themselves in the sediment were significantly more exposed to predation.

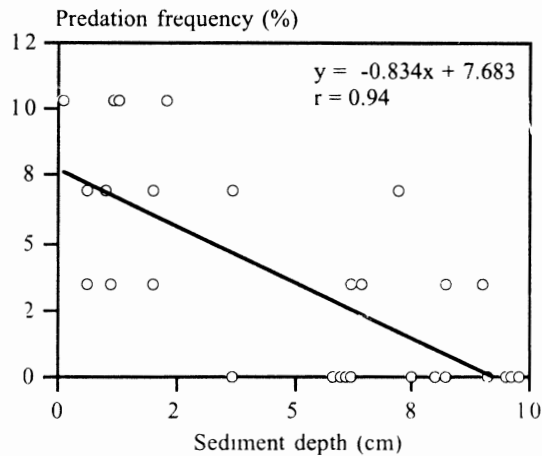
In total, 40 % of the juveniles were preyed within the first month, whereas only 19 % during the following two months.

**Enclosure experiment.**

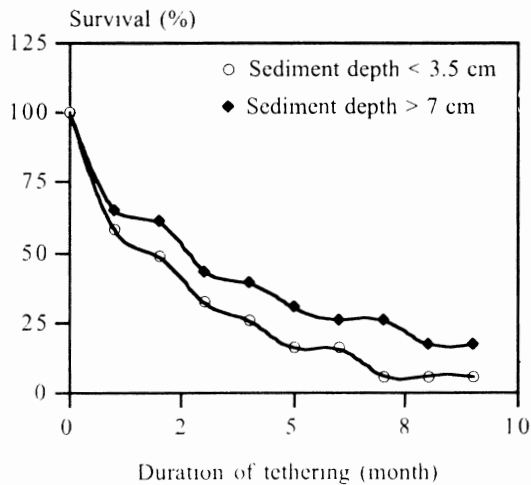
In the enclosure experiment a higher predation by fish than by crabs occurred in the smaller size classes. During 10 days 180 juveniles were preyed upon because the snails could not hide, further emphasizing the importance of hiding. Predation decreased significantly after the juvenile *C. ramosus* reached a size larger than 4.5 cm.



**Figure 2.** Predation frequency by crabs and fish on each site along the longline.



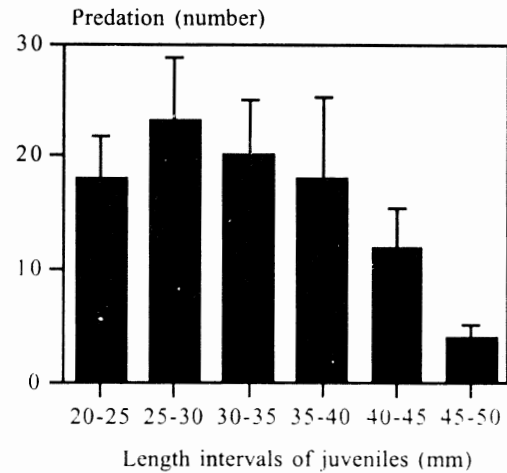
**Figure 3.** Predation frequency by crabs in relation to sediment depth.



**Figure 4.** Survival rates of juveniles preyed upon during 9 months in relation to duration of tethering, and confinement to a sediment depth of less than 3.5 cm (10 sites along the longline, n=31) and to a sediment depth of more than 7 cm (10 sites, n=23).

## DISCUSSION

Juvenile *C. ramosus* are very seldom found because they hide in crevices under objects or are buried in the sediment (Bech 1992, 1993). If this behaviour reduces predation, we would expect a higher predation on juveniles living in a habitat with a hard bottom compared to a soft sandy bottom. The result of the tethering experiment indicates that the main reason for bury-



**Figure 5.** Size dependent predation on juvenile *C. ramosus*.

ing may be to avoid predation. As expected, predation frequency is higher when the layer of sediment is too thin for burying. Juveniles along the longline sites with soft sediment (sites 11-30) were usually buried at the weekly observations whereas the juveniles on hard bottom (sites 1-10) were not. This agrees with (Ray & Stoner 1994). They found that juvenile queen conch, *Strombus gigas*, actively would select habitats where burying was possible.

The growth rate of juveniles was significantly lower on the longline than growth rates from similar sized juveniles in culture (Bech 1993), but the overall survival was satisfactory due to the relatively low predation frequency. One juvenile survived nine month tied to the longline without adding shell, while others added up to 10 mm in total length during their period of tethering. Newly made shell is thin and fragile. When a new varix is added, burying may be necessary for protection, and confinement to hard substrate could inhibit growth. Pulling up buried juveniles at the weekly observations, to establish if they were alive, could also affect growth and predation.

The following crab families with sufficient claw size for gastropod predation were observed or caught in gill nets at the study site: Dromidae, Calappidae, Portunidae and Xanthidae. *Calappa* spp. and the spiny lobster, *Panulirus argus* (Latreille), are known to use the peeling technique (Vermeij 1982; Bertness & Cunningham 1981) and both were found in the area.

The portunid *Scylla serrata* (Forsk.) is common in the area and was a voracious predator on juvenile *C. ramosus* in aquarium experiments. No juveniles were found with drilled holes, suggesting absence of predation by *Octopus* or muricid gastropods (Ray & Stoner 1994).

Species of puffer fish, *Diodon* spp. and *Arothron* spp., and the parrotfish *Scarus* spp. are well known gastropod predators (Palmer 1979; Bertness & Cunningham 1981) and common in the area (Satapoomin pers. comm.). Other predatory fish in the area are triggerfish and groupers. Norton (1988) observed that only fish capable of crushing prosobranch gastropods will eat them, because they can not be digested with operculum and shell intact. The distribution of predator species is mainly correlated to the size of the prey. In the tethering experiment crabs were the dominant predators of juvenile *C. ramosus* with a total length from 4 to 6 cm. Shell fragments from the enclosure experiment indicated that fish were the most dominant predators of smaller sized juveniles. It must be noted, that the unnaturally high density of juveniles in the cages without hiding possibilities further enhanced predation. Search images of the predators could further increase predation. The snails were denied access to protection by the use of hard bottom cages which could change the predator species, because *C. ramosus* is nocturnal (Bech 1993). Predators hunting by vision had a better chance than under natural conditions, where the snails would have been buried during the day.

The crushing technique requires a predator which can handle the whole snail in mouth or claw. The peeling technique only requires that the predator can break away the shell wall with its claw. In relation to its body size, a crab can handle larger gastropod prey than a fish.

Survival of queen conch, *Strombus gigas*, increases with increasing shell length (Iversen *et al.* 1986; Appeldorn 1984; Stoner & Sandt 1992). Recommendations for release size for the queen conch range

from 4 cm shell length (Berg 1976) to 10 cm or larger (Jory & Iversen 1983). A direct comparison with *Chicoreus* is not possible, due to morphological differences. Juvenile *C. ramosus* have more pronounced spines than *Strombus gigas* at a size of 4 cm in total length. According to Palmer (1979), spines are an important shell characteristic to minimize predation on gastropods. Moreover *Fasciolaria tulipa* is among the most important predators on *Strombus gigas* indicating that size and escape behaviour are more important for the queen conch than spine length and shell thickness (Stoner & Davis 1994). Species of *Fasciolaria* lack a drill apparatus and overcome prey using forceful introduction of the proboscis and radula leaving an undamaged shell (Ray & Stoner 1994). Selection in the prey species is in close response to the nature of the most dominant predator. Marking-recapture studies using shells occupied by hermit crabs indicate, that 2/3 of shell damage is due to fish in Panama Bay (Bertness & Cunningham 1981).

From the tethering experiment a tendency towards higher predation frequency on new juveniles on the longline was noted (Fig. 4). During the first month of tethering, 40 % of the predation occurred, and juveniles confined to a hard sediment, inadequate for burying, were preyed at a similar rate as juveniles on a soft sediment, indicating that even though they had the possibility to bury, they did not use it. This inexpedient behaviour seems to decrease with duration of tethering (Fig. 4). There is a possibility that hatchery-reared juvenile *C. ramosus* behave different than wild juveniles. It has been observed both for abalone (Tegner & Butler 1985) and the queen conch (Stoner & Davis 1994) that hatchery reared juveniles hide or bury significantly less than wild juveniles, thereby increasing their vulnerability to predation. This difference vanishes with time in nature. Further studies are needed to make comparisons between wild and hatchery reared *C. ramosus*, but at present it will be a difficult task, because wild juveniles are hard to find.

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