FIELD RELEASE OF CULTURED MURICID GASTROPODS
(CHICOREUS RAMOSUS) AT ARTIFICIAL REEFS IN THE
ANDAMAN SEA, THAILAND

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ABSTRACT

Hatchery-reared juvenile *Chicoreus ramosus* (average total length 7.0 cm) were released at artificial concrete reefs to determine rates of growth, mortality and dispersion. During the eight months experiment, growth rates of the released juveniles were comparable to juveniles cultured in land based aquaculture systems. Mortality was very low (< 5%), but dispersion halved the released stocks after 97 days. The released juveniles migrated mainly from one concrete module to another, because the modules constitute islands in terms of food. Restocking of *C. ramosus* on artificial reefs could become an efficient method to establish self sustainable populations.

INTRODUCTION

Widespread depletion of commercially important species of marine gastropods has resulted in increasing interest in enhancement and restoration of wild populations through releases of hatchery-reared individuals.

Abalone is by far the most commercially important gastropod cultured, constituting more than 65% of the world harvest of marine gastropods (Sheehy & Vik 1981). Abalone is cultured by release of juveniles in Japan, United States, Australia, New Zealand, France, Canada and Taiwan (Chen 1984; Ebert & Houk 1984; Leighton 1989; Fallu 1991).

Throughout the Caribbean region, the queen conch *Strombus gigas* has successfully been sea-farmed by the release of juveniles since the beginning of the eighties (Appeldorn 1990; Stoner & Davis 1994). In many parts of the Pacific Ocean both *Turbo marmoratus* and *Trochus niloticus* have been both transplanted (Zoutendyk 1989) and sea-farmed successfully (Heslinga 1979; Hoffschir 1990).

As natural stocks of the commercially important muricid *C. ramosus* have declined throughout the Andaman Sea (Aungtonya & Khokiatthi Wong 1992) interest in its sea-farming potential have increased (Bech 1994; Nugranad et al. 1994). During the Tropical Marine Mollusc Programme (TMMP) most problems concerning rearing of juvenile *C. ramosus* from eggs in land based aquaculture systems have been solved (Nugranad 1992; Nugranad et al. 1994; Steenfeldt & Bussarawit 1992). But on-growing of juveniles to commercial size in land based aquaculture systems is hardly feasible, because of their high demand of costly food and relatively slow growth rate (Steenfeldt 1992; Bech 1994). The advantage of the sea-farming technique is that the released stocks do not require any maintainance from release to harvest. But it is essential to release in areas where losses due to predation, starvation and emigration are minimized.

*C. ramosus* is carnivorous and the juveniles have been shown to grow well on a diet consisting of sedentary organisms, such as
bivalve spat and barnacles (Steenfeldt & Bussarawit 1992; Bech 1993; Nugranad et al. 1994). Experiments have furthermore shown that the snails prefer areas with current and sandy sediment opposed to muddy sediment (Khokiatthi Wong 1992; Bech 1993).

Artificial reefs are man made structures that serve as shelter and habitat, breeding area and shoreline protection - leading to an increase in fishing grounds mainly for small scale fisheries. Thailand initiated an artificial reef construction programme in 1978 and 34 reef sets were constructed in the following 10 years in seven coastal provinces in the Gulf of Thailand and the Andaman Sea (White et al. 1990).

The artificial concrete reefs were chosen as release sites because the blocks constitute islands in terms of food. They are covered with large amounts of barnacles and bivalve spat (Bech 1995a). The modules are located in an area with strong currents, and the coarse sediment very close to the blocks supply cover for the snails when they bury themselves. The concrete blocks are surrounded by muddy sediment disliked by the snails.

The intentions with this experiment was to investigate if the released stocks of juvenile C. ramosus stay in the vicinity of the concrete modules with a satisfactory growth and survival rate.

If an alternative use for the numerous artificial reefs in South East Asia could be found, this method could be an important coastal management tool in future.

**MATERIALS AND METHODS**

The juvenile C. ramosus used in these experiments were reared from eggs at Prachup Khiri Khan Coastal Aquaculture Development Center, Thailand and transported to Phuket Marine Biological Center (PMBC) by car.

At PMBC, 1,200 juveniles were tagged with numbers embedded in epoxy cement. Numbers and corresponding total lengths of the juveniles were recorded. The epoxy number was always placed on the last intact varix so that growth could be recorded both as increment in total length and as the addition of varices.

If a new varix was in progress, it was recorded as the widest measurement to the nearest millimetre on the newly added shell, using callipers. The tagging technique proved to be very efficient and very few numbers were lost.

The juveniles were transported by boat to the artificial reef at Koh Lanta which is located 60 km from PMBC.

The artificial reef at Koh Lanta was installed in 1990 and consists of 2,160 concrete modules, each 1 x 1 x 1 meter, and 720 modules measuring 2 x 2 x 2 meter, shaped like the edges of a dice. The reef modules have been dumped randomly from a boat 8 km off the west coast of Koh Lanta in a 10 x 2 km area by the Department of Fisheries, Thailand.

The first attempts to release juveniles in the area failed due to interference from poachers who removed buoys marking the sites. The following two attempts were successful, because the sites were located using a satellite navigator (GPS) and no buoys marked the sites. Two different aggregations of modules within that area were chosen: station 1, (N 7°40.418' E 98°58.151') composed of 1 m³ modules at 9 meters depth, and station 2 (N 7°40.599' E 98°58.273') with 8 m³ modules at 12 meters depth.

At each station, 3 concrete modules were left open and 3 modules surrounded individually by a fence which was made of strong metal mesh (mesh size 1 cm). The 60 cm wide metal mesh was buried about 20 centimetres in the bottom and anchored to the bottom with iron poles. Within each of the 6
areas surrounded by a fence, 100 juveniles were released, and in each of the 6 areas without fence 100 juveniles were released. The snails had an average total shell length of 7 cm. Growth rate was recorded at each sampling by measuring total length of 10 snails in each of the 12 areas, and by measuring addition of new varices. Estimates of survival was difficult to make. It was not possible to find all snails, even in a fenced area, because approximately 70% were buried. The fences around the 6 modules prevented emigration effectively. The only possible impact on the population size inside a fence would be from predation or natural death. If mortality was caused by stress or starvation, the empty shell was easily found. If mortality was caused by crabs, shell fragments were found because crabs use the peeling technique on juveniles of this size. Predation by fish was impossible to record because the shell fragments would disappear, but it was not likely to occur on juveniles of this size (Bech 1995b).

Survival inside each fence was calculated as 100 individuals originally released minus mortality recorded as empty shells or shell fragments found inside the fence. Furthermore, the assumption was made that visible or buried snails were estimated at each module in proportion to population size. Survival at the modules without fence was estimated by the proportion visible around the modules with a fence compared to the proportion visible around the modules without fence.

By using the known population size inside the three fences and the average amount of snails visible without digging in the sediment, a constant factor was calculated as follows:

\[ P_a = \left( \frac{V_1}{100 - M_1} \right) \cdot \left( \frac{V_2}{100 - M_2} \right) \cdot \left( \frac{V_3}{100 - M_3} \right) \]

The average amount of visible snails in relation to survival inside the areas (Pa) with fences were used to calculate survival in the areas without fences using \( S = 100 - M \)

\[ S_4 = \left( \frac{V_4}{P_a} \right); \quad S_5 = \left( \frac{V_5}{P_a} \right); \quad S_6 = \left( \frac{V_6}{P_a} \right) \]

\( M_1, M_2, M_3 \): mortality inside the areas with fences.

\( V_4, V_5, V_6 \): number of snails visible inside the areas with fences.

\( P_a \): average amount of visible snails in relation to population size.

\( S_4, S_5, S_6 \): number of snails visible inside the areas without fences.

\( S_4, S_5, S_6 \): estimated population size inside the areas without fences.

Numbers of all visible snails were recorded to estimate migration between the areas without a fence. Total counts in the areas could not be made because of the cryptic nature of the snails. Therefore, an estimate of migration between the modules was made using the equation constant \( P_a \).

At station 1, a pile of gill net, partly covered with sedentary organisms, was anchored to the bottom. The net was located in the central part of the modules and served as a trap for migrating snails. Snails caught in the gill net were measured at each sampling, and subsequently placed in the areas where they were released at the start of the study.

Survival rate and estimates of migration were recorded during 97 days until some of the fences were destroyed. Growth rates were recorded during 8 months and compared to growth rates obtained from C. ramosus cultured in land based aquaculture systems. The snails were 7 months at the time of release and juveniles were simultaneously reared for one year in cement tanks to enable comparison of growth at Prachuap Khiri Khan Coastal Aquaculture Development Center (Nugranad et al. 1994).
RESULTS

The overall mortality in the fenced areas was very low, only 26 juveniles were found as empty shells during 97 days.

The growth rate of the released juveniles was not significantly different from growth rates of juveniles held in land based aquaculture units.

In areas without fence the population size decreased to an average of 75 % after two months, and 50 % after four months. The calculated decrease was mainly due to emigration.

![Graph showing growth rates of juveniles released at artificial reef (AR) and at Prachuap Khiri Khan Coastal Aquaculture Development Center (PKAC).](image)

**Figure 1.** Growth rates of juveniles released at the artificial reef (AR) and at Prachuap Khiri Khan Coastal Aquaculture Development Center (PKAC).

In terms of addition of new varices, growth was highly variable and depended on the total length of the snail. Larger snails have longer inter-varix periods and slower varix growth than smaller individuals. Consequently, only snails of identical lengths could be compared. The highest varix growth was recorded in a 54.5 mm juvenile which completed a new varix within 40 days and thereby increased its total length to 62 mm.

![Bar chart showing estimated population size in the three areas without fences at station one.](image)

**Figure 2.** Estimated population size in the three areas without fences at station one.

Migration from one module to another was not recorded during the first 23 days. But migration between the areas occurred frequently after 51 days. Estimated migration at the second sampling was 4 juveniles from module 1 to module 3, 12 juveniles from module 3 to module 2 and 7 juveniles migrated from module 3 to module one. Estimated migration between the modules declined at the third sampling. After 23 days 8 juveniles were found entangled in the gill net trap, 9 juveniles after 51 days and 7 after 97 days.

DISCUSSION

Estimates of mortality could only be obtained in the areas with fences where mor-
tality could be separated from emigration. The cause of death was most probably stress after handling and transportation because no marks indicating predation on the empty shells were found. Besides, mortality decreased with time after release indicating that starvation was not the cause. Experiments with predation on juvenile *C. ramosus* in relation to size have shown, that little predation occurred when the juvenile exceeded 4.5 cm in total length (Bech 1995b). The only predators known to eat juvenile *C. ramosus* without leaving a mark on the shell are the carnivorous gastropods *Fasciolaria* spp. or *Conus* spp. (Bech 1995b). But the fence would prevent any gastropods larger than 1 cm from entering the area, making it safe to presume that mortality was mainly caused by stress.

The growth rate of the juveniles was similar to juveniles cultured in cement tanks, indicating feasibility of the sea farming approach. However, the population size of juveniles around the concrete modules in the open areas decreased due to emigration. But a considerable amount of juveniles migrated from one concrete module to another showing that the blocks provide both shelter and food compared to the surrounding muddy sand flats. The gill net trap caught surprisingly many juveniles if the event of trapping is supposed to be by chance. It is possible that the juveniles actively seek any shelter after they have left the safe environments at the concrete module. *C. ramosus* migrate toward the current and locate their prey by the scent (Bech 1992; 1993). The gill net trap could be located as a food source by chemoreception, because it was covered by sedentary organisms like the modules. But with this experimental set-up it is impossible to distinguish between the different factors.

The results of this experiment shows that commercial sea-farming of *C. ramosus* on artificial reef only would be feasible if the released stocks were to be reared in enclosures, because of their migrating nature. A similar strategy has been used in the culture of *Strombus gigas*, where the commercial Caicos conch farm at British West Indies has sealed of a small bay with a fence to prevent loss due to migration during the on-growing of juvenile queen conchs (Davis et al. 1989). In a land based aquaculture system there is no emigration, but the cost-benefit between the two methods depends on the loss of harvest in open culture, compared to the cost of rearing in closed systems.

Success in enhancing gastropods with hatchery reared stocks has been variable. Saito (1984) reported recapture rates of *Haliotis discus hannai* from 5 to 10%. Tegner & Butler (1985) only recovered 1% of their out-planted red abalone (*Haliotis rufescens*). But recapture rates from 40 to 50% after 2.5 years have been reported from restocking abalone on artificial reefs (Hahn 1989).

Restocking of *C. ramosus* on artificial reefs could become an efficient method to establish self sustainable populations. The present experiment indicates that the released stocks had a satisfactory growth rate, they migrated from module to module where there was plenty of food and only a few were lost due to predation. The establishment of reproducing populations of *C. ramosus* at different artificial reefs along the coast of the Andaman Sea could support a high flow of larvae and thereby support the recruitment in large areas.

To avoid interference by the human factor stocks should be released in sanctuaries or in areas where supervision and control is possible. If remote areas are chosen, buoys should be avoided because they attract poachers. Site identification should be done with a GPS satellite navigator. On the sea bottom at the release site both exposed and hidden marks should be used to enhance underwater navigation in the area and to avoid confusion if exposed marks are lost due
to poachers. Experiments over longer time are needed to show if the immigration and emigration decline to a steady state and whether the stocks reach sexual maturity and reproduce.

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REFERENCES


