GROWTH AND SURVIVAL IN THE MANGROVE SNAIL *LITTORARIA INTERMEDIA* (PHILIPPI, 1846)

Peter Daugbjerg Jensen[1], Jens Tang Christensen[1] & Donald J. Macintosh[2]
1) Department of Marine Ecology, Institute of Biological Sciences, The University of Aarhus, Finlandsgade 14, DK-8200 Aarhus N; 2) Centre for Tropical Ecosystems Research, Dept. of Ecology and Genetics, Institute of Biological Sciences, The University of Aarhus, Ny Munkegade, DK-8000 Aarhus C.

ABSTRACT

Growth of *Littoraria intermedia* was measured during a 42-day interval and a Gompertz curve fitted to the data. The growth was found to be rapid though highly variable among individuals. An average snail reached 95% of the asymptotic size of 11.69 mm in 26 weeks. Significantly more small than large individuals were lost during the study period. It is speculated that the loss of small individuals is due to predation. Examination of 46 shells for scars indicates that the predation could be from shell-crushing crabs.

INTRODUCTION

An abundant fauna of littorinids of the genus *Littoraria* is found in the mangroves of the Indo-Pacific region. Reid (1986, 1989) has given a detailed account of the taxonomy, geographical distribution and anatomy of the genus, but much is still to be learned about their ecology. Mangrove-dwelling species spend all of their adult lives on stems, prop-roots and leaves of the trees, while larvae of all Indo-Pacific species are pelagic.

Littoraria intermedia (Philippi, 1846) is a widespread member of the genus and is one of at least nine *Littoraria* species recorded from Thailand. It is found on stems, stilt roots and in the lower part of the canopy, but is rarely found more than 2-3 m above the ground (Reid 1986). The species is highly motile and the lower limit of its distribution is determined by the water level since snails crawl upward with the rising tide to avoid the submersion. Adult *L. intermedia* depend on a more or less solid substratum for movement and are unable to crawl on the muddy surface of the mangrove floor. Consequently, horizontal movement can only be through adjacent vegetation.

Contrary to the shells of littorinids on open shores, the shells of *Littoraria* are not eroded and any abnormality of the shell is likely to be the result of a failed attack by predators. Failed attempts of crab predation on *Littoraria* often result in a V-shaped or jagged breakage. After further growth the attack results in a scar in the shell that remains throughout life. Schindler *et al.* (1994) found that small species of blue crabs (*Callinectes sapidus*) preying on *L. irrorata* chipped their way through the aperture. The attempts often resulted in rejection of the snail, alive but with a scar. In species of *Littoraria*, correlation between shell thickness, shell size and vertical zonation has been found. Species inhabiting low levels are found to be smaller and with a thicker shell than species from high levels. Possibly, species occupying lower levels are more susceptible to predation from crabs, which will cause selection for thicker shells (Reid 1986; Reid 1992). Among temperate periwinkles a relationship between shell size and predation from crabs is found. Shell crushing crabs could only handle the small sizes of *Littorina littorea* (Hylleberg & Christensen 1978).

Growth rate is an interesting parameter because it is related to the resource-allocation and life history strategy of a species. The present study tracks growth and disappearance of marked individuals from an experimental population of *L. intermedia* in a *Rhizophora* replanting.

MATERIALS AND METHODS

The study was carried out in a reforested area of the mangrove forest in Muang District, Ranong Province, Southern Thailand. The main study area was situated next to Klong Ngao Estuary. The estuary is constantly water bearing and during the experiment the study area was inundated twice daily. The area was replanted in 1994 with the mangrove *Rhizophora mucronata*. The trees are spaced 1.4 m apart and at the time of the experiment their height ranged between 0.75 m and 2.76 m. At the start of the experiment the ground between the replanted mangrove trees was cleared of vegetation to prevent the snails from leaving the study area through this vegetation.

A total of 323 *L. intermedia* were individually marked with bee-dots. The shell of each snail was air dried for five minutes after which the bee-dot was fixed on the shell with epoxy glue. The shell height was measured from apex to the anterior end of the lip to the nearest 0.05 mm with vernier callipers. Since erosion of the shell apex is rare in the mangrove habitat, change in total length is a reliable measure of growth of the shell. Growth increments of individual snails of different initial sizes during a fixed time interval (cross-sectional data) were used in the construction of a growth curve. The marked snails were released on trees from which all other snails had been removed. At the end of the growth experiment the shells of 46 of the tagged snails were examined for scars. Scars were counted from the start of the teleoconch after the sinusigera ridge until the second whorl from the bottom. In this way scars on the last whorl resulting from handling during marking were omitted.

RESULTS

Growth increments were obtained from 89 individuals collected after a period of 42 days. Initial (S1) and final (S2) lengths were ln-transformed, ln S2 - ln S1 was plotted against ln S1, and a straight line fitted to the plot (Fig. 1).

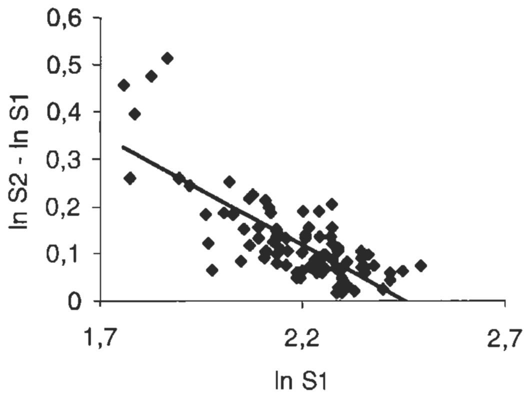

Fig. 1. Ford-Walford plot of transformed growth increments (ln S2 – ln S1) during 42 days of 89 *Littoraria intermedia* plotted against the transformed initial size of the shell (ln S1). Fitted line: (ln S2 - ln S1) = -0.4674lnS1 + 1.1493;

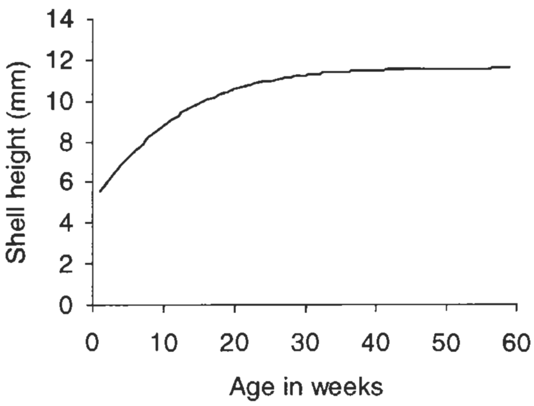

Fig. 2. A Gompertz curve constructed from the growth data in Fig. 1.

This model resulted in a better fit to data than both the Von Bertalanffy and logistic models.

$r^2 = 0.58$.

A Gompertz curve was constructed to approximate the growth of an average *L. intermedia* (Fig. 2).

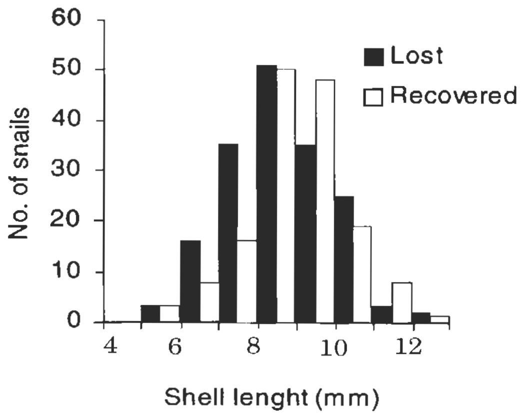

Fig. 3. Distribution of initial shell lengths of marked snails recovered after 13 days compared to initial shell lengths of snails that were lost by the end of that period.

The growth of the snails was found to be rapid. An average snail will have reached 95 % of the asymptotic size of 11.69 mm in approximately 26 weeks. There was considerable individual variation in growth rate, and individuals larger than the estimated asymptotic size were found.

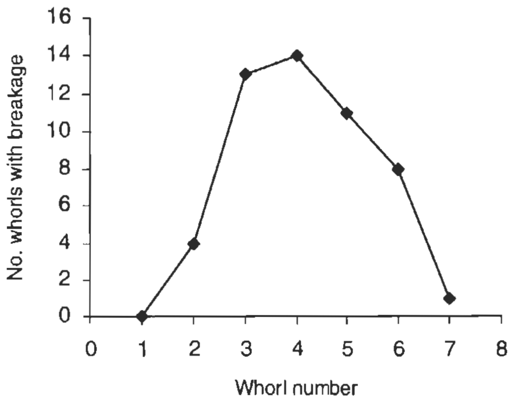

Fig. 4. Distribution of scars on the upper shell whorls of *L. intermedia*.

Thirteen days after release, 145 marked snails were found on their original tree, eight snails were found on other trees than those on which they were released.

The size frequencies for both lost and recovered snails were normally distributed (Fig.3). The average initial shell length of recovered snails (8.95 mm; SD 1.50; n = 153) was significantly higher ($z = 5.83$, $P<0.05$) than that of lost snails (8.12; SD 1.83; n = 170) (Fig. 3). The total loss of marked snails during the study corresponded to an instantaneous loss rate of 0.03 per day.

Eight of the 46 examined shells had no scars. On the remaining 38 shells the highest number of scars were found on whorl number four (Fig 4).

DISCUSSION

Growth is a complex process under the influence of both environmentally and genetically determined parameters. Using cross sectional data to describe growth has the advantage that individuals of different initial sizes are exposed to the same conditions, thus reducing the influence of seasonal change in environmental conditions on the resulting growth curve. The drawback of describing growth with cross sectional data during a short time span is the lack of information on seasonal growth variation. The growth increments could be obtained from a period with an extreme growth pattern e.g. possibly reduced or no growth during the dry season, which would result in an underestimate of the growth rate. Consequently, the growth model is only a valid description of growth of the population under observation during the specific time span covered by the data and under the prevailing environmental conditions. Furthermore, growth models based on cross-sectional data assume that all individuals included in the data set follow the same growth trajectory (Kaufmann 1981). Despite these

restrictions, measuring cross sectional growth increments is still a fast and cheap way of obtaining knowledge on growth of intertidal gastropods such as *Littoraria* and is very useful for comparative purposes.
In the present study the growth of *L. intermedia* was found to be rapid with the snails reaching 95% of the asymptotic size in only 26 weeks. Only few comparative data are available on the growth rates of *Littoraria*. A study on *Littoraria pallescens* (Philippi, 1846) showed that these snails reach their asymptotic size slower than the snails from the present study (Boneka 1997). Most growth studies on members of the family Littorinidae have concentrated on the genus *Littorina* in temperate areas where low overall growth rates are associated with seasonal fluctuations in growth. Changes in growth associated with season are shown, e.g. by Chow (1987) and Ekaratne & Crisp (1984). Burgett *et al.* (1987) found seasonal variation in growth of large *Littoraria angulifera* (Lamarck, 1822) (>15 mm) from Panama whereas small individuals (<15 mm) from the same species showed no variation associated with season. This indicates that although there is some seasonal variation in growth response in this tropical area the influence from season is less pronounced than in the temperate and subtropical areas. Chow (1987) showed in a study comparing three *Littorina* species, that they approach the asymptotic size considerably slower than the *L.intermedia* in the present study. This can, at least partly, be explained by the influence of temperature on food production and growth rate.
The instantaneous loss rate of 0.03 per day may not have been due solely to mortality. Some marked snails may have been able to escape from the study area and a few may have been overlooked. However, since the mangrove floor consists of soft mud and vegetation between adjacent trees was removed, emigration is not likely to play a significant role. It appears that the snails from this study are not long lived and that the turnover in the population is relatively high. Judging from the large proportion of snails with scars on the shell it is likely that predation, probably from crabs, is an important mortality factor.
The loss of snails was biased towards the smaller individuals. Also the distribution of healed scars on the shells indicates that the smaller individuals suffer from a predation pressure. If the predation continued on larger snails an equal number of scars would be expected on the later whorls which not are the case (Fig. 4). Predation from crabs crushing the whole shell or clipping through the aperture is well known from other studies (Zipser & Vermeij 1978; Reid, 1992; Schindler *et al.* 1994). Cook & Freeman (1986) have shown that small snails have thinner shells than large individuals of the same species, see also Cook & Kenyon (1993). Larger snails are typically found at a higher level than small individuals of the same species (Hughes & Jones 1985; Reid 1986). Although crabs were not seen actively preying on *L. intermedia*, this is believed to play an important role in the structuring of the *Littoraria* population in concern.

ACKNOWLEDGEMENTS

This work was supported by cenTER, Aarhus, the Mangrove Forest Research Centre, Ranong, Thailand, and Danish-SE Asian Collaboration in Tropical Coastal Ecosystems Research and Training (Ref. No. 1230324), which is funded by DANCED. Thanks are due to the staff at the field station in Ranong. Many thanks to Mr. Hakon R. Jalk and Miss Karen Touborg for invaluable help during P.D. Jensens stay in Thailand.

REFERENCES

Boneka, F. B., Lumingas, L. L. J. & Saroinsong, V. (1997). Growth and mortality of *Littoraria pallescens* with emphasis on two colour morphs, in northern Sulawesi, Indonesia. - *Phuket Marine Biological Center Special Publication* **17** (1): 33-36.

Burgett, J. M., Cubit, J. D. & Thomson, R. C. (1987). Seasonal growth patterns in the tropical littorinid snails *Littorina angulifera* and *Tectarius muricatus*. - *The Veliger*, **30** (1): 11-23.

Chow, V. (1987). Patterns of growth and energy allocation in northern California populations of *Littorina* (Gastropoda: Prosobranchia). - *J. Exp. Mar. Biol. Ecol.*, **110**: 69-89.

Cook, L. M. & Freeman, P. M. (1986). Heating properties of morphs of the mangrove snail *Littoraria pallescens*. - *Biological Journal of the Linnean Society*, **29**: 295-300.

Cook, L. M. & Kenyon, G. (1993). Shell strength of colour morphs of the mangrove snail *Littoraria pallescens*. - *J. Moll. Stud.*, **59**: 29-34.

Ekaratne, S. U. K. & Crisp, D. J. (1984). Seasonal growth studies of intertidal gastropods from shell micro-growth band neasurements, including a comparison with alternative methods. - *J. mar. Biol. Ass. U. K.*, **64**: 183-210.

Hughes, J. M. & Jones, M. P. (1985). Shell colour polymorphism in a mangrove snail. - *Biological Journal of the Linnean Society*, **25**: 365-378.

Hylleberg, J. & Christensen, J. T. (1978). Factors affecting the intra-specific competition and size distribution of the periwickle *Littorina littorea* (L.). - *Natura Jutlandica,* **20**: 193-202.

Kaufmann, K. W. (1981). Fitting and Using Growth Curves. - *Oecologica*, **49**: 293-299.

Reid, D. G (1986). *The littorinid molluscs of mangrove forrest in the Indo-Pacific region*. - London, British Museum, Natural History Publication. 228 pp.

Reid D. G. (1989) The comparative morphology, phylogeny and evolution of the gastropod family Littorinidae. - *Phil. Trans. R. Soc. Lond.* B, 324: 1-110.

Reid, D. G (1992). Predation by crabs on *Littoraia* species (Littorinidae) in a Queensland mangrove forrest. - *Proceedings of the Third International Symposium on Littorinid Biology*, 141-151.

Schindler, D. E., Johnson, B. M., MacKay, N. A., Bouwes, N. & Kitchell, J. F. (1994). Crab:snail size-structured interactions and salt marsh predation gradients. - *Oecologia*, **97**: 49-61.

Zipser, E. & Vermeij, G. J. (1978). Crushing behaviour of tropical and temperate crabs. - *J. Exp. Mar. Biol. Ecol.*, **31**: 155-172.