

## VERTICAL DISTRIBUTION OF THE PERIWINKLE, *LITTORARIA PALLESCENS*, WITH EMPHASIS ON THREE COLOUR MORPHS, NORTH SULAWESI, INDONESIA

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### ABSTRACT

The proportions of three colour morphs of *Littoraria pallescens* (Philippi 1847) were relatively constant from May to October 1994. The dark morph was most common (78 %), followed by the yellow, and the orange morph. The shell length showed homogeneity among morphs. The mean length of dark morphs was 11.9 mm, the yellow 12.1 mm, and the orange 12.8 mm respectively. Kruskal-Wallis test revealed no difference with respect to shell thickness of the three colour morphs. The mean shell length was studied on four different substrata: *Avicennia*, *Rhizophora*, bark and leaves of *Avicennia*. The mean length of *L. pallescens* was larger on *Rhizophora* than on *Avicennia*. The shell length was larger on bark than on leaves. There was no significant relationship between shell length and height above ground level of dark and yellow morphs, both for line slope and position. There was no significant difference of shell properties, and no ecological segregation among three colour morphs of *L. pallescens*.

### INTRODUCTION

Tropical periwinkles of the genus *Littoraria* encompass species which live on bark (also roots) and on leaves of mangrove trees. The bark-living species tend to be monomorphic and cryptic, whilst the leaf-living species are polymorphic for shell colour (e. g., Reid 1986; Cook & Garbett 1989).

On the mangrove trees of Bunaken Island, North Sulawesi, *L. scabra* and *L. pallescens* are common and obviously exhibit microhabitat segregation (Boneka 1994). The *L. scabra* exclusively occupies bark, but sometimes extend onto leaves; and about three quarter of the *L. pallescens* population occur on leaves.

*L. pallescens* is a widespread species in the Indo-Pacific region, and has a planktonic larval stage in the life cycle (Reid 1986). After settlement the species is effectively semi-terrestrial, and polymorphic for shell colour ranging from orange pink, pale yellow, to dark brown. In spite of the variation in sculp-

ture, size, and colour, there seems to be no reason to taxonomically subdivide the species since the anatomical characters are constant, particularly the form of the penis (Reid 1986). Cook & Garbett (1992) found that there is no evidence of pairing based on colour morph. Colouration not only affects the visual properties of a shell, but also its thermal properties. Dark morphs are presumed to absorb more heat from solar radiation than light morphs. *L. pallescens*, inhabiting mangrove leaves may be more exposed to solar radiation than *L. scabra* occupying bark and roots; thus, having light shell colour is probably a advantage.

Indeed, polymorphism may reflect differential survival at an energetic cost. The pale yellow colour was considered to lack pigment. It could, therefore, be suspected that the pale yellow shells would compensate their lack of pigment for another benefit in shell characters. The excellence in one aspect usually causes poor performance in another (Hughes 1980).

The questions that may be asked are (1) regarding tropical seasons, do colour morph proportions change seasonally? (2) is there any poor performance which is compensated in shell characters? Cook (1990a), Reid (1992), and Cook & Kenyon (1993) have worked along this line; however, the question is still not completely understood. The present study is to document and compare morph properties in relation to previous findings from different locations, and also to relate those aspects with other environmental factors which may contribute to maintenance of the polymorphism in *L. pallescens*.

## MATERIALS AND METHODS

The study was carried out at Bunaken Island, the Marine National Park, a popular tourist destination, situated about 8 km to the Northwest of Manado Bay, North Sulawesi. The mangrove genera *Avicennia* and *Sonneratia* are common, occasionally also *Rhizophora* and *Bruguiera*. At the study site, the trees are generally over 8 m tall. The mangrove area is 50-100 m wide extending from shore line to the seagrass beds or coral reef lagoon. There is no evidence that tourists and local people collect and utilize the snails.

*L. pallescens* was collected by hand. Sampling was monthly, during low tide, from *Rhizophora* and *Avicennia* in the mangrove. Height above the ground of individuals was studied on one occasion in August 1994. The size of each morph was measured from the apex to the anterior edge of the lip by using sliding callipers to the nearest 0.05 mm. To measure the relative shell thickness, Reid's (1992) procedure partly was followed. An index of shell thickness is the ratio of mass and volume. Shell mass was individually measured to the nearest 0.01 g, whilst volume to the nearest 0.0125 ml. Thirty individuals of each morph (shell length 15-18 mm), were chosen from the collection, and the soft bodies were removed using NaOH

solution. Cook & Kenyon (1993) actually measured shell thickness just inside the aperture using a micrometer.

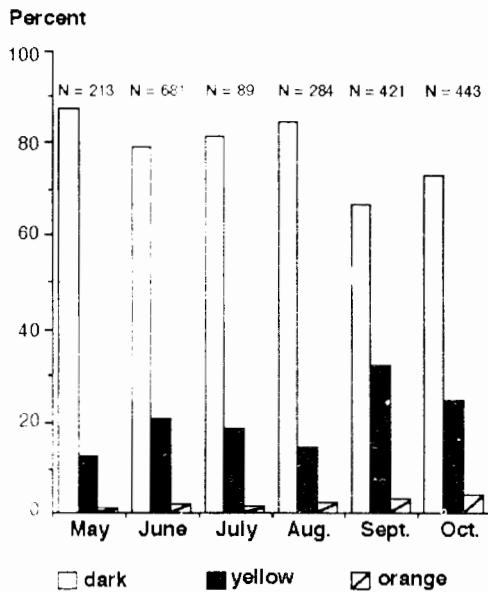
Differences among morphs were statistically tested using  $\chi^2$  test for morph proportion, One-Way ANOVA for length distribution, Kruskal-Wallis for shell thickness, and Z-test to compare coefficients of the geometric mean regression of shell length and altitude (vertical zonation) of the *L. pallescens* on the trees in mangrove.

## RESULTS AND DISCUSSION

### Frequency of colour morphs

A light coloured shell is considered as a way to reduce heat gain from the environment, as suggested by, *e. g.*, Vermeij (1973) and Newell (1976). Therefore, regarding tropical seasons, the morph proportion of *Littoraria pallescens* was speculated to change seasonally in accordance with the changing monsoons. The result obtained, however, does not provide evidence of seasonally changing morph frequencies. Fig. 1 shows the occurrence of each morph and its proportion from May to October 1994. The dark morph is dominant (78.13 %), followed by the yellow (19.92 %), and the orange (1.98 %), on an average. The proportion was constant for six months ( $\chi^2 = 18.63$ ;  $p < 0.01$ ). May-June is a transition period from rainy to dry season, whilst October is the early period of the rainy season. Turnover of the population needed to be observed.

Within the geographical range of *Littoraria pallescens*, the three morphs also have fairly constant proportions (*e. g.*, Cook & Garbett, 1989). The mean frequency was 63.2 % of the dark morph in Papua New Guinea (Cook 1990b), similar to the range in the present study area. It means that the major factor controlling the morph proportions of *Littoraria pallescens* is constant throughout the lifetime of any individual, and hence likely to be genetical. The pelagic larval stage may play an important role in maintaining



**Figure 1** *Littoraria pallescens*, frequency of shell colour morphs occurrence; Bunaken Island, 1994.

genetic continuity. Phenotypic variation, on the other hand, was evident in the European periwinkle *Littorina littorea* (Hylleberg & Christensen 1977; 1978). The variation could be related to particular local environmental variables such as predation, exposure, and food availability. Phenotypic plasticity responses of other marine fauna to environmental pressure, have recently been shown by Lumingas & Guillou (1994) who worked on sea urchin.

Cook (1990b) found that the frequency of dark *L. pallescens* was lower when it occurs alone. A higher frequency occurred where leaves were occupied by a second sympatric species, resembling the dark morph, such as *L. subvitata* in Kenya, and *L. intermedia* in Phuket. Predators may not be able to distinguish species of dark coloured snails. Therefore, predation may be a factor regulating the distribution and the proportion of dark morphs of *L. pallescens* in nature. Cook & Garbett (1992) found that the non-dark morphs may survive better than the dark ones. Yet the present results do not

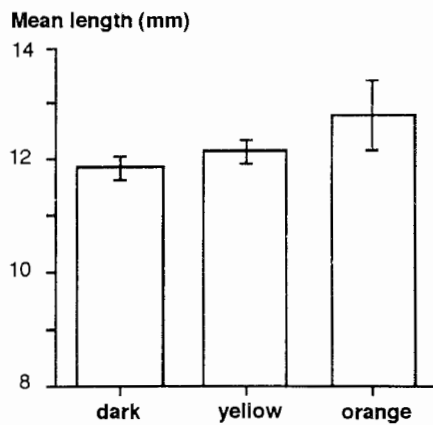
reflect predation on a particular morph. From an evolutionary point of view, the morph frequency could be a selection for crypsis against heterogeneous background of substrata by visual predators (Reid 1986). At the lower level of the tree, dark coloured shells are cryptic against the uniformly brown trunk, perhaps a further contribution to avoidance of attack by crabs. Thus predation is a powerful selective agent for maintaining polymorphism. The most important predation on *Littoraria* in mangrove comes from aquatic predators (Reid 1992; Boneka 1995). There is no information available about the predation by bird in the area.

In the present study, the morph frequency on two different mangrove trees, *Avicennia* and *Rhizophora* was examined. The result was homogenous ( $\chi^2 = 4.9510$ ;  $p > 0.05$ ). This does not agree with the frequency in Phuket reported by Cook (1990b).

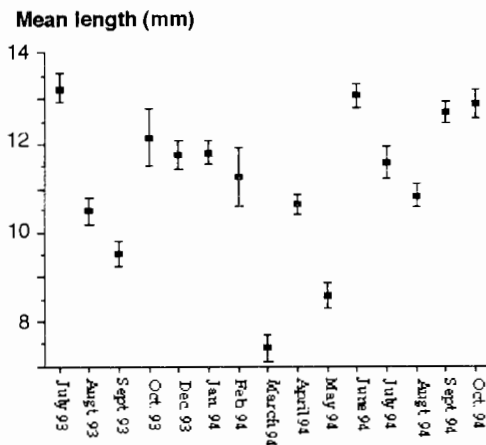
#### Shell length; colour morph and predation

There were no shell length differences among the three colour morphs: the dark, the yellow and the orange ( $F = 0.67$ ;  $p > 0.01$ ). The mean size of the dark morph was 11.85 mm (SE = 0.22), the yellow 12.12 mm (SE = 0.23), the orange 12.76 mm (SE = 0.64) (Fig. 2). This was also found during March-May, when the appearance of many juveniles reduced the population mean shell length considerably (Fig. 3). Selective predation is another factor which can influence the mean shell length of a population. Boneka *et al.* (1995) collected gastropod shells along the beach of Bunaken Island, and it was hard to find empty shells of *Littoraria*. This suggested that the littorinid population in the mangrove might be controlled by shell breaking predators. Grapsid and portunid crabs were common in the study site. From laboratory trials, grapsid crabs tended to select smaller shells. Portunid crabs such as *Scylla serrata*, *Thalamita crenata*, and *Portunus pelagicus*, having strong claws, likely preyed on the bigger ones. Predators often show a tendency to select prey based on

visual appearance. Prey selection reflects a search image, which again is a result of preference and accessibility. Preference is affected by prey size, type, and palatability whereas accessibility is influenced by colouration, size, and microhabitat choice (e.g., Main 1985).



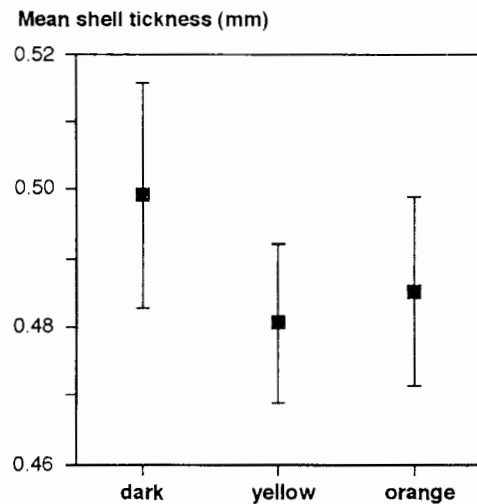
**Figure 2.** *Littoraria pallescens*, mean length of the three colour morphs, collected during the dry season 1994, Bunaken Island. Bar= standard error.



**Figure 3.** *Littoraria pallescens*, size (length) distribution. Bar= standard error.

### Shell thickness.

Although the yellow shells were easily damaged during washing and removal of soft bodies, the relative shell thickness was similar among morphs of similar size (Fig. 4). Obviously, the energy saved on production of pigment was not reflected in the shell thickness. This finding agrees with Cook & Kenyon (1993) who concluded that colour morph is sometimes, not always, associated with differences in shell characteristics.

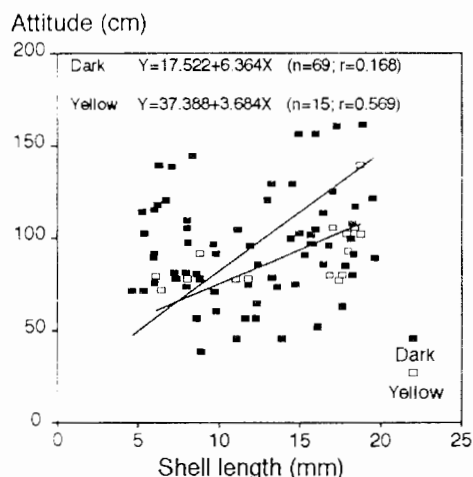


**Figure 4.** The mean shell thickness index of *Littoraria pallescens*, August '94; Bar = standard error.

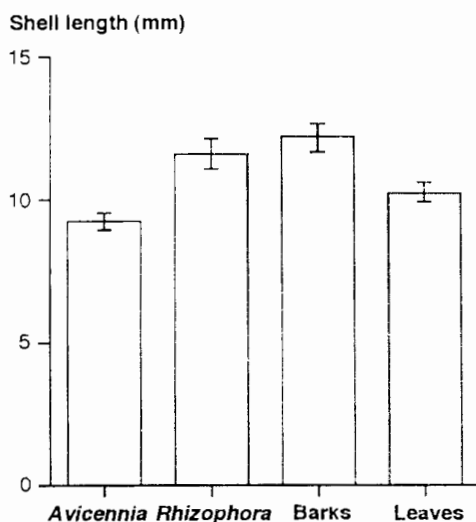
### Shell length; substrate and vertical zonation

The vertical distributions of the dark and the yellow morphs were compared on *Avicennia* (Fig. 5) by means of regression analysis. The geometric means of the vertical zonation were calculated. Both the slope line ( $Z = 2.34$ ;  $p > 0.01$ ) and the line position ( $Z' = 1.50$ ;  $p > 0.05$ ) revealed no significant differences. For yellow morphs, however, there was a slight tendency that shell length increased with height above the ground surface ( $r = 0.55$ ;  $t = 2.2815$ ;  $p < 0.01$ ), but not for the dark morphs ( $r = 0.17$ ;  $t = 1.4121$ ;  $p > 0.05$ ). The small size group was expected to be located at the lower level of the trees because of an assumed lower tolerance to des-

iccation. Boneka (1994) found that the relatively small *L. pallescens* was less resistant to dry conditions than *L. scabra*. Obviously it is necessary to conduct further studies. Experiments can show whether the vertical distribution is related to body size or a general physiological difference among the species.



**Figure 5.** *Littoraria pallescens*, the geometric mean regression curve of shell length and altitude level on the *Avicennia* trees; August 1994, Bunaken Island.



**Figure 6.** Shell length sizes of *Littoraria pallescens* on various substrata. Barks and leaves of *Avicennia*; Bunaken Island. Bar = standard error.

The mean shell length was studied on four different substrata: *Avicennia*, *Rhizophora*, bark and leaves of *Avicennia* (Fig. 6). Z-test revealed that the mean size of *L. pallescens* on *Rhizophora* was bigger than on *Avicennia* ( $Z = 3.8602$ ;  $p < 0.01$ ). The shell length was bigger on bark than on leaves ( $Z = 3.1935$ ;  $p < 0.01$ ). The foliage of *Rhizophora* is located relatively higher than that of *Avicennia*, so snails were forced to a higher altitude on *Rhizophora*. The two species of trees also differ in morphology. *Rhizophora* provide prop roots as a significant substratum.

### Vertical zonation; behaviour

The mangrove snail, *L. pallescens*, is a well adapted supratidal species. When sampled during neap tide, *L. pallescens* were found 50-380 cm above the ground surface, and mainly above the tidal level. However, when observed by snorkelling with underwater torch during high spring tide, *L. pallescens* was commonly found submerged on leaves. Leaves as substratum are like islands where *L. pallescens* would be trapped by the raising tide, compared with the more active *L. scabra* which is capable of avoiding the submersion. During high spring tide, *L. scabra*, especially the adult, moved above water surface along the bark. Thus vertical zonation between these two species as reported by Boneka (1994) was just a temporal pattern during the low tide.

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