

## Shell-color polymorphism of intertidal gastropods in Chuuk State, Federated States of Micronesia

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### Abstract

I investigated the relationship between shell color of *Nerita plicata* gastropods and habitat background color in Piis and Romanum Islands, Chuuk State, Federated States of Micronesia. The brightness of habitat background color ranged from 10 to 80, whereas the brightness of shell color varied from 40 to 98. The shell color was usually brighter than the habitat background color, suggesting that *N. plicata* inhabits backgrounds that are darker than its shell color. Only snails with brighter shell colors inhabited brighter backgrounds. By contrast, darker backgrounds were inhabited by snails with several types of shell color. My findings indicate that *N. plicata* may adapt to different environments by means of shell-color polymorphism.

**Keyword:** background, polymorphism, shell color

### Introduction

Color and color-pattern polymorphism within animal species may be attributed to different modes of selection, such as selection for crypsis (e.g., BYERS 1990), sexual selection (e.g., ENDLER 1983), climatic selection (e.g., MIURA *et al.* 2007), or frequency-dependent selection (e.g., OLENDORF *et al.* 2006). Intertidal gastropods live under variable temperature and salinity regimes, and face changing wave action, habitat type, prey type, desiccation and predation risks, and other environmental factors (HUGHES 1986; LITTLE and KITCHING 1996). *Nerita plicata* is a gastropod distributed within the reef region of the upper intertidal zone of the Indo-Pacific Ocean, and it is known to exhibit shell-color polymorphism (ABBOTT and DANCE 1985; NEVILLE 2003). High intertidal neritid species, including *N. plicata*, are known to be better temperature regulators than low intertidal species (VERMEIJ 1971a). In addition, *N. plicata* changes the direction of its shell to face the sun at the time of emersion (WARBURTON 1973). These behaviors may help *N. plicata* adapt to changing temperatures in the upper intertidal zone. On the other hand, visual selection by predators may underlie shell-color polymorphism in *N. plicata* (BYERS 1990; McKILLUP and McKILLUP 2002). The species inhabits substrates of varying background color, including basalt rocks, limestone, and beach rocks, in the upper intertidal regions of the tropical Pacific Ocean (VERMEIJ 1971b).

In the present study, I investigated the relationship between shell color of *N. plicata* and habitat background color in Piis and Romanum Islands, Chuuk State, Federated States of Micronesia.

### Materials and Methods

This study was conducted in August 2011, in Piis and Romanum Islands, Chuuk State, Federated States of Micronesia.

The shell color and habitat background color of each snail were recorded using a digital camera. The shell color and habitat background color varied according to time and weather conditions. Therefore, to adjust the quality of the photographs, standard colors (black and white substratum) were also photographed on each occasion. The colored photographs were adjusted to monochrome color using Photo Shop. For each shell area and habitat background area, the brightness of 3 points was calculated by Photoshop, and each value was adjusted using following formula:

Adjusted value = (sample brightness - standard black brightness) / (standard white brightness - standard black brightness)  $\times$  100

A value of 0 indicated that the color was fully black; a value of 100 indicated that the color was fully white.

### Results

The brightness of habitat background color ranged from 10 to 80, whereas the brightness of shell color varied from 40 to 98 (Fig. 1). The shell color was usually brighter than the habitat background color. Only snails with brighter shells inhabited brighter backgrounds. By contrast, darker backgrounds were inhabited by snails with several types of shell color.

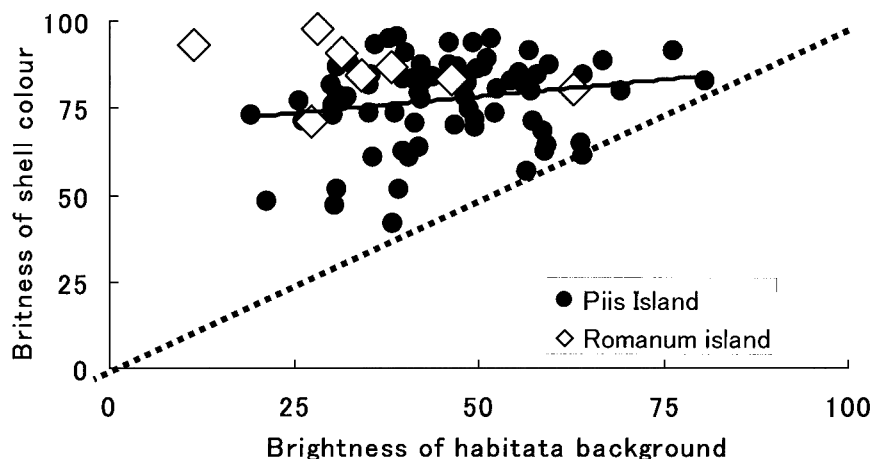


Fig. 1 Relationship between brightness of shell color and brightness of habitat background. A value of 0 indicates that the color is fully black; a value of 100 indicates that the color is fully white.

### Discussion

In the present study, only snails with brighter shells inhabited brighter backgrounds. By contrast, darker backgrounds were inhabited by snails with several types of shell color. This finding indicates that *N. plicata* exhibits shell-color polymorphism, and that this polymorphism is strongly related to habitat background color.

Temperature can greatly affect the metabolism of gastropods (e.g., HUGHES 1986). Metabolic activities may be accelerated if the body temperature increases within a range that does not impede normal physiology. The difference in body temperature between *N. plicata* individuals living in beach rock (white-colored background) and basalt rock (dark-colored background) environments was 1-2 °C (Kawai, personal communication). Similar differences in body temperature have been recorded between banded and unbanded morphs in *Cepaea* and other snail species (JONES 1973; RICHARDSON 1974; HEATH 1975). When the body temperature of the land snail *C. hortensis* was increased from 25 °C to 26 °C, oxygen consumption increased from 2.6% to 4.5% (STEIGEN 1979). This finding indicates that a small temperature increase may have a relatively small effect on physiology in the short term. However, a long-term temperature differential may significantly influence rates of growth, reproduction, mortality, and other physiological conditions.

Many other environmental factors affect the frequencies of shell-color morphs in gastropods. Juveniles of a muricid snail, *Concholepas concholepas*, exhibit shell-color plasticity depending on the coloration of prey species (MANRÍQUEZ *et al.* 2009). Frequencies of shell-color morph may depend on parasites and predation (BYERS 1990; MCKILLUP and MCKILLUP 2002), with environmental gradients in temperature, salinity, and wave action frequently affecting the evolution of color polymorphisms (ETTER 1988; SOKOLOVA and BERGER 2000; MIURA *et al.* 2007). Shell-color polymorphism in some gastropods results from complex interactions between selective forces (JONES *et al.* 1977); the observed shell-color polymorphism of *N. plicata* may be derived from complex interactions between several such selective forces.

*N. plicata* is thought to have a comparatively long, free-swimming larval stage (KANO 2006), suggesting that the genetic differentiation underlying the observed shell variation in proximate populations is not large. In the present study, I observed similar trends in the frequency distribution of shell-color morphs between Piis and Romanum islands (Figure 2). However, the frequency of shell color variation differed according to habitat background brightness. This finding implies that genetic differentiation may contribute to shell-color polymorphism in *N. plicata* populations. To elucidate such genetic influences, I intend to conduct further detailed analyses using microsatellite DNA markers.

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