Distribution and Gut Contents of the Green Snail Turbo marmoratus in Tokunoshima Island, Ryukyus(southern Japan)

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Distribution and Gut Contents of the Green Snail *Turbo marmoratus* in Tokunoshima Island, Ryukyus (southern Japan)

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Abstract: Surveys of the distribution and gut contents of the green snail *Turbo marmoratus* from the tidal and subtidal zones in Tokunoshima Island were conducted to determine effective methods for culture and release of seeds for enhancement of this natural resource. Juveniles of *T. marmoratus* less than 75 mm in shell height were found only in the tidal zone, while individuals of more than 100 mm in shell height were found only in the subtidal zone. Migration of *T. marmoratus* from the tidal to subtidal zone appears to occur with growth between 75-100 mm in shell height. Investigation of the gut contents revealed that *T. marmoratus* is primarily herbivorous. Food for culture and effective techniques for the release of the seeds are discussed.

Key words: *Green snail, Turbo marmoratus, Vertical distribution, Habitat, Gut content, Ryukyus, southern Japan*

Introduction

The green snail, *Turbo marmoratus* (Gastropoda, Turbinidae), has been widely used as a food item in tropical and subtropical western Pacific regions, as well as a material for shell craft in Korea, China, Japan and Europe for hundreds of years (Arakawa 1985). Over the past twenty years, the populations of the green snail in the Ryukyu Islands (southern Japan) and Southeast Asia have markedly decreased and become endangered because of heavy overfishing (Chantrapornsyl 1995). Prefectural Sea Farming Cooperatives in both Okinawa and Kagoshima initiated seed production and release projects of the green snail to help sustainable propagation of the natural resource of this species (Komatsu *et al.* 1995, Manu *et al.* 1996). In order to select the most suitable sites for releasing green snail seeds, it is necessary to detail the distribution, habitat and food habits of the animal (Yoshiya *et al.* 1987). Although the habitat of the green snail in Tokunoshima Island has been preliminarily reported by Honma (1987), Yamaguchi (1988), and Yamaguchi and Kikutani (1989), its vertical distribution was not well known. However, this information is necessary to select the optimal sites for release of the seeds. Further, a survey on the gut contents of the green snail, as well as the distribution of the marine algae around their natural habitat, was necessary to clarify the nutrient sources for the culture of green snails.

This paper aims to clarify the change of habitat with growth of the green snail. Also the best food items for culturing the green snail and the most effective techniques for releasing seeds are discussed.

Materials and Methods

Green snails for the shell height analysis were collected during April to July of 1989 from the reef tidal zone of 9 sites in Tokunoshima Island (27°45'N, 129°E) at low tide, and collected using SCUBA during May to July of 1989 from the subtidal reef slopes of 12 sites down to a depth of 15 m (Fig. 1). Snails were gathered while walking in the tidal zone 3 hours a day for 21 days at low tide, and those in the subtidal zone were caught during 3 dives (one hour each dive) a day at each site for 12 days. Green snails for the gut content analysis were collected in August of 1989 and 2000. All collections were made in the daytime. Shell height (SH), shell width (SW) and total wet weight (TW) with shell of green snails were measured. The data were analyzed based on four vertical zones: tidal zone, subtidal zones of the depth of 0-5 m, 5-10 m and 10-15 m. The values of the mean and standard deviation of the shell height were calculated for each vertical zone.

The benthic marine algae were collected in May of 1989 and in June of 2000. Algae in the tidal zone were collected during a 3-hour walk each day for 9 days at low tide, and those in the subtidal zone were collected during 2 dives (two hours each dive) a day for 6 days. All algal specimens were preserved in 3.5% formalin seawater and identified in the laboratory. Snails for checking gut contents were frozen. Gut contents were placed on a glass

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slide under a cover slip and identified under a microscope. The abundance of gut contents was classified based on frequency into four ranks: (r) rare, (+) little, (++) common, (+++) abundant.

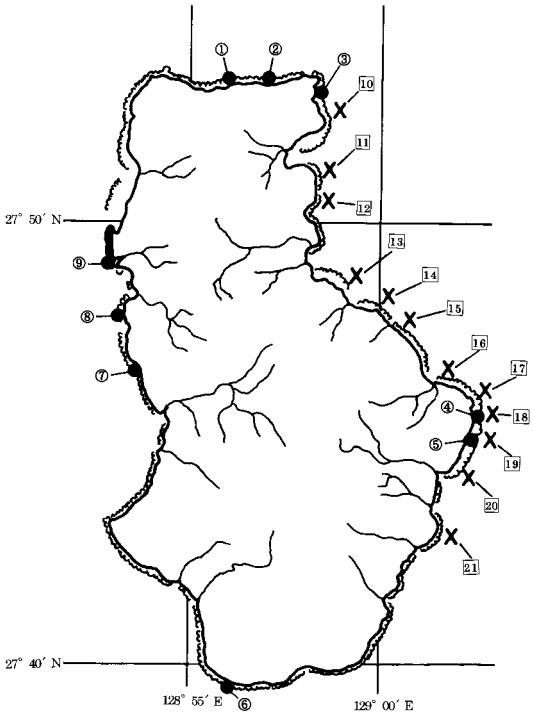

Figure 1. Map of Tokunoshima Island showing the sites (1-9: tidal zone, 10-21: subtidal zone) in which green snails *Turbo marmoratus* were collected during April-July of 1989: 1. Tete, 2. Kanami-nagahama, 3. Kanami, 4. Shoda, 5. Tokuwase, 6. Isenzaki, 7. Senma, 8. Innojouhuta, 9. Asama, 10. Nakashiotobiya, 11. Aze, 12. Kuroaze, 13. Boma, 14. Honsaki, 15. Shimokushi, 16. Inokawa, 17. Kaminomine, 18. Shoda, 19. Tokuwase, 20. Kametoku and 21. Kametsu.

Results

Composition of the shell height of green snails

A total of fifty green snails was collected from the inside of small crevices in the tidal zone. The frequency of the shell height of green snails collected from the tidal zone (Fig. 2 A) revealed that it ranged from 25 mm to 75 mm SH (40 ± 4.2 mm, n=50), and the size class between 35-40 mm SH was the most abundant (42%).

One hundred and seventeen green snails were collected under overhangs and inside caves in the subtidal zone of fore reef slopes down to a depth of 15 meters. The frequency of shell height of green snails from the subtidal zone (Fig. 2 B-D) showed that it ranged from 100 mm to 215 mm. At depths of 0-5 m, green snail SH ranged widely from 100 mm to 205 mm (176.1 ± 8.1 mm, n=69); 5-10 m, from 150 mm to 215 mm (180.9 ± 3.5 mm, n=35); 10-15 m, the number of individuals was reduced and SH ranged from 150 mm to 200 mm (179.6 ± 22.9 mm, n=13). Individuals larger than 150 mm SH appeared at all depths in the subtidal zone and showed a tendency to increase in SH with depth.

Young individuals of less than 75 mm SH which were distributed in the tidal zone were not found in the subtidal zone.

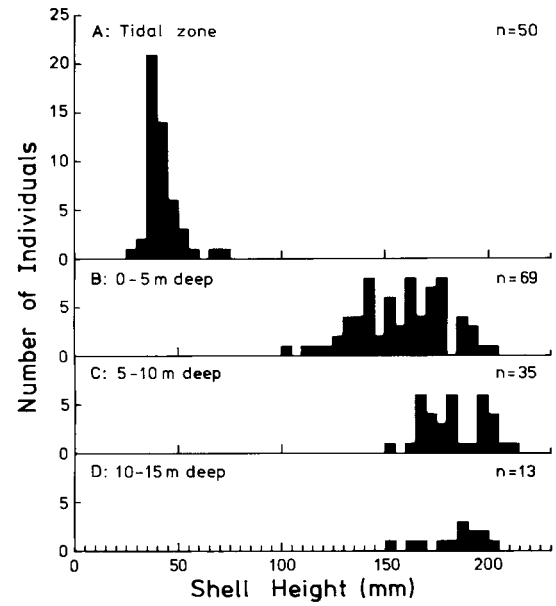

Figure 2. Vertical distribution of green snails from the tidal zone (A) to the subtidal zone (B-D) in Tokunoshima Island during April-July of 1989.

Algal vegetation

Taxa of benthic marine algae found around the habitat of the green snail are shown in Table 1. Most algal taxa collected were tropical ones. The algal vegetation in the tidal zone was different from that of the subtidal zone.

The number of green and blue-green algae in the tidal zone exceeded that in the subtidal zone, while opposite relationship was found in the number of brown algae. Some algae mainly distributed in the subtidal zone were sometimes also found in the tide pools. *Monostroma*

nitidum, *Enteromorpha* spp., *Ulva conglobata* and Ectocarpaceae spp. are annual algae, and formed large associations in the zone in spring and early summer. *Dictyopteris undulata*, Melobesioideae spp. (calcareous coralline algae) and *Melamansia glomerata* were luxuriantly growing in open areas among the reef coral community in the subtidal zone. *Dictyopteris undulata* is an annual alga and grows up to about 30 cm in height. *Melamansia glomerata*, a small perennial alga, has blades and a thick stem that is 1-5 cm in height

Gut contents of green snails

The gut contents of 5 green snails from the tidal zone are shown in Table 2. Fourteen algal taxa were identified, of which blue-green algae, mainly *Lyngbya* sp. *and Rivularia* (?) sp. were dominant. Coralline algae (Melobesioideae spp. and *Jania* sp.), calcareous sand and red spherical cell-like particles (5-10 μm in diameter) were also abundant. *Sphacelaria* sp. was found in the gut of all the specimens. Remnants of a few small animals were also identified in these gut contents. *Monostroma nitidum*, *Ulva conglobata*, *Caulacanthus usutulatus* and *Bostrychia tenella*, which were distributed in the upper tidal zone, were not included in the gut contents.

Seventeen algal taxa were identified from the gut contents of the 2 green snails collected from the subtidal zone (Table 2). Red algae such as coralline algae (*Mesophyllum*, *Amphiroa*, *Jania* and *Cheilosporum* species) and *Melamansia glomerata* were found to be abundant. The green snails were found to have been feeding on only the blades of *Melamansia glomerata*, and did not ingest the hard parts such as the stem and holdfast. Many benthic foraminifera (*Baculogypsina*, *Calcarina* species and others) also occurred in the gut contents.

Although both juvenile green snails in the tidal zone and adults in the subtidal zone fed on coralline algae and other relatively small marine algae, the other algal components of the gut contents were quite different. Both juveniles and adults did not ingest such larger and erect algae as *Dictyopteris undulata* (abundantly distributed in the subtidal gone), *Sargassum* spp., *Liagora* spp. and *Galaxaura* spp.

Table 1. Taxa of the benthic marine algae found around the habitat of the green snail *Turbo marmoratus* in Tokuno-shima Island. r: rare, +: little, ++: common, +++: abundant.

Taxa	Tidal zone	Subtidal zone
Green algae (Chlorophyta)		
Monostroma nitidum	++	
Blidingia spp.	+	
Enteromorpha spp.	++	
Ulva conglobata	++	
Cladophora spp.	+	+
Cladophoropsis spp.	+	+
Dictyosphaeria spp.	+	
Caulerpa spp.	r	++
Halimeda spp.		++
Brown algae (Phaeophyta)		
Ectocarpaceae spp.	++	+
Sphacelaria spp.	+	+
Dictyota spp.		+
Dictyopteris undulata		+++
Distromium decumbens		++
Lobophora variegata		++
Zonaria stipitata		++
Padina spp.	+	++
Sargassum spp.	+	++
Red algae (Rhodophyta)		
Liagora spp.	+	++
Galaxaura spp.		++
Gelidium pusillum	++	r
Gelidiella acerosa	++	
Amphiroa spp.		++
Cheilosporum spectabile		+
Jania spp.	++	+
Melobesioideae spp.	++	+++
Peyssonnelia spp.		++
Caulacanthus usutulatus	+	
Hypnea pannosa	+	++
Gelidiopsis spp.	+	+
Coelothrix irregularis	++	+
Ceramiaceae spp.	+	++
Acrocystis nana	+	
Laurencia spp.	++	++
Melamansia glomerata		+++
Bostrychia tenella	+	
Blue-green algae (Cyanophyta)		
Lyngbya spp.	++	+
Symploca hydnoides		+
Hydrocoleum spp.	+	
Phormidium spp.	+	
Calothrix spp.	++	
Gardnerula sp.	+	+
Rivularia spp.	+	
Brachytrichia quoyi	+	

Table 2. Gut contents of green snails *Turbo marmoratus* from the tidal and subtidal zones of Tokunoshima Island. Numbers 1-5 and 6-7 of green snails were collected from the tidal zone (August of 2000) and the subtidal zone (August of 1989), respectively. r: rare, +: little, ++: common, +++: abundant.

	Individual number	1	2	3	4	5	6	7
	Shell height (mm)	50	53	58	72	74	-	-
	Shell width (mm)	44	47	46	70	71	-	-
(Gut contents)	Total fresh weight (g)	46.5	49.0	55.5	137.6	152.2	1,345	1,675
SEAWEEDS								
Green algae (Chlorophyta)								
Blidingia sp.		r		+				
Cladophora sp.					+	r		
Cladophoropsis sp.			r		r			
Caulerpa webbiana		r						r
Halimeda velasquezii							+	
Brown algae (Phaeophyta)								
Ectocarpaceae spp.							+	r
Sphacelaria sp.		+	r	++	r	+	+	+
Dictyota sp.								+
Lobophora variegata								+
Zonaria (?) sp.							r	r
Red algae (Rhodophyta)								
Mesophyllum simulans (?)							+	
Melobesioideae spp.		+			++	++		
Amphiroa foliacea (?)							++	+++
Amphiroa fragilissima							+	++
Cheilosporum spectabile							++	+
Jania sp.		r	++		+		+	+
Peyssonnelia sp.								+
Hypnea (?) sp.							r	
Gelidiopsis (?) sp.				++	+	r		
Melamansia glomerata							+++	+++
Blue-green algae (Cyanophyta)								
Schizothrix (?) sp.						r		
Lyngbya sp.				+	++	+++		
Calothrix sp.				+	+	r		
Rivularia sp.					r			
Rivularia (?) sp.		+++	+++	+++	+	+		
Cyanophyceae spp.							r	+
Diatoms (Bacillariophyta)								
Bacillariophyceae spp.			+				r	+
ANIMALS								
foraminifera		+	+	+	r	+	+++	+++
scales of sponges		r	r	r	r	r	+	+
hydrozoa		r						++
nematoda					r	r		+
copepoda					+	+	+	+
bryozoa			r		r	r	r	r
juvenile snails		+		r			+	+
OTHERS								
calcareous sand		+	+	+++	++	+		
red spherical cell-like particles		++	++	++	+	+		

Discussion

Juvenile green snails less than 75 mm SH were found only inside of small crevices in the tidal zone of exposed reef flats facing the ocean. Young and adults more than 100 mm SH were found only on the reef slopes of the subtidal zone. These results and the preliminary observations of Honma (1987) and Yamaguchi and Kikutani (1989) suggest that the green snail migrates to the subtidal zone with growth after settling in the tidal zone and growing up to 70-80 mm SH. A similar migration of achaeogastropods has been also reported for *Turbo (Batillus) cornutus* (Yoshiya *et al*., 1988) and *Trochus niloticus* (Nash, 1985).

The green snail was determined to be primarily herbivorous based on observation of the gut contents in the present study, but only a few small animals which are generally associated with marine algae were found in the gut contents. Individuals in the tidal zone were found to have ingested many blue-green algae, calcareous algae and sand, while ones in the subtidal zone had ingested many calcareous algae, *Melamansia glomerata* and foraminifera. Tsuda and Randall (1971) reported that *Turbo argyrostoma* and *T. setosus* were herbivores and detritus feeders, and that both species ingested an abundance of blue-green algae and calcareous materials. It seems that these species feed on various marine algae, and have a preference for coralline and blue-green algae.

The difference of the gut contents between juveniles and adults of green snails is considered to be mainly due to the different marine algal flora between the tidal and subtidal zones. Despite the abundance of *Dictyopteris undulata* around the adult green snail's habitat, probably it does not feed on this alga because it contains some repellent chemicals for snails (Taniguchi *et al*. 1993). Further experimentation needs to be conducted to clarify the food preference in green snails at various life stages.

The diet for culture and the location for seed release should be selected carefully because the food supply from algal flora and also potential predator pressure between tidal and subtidal zones are likely to vary markedly. However, as a result of this study, juveniles less than 70 mm SH should be released in the tidal zone for most effective survival. Adult green snails ingest mainly *Melamansia glomerata* and coralline algae, so they should be released in the subtidal zone where these red algae grow luxuriantly.

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琉球列島徳之島におけるヤコウガイの分布と消化管内容物

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ヤコウガイの増養殖のために､琉球列島徳之島のサンゴ礁域の潮間帯から漸深帯におけるヤコウガイの分布と消化管内容物を調査した。殻高75mm以下の個体は潮間帯に生息するが、殻高100mm以上の個体は、大型個体ほど深い水域で発見されたことから、ヤコウガイは成長に伴い潮間帯から漸深帯に移動して行く可能性が示唆された。ヤコウガイは植食性であることが確認されたが、成育段階によって生息水深および摂餌している藻類が異なるので、本種の養殖や種苗の放流にあたっては、餌料や放流適地の検討を十分に行う必要がある。

キーワード: ヤコウガイ、垂直分布、生息場所、消化管内容物、琉球列島、南日本