Bull. Natn. Sci. Mus., Tokyo, Ser. C, 22(3,4): pp. 53–61, December 22, 1996

A New Species of *Mandarina* (Pulmonata, Camaenidae) from Anijima of the Bonin Islands

By

Satoshi CHIBA

Institute of Biology and Earth Science, Shizuoka University,
836 Oya, Shizuoka, 422

Abstract A new species of *Mandarina* PILSBRY, 1894 (Pulmonata, Camaenidae), *Mandarina anijimana* sp. nov., is described from Anijima in the Bonin Islands. Although this new species and *Mandarina chichijimana* CHIBA, 1989 have similar genital morphology, they can be discriminated by differences in color polymorphisms. Genetic and paleontological studies support the idea that these species have evolved independently on different islands. I suggest that their resemblance in genital morphology results from convergent or parallel evolution in the two lineages.

Introduction

The land snail genus *Mandarina* PILSBRY, 1894 is an example of the endemic elements that have undergone remarkable radiation within the Bonin Islands. Taxonomic studies of *Mandarina* have been done by various authors (e.g. PILSBRY, 1894, 1901, 1902; EMURA, 1943; MINATO, 1978; KUROZUMI, 1988; CHIBA, 1989, 1991), and ten extant and five extinct species have been described. However, discrimination of these species is difficult because of their high intraspecific variability. *Mandarina chichijimana* CHIBA 1989, an endemic species of the Chichijima Islands, is the most problematic example.

Populations of *M. chichijimana* have been tentatively discriminated into three morphotypes, forms A, B, and C, by CHIBA (1989). Living specimens of form A occur on Anijima, form B occur on Chichijima and form C occur on Ototojima. CHIBA (1989) reported the occurrence of form A in Pleistocene deposits of Chichijima. However, basic patterns of color polymorphisms of form A from Chichijima are clearly different from those of form A from Anijima, and the former corresponds to that of form B from Chichijima (CHIBA, 1996). In addition, snails with intermediate morphology between form A and B are found in fossil samples from Chichijima (CHIBA, 1996). On the basis of electrophoretic studies, form A from Anijima and form B from Chichijima are genetically distinct. Average of the Nei's genetic distances is 0.13, and this implies that these form are genetically equivalent to different species status (THORPE, 1983; WOODRUFF *et al.*, 1988). In addition, the genetic distance between form A and

form B exceeds the distances between form B and all other species of *Mandarina* (CHIBA, 1991). In this paper, I describe form A of Anijima as a new species of the genus, describe two other species that have been confused with this species, and discuss the validity of treating genital morphology as a character for distinguishing species. In addition, I discuss the possibility of parallel or convergent evolution in shell shape and genital morphology in the populations of the different islands. The specimens used are deposited in the Department of Zoology, National Science Museum, Tokyo (NSMT) and in the Department of Geology of the same museum (NSM).

Systematic Description

Order Stylommatophora
Family Camaenidae
Genus ***Mandarina*** PILSBRY 1894

Type species: *Mandarina mandarina* SOWERBY, 1839.

Diagnosis: Shell solid, variable in shape. Shell medium to large (20～80 mm) with a large protoconch (approximately from 1/4 to 1/3 of diameter). Spire high to low. Some species with umbilicus or sharp peripheral angle. Coloration variable within each species, but commonly with 2–4 reddish brown bands or without color bands. Penis cylindrical in shape, with thick sheath and without penial appendix. Internal part of uppermost penis with verge. Internal penial wall ornamented with several numbers of strongly or weakly folding pilasters.

Distribution: Bonin Islands (Mukojima, Nakodojima, Chichijima, Anijima, Ototojima, Minamijima, Hahajima, Anejima, Meijima, Imotojima, Mukoujima, Hirashima).

Mandarina anijimana sp. nov.

Figs. 1–1, 3–1, 4–1

1989. *Mandarina chichijimana* CHIBA; CHIBA, p. 231, figs. 5, 6a, 8.

Diagnosis: Medium-sized species of *Mandarina* characterized by shells with flat spire and clear umbilicus (Table 1). Commonly shell has no color bands or has two bands on light yellow background. Specimens with four bands are rare. Penis small, uniformly thin; internal wall sculptured by 7–8 rows of regularly, equilaterally folded pilasters from upper to basal portion; verge large, conical in shape without any sculptures except for weak longitudinal and lateral regular cords.

Description: Genital system with slender flagelum externally and with a sharp and slender tip. Epiphallus uniformly thin. Penis uniformly thin and covered by sheath at the basal portion. Usually, penis far thinner than vagina.

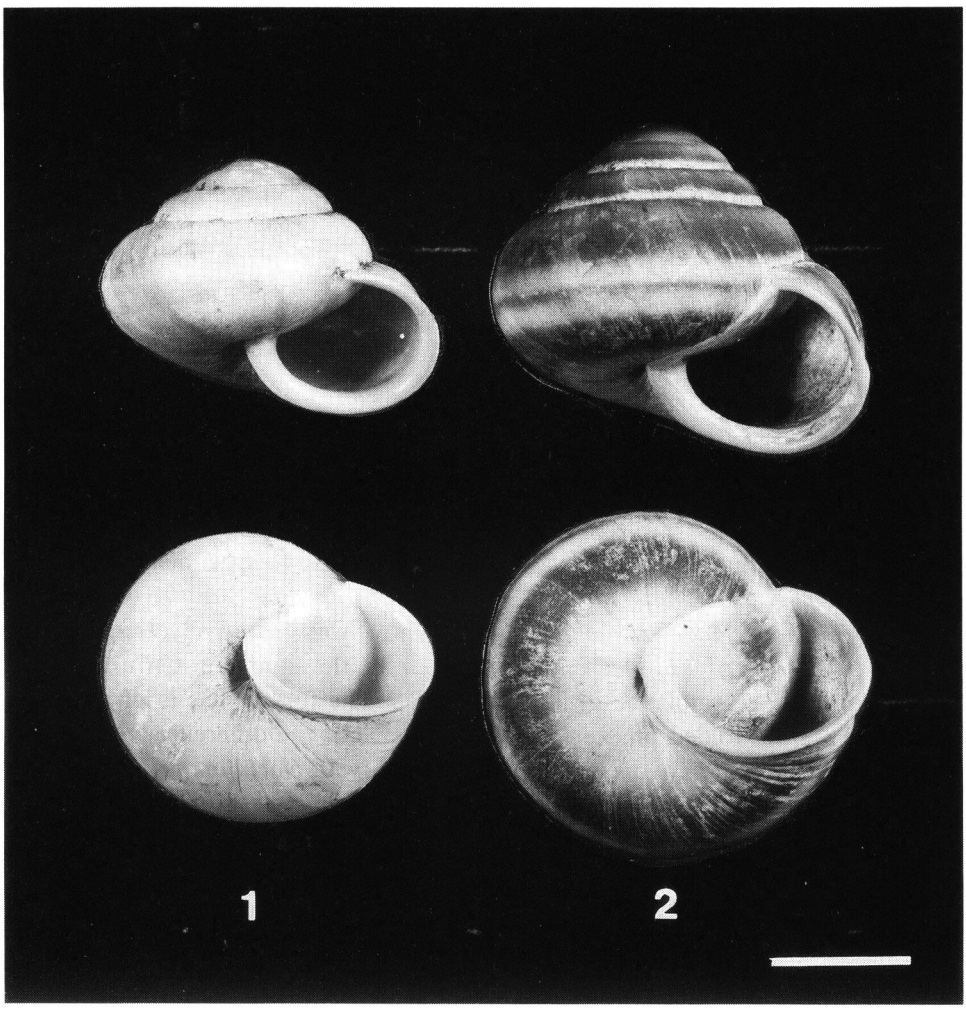

Fig. 1. 1: *Mandarina anijimana* sp. nov., (NSMT Mo 70554) from a site 500 m northwest of Mt. Mikaeri in Anijima. 2: *Mandarina* sp. (NSMT Mo 70559) from Hironezaki in Ototojima. Scale bar = 1 cm.

Internally, penial wall are sculpted by 7–8 rows of regularly, equilaterally folded, unmerging, equal size pilasters. Verge large, longer than wide, sculptured with weak longitudinal and lateral regular cords.

Shell solid, medium in size. Spire low in height. Umbilicus clearly open. Body whorl rounded or with weak peripheral angle. Aperture circular in shape. Periostome moderately thick and slightly reflected. Base rounded and convex. Shell with light yellow background, and commonly, bands completely missing or present as narrow bands on the periphery and surrounding umbilicus. Specimens

Table 1. Measurements (in mm) of *Mandarina mandarina*, *Mandarina chichijimana*, and *Mandarina* sp. from Chichijima Islands. Abbraviations: D, shell diameter; H, shell height; W, number of whorls; U, breadth of umbilicus.

Specimen	D	H	W	U	H/D	U/D
Mandarina anijimana n. sp.						
NSMT Mo 70554	23.3	17.5	2.7	3.1	0.75	0.13
NSMT Mo 70555	24.0	18.6	2.8	3.0	0.78	0.12
NSMT Mo 70556	22.0	17.8	2.8	2.2	0.81	0.10
Mandarina chichijima CHIBA						
NSM PM 15981	28.9	19.7	2.6	4.4	0.68	0.15
NSM PM 15982	28.8	19.8	2.5	4.2	0.69	0.14
NSMT Mo 70557	22.5	19.0	3.0	0	0.84	0
NSMT Mo 70558	25.2	19.5	3.0	0	0.77	0
Mandarina sp.						
NSMT Mo 70559	25.7	21.8	3.2	1.8	0.85	0.07
NSMT Mo 70560	25.8	20.9	2.9	1.8	0.81	0.07

with four bands are also found, but they are rare relative to specimens with other color patterns.

Comparison: *Mandarina anijimana* sp. nov. was tentatively treated as a variant (form A) of *Mandarina chichijimana* in the study of CHIBA (1989) because of close resemblance in their genitalia. The former has a longer penis with more tightly folded pilasters than the latter, but the differences are minor. Shells of *M. anijimana* are discriminated from living *M. chichijimana* by their flat spire and clear umbilicus. The shell form of *M. anijimana* is similar to fossil *M. chichijimana*, but the color patterns are different: specimens with missing color bands or with two bands, commonly found in *M. anijimana* are never found in *M. chichijimana*. The position of the peripheral angle of the former is consistently lower than of the latter. *Mandarina* sp. that were described as a variant of *M. chichijimana* can be descriminated from *M. anijimana* by the background color, spire height and breadth of umbilicus.

Material: Holotype NSMT Mo 70554; paratypes, NSMT Mo 70555, NSMT Mo 70556.

Type locality: A site 500 m northwest of Mt. Mikaeri (Anijima).

Distribution: Anijima.

Mandarina chichijimana CHIBA 1989

Figs. 2, 3–2, 4–2

1969. *Mandarina mandarina* (SOWERBY); HABE, p. 21. pl. 2, figs. 5–7.
1973. *Mandarina mandarina* (SOWERBY); HABE, p. 51, pl. 4, figs. 6–8.
1978. *Mandarina mandarina* (SOWERBY); MINATO, p. 38, 41, 49, figs. 1, 6–7.
1989. *Mandarina chichijimana* CHIBA; CHIBA, p. 231, figs. 5, 6a, 8.

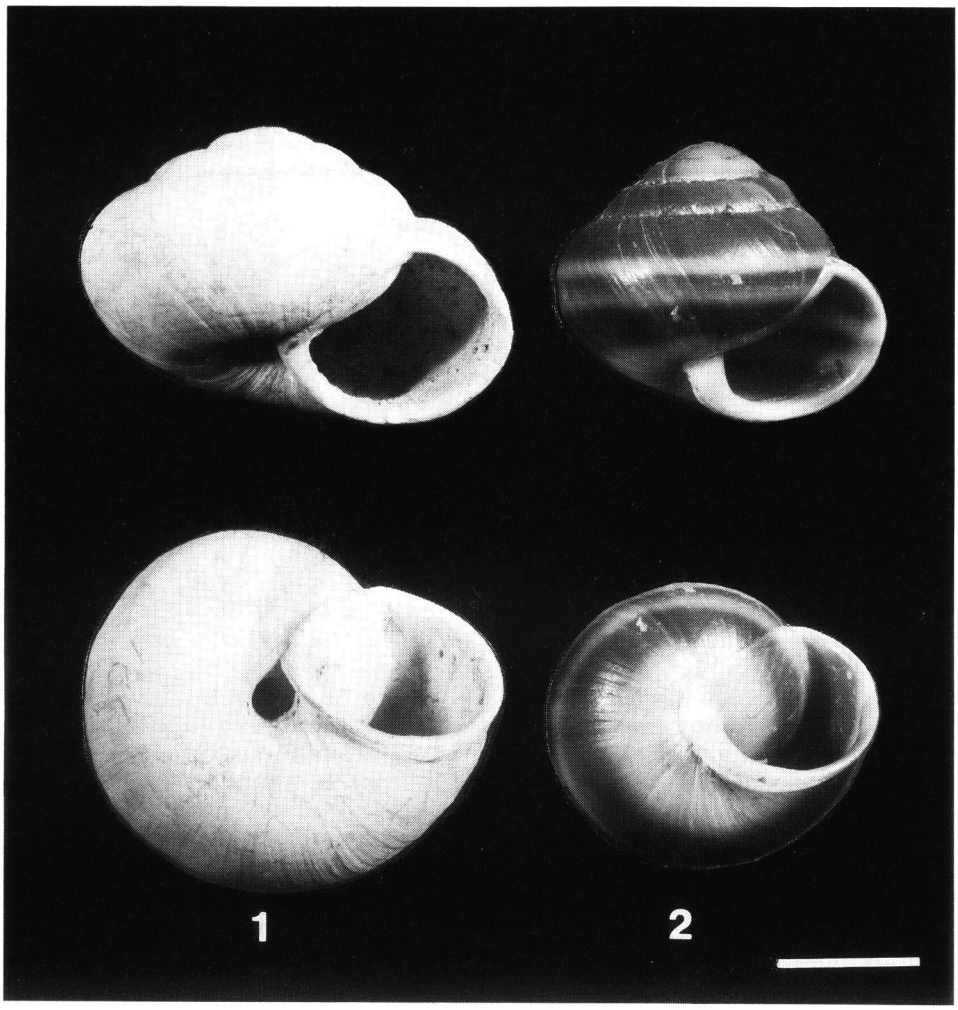

Fig. 2. 1: *Mandarina chichijimana* CHIBA, 1989 (NSM PM15981) from John beach (Pleistocene). 2: *Mandarina chichijimana* CHIBA, 1989 (NSMT Mo 70557) from John beach. Scale bar = 1 cm.

Holotype: UMUT RM18415a (see CHIBA, 1989).

Type locality: Minamizaki (Chichijima).

Diagnosis: Medium-sized species of *Mandarina* characterized by shells with wide range of shape variation. Shells with four color bands on a light yellow background. Penis small, uniformly thin; internal wall sculptured by 7–8 rows of regularly, equilaterally folded pilasters from upper to basal portion; verge large, conical in shape without any sculptures except for weak longitudinal and lateral regular cords.

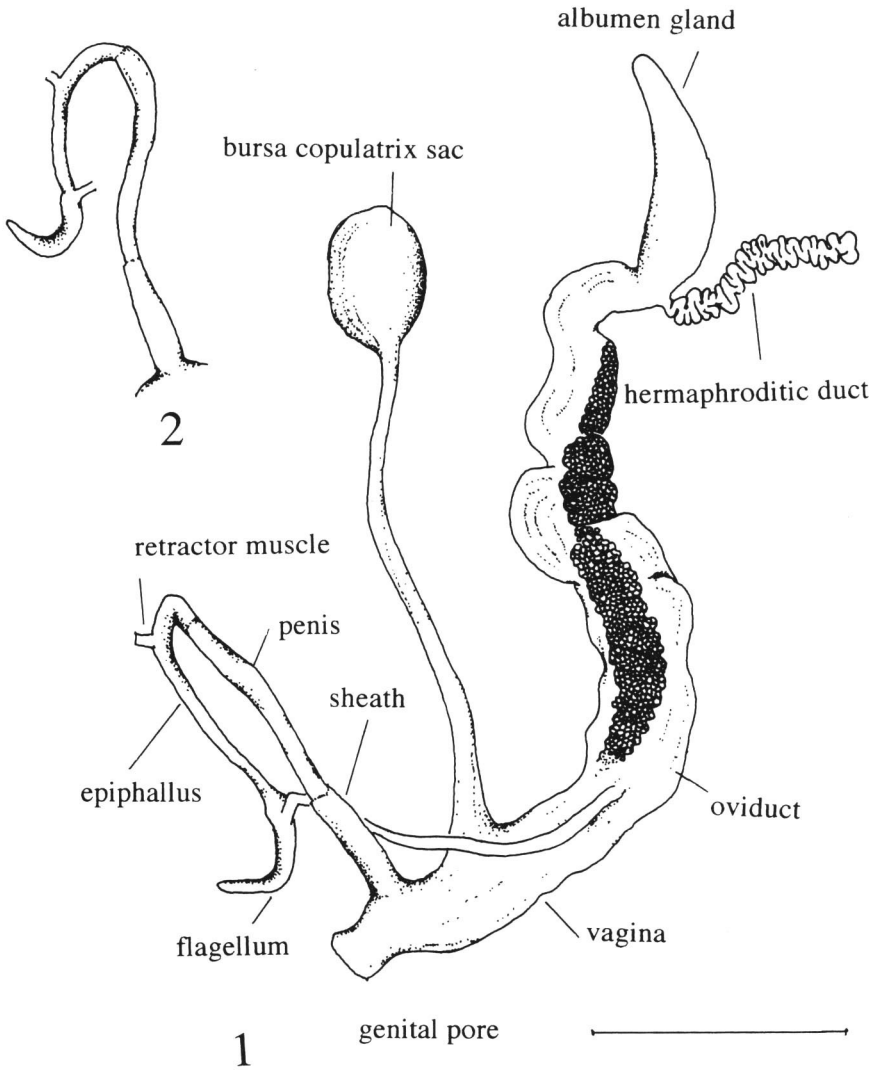

Fig. 3. 1: Genital morphology of *Mandarina anijimana* sp. nov. 2: Morphology of male penis of *Mandarina chichijimana* CHIBA, 1989. Scale bar = 1 cm

Description: Shell solid, medium in size. Spire from low to high (Table 1). Fossil specimens before 25 ka possess clear umbilicus, but it is missing in the living specimens. Body whorl rounded or with peripheral angle. Aperture circular in shape. Periostome moderately thick and slightly reflected. Base rounded and convex. Shell with light yellow background and with four bands on the whorl.

Comparison: Shells with two color bands or without bands that are common in *M. anijimana* are never found in the southern area of Chichijima.

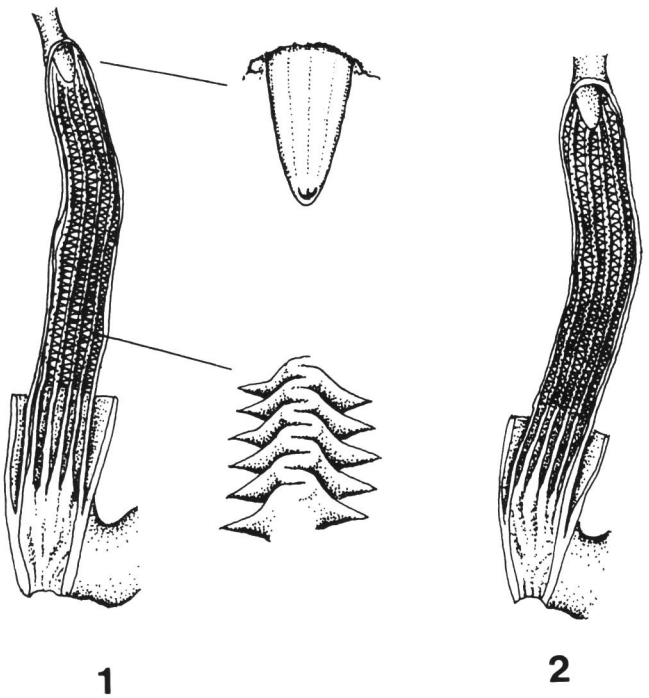

Fig. 4. Internal penial morphology of *Mandarina anijimana* sp. nov. (1) and *Mandarina chichijimana* CHIBA, 1989 (2).

Although these color patterns are found in the populations of northern Chichijima, their frequency is very low (CHIBA, 1996). Differences in the genitalia between *M. anijimana* and *M. chichijimana* are negligible except for the length of the penis and tightness of the foldings of the pilasters.

Material: paratypes, NSMT Mo 70557, NSMT Mo 70558, NSM PM 15981, NSM PM15982.

Distribution: Southwestern Chichijima.

Mandarina sp.

Fig. 1–2

1989. *Mandarina chichijimana* CHIBA; CHIBA, p. 231, figs. 8.

Diagnosis: Medium-sized species of *Mandarina* characterized by shells with high spire and small umbilicus. Commonly shell has four bands on light pink or orange background.

Description: Shell solid, medium in size with high spire (Table 1). Body whorl rounded. Aperture circular in shape. Periostome moderately thick and

slightly reflected. Base rounded and convex. Shell with light pink or orange background, and, commonly, four bands present on the whorl.

Comparison: This species was described as a variant (form C) of *M. chichijimana*. Shell form of this species is intermediate between *M. chichijimana* and *M. anijimana*, but color of the background of the whorl is unique. Genital morphology is unknown at present, and taxonomic position of this species is not clear.

Material: NSMT Mo 70559, NSMT Mo 70560.

Distribution: Ototojima.

Discussion

Genital morphology has been regarded as an important character for descriminating species and for inferring phylogenetic relationships in land snails (e.g. EMBERTON, 1988). *Mandarina chichijimana* and *M. anijimana* are sufficiently genetically distant to be conferred the rank of separate species (CHIBA, 1991), but their genital morphologies are very similar. In contrast to genital morphology, color polymorphisms clearly discriminate these species (CHIBA, 1996). It is well known that color polymorphisms are influenced by environmental conditions, and brightness of background color or thickness of the color bands may be very sensitive to changes in temperature and predation pressure. However, when environmental differences are minor, composition of the basic components of color polymorphism may be useful marker to identify taxonomic units. Recent studies of carabid beetles suggest that perfectly identical morphology of genitalia can evolve independently in different lineages (SU *et al.*, 1996). Resemblance of genitalia morphology in different populations does not necessarily imply close phylogenetic relationships or conspecificity.

The three species *M. chichijimana*, *M. anijimana*, and *M.* sp. are endemic to Chichijima, Anijima, and Ototojima, respectively. The similarity in shell shape of populations of *M. chichijimana* and *M. anijimana* suggests that the similarity is produced independently in distinct lineages in different areas. Other species of *Mandarina* in the Chichijima Islands show similar patters. For example, *Mandarina hirasei* PILSBRY, 1902 has been recorded from Chichijima and Ototojima, but Ototojima populations have shells with a color band which is absent in Chichijima populations and in *Mandaria io* CHIBA, 1989 an ancestoral species of *M. hirasei* on Chichijima. This suggests parallel evolution in shell shape. The results imply that populations on these islands are restricted to their respective islands and have been isolated to become different species.

Acknowledgements

I wish to thank Drs. Itaru HAYAMI, Kazusige TANABE, Katumi ABE, Tatuo OJI, and Kiyonori TOMIYAMA for helpful suggestions on this study. I am also grateful to Dr. Robert M. ROSS for critical reading of the manuscript.

References

CHIBA, S., 1989. Taxonomy and morphologic diversity of *Mandarina* (Pulmonata) in the Bonin Islands. *Trans. Proc. Palaeont. Soc. Japan*, New Series., (155): 218–251.

———, 1991. Evolutionary history of *Mandarina* (a genus of land snail) in the Bonin Islands. Ph. D. Diss., Univ. Tokyo, Tokyo.

———, 1996. A 40000 year record of discontinuous evolution of island snails. *Paleobiology*, 22: 177–188.

EMBERTON, K. C., 1988. The genitalic, allozymic, and conchological evolution of the eastern North American Triodopsinae (Gastropoda: Pulmonata: Polygyridae). *Malacologia*, 28: 159–273.

EMURA, S., 1943. On the systematic position of the genera *Mandarina* and *Dolicheulota*. *Venus*, 13: 34–38.

HABE, T., 1969. Mollusca in the Bonin Islands. *Iden*, 23: 19–25. (In Japanese.)

———, 1973. Fossil land snails from Minami-jima, Bonin islands. *Sci. Rep., Tohoku Univ.*, 2nd Ser. (Geol.), 6: 51–53.

KUROZUMI, T., 1988. Species composition and abundance of land mollusks and factors affecting their extinction in the Ogasawara (Bonin) Islands. *Ogasawara Research*, 15: 59–109. (In Japanese with English abstract.)

MINATO, H., 1978. Speciation of the genus *Mandarina* from the Ogasawara Islands (Pulmonata, Camaenidae). *Mem. Natn. Sci. Mus. Tokyo*, (11): 37–51. (In Japanese with English summary.)

PILSBRY, H. A., 1894. Helicidae. *Manual of Conchology* (2), 9: 366.

———, 1901. New Japanese marine, land and fresh water Mollusca. *Proc. Nat. Acad. Sci. Philadelphia*, 53: 358–407.

———, 1902. New land mollusca from Japan and the Bonin Islands. *Ibid*, 54: 25–32.

RICHARDSON, M. D., N. A. VIGORS, G. T. RAY, E. T. BENNET, O. RICHARD, J. E. GRAY, R. M. BUCKLAND, & G. B. SOWERBY, 1839. Zoology of Captain Beechey's Voyage, pp. 143.

SU, Z. H., T. OHAMA, T. S. OKADA, K. NAKAMURA, R. ISHIKAWA, & S. OSAWA, 1996. Phylogenetic relationships and evolution of the Japanese Carabinae ground beetles based on mitochondrial ND5 gene sequences. *J. Mol. Evol.*, 42: 124–129.

THORPE, J. P., 1983. Enzyme variation, genetic distance and evolutionary divergence in relation to levels of taxonomic separation, pp. 131–152. *In* G. S. Oxford and D. Rollinson (eds.), Protein Polymorphism: Adaptive and Taxonomic Significance. London, Academic Press.

WOODRUFF, D. D., K. C. STAUB, E. S. UPATHAM, V. VIYANANT, & H. C. YUAN, 1988. Genetic variation in *Oncomelania hupensis: Schistosoma japonicum* transmitting snails in China and the Philippines are distinct species. *Malacologia*, 29: 347–361.