COMPARATIVE SHELL MORPHOLOGY OF *LYMNAEA (BULLASTRA) CUMINGIANA* (PULMONATA: LYMNAEIDAE) AND RELATED TAXA IN THE INDO-PACIFIC REGION

RB Monzon[1], V Kitikoon[2], N Thammapalerd[2], P Temcharoen[3], S Sornmani[2] and V Viyanant[4]

[1]Department of Parasitology, UP College of Public Health, Manila, Philippines; [2]Faculty of Tropical Medicine, Mahidol University, Bangkok; [3]Faculty of Public Health, Mahidol University, Bangkok; [4]Faculty of Science, Mahidol University, Bangkok, Thailand

Abstract. Comparative shell morphology using both quantitative and qualitative parameters was employed to investigate the taxonomic relationship between the endemic Philippine species, *Lymnaea (Bullastra) cumingiana* and five other lymnaeid "species" in the Indo-Pacific region, namely: *L. (Radix) quadrasi* (Philippines), *L. (Radix) rubiginosa* (Indonesia), *L. (Radix) rubiginosa* (Thailand), *L. (Radix) viridis* (Guam) and *L. (Radix) viridis* (Hong Kong). Fifty randomly chosen adult specimens of each species were studied and compared, although only field-collected specimens were studied for the first four groups and laboratory-raised specimens for the last two group. Results strongly suggested that *L. cumingiana* is a distinct species among the rest. *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) exhibited great affinity towards each other. Likewise, the two geographical isolates of *L. viridis* were practically identical to each other except for some minor size differences.

INTRODUCTION

The family Lymnaeidae comprises a large group of common freshwater pulmonate snails found in nearly all parts of the world. Many lymnaeids are of medical and veterinary importance since they serve as intermediate hosts to various blood, liver and intestinal flukes which may affect man directly or accidentally as parasitic zoonoses.

An analysis by Ewers (1964) of the snail hosts recorded for 279 species of flukes parasitizing mammals and birds indicated that pulmonates play a very important role. When snail families are considered and ranked according to the frequency in which they are involved in the transmission of these flukes, Planorbidae and Lymnaeidae occupy the first two places among the top ten.

Few if any prosobranch families will be found to support a richer fauna of digeneans than the planorbids and lymnaeids which have species that seem especially suitable as intermediate hosts based on the large number of different cercariae known to develop in them (Brown, 1978). For example, nearly 30 cercarial species have been recorded for *Lymnaea stagnalis* in Europe (Erasmus, 1972); Cort *et al* (1937) mentioned 21 species from the North American *L. emarginata* Say and in South Africa, Porter (1938) found 43 species in *L. natalensis* Krauss.

Among the three lymnaeid species known in the Philippines, *Lymnaea (Bullastra) cumingiana* has recently gained medical attention because it is eaten raw extensively in some provinces of northern Luzon (Cabrera *et al,* 1984, 1986) and has been proven to be responsible for transmission of human echinostomaisis due to *Echinostoma malayanum* (Monzon and Kitikoon, 1989).

Prior to this, *Lymnaea (Austropeplea) philippinensis* and *L. (Radix) quadrasi* (=*L. swinhoei var. quadrasi?* von Moellendorf) were proven to be of medical importance as the intermediate hosts of *Fasciola hepatica* and *F. gigantica* (De Jesus, 1935; Manipol, 1936; Valasquez, 1972) while Tubangui (1932) also found the early developmental stages of *Euparyphium murinum* Tubangui 1931, an intestinal fluke of rats, and *Echinostoma revolutum* Froelich 1802, an intestinal fluke of domestic ducks and chickens in *L. quadrasi.*

The outstanding variety of larval digeneans supported by some snail species is partly due to their abundance and wide distribution which

result in greater contact with the miracidia or eggs of numerous species of parasites. But it may also reflect physiological characters which predispose some snails to be utilized as hosts (Brown, 1978).

All digenetic trematodes require a vertebrate host for the adult stage and a molluscan host for development of some of their larval stages. The geographical range of a parasite is thus limited by the range of its hosts. Its effective range of transmission is only where all the hosts occur together so that the life cycle can be completed. Evidence has also become increasingly strong in favor of a very high degree of specificity in trematode-mollusk relationships. The host restriction between larval stages of flukes and their snail hosts is usually much greater than it is between the adult form and their vertebrate hosts (Wright, 1960). This implies that the control of snail-transmitted helminthiases requires a thorough knowledge and understanding of the biology and other ecological characteristics of the snail hosts involved.

The taxonomy of lymnaeids presents some of the most confusing problems (Wright, 1971). Parasitologists and malacologists often disagree on the taxonomic status of many members of this family. Some consider all lymnaeids to be under only one genus, *Lymnaea;* while others recognize additional genera such as *Pseudosuccinea, Bulimnea, Acella* Haldeman, *Fossaria* and *Stagnicola* Jeffreys. And still others regard the latter genera as subgenera of *Lymnaea* (Malek, 1962; Malek and Cheng, 1974).

Hubendick (1951) stated that it is generally known among malacologists that species systematics and species demarcation within the Lymnaeidae are unusually obscure due to the great number of species described and the gliding transitions between them which have often made it impossible to identify specimens found. He made revisions of the taxonomy of the Lymnaeidae of the world based primarily on shell morphology and a few characteristics of the male reproductive tract. In so doing, he was able to reduce nearly 1,800 specific names to approximately 40 and included them in 2 genera: *Lymnaea* and *Lanx*. Based on purely morphological studies, he concluded that a phylogenetic diagram of even the main relations within the family was impossible to construct because "no clear evolutionary lines (have) appeared and none have, in any case, been proved".

Anatomical similarities among different species and variations within one species have indeed created a number of unusual taxonomic problems among the lymnaeids and these have obscured systematic relationships (Inaba, 1969). Confusion of the systematics in this family has its source in the extremely great morphological range of variation within the species and the great morphological uniformity within the genus *Lymnaea* in its entirety (Hubendick, 1951).

The more recent studies on shell characters, chromosome number and immunological results have confirmed distinct species groupings in the Lymnaeidae. Thus, to include all lymnaeid species in one genus, *Lymnaea,* oversimplifies important relationships. It has become evident that certain anatomical traits obscure relationships because of convergence or parallel development (Davis, 1978).

It was therefore the objective of this paper to compare *Lymnaea (Bullastra) cumingiana* with five other "species" in the Indo-Pacific region, namely: *Lymnaea (Radix) quadrasi* (Philippines, *L. (R.) rubiginosa* (Indonesia), *L. (R.) rubiginosa* (Thailand), *L. (R.) viridis* (Guam) and *L. (R.) viridis* (Hong Kong) using classical comparative shell morphology (conchology). More advanced techniques can be used later to verify or refute the conclusions presented in this paper.

MATERIALS AND METHODS

Adult specimens of *Lymnaea (Bullastra) cumingiana* and *L. (Radix) quadrasi* were collected by handpicking from their natural habitats in the Philippines (ricefields of Echague, Isabela and at Sampaloc lake, San Pablo, Laguna) where they usually exist, from 1988-1991. *L. (R.) rubiginosa* (Indonesia) was collected from the suburbs of Jakarta and sent to Bangkok through the courtesy of an Indonesian student. *L. (R.) rubiginosa* (Thailand) was obtained from klongs at the Salaya campus of Mahidol University. Lastly, the *L. (R.) viridis* colonies from Guam and Hong Kong were stock cultures received from Dr John Burch and maintained at the Applied Malacology Center, Department of Tropical Medicine, Faculty of Tropical Medicine, Mahidol University for the last 6 years.

All species were maintained at the snail room

of the Applied Malacology Center, Department of Tropical Medicine, Faculty of Tropical Medicine, Mahidol University, Bangkok, Thailand, in large wide mouthed clear glass containers (18 cm in depth and 24.5 cm in diameter) containing about 5 l of filtered dechlorinated water. Aeration was supplied constantly and they were regularly fed with lettuce leaves and granular commercial aquarium fish food. Water was changed at least once a week or when the water looked unclean. Sterile soil was also added into the culture as a supplementary source of calcium and other inorganic minerals. All colonies were kept under similar environmental conditions in the snail room which was airconditioned only during the day.

The shell morphology of 50 randomly chosen adult specimens of each species was studied. Specimens of *Lymnaea cumingiana, L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) were all field-collected while those of *L. viridis* (Guam and Hong Kong) were laboratory raised.

Measurements for length, width, aperture length and width were taken to the nearest 0.02 mm using a Vernier caliper (Mitutoyo, Japan) and the whorl count was determined (to the nearest quarter of a revolution) under the stereoscope.

Basic morphological characteristics were likewise compared. Unique and other special qualitative descriptions were noted. Descriptive and inferential statistics for conchological measurements were derived using a CASIO fx-3900Pv scientific calculator and the MICROSTAT statistical program (using an IBM-compatible personal computer).

RESULTS

Shell measurements from 50 randomly chosen specimens of each of the six lymnaeid species in this study (Figs 1-6) were obtained using a vernier caliper. Only field-collected adults were used for *Lymnaea cumingiana, L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) while laboratory-bred adult specimens were used for *L. viridis* (Guam and Hong Kong).

Table 1A summarizes the measurements obtained for shell length and width, aperture length and width and whorl count from the four field-collected species [*L. cumingiana, L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand)] while

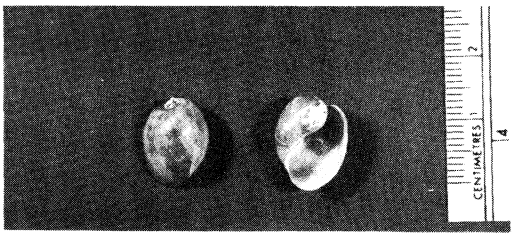

Fig 1—*Lymnaea (Bullastra) cumingiana* (Philippines)

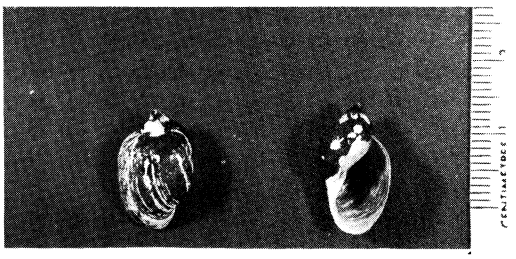

Fig 2—*Lymnaea (Radix) quadrasi* (Philippines)

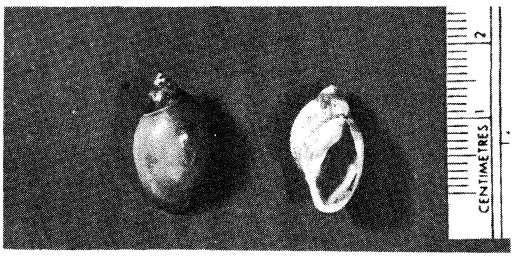

Fig 3—*Lymnaea (Radix) rubiginosa* (Indonesia)

Fig 4—*Lymnaea (Radix) rubiginosa* (Thailand)

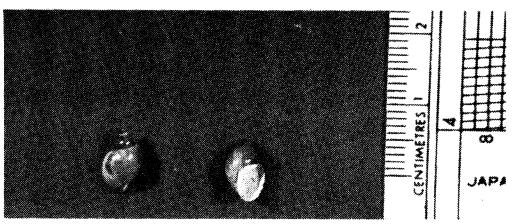

Fig 5—*Lymnaea (Radix) viridis* (Guam)

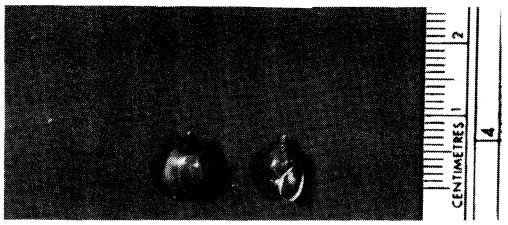

Fig 6—*Lymnaea (Radix) viridis* (Hong Kong)

Table 1B summarizes the measurements obtained for the same parameters from the two laboratory raised species [*(L. viridis* (Guam) and *L. viridis* (Hong Kong)].

In the case of Table 1A, overall statistical significance for the difference among means of the four groups was first determined by one-way analysis of variance (ANOVA). If the F-test proved significant ($p < 0.01$), the groups were then compared pairwise using the *t*-test. However, measurements from the two isolates of *L. viridis* described in Table 1B were immediately subjected to *t*-test analysis to determine whether their means differed significantly from each other.

Among the field collected specimens (Table 1A), statistical analysis revealed that *L. rubiginosa* (Thailand) had the greatest mean shell length (18.98 mm) and that it differed significantly from the three other species ($p < 0.05$). It was followed, in decreasing order, by *L. quadrasi* (18.16 mm), *L. rubiginosa* (Indonesia) (17.71 mm) and *L. cumingiana* (17.20 mm). However, *L. cumingiana* was significantly shorter than all except *L. rubiginosa* (Indonesia) while *L. quadrasi* and *L. rubiginosa* (Indonesia) did not differ significantly from each other.

With regards to mean shell width, however, *L. cumingiana* had the widest mean shell diameter (12.16 mm), significantly larger compared to the rest ($p < 0.05$). It was followed by *L. quadrasi* (10.02 mm), *L. rubiginosa* (Thailand) (10.16 mm) and *L. rubiginosa* (Indonesia) (9.79 mm), all three of which did not differ significantly from each other.

Measurements for mean aperture length and

Table 1A

Basic shell measurements of 50 field-collected specimens of *L. cumingiana, L. quadrasi, L. rubiginosa* (Indonesia and Thailand) (All in mm except for whorl count).

Shell aspect measured	Snail species measured			
	L. cumingiana	*L. quadrasi*	*L. rubiginosa* (Indo)	*L. rubiginosa* (Thai)
1. length:				
× ± sd*	17.20 ± 1.93^{a}	18.16 ± 1.26^{b}	$17.71 \pm 2.14^{a,b}$	18.98 ± 2.28^{c}
range	14.00 – 22.30	16.28 – 21.34	14.36 – 22.86	15.10 – 23.65
2. width:				
× ± sd	12.16 ± 1.55^{a}	10.02 ± 1.00^{b}	9.79 ± 1.35^{b}	10.16 ± 1.27^{b}
range	9.60 – 16.55	8.30 – 12.52	7.95 – 12.25	8.20 – 13.05
3. aperture length:				
× ± sd	15.24 ± 1.71^{a}	13.53 ± 1.30^{b}	12.58 ± 1.43^{c}	13.46 ± 1.53^{b}
range	12.20 – 19.20	10.85 – 15.86	9.85 – 15.54	10.40 – 17.20
4. aperture width:				
× ± sd	9.83 ± 1.19^{a}	6.78 ± 0.89^{b}	5.97 ± 0.72^{c}	6.89 ± 0.97^{b}
range	7.40 – 12.70	5.30 – 8.64	4.50 – 7.84	5.20 – 9.50
5. whorl count:				
mode	3.50	4.50	3.75	4.50
range	2.75 – 4.00	3.50 – 4.75	3.50 – 4.25	3.75 – 4.75

* = groups with different superscripts in the same row have significantly different means from each other ($p < 0.05$).

Table 1B

Basic shell measurements of 50 laboratory raised specimens of *Lymnaea viridis* (Guam) and *L. viridis* (Hong Kong) (All in mm except for whorl count).

Shell aspect measured	Snail species measured	
	L. viridis (Guam)	*L. viridis* (Hong Kong)
1. length:		
× ± sd	8.65 ± 0.91	9.08 ± 0.66*
range	6.68 − 10.12	7.70 − 10.64
2. width:		
× ± sd	4.75 ± 0.60	5.00 ± 0.35*
range	3.64 − 5.90	4.30 − 6.00
3. aperture length:		
× ± sd	5.58 ± 0.71	5.73 ± 0.45
range	4.32 − 7.20	4.72 − 7.02
4. aperture width:		
× ± sd	3.02 ± 0.56	3.13 ± 0.33
range	2.14 − 5.04	2.44 − 3.90
5. whorl count:		
mode	4.50	4.50
range	3.75 − 4.75	3.75 − 5.00

* = signifies a significant difference between the two groups means ($p < 0.05$) as shown by *t*-test

width followed an identical distribution, namely: *L. cumingiana* (15.24 mm and 9.83 mm, respectively) significantly larger than the rest ($p < 0.05$), followed by *L. quadrasi* (13.53 mm and 6.78 mm, respectively) and *L. rubiginosa* (Thailand) (13.46 mm and 6.89 mm, respectively) which were not significantly different from each other, and lastly by *L. rubiginosa* (Indonesia) (12.58 mm and 5.97 mm, respectively) which exhibited the smallest values [*ie, L. cumingiana* > *L. quadrasi* = *L.rubiginosa* (Thailand) > *L. rubiginosa* (Indonesia)].

Whorl counts could not be determined from some specimens which had eroded apices. The mode (most frequently occurring value) instead of the mean was chosen as the measure of central tendency since measurements were truncated (*ie* rounded off to the nearest fourth of a whorl). The highest modal whorl count (4.50) was observed in specimens of *L. quadrasi* and *L. rubiginosa* (Thailand) while the lowest (3.50) in *L. cumingiana.*

The shell measurements from *L. viridis* (Guam and Hong Kong) (Table 1B) were not suited for comparison with the first four species described above since they were based purely on laboratory raised specimens. It has been generally observed that laboratory raised individuals tend to exhibit stunted growth as compared to their field-collected counterparts. Thus, the two geographical isolates of *L. viridis* were compared only to each other.

The *t*-test for difference between two sample means revealed that *L. viridis* (Hong Kong) was significantly larger ($p < 0.05$) than *L. viridis* (Guam) with respect to shell length and width only. There was no significant difference however in their mean aperture length and width. Their modal whorl counts (4.50) were also identical.

Qualitative shell characteristics were also noted, namely: size, color, shape, surface markings, shell composition, sutures, spire, columella, aperture shape and peristome. The details are presented in Table 2.

Lymnaea cumingiana, L. quadrasi, L. rubiginosa (Indonesia) and *L. rubiginosa* (Thailand) were all medium sized (10-30 mm in length) while *L. viridis* (Guam) and *L. viridis* (Hong Kong) were small (< 10 mm in length). The shells of all species were basically brownish in color but the shade varied

Table 2

Descriptions of shell characteristics among the six lymnaeid species under study.

Shell character examined	Snail species					
	L. cumingiana	*L. quadrasi*	*L. rubiginosa* (I)	*L. rubiginosa* (T)	*L. viridis* (G)	*L. viridis* (HK)
1. size:	medium	medium	medium	medium	small	small
2. color*:	pale or light yellow brown	light to dark brown	light to dark brown	light to dark brown	light to dark brown	light to dark brown
3. shape:	depressed ovate	acuminate	acuminate	acuminate	acuminate	acuminate
4. surface markings:	smooth with fine axial striations	smooth or rough** with more distinct striations	smooth or rough** with more distinct striations	smooth or rough** with more distinct striations	smooth	smooth
5. shell composition:	delicate and brittle	hard and thick	hard and thick	thick and hard	thin and brittle	thin and brittle
6. sutures:	shallow	moderate	moderate	moderate	moderate to deep	moderate to deep
7. spire:	low and depressed	prominent but apex usually eroded	prominent but apex usually eroded	prominent but apex usually eroded	prominent and sharp, apex occasionally eroded	prominent and sharp, apex occasionally eroded
8. columella:	thin and straight	twisted with fold or plait at apertural margin	slightly twisted	slightly twisted	slightly twisted	slightly twisted
9. aperture shape:	ovate	semi-ovate, "ear-like"	semi-ovate, "ear-like"	semi-ovate, "ear-like"	semi-ovate	semi-ovate
10. peristome:	thin and straight sharp and brittle	thick and sharp; columellar lip curved back slightly	thick and sharp; columellar lip curved back slightly	thick and sharp; columellar lip curved back slightly	thin and sharp; columellar lip curved back slightly	thin and sharp; columellar lip curved back slightly

* = darker shade more common in field-collected specimens
** = periostracum usually eroded by whitish streaks and cavities

according to the source, *ie* field-collected specimens tended to be darker than their laboratory raised counterparts. All species were acuminate in shape except for *L. cumingiana* which was depressed ovate.

Surface markings were most prominent in *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand). They consisted of white streaks (concretions) and cavities, probably calcareous in origin, which contrasted to the basically brown background of the periostracum. *L. cumingiana, L. viridis* (Guam) and *L. viridis* (Hong Kong) were usually devoid of these markings although fine axial striations were prominent in larger specimens of *L. cumingiana.* Likewise, *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) possessed a hard and thick shell which contrasted sharply with the delicate, thin and brittle shells of *L. cumingiana, L. viridis* (Guam) and *L. viridis* (Hong Kong).

Sutures were shallow for *L. cumingiana* due to its ovate shape while the rest had moderate or slightly prominent sutures to correspond with their acuminate shape. The spire was uniquely low

and depressed for *L. cumingiana* but prominent for the rest. However the apices of field collected specimens were usually eroded for *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) but only rarely for the laboratory bred *L. viridis* (Guam) and *L. viridis* (Hong Kong).

The columella was thin and straight for *L. cumingiana* but twisted for the rest. As for aperture shape, that of *L. cumingiana* was ovate; it was semi-ovate for the rest but particularly "ear-like" for *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand). Lastly, the peristome was thin and sharp for *L. cumingiana, L. viridis* (Guam) and *L. viridis* (Hong Kong) in contrast to the thickness observed in *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand). It was also straight throughout in *L. cumingiana* but the lower lip of the columella that merges with the peristome was found to be curved back (deflected) slightly in the five other species.

DISCUSSION

Data on the external shell morphology of the six groups studied [Tables 1 (A, B), 2] strongly suggest that *L. cumingiana* is a distinctly different species from the rest. Most of the characteristics described (shape, surface markings, spire, columella, etc) were unique for this species. Shell measurements also revealed that *L. cumingiana* had the largest mean shell width (12.16 mm), aperture length (15.24 mm) and width (9.83 mm), but lowest modal whorl count (3.50).

In contrast to this, *L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand) were morphologically very similar to each other with respect to size, color, shape, surface markings, spire, columella, aperture shape and peristome. However, some shell measurements (specifically mean aperture length and aperture width) suggested a closer affinity between *L. quadrasi* and *L. rubiginosa* (Thailand).

In a group of their own were the two geographical isolates of *L. viridis* from Guam and Hong Kong which had practically identical qualitative shell characteristics. However, the population from Hong Kong was significantly larger than that from Guam ($p < 0.05$) with respect to mean overall length and width.

Conclusions based on comparative shell morphology should be derived cautiously. The great influence of environmental factors on the growth of snail species is one disadvantage in employing comparative shell morphology for taxonomic purposes. In this study for example, comparisons were valid only among the four field-collected species [*L. cumingiana, L. quadrasi, L. rubiginosa* (Indonesia) and *L. rubiginosa* (Thailand)] and between the two laboratory raised species [*L. viridis* (Guam) and *L. viridis* (Hong Kong)]. Comparison between the two groups were not feasible since laboratory-bred adult specimens are almost always smaller than their field-collected counterparts.

The maximum sizes obtained from the field were never attained among snails raised in the laboratory. For example, Benthem Jutting (1956) reported the length (height) and width of *L. rubiginosa* from Indonesia to range from 30-34 mm and 18-20 mm, respectively. Not even the largest *L. rubiginosa* specimen examined in this study (length = 23.65 mm and width = 13.05 mm) came close to the lower limits of the ranges given. Likewise, measurements of the other species in this study were lower than those reported in the literature.

What can account for these differences? Nutritional factors could be one of the reasons for the stunted growth of laboratory-bred snails or those initially field-collected and then raised in the laboratory. They were given only lettuce and commercial fish food which may have been insufficient to insure optimal growth, compared to the abundance and diversity of foods which are available in their natural habitats.

Differences in water quality (pH, hardness, etc) between the natural and artificial habitats are also another possibility since thinner shells were noted for laboratory raised individuals. The amount of calcium deposited as shell is a function of the calcium concentration of the medium and the amount entering the body. Ecological studies have verified that shells are often thin in land and freshwater environments where calcium is not readily available (Boycott, 1934). Hubendick (1947) was also of the opinion that shell size is less dependent on hereditary fixed specific or racial conditions than on such environmental conditions as food supply or the annual periodicity of the limnic climate; for example, thickness of the cal-

careous wall of the shell depends on the chemical composition of the water.

Since there was also a strong tendency for field-collected snails to be naturally infected with various parasites, this could have indirectly contributed to their larger sizes compared to uninfected laboratory-bred specimens.

This possibility is illustrated by individual snails of the genera *Hydrobia (Peringia)* and *Bulimus* which attain an unusually large size. A high percentage of these giant forms were found infected with larval trematodes which may bring about partial or complete destruction of the gonads (Rothschild, 1936; Boettger, 1952). Infected snails grew at a rate faster than normal (Rothschild and Rothschild, 1939). The cause of this unusual growth, whether from gonad destruction or as a result of compounds from the parasite is unknown although a hormonal deficiency is an obvious possibility since decreased growth rate has been observed to occur at the time of gonad ripening in some gastropods (Boettger, 1952).

Several other workers have reported enhanced growth, at least temporarily, among mollusks harboring larval trematodes (Wesenberg-Lund, 1934; Rothschild, 1938, 1941a, b; Lysaght, 1941; Hoshina and Ogino, 1951; Menzel and Hopkins, 1955a, b; De Andrade, 1962; Chernin, 1960; Pan, 1962, 1965) while a few (Pesigan *et al,* 1958; Moose, 1963; Zischke and Zischke, 1965) have reported the opposite - a retardation in growth among infected snails.

One of the most detailed studies on possible enhanced growth of parasitized snails was done by Pan (1965) who showed that *Biomphalaria glabrata* adolescents which were mass infected with *Schistosoma mansoni* had greater shell diameters than uninfected snails between the second and sixth weeks after infection. However, based on his studies on *Nitocris dilataus,* parasitized by *Acanthatrium anaplocami* and *Physa sayii* parasitized by *Echinostoma revolutum,* Cheng (1971) countered that although there were greater amounts of calcium deposited in the shells of parasitized snails, there was no increase in soft tissue weight, and hence, true enhanced growth may not have occurred or at least was not a consistent phenomenon.

What is important from the above results is that greater shell sizes tend to occur among infected specimens as reported by Chernin (1960) and Pan (1962, 1965).

More directly related to this study was the finding of Wesenberg-Lund (1934) that parasitized *Lymnaea auricularia* often had "ballooned" shells. And thus, conclusions based on differences in shell dimensions, especially when field-collected and laboratory-bred *Lymnaea* spp specimens are compared, should be arrived at cautiously.

REFERENCES

Benthem Jutting WSS Van. Systematic studies on the non-marine mollusca of the Indo-Australian archipelago. *Treubia* 1956; 23 : 259-477.

Boettger CR. Grossenwachstum und Geschlechsreife bei Schnecken und pathologischer Riesenwuchs als Folge einer gestorten Wechselwirkung beider Faktoren. *Zool Anz Suppl* No. 17, 1952; 468-87.

Boycott AE. The habitats of land mollusca in Britain. *J Ecol* 1934; 22 : 1-38.

Brown DS. Pulmonate molluscs as intermediate hosts for digenetic trematodes. In: Fretter V, Peake J, eds. Pulmonates, Vol 2A. Systematics, evolution and ecology. London: Academic Press, 1978: 287-333.

Cabrera BD, Jueco NL, Monzon RB, Cabrera BGG. Cathaemasiasis, a new parasitic disease entity in man (a case report). *Acta Med Philip* 1984; 20: 160-2.

Cabrera BD, Monzon RB, Sripawit A. Epidemiological aspects of human cathaemasiasis in the Philippines (a newly discovered parasitic infection). *Trans Natl Acad Sci Technol Repub Philipp* 1986; 8: 175.

Cheng TC. Enhanced growth as a manifestation of parasitism and shell deposition in parasitized mollusks. In: Cheng TC, ed. Aspects of the biology of symbiosis. Baltimore, Maryland: University Park Press, 1971: 103-37.

Chernin E. Infection of *Australorbis glabratus* with *Schistosoma mansoni* under bacteriologically sterile conditions. *Proc Soc Exp Biol Med* 1960; 105 : 292-6.

Cort WW, McMullen DB, Brackett S. Ecological studies on the cercariae in *Stagnicola emarginata angulata* (Sowerby) in the Douglas lake region, Michigan. *J Parasitol* 1937; 23 : 504-32.

Davis GM. Experimental methods in molluscan systematics. In: Fretter V, Peake J, eds. Pulmonates, Vol 2A. Systematics, evolution and ecology. London: Academic Press, 1978: 99-170.

De Andrade RM. Ecologia de *Australorbis glabratus* em

Belo Morizonte, Brasil. III. Indices de infeccao natural por *Schistosoma mansoni* segundo os diametros dos caramujos. *Rev Brasil Biol* 1962; 22 : 383-90 (Port).

De Jesus Z. *Lymnaea philippinensis,* an intermediate host of *Fasciola hepatica* with some observations on the bionomics of the parasite. *Philipp J Sci* 1935; 58 : 299-315.

Erasmus DA. The Biology of Trematodes. London: Edward Arnold, 1972.

Ewers WH. An analysis of the molluscan hosts of the trematodes of birds and mammals and some speculation on host-specificity. *Parasitology* 1964; 54 : 571-8.

Hoshina T, Ogino C. Studien üeber *Gymnophalloides tokiensis* Fujita, 1925. I. Uber die einwirkung der Larvalen Trematoda auf die chemische Komponente und das Wachstum von *Ostrea gigas* Thunberg. *J Tokyo Univ Fish* 1951; 38 : 335-50.

Hubendick B. Die Verbreitungsverhaltnisse der Limnischen Gastropoden in Sudschweden. *Zool Bidr Uppasala* 1947; 24 : 112.

Hubendick B. Recent Lymnaeidae. Their variation, mophology, taxonomy, nomenclature and distribution. *Kungl Svenska Vet-Akade-miens Handlinger Stockholm* 1951; Band 3, No. 1.

Inaba A. Cytotaxonomic studies of lymnaeid snails. *Malacologia* 1969; 7 : 143-68.

Lysaght AM. The biology and trematode parasites of the gastropod *Littorina neritoides* (L.) on the Plymouth breakwater. *J Mar Biol Ass UK* 1941; 25 : 481-8.

Malek EA. Laboratory Guide and Notes for Medical Malacology. Minnesota: Burgess Publishing, 1962.

Malek EA, Cheng TC. Medical and Economic Malacology. New York: Academic Press, 1974.

Manipol FS. The molluscan hosts of *Fasciola gigantica* in the Philippines. *Natl Appl Sci Bull* 1936; 5 : 335-6.

Menzel RW, Hopkins SH. Effects of two parasites on the growth of oysters. *Proc Natl Shellfish Assoc* 1955a; 45 : 184-6.

Menzel RW, Hopkins SH. The growth of oysters parasitized by the fungus *Dermocystidium marinum* and by the trematode *Bucephalus cuculus. J Parasitol* 1955b; 41 : 333-42.

Monzon RB, Kitikoon V. *Lymnaea (Bullastra) cumingiana* Pfeiffer (Pulmonata: Lymnaeidae): second intermediate host of *Echinostoma malayanum* in the Philippines. *Southeast Asian J Trop Med Public Health* 1989; 20 : 453-60.

Moose JW. Growth inhibition of young *Oncomelania nosophora* exposed to *Schistosoma japonicum. J Parasitol* 1963; 49 : 151-2.

Pan CT. The course and effect of infection with *Schistosoma mansoni* in *Australorbis glabratus. J Parasitol* 1962; 48 : 20.

Pan CT. Studies on the host-parasite relationship between *Schistosoma mansoni* and the snail *Australorbis glabratus. Am J Trop Med Hyg* 1965; 14 : 931-76.

Pesigan TP, Hairston NG, Tauregui JJ, *et al.* Studies on *Schistosoma japonicum* infection in the Philippines. 2. The molluscan host. *Bull WHO* 1958; 18 : 481-578.

Porter A. Public South African Inst Med Res 1938; 8 : 1-492.

Rothschild M. Gigantism and variation in *Peringia ulvae* Pennant 1777, caused by larval trematodes. *J Marine Biol Assoc UK* 1936; 20 : 537-46.

Rothschild M. Further observations on the effect of trematode parasites of *Peringia ulvae* (Pennant, 1777) in the laboratory. *Novitates Zool* 1938; 41 : 84-102.

Rothschild A, Rothschild M. Some observations on the growth of *Peringia ulvae* (Pennant) 1777 in the laboratory. *Novitates Zool* 1939; 41 : 240-7.

Rothschild M. The effect of trematode parasites on the growth of *Littorina neritoides* (L.). *J Mar Biol Ass UK* 1941a; 25 : 84-102.

Rothschild M. Observations on the growth and trematode infections of *Peringia ulvae* (Pennant, 1777) in a pool in the Pamar Saltings, Plymouth. *Parasitology* 1941b; 33 : 406-15.

Tubangui MA. Observations on the life histories of *Euparyphium murinum* Tubangui 1931 and *Echinostoma revolutum* Froelich, 1802. *Philipp J Sci* 1932; 47 : 497-513.

Velasquez CC. Mollusks of Parasitological Significance in the Philippines. Diliman: University of the Philippines Press, 1972.

Wesenberg-Lund CJ. Contributions to the development of the Trematoda Digenea. Part II. The biology of the freshwater cercariae in Danish waters. *Kgl Dan Vidensk Selsk Skr* 1934; 5 : 1-223.

Wright CA. Relationships between trematodes and molluscs. *Ann Trop Med Parasitol* 1960; 54 : 1-7.

Wright CA. Flukes and Snails. London: George Allen and Unwin, 1971.

Zischke JA, Zischke DP. The effects of *Echinostoma revolutum* larval infection on the growth and reproduction of the snail host *Stagnicola palustris. Am Zool* 1965; 5 : 707-8.