SNAILS OF MEDICAL IMPORTANCE IN SOUTHEAST ASIA

by

TROPMED TECHNICAL GROUP

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TROPMED Technical Meeting

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INTRODUCTION

Snails are generally distributed in various water resources of tropical countries, and certain species have been considered as of medical importance since they serve as intermediate hosts of many parasitic diseases. Existence of some snails such as *Oncomelania* spp., *Tricula* spp. and *Bithynia* spp. in major water resource development schemes of Southeast Asian Region may cause adverse effects on the socioeconomic development of the country because of the potential spread of snail-borne parasitic diseases. Snail-transmitted diseases especially opisthorchiasis (in Thailand and Laos), schistosomiasis (in the Philippines, Indonesia, Laos and Kampuchea), angiostrongyliasis, and echinostomiasis are considered as diseases of public health importance in this region. However, the information in many aspects such as snail fauna, ecology and the dynamics of disease transmissions are still limited and widely scattered.

It is also a fact that among the snails of medical importance there is a wide gap of mutual agreement in taxonomic term. Very often references made on snails and their ecological aspect in this region lead to misunderstanding and confusion. To clarify the problem, evidences from various research laboratories in this region should be gathered, verified and agreed upon.

Consequently, the SEAMEO-TROPMED Technical Meeting on Snails of Medical Importance in Southeast Asia was organized at the Faculty of Tropical Medicine with the aim to review and gather all updated information of snails under 7 families, e.g., Ampullariidae, Bithyniidae, Lymnaeidae, Planorbidae, Pomatiopsidae, Thiaridae and Viviparidae which exist in this region. The discussions were limited within the context of snail distribution, taxonomy, ecology, host parasite relationship, disease transmission and technology in control programme in Southeast Asian countries. It is expected that the outcome of this meeting can be used as guidance for future training programme and research in control of snail mediated diseases.

The technical meeting was convened during 25th-28th June 1985 and the participants were

Table 1

An outline of classification of medically and potentially important freshwater gastropods existing in Indonesia, Malaysia, the Philippines and Thailand.

Class GASTROPODA Cuvier 1797
- Subclass Prosobranchia Milne Edwards 1848
  - Order Mesogastropoda Thiele 1927
    - Superfamily Viviparoidea Gray 1847
      - Family Ampullariidae Guilding 1828
        - Genus *Pila* Röding 1798
          - *Pila ampullacea* Linnaeus 1758
          - *P. globosa* Swainson
          - *P. gracilis* Lea 1856
          - *P. luzonica* Reeve
          - *P. pesmei* Morlet 1889
          - *P. polita* Deshayes 1830
          - *P. scutata* Mousson 1848

during 1978-1983. The eligible donors were limited to those between 18 to 60 years of age and who had satisfactorily passed the routine

SGPT among different age group was in a reverse order as against the pattern shown with the case of HBsAg positivity.

Table 1 (cont'd)

Family Viviparidae Gray 1847
Genus *Bellamya* Jousseaume 1886
Bellamya javanica Von dem Busch 1844
B. philippinensis Neville
Genus *Filopaludina* Habe 1964
Subgenus *Filopaludina* s. str.
Filopaludina (Filopaludina) sumatrensis polygramma Martens 1860
Subgenus *Siamopaludina* Brandt 1968
Filopaludina (Siamopaludina) martensi martensi Frauenfeld 1865
Genus *Taia* Annandale 1818
Taia polyzonata Frauenfeld
Genus *Viviparus* Montfort
Vivipara angularis Müller
Superfamily Rissooidea H. & A. Adams 1854
Family Bithyniidae Walker 1927
Genus *Bithynia* Leach 1818
Subgenus *Digoniostoma* Annandale 1921
Bithynia (Digoniostoma) funiculata Walker 1927
B. siamensis goniomphalos Morelet 1866
B. s. siamensis Lea 1856
Digoniostoma truncatum Eydoux & Souleyet 1852
Family Pomatiopsidae Stimpson 1865
Subfamily Pomatiopsinae Stimpson 1865
Genus *Oncomelania* Gredler 1881
Oncomelania hupensis lindoensis Davis & Carney 1972
O. h. quadrasi Mollendorff 1895
Subfamily Triculinae Davis 1979
Genus *Robertsiella* Davis & Greer 1980
Robertsiella gismanni Davis & Greer 1980
R. kaporensis Davis & Greer 1980
Genus *Tricula* Benson 1843
Tricula aperta Temcharoen 1971
T. bollingi Davis 1968
Superfamily Cerithioidea (Fleming) H & A. Adams 1858
Family Thiaridae Gray 1847
Subfamily Thiarinae Gray 1847
Genus *Melanoides* Olivier 1804
Melanoides tuberculata O.F. Müller 1774
Genus *Tarebia* H. &. A. Adams 1854
Tarebia granifera Lamarck 1822
Genus *Sermyla* H. & A. Adams 1554
Sermyla riqueti Grateloup 1840
Genus *Thiara* Roding 1798
Thiara scabra O.F. Müller 1774

Table 1 (cont'd)

Subfamily Melanatriinae Thiele 1929
Genus *Brotia* H. Adams 1866
Brotia asperata Lamarck
B. costula Rafinesque 1833

Subclass Pulmonata Cuvier 1817
Order Basommatophora Keferstein 1864
Superfamily Ancyloidea Rafinesque 1815
Family Planorbidae Rafinesque 1815
Subfamily Bulininae Herrmannsen 1847
Genus *Indoplanorbis* Annandale & Prashad 1920
Indoplanorbis exustus Deshayes 1834
Subfamily Planorbinae Rafinesque 1815
Genus *Hippeutis* Charpentier 1837
Subgenus *Helicorbis* Benson 1850
Hippeutis (Helicorbis) umbilicalis Benson 1836
Genus *Gyraulus* Chaprentier 1837
Gyraulus convexiusculus Hutton 1849
G. sarasinorum Bollinger 1914
Genus *Segmentina* Fleming 1818
Subgenus *Polypylis* Pilsbry 1906
Segmentina (Polypylis) hemisphaerula Benson 1842
Subgenus *Trochorbis* Benson 1855
Segmentina (Trochorbis) trochoideus Benson 1836

Superfamily Lymnaeoidea Rafinesque 1815
Family Lymnaeidae Rafinesque 1815
Genus *Austropeplea* Cotton 1942
Austropeplea philippinensis
A. ollula
Genus *Bullastra* Bergh 1901
Bullastra cumingiana
Genus *Lymnaea* Lamarck 1799
Subgenus *Radix* Montfort 1810
Lymnaea (Radix) viridis Quoy & Gaimard 1832
Lymnaea (Radix) auricularia Linnaeus 1758
Lymnaea (Radix) a. rubiginosa Michelin 1831
L. (R.) a. swinhoei H. Adams 1866
Genus *Radix* Montfort 1810
Radix quadrasi von Mollendorff 1898

In many reports, all lymaeids in Southeast Asia and the Western Pacific are included in the Holarctic genus *Lymnaea*. However, the southern and southeastern Asian and Australasian lymnaeids belong to a different stock from the Holarctic *Lymnaea stagnalis*, the type species of the genus *Lymnaea*. Two species groups (genera or subgenera) of Lymnaeidae occur in Thailand and the Western Pacific region, *Radix* and *Austropeplea*. In addition, *Bullastra*, which was named for the Philippine species *cumingiana*, may prove to belong to a third group generically distinct from *Radix* and *Austropeplea;* or it may be congeneric with one of the latter two. If *Bullastra* is shown to be congeneric with *Austropeplea*, then *Bullastra* will replace the name (Burch, 1980; Upatham *et al.*, 1983).

Table 2

The distribution of medically important snails as listed to species arranged by families alphabetically.

Family	Genus-Species	Geographic location			
		Indonesia	Malaysia	Philippines	Thailand
Ampullariidae	*Pila ampullacea*	x	x	o	x
	P. globosa	o	o	x	o
	P. gracilis	o	o	o	x
	P. luzonica	o	o	x	o
	P. pesmei	o	x	o	x
	P. polita	x	o	o	x
	P. scutata	x	x	o	x
Bithyniidae	*Bithynia (Digoniostoma) funiculata*	o	o	o	x
	B. (D.) siamensis goniomphalos	o	o	o	x
	B. (D.) s. siamensis	o	o	o	x
	Digoniostoma truncatum	x	o	o	o
Lymnaeidae	*Austropeplea philippinensis*	o	o	x	o
	A. ollula	o	o	o	x
	Bullastra cumingiana	o	o	x	o
	Lymnaea (Radix) viridis	o	o	o	x
	L. (R.) auricularia rubiginosa	x	x	x	x
	L. (R) a. swinhoei	o	o	x	x
	Radix quadrasi	o	o	x	o
Planorbidae	*Hippeutis (Helicorbis) umbilicalis*	x	o	o	x
	Indoplanorbis exustus	x	x	x	x
	Gyraulus convexiusculus	x	x	x	x
	G. sarasinorum	x	o	o	o
	Segmentina (Polypylis) hemisphaerula	x	o	o	x
	S. (Trochorbis) trochoideus	x	o	o	x
Pomatiopsidae	*Oncomelania hupensis quadrasi*	o	o	x	o
	O. h. lindoensis	x	o	o	o
	Robertsiella gismanni	o	x	o	o
	R. kaporensis	o	x	o	o
	Tricula aperta	o	o	o	x
	T. bollingi	o	o	o	x

Table 2 (cont'd)

Family	Genus-Species	Geogarphic location			
		Indonesia	Malaysia	Philippines	Thailand
Thiaridae	*Brotia asperata*	x	o	x	o
	B. costula	x	x	o	x
	Melanoides tuberculata	x	x	o	x
	Sermyla riqueti	o	o	o	x
	Tarebia granifera	x	x	o	x
	Thiara scabra	o	x	o	x
Viviparidae	*Bellamya javanica*	x	o	o	o
	B. philippinensis	o	o	x	o
	Filopaludina (Filopaludina) sumatrensis polygramma	o	x	o	x
	Filopaludina (Siamopaludina) martensi martensi	o	o	o	x
	Taia polyzonata	o	x	o	o
	Viviparus angularis	o	o	x	o

x = parasitologic importance.
o = no parasitologic importance or no information available.

malacologists and researchers from Indonesia, Malaysia, the Philippines and Thailand and the World Health Organization.

CLASSIFICATION AND DISTRIBUTION

It was agreed at this technical meeting that approximately 45 species of freshwater snails in 7 families are known or suspected to transmit human parasitic diseases in Southeast Asian Region. The classification and distribution of known and suspected medically important species of these snails are summarized in Tables 1 and 2 respectively.

It should be noted here that among the 45 species, some snails have been studied to a greater extent than the others because they serve as intermediate hosts of widespread or severe infections. The examples are *Oncomelenia* spp. and *Tricula* spp. which are responsible for the transmission of oriental schistosomiasis. In contrast, there are also some snails from which no information are available. These snails are those that transmit some low prevalence parasitic infections, for example *Thiara* sp. and *Segmentina* spp.

The details on their taxonomy (similarity and dissimilarity), ecology, disease transmission and control measures of each family are summarized in the following chapters.

PROSOBRANCHIA : VIVIPAROIDEA

Family Ampullariidae

Snails in family Ampullariidae are generally large, adults 25 mm up to more than 100 mm in length, globose, subglobose or oval, spire usually depressed, less than half of the total shell length; aperture elongate, not round, with concentric calcareous operculum. *Pila* is the only genus of family Ampullariidae represented in South and Southeast Asia.

Pilid snail has short rostrum which carries a tentacle like process (pseudopodia) on either side. The left side is elongated into a tubular siphon during aerial respiration. Tentacles are very long and thin, the eyes are placed on separate stalks beside the tentacle. Mantle cavity is separated into two parts by septum: the right side contains the gill and the left side serves as a lung. The male organs do not show a genuine verge, but a pseudoverge is formed by a part of the mantle edge. The well developed jaw consists of corneous, fibrous layers. Radular with 7 teeth in one row, rhachis with 2 or 3 pointed cusps on either side of the large mesoconal, laterals and marginals with few cusps only.

The male sexual organs show cream-coloured testes of platelike structure attached to the digestive glands. Fine vasa efferentia unite into the vas deferens, which leads to the vesicular seminalis. The thick spermatheca duct shows a thick glandular portion, which leads to the mantle cavity. The mantle edge bears a glandular flap, free end is rolled into the penis-sheath which is only a simple process of the inner surface of the mantle During copulation the genital papilla, into which the spermatheca duct ends, forms a connection with the male genital opening and the copulatory organ (Benthem Jutting, 1956; Brandt,1974).

The pilid snails in Southeast Asian countries are not only intermediate host of trematodes and nematodes, but are also of economic importance as the mollusks are eaten locally or exported for consumption.

Taxonomy

The taxonomy of ampullariids in Indonesia, Malaysia, Thailand and the Philippines so far has been based mainly on shell morphology. There have been some discrepancies on

Table 3

General shell morphology and other characteristics used for taxonomic classification of *Pila* spp. in Southeast Asia.

Species	Indonesia	Malaysia	Philippines	Thailand
P. ampullacea	globose last whorl, low spire, ornated with violet-brown band, length up to 100 mm	globose body whorl, very low spire, brown spiral band and white inner lining of aperture, the length is 55-115 mm and the width is 55-105 mm	not present	shell ovate-conical with thin shell, generally white lip
P. globosa	not present	not present	no information	not present
P. gracilis	not present	not present	not present	shell ovate-conical, moderately thick, with spiral bands, and usually much smaller than *P. ampullacea*
P. luzonica	not present	not present	no information	not present

Table 3 (cont'd)

Species	Indonesia	Malaysia	Philippines	Thailand
P. pesmei	not present	shell with dark green spiral bands, has a thick yellow to orange lip, 25-26 mm long and 20-35 mm wide	not present	shell ovate conical, with a thick orange lip
P. polita	shell globose last whorl but more ovate with elevated spire, without spiral band, up to 75 mm in length	no information	not present	peridium very glossy, shell ovoidal with elevate spire, inner surface of operculum steel blue
P. scutata	very similar to *P. ampullacea*, but very much smaller (shell length up to 50 mm) with steplike descending spire	globular shell, about 6 whorls outer surface shiny olive brown with weak bands, inner lining bluish nacreous, operculum is calcareous with concentric rings, L 25-50 mm W 20-30 mm	not present	shell ovate-conical, very thin and without bands

the features of identifications. The dissimilar characteristics are listed in Table 3. However, come anatomical structures of the snails can be used for taxonomic classification, such as penis and radula. The characteristics of each species are shown in Tables 3 & 4 a & b.

Ecology

In general, ampullariid snails inhabit stagnant water such as lakes, marshes, ponds and rice fields, in the mud, on the bottom or among aquatic vegetation. They also live in slow running or sluggish streams and rivers. The small white eggs are laid in cluster on dry bank near water in June or at the beginning of the rainy season depending on geographic locations. They also lay eggs on various kinds of substrates such as on cement banks, twigs, wooden poles and branches of aquatic plants few feet above water as well as hidden under the grasses or weeds. When the young snails hatch, they drop into the water and develop into adults. *Pila* snails can hibernate during the dry season under moist mud by closing their opercula and waiting for the next rainfall. The foods of *Pila* snails are aquatic weeds which include *Valisneria* spp., *Pistia startiotes*, *Ceratophyllum demersum*, *Ipomoea reptans*, *Eichornia crassipes*, filamentous algae and occasionally *Cyperus radiatus* (Crook *et al.*, 1962).

Table 4a

General characteristics of testis, penis, penis sheath and rudiment penis of *Pila ampullacea*, *P. polita* and *P. scutata*.

Species	Testis	Penis		Penis sheath	Rudiment penis	
	colour	colour	form	colour	colour	form
P. ampullacea	milky white	cream	long & slender	greyish black	greyish black	like a penis, properly developed
P. polita	light yellow or orange	cream	longer & more slender	greyish black	greyish black	as a thickened mantle-edge, or sometimes lacking
P. scutata	orange	cream or light yellow	long & slender	cream or light yellow	cream or light yellow	like a penis, not properly developed

Table 4b

Radula teeth of *Pila ampullacea*, *P. polita* and *P. scutata*.

Species	Number of cusps			
	Central	Lateral	Marginal 1	Marginal 2
P. ampullacea	5	4	1	1
P. polita	7	4	1	1
P. scutata	7	4	2	2

Host-parasite relationship

Two groups of parasites of medical importance, *Echinostoma* spp. and *Angiostrongylus* sp., are reported to develop in *Pila* snails. The infection rates of *A. cantonensis* in *P. scutata* was 5.9% in Indonesia (Margono, 1970; Margono and Ilahude, 1974) and *A. malaysiensis* in *P. scutata* was 14.6% in Malaysia. (Lim and Ramachandran, 1979). In Thailand, *A. cantonensis* was 0.4% in *P. polita* and 1.1% in *P. ampullacea* (Bhaibulaya, 1974). Metacercariae of *Echinostoma ilocanum*, *E. lindoensis* and *E. malayanum* are found in these snails (Bhaibulaya *et al.*, 1964, 1966).

Angiostrongylus cantonensis is a causative agent of eosinophilic meningoencephalitis in man. Cases with central nervous system involvement or even fatal cases have been reported in Thailand among persons who have consumed inadequately cooked snails. Angiostrongyliasis, so far, has not been reported in the other three countries (Punyagupta, 1965).

Echinostomiasis is endemic in Southeast Asia. *Echinostoma lindoensis* has been reported in the inhabitants of three villages in central Sulawesi (Celebes) and *E. ilocanum* was endemic among some Indonesian lunatics (Sandground, 1939; Bonne *et al.*, 1953;

Hadidjaja and Oemijati, 1969). Two human cases of *E. malayanum* were reported in Malaysia, in a Tamil coolie and in a small Indian girl (Lie and Virik, 1963). In Thailand patients were found to harbour *E. ilocanum* during the clinical trial of praziquantel in human opisthorchiasis at the Hospital for Tropical Diseases, Bangkok (Radomyos *et al.*, 1982).

Pila snails are consumed by various methods. In Indonesia and Malaysia, the snails are well cooked before eaten. The Malays eat the muscular portions of the snails and discard the alimentary tract, while the Chinese and Indians eat the whole snails after removing the shells. The snails are considered to have medicinal value to both the Chinese and Indians. In the Philippines, the spire of the shell is cut off and cooked thoroughly in coconut milk mixed with spices. The animal is sucked or picked out with a tooth pick. In Thailand, thousands of snails are eaten each week in many areas. The snails are put on the fire until they are half cooked, operculum opened, the foot parts were taken out, chopped and mixed with fish sauce, chilli and lime juice prior to eating with sticky rice.

Control

There is no study on the control of *Pila spp.* in Southeast Asian region.

On the contrary, *Pila* snails are known to eat plants and egg masses of other snails. Some work is being conducted in Thailand on the use of *Pila* as a biological control agent of disease-transmitting snails by competition for food and elimination of eggs of the target snails.

Recommendations

Studies on taxonomy of Ampullariidae are recommended as follows: reproductive systems, iso-enzyme, geographic distribution in Southeast Asian countries, genetics, and geographical variation (shell morphology).

There is a need to correlate the results of iso-enzyme and genetical studies with morphology.

More bionomic studies are needed especially as these snails are of medical and economic importance.

In host-parasite relationship the studies on transmission dynamics are recommended as follows: susceptibility rates of *Angiostrongylus* in various species of *Pila*, transmission of *Angiostrongylus* from *Pila* through vegetables; and viability of infective larvae of *Angiostrongylus*.

In control measures, studies on the effects of molluscicides on *Pila* snails should be conducted so that basic information is available whenever required. It is necessary to determine the desirability and feasibility of control for these species before control is implemented.

On economic aspect: As these snails are considered to have potential economic importance, the nutritional value of the snail should also be thoroughly studied. However, the food value of the snail should be promoted only in countries where the snails are eaten properly cooked. Farmers cultivating the snails should be educated on keeping them parasite free. There is no parasitie problem in exportation of canned snails.

Family Viviparidae

The size of snails in family Viviparidae is usually medium to large. The snail is dextral, with a corneous concentric operculum. The shell is subglobose, ovate-conic, pyramidal or turreted, smooth or sculptured with spiral lines or ridges or tubercles, and with or without colour bands. Female is ovoviviparous; male with the right tentacle transformed into a male copulatory organ.

In Indonesia, there are 4 genera *(Angulyagra, Bellamya, Glaucostracia* and *Torotaia)* comprising 14 species. Only *Bellamya javanica* is reported to be a snail of medical importance (Bonne and Sandground, 1939; Sandground and Bonne, 1940).

In Malaysia, family Viviparidae is represented by genus *Filopaludina*, formerly called *Bellamya*, and genus *Taia*. Snail species that have been recognized as medical importance are *Filopaludina (Filopaludina) sumatrensis polygramma*. *F. (Siamopaludina) martensi martensi* and *Taia polyzonata* (Palmieri *et al.*, 1977; Palmieri and Palmieri, 1980).

In the Philippines, only *Viviparus angularis* (Velasquez, 1964; Chin, 1983) and *Bellamya philippinensis* (Ito *et al.*, 1977), have been reported to be snails of importance in family Viviparidae.

In Thailand, there are 8 genera of the family Viviparidae, namely *Filopaludina, Trochotaia, Eyriesia, Idiopoma, Mekongia, Sinotaia, Anulotaia* and *Cipangopaludina*. Only one genus *Filopaludina* has been reported to be the snail of medical importance (Brandt, 1974) These include *Filopaludina (Filopaludina) sumatrensis polygramma*, and *Filopaludina (Siamopaludina) martensi martensi*.

Taxonomy

There are some confusion in identifying genera and species of snails in family Viviparidae among the Southeast Asian countries. *Vivipara* or *Viviparus, Bellamya* and *Filopaludina* are called as the generic names of viviparid snails in the Philippines, Indonesia, Thailand and Malaysia, respectively.

In older literatures, all Philippine Viviparidae were placed in the Holarctic genus *Viviparus*. However, members of the subfamily Viviparidae to which this genus belongs do not occur in southern and southeastern Asia as well as in Africa (Brown, 1980), while *Filopaludina*, formerly called, i.e., *Paludina, Vivipara, Bellamya, Siamopaludina.*, was united with the African genus *Bellamya* in the subfamily Bellamyinae (Brandt, 1974).

The generic assignments in the Southeast Asian Viviparidae are based largely on adult shell characters, a practice which is not altogether satisfactory (Upatham *et al.*, 1983). Therefore, this paper presents the current identification published. As future changes are made in the taxonomy of the snails, the identification key will have to be revised accordingly. Since, the identification has not yet been agreed upon, the details of characteristics used at present to identify the medical important molluscan species in this family will be described individually as follows:

Bellamya javanica: Shell is pyramidal with elevated spire and rounded base; brownish green or yellowish-green under an olive somewhat fibrous epidermis; striated with fine undulating transverse lines. In addition, there is a spiral sculpture of fine striae and thread-like keels. Of the latter some three to five are more raised than the others. These raised keels which are for the greater part periostracal, can coincide with narrow spiral colour bands. Periphery is angulate or weakly keeled; in fully mature specimen is rounded. The surface of fresh shells is moderately glossy.

There are 6-7 whorls, regularly increasing in size. Sutures are distinct, but not deep. The top is pointed, rather sharp, but is often eroded. The base is rounded below the peripheral keel. Umbilicus is open, but not wide, sometimes is bordered by a keel.

Aperture is oblique. broad-ovate, somewhat pointed above, rounded or gutter-shape below. In specimens with a marked peripheral keel (usually when the shells are not fully mature), the aperture is angular at that point. Peristome is continuous in old shells; in the younger ones there is an interruption on the parietal side where the peristome forms a thin film against the penultimate whorl. Peristome is not reflected, sometimes lined with black. The columellar margin is generally thickened in adult shells.

Operculum is horny, with a subcentral nucleus. Growth rings are concentric. The operculum has the same broad-ovate form as the aperture; it fits in within the aperture but at a certain level below the rim.

Dimensions: The height is about 34-40 mm, the width ranges between 22 and 26 mm and the height of aperture is between 16 and 17 mm (Benthem Jutting, 1956).

Bellamya philippinensis: There is no detail of shell morphology of *Bellamya philippinensis* in the literature. Ito *et al.*, (1977) collected freshwater snails on Leyte Island which was later identified by Habe as *B. philippinensis*. However, taxonomy still needs clarification.

Filopaludina (Filopaludina) sumatrensis polygramma: The body whorl is rounded or somewhat angled at the periphery. The umbilicus is closed. There are 4 or 5 colour bands between suture and periphery, and there is no subsutural shoulder. The periphery may be carinated. The marginal tooth contains 15-16 cusps.

Filopaludina (Siamopaludina) martensi martensi: Shell is large, thick, solid, with olive-green periderm which turns brown or blackish with age. The body whorl is large, inflated, with more or less distinct spiral ridges but rarely with darker spiral bands. Umbilicus is either completely closed or, rarely, somewhat open, never with a periomphalic carina. Aperture is large, broadly ovate, angled above, bluish-white within.

Taia polyzonata: Shell is similar in measurement to that of *Filopaludina sumatrensis.* It has fine microsculpture and the colour varies from greenish-yellow to greenish-brown with dark brown spiral bands. The thin operculum is brownish and glossy on the inner surface (Palmieri and Palmieri, 1980).

Ecology

The species of family Viviparidae in general inhabit in stagnant water, such as lakes, marshes, ponds, rice fields and also sluggish rivers and ditches.

No ecological studies have been carried out in Southeast Asia concerning these viviparid snails, except in Malaysia. *Filopaludina (S.) m. martensi* is found in village ponds and slow-moving streams where there are abundance of vascular plants. They prefer acidic water, pH around 6.9, with nitrate content around 0.8 mg/l and moderate hardness 70 mg/l of calcium content (Palmieri and Palmieri, 1980). *F. (S.) m. matrensi* is found in still water with few vascular plants. *Taia polyzonata*, however, is found in clear open ponds with little vegetation, and they are usually attached to rubbish found in the ponds. They prefer slighly alkaline water, average pH 7.3, and low nitrate (average 33 mg/l) and low calcium level (Palmieri and Palmieri, 1980). These three species are filter feeders of algae and organic matter.

Host-parasite relationship

In Indonesia there has been no study on the transmission dynamics of *B. javanica*, although it serves as intermediate host of *Echinostoma* spp.

The three species of viviparid snails in Malaysia have been reported to harbour echinostome cercaria, cyathocotylid cercaria and a xiphidiocercaria.

Vivipara angularis is the only viviparid in the Philippines which has the potential of medical importance. It is the first and second intermediate host of *Euparyphium paramurinum* Velasquez. Gravid adults were obtained from the intestines of experimental guinea pigs, mice, rats, and dogs fed with infected snails (Velasquez, 1964).

This snail is widely eaten by the Filipinos. Among 1,134 *Vivipara angularis* snails examined from public markets at one time, 935 or 82.4% were naturally infected with metacercariae of *Euparyphium paramurinum* and *Echinostoma revolutum* in the pericardial sac, kidney, and gills (Chin, 1983).

The zoonotic potential of these parasites should be considered. *Echinostoma revolutum* was reported in Malaysia to establish itself in man as four other echinostome species, such as *Echinostoma ilocanum*, *Euparyphium recurvatum*, *Euparyphium malayanum*, and *Echinostoma lindoense* (Bonne *et al.*, 1953).

In addition to echinostome metacercariae, *V. angularis* were shown to harbour parasitic adults and rhabditiform larvae of *Strongyloides* sp. (29 out of 1,134 or 2.6%) (Chin, 1983).

Vivipara angularis has also been discovered to be a potential intermediate host of *Angiostrongylus cantonensis* in the Philippines.

In *Bellamya philippinensis*, 8 types of cercariae were found, these are two furcocercous cercariae, one monostome cercariae, three echinostome cercariae and two xiphidiocercariae (Ito *et al.*, 1977). The adult morphologies of two furcocercous cercariae have been preliminary identified as Cyathocotylidae and Sanquinicolidae, while those of monostome cercariae were Notocotylidae. The others were Echinostomatidae, Microphallidae.

In Thailand, *Filopaludina (Filopaludina) sumatrensis polygramma* and *Filopaludina (Siamopaludina) martensi martensi* are edible snails and also transmit the trematode parasites of Echinostomatidae (Brandt, 1974). There are 4 species of *Echinostoma* recovered from some Thai natives. They are *Echinostoma malayanum*, *Hypodereaum conoideum* (Bhaibulaya *et al.*, 1964), *E. revolutum* (Bhaibulaya *et al.*, 1966), and *E. ilocanum* (Radomyos *et al.*, 1982). Unfortunately, *Filopaludina* species acting as either the first or secondary snail intermediate hosts have not been further investigated as with the species of the families Ampullariidae, Lymnaeidae, and Planorbidae. Thus, the life histories of these intestinal flukes in the Thai Viviparidae need more investigation prior to conclusion.

Control

No control measure has been carried out for family Viviparidae in Southeast Asia.

Recommendations

For mutual understanding, the nomenclature for various taxa needs to be resolved.

On ecology and host-parasite relationship indepth studies on the biology, population and transmission dynamics should be carried out according to the country's priority. In addition, the biological effects of pollutants on these edible snails should be studied to avoid the health harzard.

Since Viviparid snails are eaten by people, infected inhabitants should be treated so that the parasites' eggs contamination in snail habitat will be reduced.

PROSOBRANCHIA : RISSOOIDEA

Family Bithyniidae

Snails of the family Bithyniidae are found to be present in all continents including Indo-pacific islands. Generally, the snail size is small, ranged from 6.5-14.8 mm in length and 3.0-9.6 in diameter. Shell is ovate-conoidal, brownish, corneous or olive-coloured and mostly with very delicate spiral lines but never with strong sculpture. Aperture is round or ovate. Operculum is calcareous and mostly with paucispiral nucleus.

Many different genera and species belong to the family Bithyniidae, but only a few species of genus *Bithynia* are found to be medically important.

Taxonomy

In Indonesia, the family Bithyniidae consists of four genear : *Digoniostoma*, *Emmericiopsis*, *Gabbia* and *Wattebledia* (Benthem Jutting, 1956, 1959). Only *Digoniostoma truncatum* plays an important role in veterinary field. *D. truncatum* was first described as *Paludina truncatum* but many authors considered it as *Bithynia truncatum* Thiele (1931) and Brandt (1974) classified *Digoniostoma* as a subgenus of *Bithynia*, but Wenz (1938) considered it as a subgenus of *Bulimus*.

In Thailand, the family Bithyniidae consists of three genera: *Bithynia*, *Hydrobioides* and *Wattebledia*, but only snails of the genus *Bithynia* are of medical importance (Brandt, 1974). The genus *Bithynia* is divided into 2 subgenera, namely subgenera *Gabbia* and *Digoniostoma*. Subgenus *Gabbia* includes the following species: *Bithynia (Gabbia) wykoffi*, *B. (G.) walkeri* and *B. (G.) pygmaea*, and subgenus *Digoniostoma* consists of *Bithynia (Digoniostoma) funiculata*, *B. (D.) siamensis siamensis*, *B. (D.) S. goniomphalos*, and *B. (D.) pulchella*. Snails of the subgenus *Gabbia* are not of medical importance, whereas those of the subgenus *Digoniostoma* are, except the species *pulchella*. The specific characteristics which are used to classify the bithyniid snails are presented in Table 5.

Ecology

In Java, Indonesia, *D. truncatum* inhabits stagnant water, such as marshes, lakes, ponds and rice-fields, ditches and sluggish rivers. They live at the bottom, on surface or among mud and aquatic weeds. The results of the study of the molluscan fauna of the water-hyacinth *(Eichornia crassipes)* root system in several lakes, marshes and rivers in Lampung, South Sumatra and Java indicated that 7.14% of the water-hyacinth roots examined from Lake Bagendit, West Java, was inhabited by *D. truncatum*.

In Thailand, the bithyniid snails are found in rice fields, canals, banks of water reservoirs

Table 5

Some specific characteristics of medically important bithyniid snails.

Species Characteristics	*Bithynia (Digoniostoma) funiculata*	*Bithynia (Digoniostoma) siamensis goniomphalos*	*Bithynia (Digoniostoma) siamensis siamensis*
Umbilicus	funnel-shaped	wide but not funnel shaped	very narrow
Carina	very strong	weak or missing	not seen
Apex	very slightly eroded	very much eroded when old	slightly eroded
Peridium	olive-brown	brownish-olive, sometimes reddish-brown	greenish-olive or straw straw colour and glossy
Spire	short, conic truncate spire	long conic spire	sharp apex is not eroded
Average shell size	10.2-14.8 mm in length, 6.8-9.6 mm in width	10.2-14.9 mm in length, 5.6-8.5 mm in width	7.4-11.0 mm in lenght, 3.0-6.8 mm in width

with the depth of water less than 50 cm. The optimum water temperatures are between 25°C and 28°C, the pH values range from 6.9-7.1, and the total hardness is below 150 mg/l as $CaCo_3$. The food preferences are diatom of *Navicula* species (Sornmani, pers. comm.).

Host-parasite relationship

In Indonesia, *Digoniostoma truncatum*, plays an important role only in the veterinary field. Darmono and Dajajasasmita (1983) found that 8.6% of *D. truncatum* collected from 8 villages in Bali were infected with rediae and cercariae of *Paramphistoma* sp., the causative agent of the fatal paramphistomiasis in cattle.

In Thailand, *B. (D.) funiculata*, *B. (D.) s. siamensis* and *B. (D.) s. goniomphalos* are important intermediate host of *Opisthorchis viverrini*. At present, information on the bionomics of bithyniid snails and on the transmission of *O. viverrini* is rather limited. Field studies on the bionomics of *B. siamensis siamensis* and on the transmission of *O. viverrini* in Bangna, Bangkok indicated that the snail populations increased during the rainy season but declined thereafter. The infection rate of snails with *O. viverrini* was found to be about 1.6% (Upatham and Sukhapanth, 1980).

Upatham *et al.*, (1982, 1984) and Sornmani *et al.*, (1984) showed that the overall prevalence rates of opisthorchiasis in 3 villages in endemic areas in Khon Kaen, Thailand were over 80%. The present evidences indicated that the prevalence of opisthorchiasis in Thailand has markedly increased. The total estimated population which is affected by this parasite is over 6 million.

Control

In Thailand, Sa-Nguankul *et al.*, (1983) tested Bayluscide and controlled release tin formulations against medically important snails in the laboratory; in the field there is no effective way to control *Bithynia* snails either by chemical molluscicides or biological means.

Recommendations

Thailand is the only country in this region to be affected by bithyniid snails which transmits the liver fluke, *Opisthorchis viverrini*. The economic loss is significantly high as over 6 million of people are suffering from this snail-borne parasitic disease. Therefore, studies recommended were socio-economic status with special emphasis on economic loss due to the liver fluke; life tables of the medically important molluscan host of all subspecies,susceptibility of various bithyniid species to the parasite and population dynamics of snail intermediate hosts and dynamics of parasite transmission in water resource projects.

Family Pomatiopsidae

There are three genera of snails under this family which are responsible for the transmission of human schistosomes in Southeast and East Asia. These are *Oncomelania*, *Robertsiella* and *Tricula*.

The snails which belong to rissooidean Pomatiopsidae (Pomatiopsinae and Triculinae) generally vary in shell morphology, i.e. turreted, *Oncomelania* (pomatiopsine); conic, *Robertsiella* or ovate-conic, *Tricula aperta* (triculine).

Taxonomy

Species discrimination in medically important molluscan hosts is normally based on morphological characteristics, either shell morphology or anatomical traits as shown in Table 6. However, a combination of the study on the chromosomal cytology, gene-enzyme system and cross breeding test would be more valid.

Table 6

Some prominent characteristics used to identify the medically important molluscan hosts in the family Pomatiopsidae.*

Characteristics	*Oncomelania hupensis lindoensis*	*Oncomelania hupensis quadrasi*	*Robertsiella kaporensis*	*Robertsiella gismanni*	*Tricula aperta* alpha	*Tricula aperta* beta	*Tricula aperta* gamma	*Tricula bollingi*
Shell	turreted, translucent brown yellow, smooth, 6.5 to 6.7 whorls, 5.2 + 0.6mm. long with open umbilicus, weak varix, outer lip sinuate, inner lip projects beyond the base of the shell but not thickened columella	more rounded body whorl, turreted, about 3 to 5 mm long with 6 to 7 whorls, shell generally smooth with fine axial growth line, shiny, dark brown colour	ovate-conic with moderately rounded whorls and indented sutures, less than 4 mm in length with 5.5 to 6 whorls	very similar to *R. kaporensis*, can be separated by gene-enzyme systems	ovate conic, spire periphery nearly straight or concavely curved, 6.0–6.5 whorls with 4.2 + 1.11mm long, no spiral microsculpture, inner lip is expanded over the outer aperture	same as alpha but significantly smaller, 85% having raised spiral microsculpture	same as alpha, smallest in the group, 2.9 mm. in length with 5.5-6 whorls	turreted, whorls are slightly convex and the suture is rather shallow, head foot area pigmented

Table 6 (cont'd)

Charac-teristics	*Oncomelania hupensis lindoensis*	*Oncomelania hnpensis quadrasi*	*Robertsiella kaporensis*	*Robertsiella gismanni*	*Tricula aperta*			*Tricula bollingi*
					alpha	beta	gamma	
Radula (Central tooth)	NA	$\frac{1-1-1}{3-3}$, $\frac{2-1-2}{3-3}$ or $\frac{1-1-1}{2-2}$	$\frac{2-1-2}{2-2}$	$\frac{2(3)-1-(3)2}{(3)2-2(3)}$	$\frac{4(5)-1-(5)-4}{6-6}$	NA	$\frac{4-1-4}{5(6)-(6)5}$	$\frac{3-1-3}{3-3}$
Genital organ	seminal vesicle is convoluted anterior to testis and is often coiled on the posterior chamber of the stomach, the ejaculatory duct is thickened.	NA	penis is noncontractable, cuticularized papilla at tip		verge:tightly coiled, ciliated at the tip	same	same	coiled but not ciliated as *T. aperta*
Chromosome	NA	2n = 34	NA	NA	male : 2n = 29,31,31 female : 2n = 32,34	male: 2n = 31,33 female: 2n = 34	male: 2n = 29,31,33 female: 2n = 32,34	NA

NA = not available.
* Davis, 1968-1979: Davis and Carney, 1973; Davis *et al.*, 1976; Davis and Greer, 1980; Kitikoon, 1982.

Ecology

Since snails in this family are responsible for transmitting schistosomiasis, the most important water-borne parasitic disease, their ecology has been studied and reported.

(a) **Habitats of** *Oncomelania hupensis lindoensis*

The natural habitats: *Oncomelania hupensis lindoensis* are found in the virgin forest and ecotonal zones between forests and lowlands in Lindu Lake and Napu Valley, Central Sulawesi, Indonesia. These habitats remain moist throughout the year because of the seepage water from the higher area. The area has silty substrates and are well shaded by medium and high tropical vegetations. The snails in these habitats were observed crawling over soil, or attached to dead leaves or any materials floating in the water. Within the natural habitats of the foci were located in small pockets where forest vegetation bordered the shore of the lake. These spring fed areas are covered with sandy substrates, and the floor are scattered with small and medium-sized gravels, stones or rock.

The disturbed habitats: These are abandoned rice-fields, uncultivated grassy areas with rich silty soil adjacent to the rice fields and along the banks of the existing crude irrigation networks covered by dense vegetation. When oncomelanid snails are found under the grass, they are usually attached onto the roots or leaves of the grasses near the ground. Most of them are found in abundance on the roots and under the taller grasses, such as *Cyperus* spp. The snails prefer these species of grasses because they can protect themselves from direct sunlight, and also retain constant moisture. They are also found crawling on the surface of dead branches or leaves lying on the mud. Rice-fields where regular cultivations are carried out, are found to be unsuitable habitat for oncomelanid snails. The snails are very rarely found in the cultivated rice-fields. Probably they originate from irrigation ditches and are flushed down into the rice-fields (Hadidjaja and Sudomo, 1976).

(b) **Habitats of** *Oncomelania hupensis quadrasi*

Wet places are common habitats of these snails and they can be grouped as follows (Pesigan *et al.*, 1958):

Flood-plain forests and swamps: The area apparently represents the most extensive original habitat of *Oncomelania* sp. An example of this type of habitat is in Mindanao, Philippines. In agricultural countries, much forest land is cut down for rice growing.

Only in certain parts of Mindanao the natural habitat of the snail is found in an undisturbed condition. The largest snail habitat yet discovered covers the entire Manat River swamp in Davao Province. It is approximately 20 km. long by at least 2-3 km. wide. Snails were found on the forest floor in slight depression where water has accumulated. At a trial-crossing near the center of the swamp, the river has no defined channel, covering a large part of the forest with water. Snails were found all along this trial from the point of the river entrance into the swamp onwards for at least 2 km.

Similar habitats could be seen with minor variations in many other places in Mindanao. As mentioned above, the land is desirable for rice farming, and all such habitats are seen under agricultural encroachment.

Rice fields: It is not common to find *O.h. quadrasi* in well cultivated rice fields. Snails are found in fields which are either newly cut out of swamps, or are abandoned or poorly farmed. The presence of the snails, therefore, can only be accounted for on the basis of the primitive agriculture practised in some endemic areas.

Streams and creeks: The areas densely inhabited by *O.h. quadrasi*, are meandering and sluggish streams. The typical picture seen is a stream bed 3-15 metres wide at a level one meter or more below the surrounding. The stream bed is flat, clogged with vegetation and very soft. In spite of the vegetation, there is usually a moderate flow of water. Several species of fish, particularly the mudfish (*Ophicephalus* sp.) inhabit these streams and are widely caught for food. The method used in catching them is to dike off or dam a part of the stream, and then to wade in and capture the fish by hand. The repeated temporary damming of the streams prevents the water to flow through the channel. In addition, the streams are very widely used as a wallowing sites for the water buffalo (carabao), the principal work animal in the Philippines. The wallows are temporary, and many different sites may be used by the same animal. This wallowing has the same effect as the fishing by forcing the water away from any defined channel, softening the whole stream bed, and making the flow more sluggish and promoting the growth of semi-aquatic grasses and other plants, which in turn impede the water to stagnate.

Small swamps: These areas are much more like the streams in appearance. The only differences from the streams are their small size and the lesser flow of water. Like the streams, they are fished and used as carabao wallows. These small swamps, which have been called "pockets" are always located at the foot of the rather high and steep banks, and the source of their water are seepages and springs emerging below the banks.

In many places, particularly in the Sorsogon area, spring outlets may support snails without forming a well defined swampy area. Often the banks around such a spring, though rather steep, and sandy, are always wet from seeping water. Such places may be very small. Omagom Spring in Irosin, Sorsogon, which forms an *Oncomelania* habitat, has the maximum dimensions of 10×2 m. It is particularly these small swamps that have given such vivid impression of discontinuity in snail distribution that the term "colonies" have been given to individual snail-inhabited area.

Road ditches and borrow-pits: In the construction of roads in lowland areas, it is often that a rather large ditch is left on either side of the road. These ditches remain wet because of their low level, and in many places provide good habitats for *O.h. quadrasi.*

(c) **Habitats of *Robertsiella* spp:**

All three species of *Robertsiella* snails of Malaysia appear to have narrow habitat ranges. They inhabit the foothills and mountainous regions. A total of 15 district populations of *R. gismanni* (14 in Pahang and 1 in Kelantan States), 2 populations of *R. kaporensis* (both in Pahang State), and 2 populations of undescribed *Robertsiella* sp. (1 in Kedah and 1 in Perak States, near the Thai border) have been located in Peninsular Malaysia. None has so far been found in the states of Selangor and Trengganu (Greer *et al.*, 1984a).

Most *Robertsiella gismanni* and *R. kaporensis* inhabit small streams less than 4 m. in width having relatively low to moderate grades; these streams are between 31 m. to 91 m. above sea level. The undescribed *Robertsiella* sp. inhabits small streams less than 1 m. in width having relatively high grades and at elevations of over 250 m. asl. The former two species of snails are almost exclusively associated with the submerged root systems of riparian vegetation, particularly *Saracca thaipingensis*, while the undescribed *Robertsiella* sp. is found attached to rocks and sometimes on roots of yams (*Dioscorea* sp.).

(d) **Habitats of *Tricula* sp.**

The alpha and gamma races of *Tricula aperta* are found in the Mekong River, ranging from Ban Sabouxai, Suvannakhet Province, Laos, to Ban Dan, Ubon Province, Thailand. The gamma race extends to Sompamit Falls in Southern Laos and possibly to Kratie in Cambodia. The beta race of *T. aperta* occurs exclusively in the Mun River (a tributary of the Mekong) at Phibunmangsaharn District, Thailand. The two unnamed phenotypes of *T. aperta* were found only in the Mekong River, mainly in front of Moung Khong Hospital, Khong Island, Laos (Temcharoen, 1977; Upatham *et al.*, 1980; Kitikoon *et al.*, 1981)

Tricula aperta snail prefers to live only on solid substrates: base sheet rock, or under the bark of dead wood, rocks, shells and other solid materials, including dead leaves of higher aquatic plants (such as those of the shruby euphorbeaceous pheophytes, *Homonoia* spp., which are quite common along the Mekong and Mun Rivers). The *Tricula* spp. live neither in mud nor algal strands.

In the dry season, the snails are abundant, when the river current is slow, large particles sediment leaving the water relatively clean and clear. Turbidity ranges from 0 to 15 Jackson units.

Studies during 1972 to 1977 revealed the following ecological conditions: Water temperature: 27°C to 33°C., total dissolved solid: 140 to 170 mg/l; conductivity (=Ec 10 at 25 degree): 240 to 250 mg/l; pH 7.8 to 8.4 (diurnal only); dissolved oxygen : 6.2 to 7.5 mg/l; the percentage of saturation to 103% (the last value indicating supersaturation); alkalinity : 70 to 80 mg/l $CaCO_3$; total hardness : 70 to 75 mg/l $CaCO_3$; carbon dioxide : 4 to 10 mg/l.

Host-parasite relationship

Oncomelania hupensis lindoensis is the most important fresh-water mollusc in Indonesia as it is the intermediate host of schistosomiasis japonica in Central Sulawesi, namely the Lindu Lake area and Napu valley. *O.h. quadrasi* is confined to the Philippines islands and was first recognized as the intermediate host of *Schistosoma japonicum* at Palo, Leyte in 1932.

All three species of *Robertsiella* snails have been found naturally infected with *Schistosoma japonicum*-like schistosome (Greer *et al.*, 1984a). Cercarial shedding has been observed in about 0.1% of over 20,000 *Robertsiella kaporensis* taken from Sg. Kapor, Pahang, Peninsular Malaysia. *R. gismanni* has an infection rate of 0.5% (2,870 snails examined) in Sg. Wa, Pahang and 0.3% (660 snails studied) in Sg. Dayang, Pahang. The undescribed *Robertsiella* sp. from Sg. Charok Bukit Sebelah, Kedah, shows an infection rate of about 0.5% (over 5,800 snails examined).

Laboratory studies show that *Schistosoma japonicum* will not develop in all the three species of *Robertsiella* snails (Greer *et al.*, 1984b). Similarly, *Schistosoma mekongi* does not develop in *R. kaporensis* and the undescribed *Robertsiella* sp. On the other hand, the Malaysian schistosome Koyan isolate develops in *Tricula aperta* and *T. bollingi*. This finding has been taken to indicate a closer relationship between the Malaysian schistosome and *S. mekongi* when compared to *S. japonicum* (Greer *et al.*, 1984b). The conclusion is supported by electrophoretic studies on the gene-enzyme systems of these schistosomes (Yong *et al.*, 1985).

At three foci of transmission (Kuala Koyan, Kuala Tahan and Baling), *Sundamys muelleri* (a rodent previously known as *Rattus muelleri*) has been found naturally infected with the Malaysian schistosome, with an average rate of about 28% (Ambu *et al.*, 1984). Another rat, *Rattus tiomanicus*, has been found to be infected only in the Baling site.

All human cases of endemic schistosomiasis in Malaysia involve only the Orang Asli

(Leong *et al.*, 1975; Murugasu and Dissanaike, 1973; Murugasu *et al.*, 1978). Of the autopsies carried out, two Orang Asli inhabitants of Kuala Koyan had schistosomiasis (Leong *et al.*, 1975). In most areas, however, schistosome transmission has not been demonstrated.

All races of *Tricula aperta* are susceptible to *Schistosoma mekongi.* The susceptibility rates ranged from 40% to 60% (Kitikoon, 1981). They are not susceptible to any classical strains of *S. japonicum* except for *S. japonicum*-like species in Malaysia. The beta race of *T. aperta* is also susceptible to *S. sinensium* from Fang District, Chiang Mai province, Thailand (Yuan *et al.*, 1984).

Tricula bollingi is predicted to be a medically important molluscan host of human schistosome in Southeast Asian mainland. The results of susceptibility tests indicate that *T. bollingi* can carry both *S. mekongi* and *S. japonicum*-like species in Malaysia in the laboratory (Yuan *et al.*, 1984).

Control

In Indonesia, schistosomiasis control is mainly emphasized on mass treatment of the population in the endemic areas. Mass treatment using Praziquantel was already initiated since 1983, and the results have shown a drastic decrease of the prevalence rate of schistosomiasis in Lindu lake area as well as at Napu valley.

Concerning the control of the intermediate host of *Schistosoma japonicum*, namely the snail *O. h. lindoensis*, little has been done in that aspect. Since the discovery of *O.h. lindoensis* in 1971, only a schistosomiasis pilot control project was applied in 1975 (Dazo *et al.*, 1976). This pilot control project was basically an intervention study which consisted of :

(a) reduction of source of infection by treating positive cases.

(b) reduction of vectors by spraying the foci with a molluscicide and by application of agro-engineering technology.

(c) reduction of human contact with cercariae infested water by promoting environmental sanitation and health education. In this report only the snail control aspect will be discussed.

The spraying of the snail foci. Before the intervention, snail densities and snail infection rates were measured on the foci of Anca, Paku and Lombu areas. The ring method (Pesigan *et al.*, 1958) was used to measure the snail density. Each month about 240 ring samples were taken in the intervention area. Each snail was crushed and examined to obtain snail infection rates. The spraying programme was started in foci at Anca using Niclosamide (Bayluscide). A 10-40 mg/l solution of Bayluscide was applied at the rate of 10 liters per 100 square metres. The spraying programme was repeated monthly. For dry foci, a dose of 10 mg/l of Bayluscide was used, while for wet foci, spraying was carried out with a higher dose of 40 mg/l. The duration of spraying in Anca was 8 months, and in Paku area it was 10 months.

Combination of spraying and drying of the snail foci : A combination of spraying followed by drying of all the snail foci in Anca as well as in the rice field area at Paku were carried out; spraying activities were done every month.

The result showed a suppression of 50% of the snail population density in Anca and 23% in Paku. The application of combined spraying and installing drainage canals reduced the snail population density in Anca 61% and 94% in Paku.

Control measures against *O.h. quadrasi* in the Philippines consists of agro-engineering method (Blas, 1976). These are:

(1) Drainage of water-logged areas

Stream channelization: Marshy margins, seepages and small tributaries of streams in many regions provide breeding sites for host snails. Stream channelization in these snail habitats does not only improve the flow characteristics but also facilitates effective application of molluscicides. After channelization any remaining snail colonies can usually be eliminated by mollusciciding, especially when channelization is combined with clearing of vegetation.

For snail control work, stream regulation generally involves improvement of grade and stabilization, channel construction and bank protection works. The stream bed should form a continuous gradient without depression. It should be pointed out that drainage and reclamation of extensive marshy areas are highly specialized and relatively expensive operations, requiring the use of a wide range of excavating and earth moving equipment.

Seepage control: Seepage along the margins of streams or foot-hills may give rise to boggy areas, pools or even to swamps and marshes in which the intermediate host may find favourable conditions for breeding. It is, therefore, important to eliminate seepage whereever possible. When a stream is flanked by low lying level ground, a considerable area of this may be affected by seepage. In such cases, it is necessary to lower the water table on either side of the stream by construction of subsurface drainage systems such as French drains or perforated pipes laid in trenches filled with bricks or stones.

Diversion and intercepting channels: Location, design and construction of diversion works and intercepting channels play an important part in the efficient control of snails. This is especially important in snail areas that could hardly be drained due to the water coming from an upland area.

Canal lining: The relative absence of aquatic vegetation and the relatively high velocities which are possible in lined canals make them less attractive as snail habitats than earth canals. Moreover, lining reduces seepage to low-lying areas which may otherwise become potential breeding sites. However, it is first necessary to establish the cost against the practical benefits to be derived from such a step.

Drainage and irrigation schemes: Lack of drainage facilities and/or network in irrigation schemes results in the formation of stagnant pools, wet areas and seepages which are often good snail habitats. It is, therefore, important that in irrigation schemes in endemic areas, adequate drainage should be provided if snail control work is to be successful. In addition to facilitating snail control work, adequate drainage has important beneficial effects on the productivity of an irrigation scheme. There are instances of irrigation schemes that have failed to achieve the expected productivity because of lack of adequate drainage. In some places water-logging has become so serious within only a few years of the introduction of irrigation that valuable lands have been rendered useless. The reclamation of such lands may be feasible but at considerable cost. It is therefore essential that in planning irrigation schemes provision for adequate drainage be made at the outset, even though under certain conditions the implementation of this part of the development may be carried out in stages as the need arises.

The design of drainage schemes is far more difficult than the design of irrigation schemes. There are such factors of intensity and frequency rainfall, the quantity of excess irrigation water, the length of time crops can be subjected to flooding without affecting their yield, the soil properties that control the rate of movement of water, and the nature of the ground surface as it affects the movement of water overland. It must be pointed out, however, that even the approximate determination of the above factors requires a great deal of investigation and long periods of observation and often the engineer has to fall back on his experience and judgement.

Combined vegetation removal and drainage: After the vegetation had once been cleared, it has been show that combined clearing and drainage further reduced snail density by 96% of the original number. The question arises whether the cost of clearing was justified in view of the fact that the subsequent drainage might have accomplished the purpose alone. From the standpoint of snail control, the clearing may have been superfluous, but for reclamation and for the land to become productive, clearing would still be necessary.

(2) Earth Filling

Certain snail colonies are so located that they can be eradicated by covering them with earth. There can be no doubt that the method is completely effective and will require no maintenance. Unfortunately, the method is of some what limited application because it requires the presence of a nearby source of earth and such situations are not often encountered in the endemic areas.

(3) Ponding

Pongind makes an area uninhabitable for snails because of the excessive depth of water and the presence of vertical banks. The difficulty with this method lies in the requirement for vertical banks which can be made permanent only if clay or some similar cohesive material is present. If the pond banks are of a sandy nature, maintenance cos's will be much higher. Ponding, although relatively expensive, is of definite value to the people because the ponds can be utilized for fish culture.

(4) Improved rice culture

The system of rice culture in most of the endemic areas involves rudimentary preparation of the land by either a single shallow ploughing or by trampling the weeds into the mud by teams of carabaos, close and irregular planting of seedlings and no weeding at all. The system seemed obviously open to improvement, and when improved, effectively resulted in reducing or eliminating the snails in the rice fields.

(5) Chemical control

In the Philippines, chemical control is primarily used after instituting ecological methods such as clearing of vegetations and drainage of water logged areas. With limited funds, it will be best to apply molluscicides as a terminal measure when the snails are already confined to the drainage and irrigation canals and resistant pockets. The chemical being used at present for snail control is Bayluscide (Bayer 73). Studies, however, are underway for the use of plant molluscicides such as Tuba seed *(Croton tiglium)* and Tubangbakod *(Jatropha curcas)*.

Human schistosomiasis in Malaysia is not expected to be a serious problem in Malaysia as there is very limited human contact with the *Robertsiella* snail habitats. Furthermore, modern methods of agricultural and land development in Malaysia appear to destroy the habitats of *Robertsiella* snails. The apparent inability of *Robertsiella* spp. to survive in bodies of water where human contact is greater probably account for the very low prevalence of human schistosomiasis in Malaysia.

In Thailand, five conventional molluscicides (Bayluscide (Niclosamide), copper sulphate, Frescon (Tritylmorpholine), sodium pentachlorophenate (NaPCP), and Yurimin) and one controlled release molluscicide (Tributyltinoxide (TBTO) were tested against field collected alpha and gamma races of *Tricula aperta* snails at field laboratory in Khemarat, Ubol province, Thailand. LC_{50} and LC_{90} values, 95% confidence limits, and slope functions were calculated.

Among the conventional molluscicides, Frescon and Bayluscide seemed to be most effective against *T. aperta*, although Yurimin, NaPCP and copper sulphate also showed reasonable effectiveness.

Lethal concentrations of TBTO for alpha and gamma race snails decreased as the soaking time of the rubber pellets increased. LC_{50} and LC_{90} were reached at days 1 and 3, respectively, for alpha snails and day 2 for gamma snails. The gamma race snails were slightly more susceptible than alpha snails to the highest concentration of TBTO tested (5.12 mg/l.). At the lowest concentration tested (0.01 mg/l.), gamma snails were killed in one-half to one-third of the time needed to kill alpha snails (Upatham *et al.*, 1980).

Recommendations

The family name Pomatiopsidae was used for *Oncomelania*. *Robertsiella* and *Tricula* spp. The taxonomic status of *Oncomelania* sp. from Indonesia needs to be resolved. The possible occurrence of sibling species of *T. aperta* needs to be investigated.

There is a need for indepth studies on the biology of pomatiopsid snails, including their predators, environmental factors affecting their life histories. The geographical distribution of pomatiopsid snails needs to be studied in greater details. More studies on the population and transmission dynamics as well as the host-parasite relationship are needed.

PROSOBRANCHIA: CERITHIOIDEA

Family Thiaridae

Thiarid snails are worldwide in their distributions. They inhabit fresh and brackish waters of temperate, subtropical, and tropical regions. Some members are of medical importance.

The shell is elongately conic, turreted or ovate-conoidal, solid and often with sculpture. The sculpture consists of spiral ridges and/or axial ribs and often a spiral micro-sculpture. The spire often is eroded or truncate. The operculum is corneous, either pauci spiral or multispiral depending on the subfamily. The shell is generally covered with a thick brownish or olive periderm.

The females are ovoviviparous and have a non-uterine, subhaemocoelic brood pouch. Functional males have only been found in few species; females are parthenogenetic. The females have an egg-transfer groove with a birth pore which is situated underneath the right tentacle. Development of eggs to young snails takes place in the brood chamber and the young are released through the birth pore.

There are 9 genera of Thiaridae found in Indonesia, as follows: *Balanocochlis*, *Brotia*, *Faunus*, *Melanoides*, *Pachymelania*, *Paludomus*, *Sulcospira*, *Thiara* and *Tylomelania*. These 9 genera of Thiaridae consists of 91 species. Among these species, *Melanoides granifera* and *M. tuberculata*, are snails of potentially medical importance (Benthem Jutting, 1956).

A few thiarids are found in Peninsular Malaysia. They include *Melanoides tubercula ta*, *Brotia costula*, *Thiara scabra* and *T. granifera* (Palmieri *et al.*, 1977).

Many genera and species of Thiaridae can be found in the Philippines (Abbott, 1948), but only *Brotia asperata* and *Thiara riqueti* are the proven snails of medical importance. Other snails such as *Thiara (Tarebia) granifera*, *T. (Melanoides) tuberculata truncatula* and *T. (Plotiopsis) scabra* are also found to inhabit in this country but they have not yet been incriminated in the transmission of any parasite.

In Thailand, snails belonging to family Thiaridae can be divided into 2 subfamilies, namely, subfamily Thiarinae and subfamily Melanatriinae. The subfamily Thiarinae includes (1) *Thiara scabra*, (2) *Melanoides tuberculata*, and (3) *Tarebia granifera*. The subfamily Melanatriinae includes (1) *Adamietta housei* (2) *Brotia* spp. and (3) *Paracrostoma* spp. Many species of Thai Thiaridae may be potentially and medically important such as *Tarebia granifera*, *Thiara scabra*, *Brotia costula* and *M. tuberculata*.

Taxonomy

The taxonomic system of Thiaridae in Southeast Asian countries is based on shell morphology (Abbott, 1948; Benthem Jutting, 1956; Brandt; 1974). Some anatomical characters had been described by Brandt (1974) but it is not enough in detail to differentiate among the species. No cytological studies, (e.g., chromosome), electrophoresis, enzyme activities, etc. have been reported.

Ecology

In general, the thiarid snails inhabit in slow running water with muddy bottom and also stagnant water. They are often found attached to rocks or buried in the soft mud of shallow waters. As with most mollusks, the thiarid snails prefer alkaline and moderate hard water.

Information on ecology of potentially and medically Thiaridae in Southeast Asian is very limited in literature. Only *T. granifera* and *M. tubercula* had been studied in Indonesia and Malaysia.

Naturally, *T. granifera* in Indonesia can tolerate a high amount of turbidity and pollution of the water, and is also found in hot water of volcanic lakes and springs of about 30°-35°C. Although the species prefers fresh water it can also stand a considerable amount of salinity. It occurs between sea level and about 1200 m altitude. Water of streams that are exposed to direct sunlight most of the day appears to attract this species (Abbott, 1952). This snail was found to live in the same habitat, e.g. swampy areas with sandy bottom and stones scattered around, with *Oncomelania* in Central Sulawesi around lake Lindu area.

Melanoides tuberculata of Indonesia is occasionally found inhabiting in brackish water or even polluted water. It does not even avoid hot springs (35°C), or iodine springs. In Java, the highest station in the mountain that *M. tuberculata* has been found is 1600 m at Mt. Malabar.

Melanoides tuberculata in Malaysia is also found in intermittent pools where vegetation is abundant and very often in polluted waters. It prefers alkaline water, average pH 7.5 and a total hardness of 174 mg/l (Palmieri and Palmieri, 1980). They feed on organic debris and minute algae.

Host-parasite relationship

In Malaysia *Melanoides tuberculata* has been found harbouring cercariae of *Haplorchis pumilio*, *Centrocestus formosans*, *Transversotrema patialense*, *Philopthalmus* sp., *Notocotylus* sp., an echinostome-like cercaria, five types of xiphidiocercariae and gymnocephalus, spirochid, sanquinicolid and heterophid cercariae.

Brotia costula has been found as the first intermediate host of *Paragonimus westermani* (Kim and Umathevy, 1967). One survey in forest streams showed an infection rate of 0.05% (6 out of almost 12,000) (Lim, unpublished) while another survey of a stream nearby revealed 2.8% (7 out of 250) (Kwo and Lim, 1969).

Xiphidiocercaria and heterophid cercaria have been recovered from *Thiara scabra*. *T. granifera* harbours trematode infections shedding xiphidiocercaria, heterophid, sanquinicolid, and philophalmid cercariae.

In the Philippines, *Brotia asperata* has been found to be the first intermediate host of *Paragonimus westermani*. They are found along fast-flowing streams and river banks (Velasquez, 1972) together with the second intermediate host, the crab *Parathelphusa (Barythelphusa) grapsoides* (Yogore, 1957). The high prevalence rate in endemic areas is due largely to the local culinary practice of preparing "kinagang", a native dish that utilizes the juice of raw ground crab (Yogore *et al.*, 1958).

There are, however, some interesting observation in the survey on naturally infected snails and crabs which revealed that 2 out of 1,968 or 0.1% of the snails harboured the characteristic xiphidiocercaria (Tubangui *et al.*, 1950) in contrast to 100% of the crabs infected with *Paragonimus* metacercariae (Vogore *et al.*, 1958; Cabrera and Vajrasthira, 1973). It seems that such a low density of cercariae should not account for the high density of metacerceriae found in the crabs.

More recent studies confirm the low infection rate among *B. asperata* snails. A survey on those sold in Metro Manila public markets (coming from some endemic areas/provinces) showed 12 out of 1,214 or 1.0% to have sporocysts, rediae, and xiphidiocercariae (Chin, 1983).

There is a high probability that other thiarid species are involved in the life cycle of *P. westermani* in the Philippines, Other species, especially those that burrow deep within the river beds, have not yet been examined or have been obtained in very small quantities.

Thiara (*Sermyla*) *riqueti* is a thiarid mollusk in brackish water fish ponds which is often associated with algal mats. It has been found to be the first intermediate host of *Transversotrema laruei* an ectoparasitic digenetic trematode of the following fish species: *Mollienesia latipinna*, *Scatophagus argus*, *Mugil* sp., *Megalops cyprinoides*, *Tilapia mossambica*, *Anodontostoma chacunda*, *Hemiramphus georgii*, and *Therapon argenteus* (Velasquez, 1975). The role of this parasite in the mortality of pond raised fish should be studied and monitored.

Thiara riqueti also harbours early developmental stages (2 generations of rediae) of *Procerovum calderoni*, a heterophyid. The emerging cercariae penetrate and encyst in the following fish species: *Ambassis buruensis*, *Amphacanthus javus*, *Atherina balabacensis*, *Anabas testudineus*, *Butis amboinensis*, *Chanos chanos*, *Creisson validus*, *Eleutheronema tetradactyla*, *Gerris filamentosus*, *Glossogobius giurus*, *Hemiramphus georgii*, *Hepsetia balabacensis*, *Mollienesia latipinne*, *Mugil* sp., *Ophicephalus striatus*, *Pelates quadrilineatus*, and *Platycephalus indicus*. Adults were recovered experimentally from dogs, cats, ducklings, and man (Velasquez, 1975). The potential danger arising from heterophyiasis should be considered since these fish are widely eaten in all sorts of ways. *T. riqueti* is also the first and second intermediate hosts of *Paramonostomum philippinensis*, a cecal fluke of chicks and ducklings (Velasquez, 1969).

In Thailand, thiarid snails have not yet been found infected with *Paragonimus* spp.

Control

No control programme has been attempted.

In Thailand, *Melanoides tuberculata*, *Tarebia granifera* and several species of *Brotia* are being tested as possible potential biological control agents.

Recommendations

The integrated studies on taxonomy using all possible methodologies should be carried out.

To compile the medical important snails in every country and more research work on ecology and host-parasite relationship should be initiated.

Intensive study on *Brotia* in the Philippines should be carried out since this country has the only proven medically important species, and molluscicide study on *Brotia asperata* should be initiated.

PULMONATA : ANCYLOIDEA

Family Planorbidae

The snails of this family are characterized by the shell which is discoidal, sinistral (ultradextral), and globose or physoid in shape. The animal is sinistral with its pulmonary and genital apertures situated on the left side. The tentacles are long, filiform, and cylindrical, with eyes situated at their inner bases. Members of this family include haemoglobin in their hemolymph and are reddish in colour. They are hermaphroditic and lay eggs in masses.

Taxonomy

The recognition characters of the potential species of medical importance in the family Planorbidae are as follows: (Benthem Jutting, 1956; Brandt, 1974).

Indoplanorbis exustus : shell diameter 17-24 mm, height 5-12 mm, radula has a central tooth with 2 cusps, the adjoining laterals with 4 cusps and the marginals with several cusps. Radula formula : $\frac{C}{2} + \frac{10L}{4\text{-}5} + \frac{16M}{6\text{-}9} + \frac{80M}{5\text{-}0}$ (present in Indonesia, Malaysia, Philippines and Thailand).

Gyraulus convexiusculus: 6.5-8.3 mm in diameter, aperture 1.8-2 mm, whorl rounded not carinated, without spiral lines.

Gyraulus sarasinorum: smaller then *G. convexiusculus*, the top side shell is much more convex (not present in Malaysia, the Philippines and Thailand).

Segmentina (Polypylis) hemisphaerula: aperture 2.1-2.3 mm, shell diameter 7.2-8.0 mm, shell higher than that of *Hippeutis*, upper side convex, lower side flat, apex sunken, very obtuse keel and more open umbilicus, with internal lamellae (present in Philippines and Thailand, but not in Indonesia and Malaysia).

Segmentina (Trochorbis) trochoideus: smaller than *S. hemisphaerula*, more dome-shaped with sharper, subbasal keel; colour is greyish-vitreous (present in Indonesia and Thailand but not in Malaysia and the Philippines).

Hippeutis (Helicorbis) umbilicalis: aperture 1.5-2.3 mm, shell diameter 4.8-8.0 mm, shell glossy, brownish-corneous, translucent, very depressed, convex above with sunken spire, almost flat below with open umbilicus, no internal lamellae (present in Indonesia and Thailand but not in Malaysia and the Philippines).

Ecology: A summary of physical, chemical and biological aspects of ecology of *Planorbidae* is presented in Table 7.

Host-parasite relationship

The medically important snails of family Planorbidae in Southeast Asia belong to 4 genera: 1) *Indoplanorbis*, 2) *Gyraulus*, 3) *Segmentina* and 4) *Hippeutis*. Among these four genera, only 6 species can harbour several trematodes and nematode (Table 8).

Control

No information was available of molluscicidal trials on snails of family Planorbidae in Indonesia, Malaysia, and the Philippines. In Thailand, Sa-Nguankul *et al.*, (1983) tested Bayluscide and controlled release tin formulations against medically important snails.

Recommendations

The taxonomic status of *Gyraulus* and *Segmentina*, especially in Thailand should be studied in detail. The study should include

Table 7

Some ecological aspects of the medically important Planorbidae in Southeast Asia*.

Species	Ecological factors		
	Physical	Chemical	Biological
Hippeutis (Helicorbis) umbilicalis	inhabit stagnant, clear water	n.i.	n.i.
Indoplanorbis exustus	inhabit all fresh waters, either stagnant or slowly running, optimum temp. 20°-30° C	optimum pH 6-7, salinity 0-200 mg/l, can tolerate polluted waters where pH 7, total hardness 75 mg/l	live on aquatic vegetation, feed on minute algae and fine organic deposits, prefer lettuce and diatom in laboratory cultivation
Gyraulus convexiusculus	inhabit all fresh water, either stagnant or slow running; distribute in areas between sea level and about 2000 meters above sea level	can tolerate moderate polluted water where pH 7.2, total hardness 110 mg/l.	n.i.
G. sarasinorum	same as *G. convexiusculus*	n.i.	n.i.
Segmentina (Polypylis) hemisphaerula	inhabit all fresh waters, either stagnant or slow running	n.i.	attach to aquatic plants
Segmentina (Trochorbis) trochoideus	same as *S. hemisphaerula*	n.i.	attach to aquatic plants

n.i. = no information.
*(Manning and Ratanarat, 1970; Jantataeme *et al.*, 1983).

the anatomy and molecular biology, e.g. electrophoresis and genetics.

Ecological aspects of these medically important Planorbidae should also be studied so that baseline information is available in case a control programme is needed.

Study on the biology of *Indoplanorbis exustus*, e.g. life table, population dynamics, especially in countries which have problems with this snail should be conducted.

PULMONATA : LYMNAEAOIDEA

Family Lymnaeidae

The shell of Lymnaeidae is dextral and ovately long. The spire is more or less attenuated and varies in height. The columella axis is typically gyrate (spirated or twisted). The shell varies in thickness and the size of the body whorl is large.

The soft parts of the animal are dextrally coiled, and the tentacles are flattened and

Table 8

Medically important snail species of Planorbidae and their relation to disease transmission in Southeast Asia.

Snail species	Parasitic trematodes			Parasitic nematodes
	Schistosoma spindale	*Echinostoma* sp.	*Fasciolopsis buski*	*Angiostrongylus* spp.
Hippeutis (Helicorbis) umbilicalis	n.i.a.	*E. ilocanum*	n.i.a.	n.i.a.
Indoplanorbis exustus	×	*E. malayanum*	n.i.a.	*A. malayensis*
Gyraulus convexiusculus	n.i.a.	*E. ilocanum* *E. lindoensis* *E. malayanum*	n.i.a.	n.i.a.
G. sarasinorum	n.i.a.	*E. lindoensis*	n.i.a.	n.i.a.
Segmentina (Polypylis) hemisphaerula	n.i.a.	n.i.a.	×	n.i.a.
S. (Trochorbis) trochoideus	n.i.a.	n.i.a.	×	n.i.a.

*Harinasuta *et al.*, 1965; Kruatrachue and Harinasuta, 1963; Sadun and Maiphoom, 1953; Plaut *et al.* 1969; Manning and Ratanarat, 1970; Sandground, 1939; Sandground and Bonne, 1940).

× = Natural intermediate host.

n.i.a. = No information available.

triangular. The eyes are placed at the anterior parts of the bases of the tentacles. The radula consists of numerous rows of many small teeth.

The Lymnaeidae is ovoviviparous and hermaphrodite. The male and female organs are placed at the right side of the pallial cavity.

Taxonomy

The taxonomic system for the majority of the medically important snails in family Lymnaeidae in Southeast Asian countries is based almost entirely on characters of their shells. Biochemical, immunological, chromosomal, and genetic studies have recently-been introduced as a tool used for taxonomic classification.

Characteristics of lymnaeid snails which are usually used for taxonomic classification in the four countries are given below.

In Indonesia, three species of *Lymnaea* are known, i.e. *Lymnaea rubiginosa*, *L. viridis* and *L. brevispira*. Only the first species is known to be of medical and veterinary importance.

Lymnaea rubiginosa was described by Michelin in 1831 as *Lymnoeus rubiginosus.*

Many species of *Lymnaea* have been described from Indonesia, such as *Lymnaea javanica*, *L. siccinea*, *L. longulus*, *L. megaspida*, *L. buruana*. According to Benthem Jutting, (1956) they are all apparently *L. rubiginosa*. *L. rubiginosa* is a very variable species. The shell variation seems not to be bound to geographical regions. Ecological factors may influence the morphology of the shell. Following Hunbendick (1951) and Thiele's classification (1931), Brandt (1974) placed this species in the subgenus *Radix*. Zilch (1959-60), however, considered *Radix* as a separate genus.

Based on the studies on morphology (Burch, 1980, 1981; Remigio, 1983; Co, 1985), biochemistry (Batalla, 1981; Pagulayan and Enriquez, 1983), immunology (Pagulayan and Dotimas, pers comm.), chromosome (Pagulayan *et al.*,, 1983), and genetics (Pagulayan and Darvin, pers. comm.) of *Radix* and *Bullastra*, members of Lymnaeidae are generally believed to occur in the Philippines.

The first species known to be endemic in the Philippines was named by Pfeiffer (1845) as *Amphipeplea cumingiana*. This species was called "*Myxas*" *cumingiana* by Bequaert and Clench (1939) "*Lymnaea*" *cumingiana* by Hubendick (1951) and "*Mixas*" *cumingiana* by Velasquez (1971). At present, *A. cumingiana* is called *Bullastra cumingiana* (Burch, 1980; Pagulayan and Enriquez, 1983).

Anatomically, the snail is characterized by a broad and reflected mantle capable of covering the entire shell. The foot and tentacles are strikingly large. External soft parts are uniformly pigmented. The shell is distinct in having a depressed spire.

Shell surface is marked by fine growth striae. The salient radular characters are the bicuspid marginals and tricuspid laterals. The reproductive anatomy exhibits radicine traits but appears to be more primitive in some respects as shown by the less developed penis sheath, vas deferens and prostate gland.

Karyotype studies revealed that *Bullastra cumigiana* has a haploid chromosome number of 16, the lowest number yet reported for a Philippine species, which is commonly shared by 3 other species groups.

A second species was named *Lymnaea philippinensis* by Nevill (1881). Bequaert (cf. De Jesus, 1935), De Jesus (1935), Manipol (1936), De Jesus and Mallari (1938), Bequaert and Clench (1939), Velasquez (1971), and Malek and Cheng (1974) used Nevill's species name, identifying their specimens from Nevill's original description. Abbott (1948) considered *Lymnaea philippinensis* Nevill to be a synonym of "*L. (Fossaria) ollula* Gould (= *L. pervia* Martens)", a species previously known from China and Japan, and Hubendick (1951) considered all three of the above nominal species *(philippinensis, ollula* and *pervia)* to be synonyms of *L. viridis* Quoy and Gaimard, a species originally named from Guam (Pagulayan and Enriquez, 1983). *L. philippinensis* has shell less than 15 mm in length; columella is generally straight without a fold or plait at the apertural margin.

A third species was named by Mollendorff (1898) as *Lymnaea quadrasi*. This species was identified as *Radix swinhoei* (Adams) by Nevill (1881), Manipol (1936), Abbott (1948), Velasquez (1971) and Clarke (1978, pers. comm). Tubangui (1932) identified this same species as "*Lymnaea peregra* Muller". Bequaert and Clench (1939) referred to it as *Lymnaea (Radix) swinhoei* var. *quadrasi*. Hubendick (1951) considered *swinhoei* as a geographical strain of *L. auricularia* Linnaeus and included the Philippine specimens in "*L. auricularia swinhoei* Adams". Hubendick (1951; 1978, pers. comm.) described another strain from the Philippines as "*L. auricularia rubiginosa* Michellin" (Pagulayan and Enriquez, 1983). *L. quadrasi* has a twisted columella generally, making a fold or plait at the apertural margin.

Burch's (1980, 1981) classification would place "*Lymnaea*" *philippinensis* in *Austropeplea*, "*L.*" *quadrasi (? = swinhoei; ? = rubiginosa)* in *Radix*, and "*L.*" *cumigniana* in *Bullastra*.

From the above, it appears that morphology alone as a basis of nomenclature presents difficulties in the Philippines. Although there is a considerable morphological uniformity among the Lymnaeidae, there is, however, a wide range of variation within the various species and even within the same population (Hubendick, 1951). Characters supposedly considered diagnostic also are found to vary. Anatomical similarities among species as well as variation within species create a number of unusual taxonomic problems which seem to obscure systematic relationships (Inaba, 1969).

In Thailand, five species of *Lymnaea* have been reported: *Lymnaea (Radix) auricularia rubiginosa*, *L. (R) a. swinhoei*, *L. (R.) viridis* and *L. (R.) luteola* (Brandt, 1974). But Upatham *et al.*, (1983) consider *Radix* as a good species (see footnote Table 1).

L. (R.) a. rubiginosa from Southeast Asia differs from the European race by its smaller size and less inflated body whorl. Adults may vary in shell length from 12.0 to 32.0 mm. The shell is thin, translucent, corneous, with small, short, pointed spire and large, oval body whorl. The uppermost of the 5 whorls are almost flat, the penultimate whorl is somewhat convex and the last whorl is large and inflated. The side lines of the spire appear concave because of the inflated body whorl. This may be moderately shouldered below the suture. Aperture is large but not extended, moderately expanded or not, connected by a thin, sinuous callus; the outer margin of this callus is S-shaped, its columellar part shows a slightly twisted fold (Hubendick, 1951).

L. (R.) a. swinhoei is very similar to *L. (R.) a. rubiginosa*, but is generally much larger, more elongated, with more cylindrical and distinctly shouldered body whorl. Adult may vary in shell length from 24.0 to 34.0 mm.

L. (R.) viridis is a small snail. Adult may vary in shell length from 8.0 to 14.0 mm. The mountain forms from small creeks with fast current are much smaller; sometimes they may attain height of less than 5.0 mm. *L. (R.) viridis* has a well rounded body whorl, the spire is regularly conic, never concave at the side line. The spire consists of about four slightly truncate whorls separated by a rather shallow suture. The aperture is regularly oval, without angles, the left margin of the parietal and the columellar callus is regularly rounded.

L. (R.) luteola has five to six flat whorls, which are separated by a very shallow suture. The spire is short and almost blunt. The aperture is ovoidal, and the body whorl is never shouldered below the suture. Adults vary in shell length from 17.0 to 29.0mm.

Ecology

The Lymnaeidae are common freshwater snails found in nearly all parts of the world. They are found inhabiting varied habitats like grassfields, rice-fields, ditches, canals, slow-flowing streams, stagnant pools, swampy areas and other muddy places including man-made pools with aquatic vegetation. In the Philippines they prefer habitats with standing water as in Thailand. In Malaysia they also thrive in slow-moving streams. In Indonesia it inhabits all kinds of freshwater habitats.

L. (R.) a. rubiginosa is a very common freshwater snail, and it inhabits almost all types of freshwater habitats. It can tolerates waters of low oxygen tension, whether caused by stagnation or pollution. It can also stand hot spring (35°C) such as in Cipanas Hot Spring near Garut, West Java. In Thailand, the species could tolerate pH range between 6-7, and salinity range between 0-200 mg/l (Chitramvong *et al.*, 1981).

L. (R.) a. rubiginosa in Malaysia prefers alkaline water with high calcium content but can be found in large numbers in waters with only 10 mg/l in mildly alkaline waters (pH 6.5-8.0). They prefer clean slow-moving water which is oxygen rich and with certain plants, especially *Eichornia crassipes*, which also serve as substrates for the deposition of eggs. They are microherbivores feeding on algae, particularly chorophyceae, which they rasp from surfaces of vascular plants, but they do not like Myxophyceae; small numbers of invertebrates have also been found in their gut.

Studies carried out at the Institute for Medical Research, Kuala Lumpur show that the cultivation methods of wet rice in Malaysia promote the multiplication of snails by providing more suitable habitats to the *Lymnaea* snails. The use of fertilizers increases the pH of the acidic water to near neutral or alkaline values making it more favourable to the snails. Although the draining of water from the rice fields at the maturity of the rice plants eliminates most of the snails, many still survive in the irrigation canals and are carried back into the fields when the next crop of rice is planted. The practice of double cropping also ensures a favourable and stable environment for the *Lymnaea* snails.

In the Philippines, *Bullastra cumingiana* has been reported as a seasonally occurring species with very low counts during the rainy months.

Host-parasite relationship

Human and animal parasitic diseases transmitted by the snails of family Lymnaeidae are currently recognized. Of these are fascioliasis, echinostomiasis, angiostrongyliasis, cathaemasiasis and cercarial dermatitis. It is also obviously shown that one lymnaeid species can serve as the intermediate host of several genera and/or species of trematodes. The reports on the lymnaeids from the different countries in Southeast Asia are complied below.

Parasitological studies on *L. (R.) a. Lymnaea rubiginosa* from Indonesia have been reported by several workers. Margono (1970) has experimentally fed a batch of *L. rubiginosa* from Jakarta vicinity, with faeces of rat positively infected with *Angiostrongylus*-like larvae. All were dead the following day, suggesting that too massive infection was the possible cause of death. Darmono *et al.*, (1983) collected specimens of *L. rubiginosa* from 6 villages in Bali, 9.52% were infected by rediae and cercariae of *Fasciola gigantica*, when he experimentally infected them with the miracidia of the fluke. The development was followed daily and every stage of the fluke was described in detail. After 45 days the first cercariae were shed. No parasitilogical studies of *L. viridis* have been recorded from Indonesia.

In Malaysia *Lymnaea auricularia rubiginosa* is an intermediate host of many trematode larvae. The cercariae recorded from the snails are *Trichobilharzia brevis* (Basch, 1966), and three other schistosomatoid cercariae, *Sanquinicola* sp., *Spirorchis* sp. and an unidentified species. *Fasciola gigantica* (Palmieri *et al.*, 1977), 4 cercariae belonging to the family Echinostomatidae, viz. *Echinostoma audyi* (Lie and Umathevy, 1965 a), *E. histricosum* (Lie and Umathevy, 1966), *Hypoderaeum dingeri* (Lie, 1964), and *Echinoparyphium dunni* (Lie and Umathevy, 1965 b), and two strigeids, *Cotylurus* sp. and *Apatemon* sp. (Basch and Lie, 1970).

Metacercariae of echinostomes including 3 species which were recorded in humans and metacercariae of strigeids also are found in *Lymnaea auricularia rubiginosa* (Lie, 1963 a and b; Lie and Nasmary, 1973). Of these trematodes, *Trichobilharzia brevis*, commonly found in *Lymnaea* from all the rice growing states of Peninsular Malaysia, is the cause of cercarial dermatitis or sawah itch among the farmers. *F. gigantica* is also a common parasite of cattle in Malaysia.

Fasciola infection in lymnaeids in the field shows varying percentages from very high in southern Philippines to almost mild in the other parts of the country.

Actual experimental infection of *Radix quadrasi* with *Fasciola hepatica* and histopathological studies have been undertaken with the following results:

i. Age susceptibility : from 7-39 day old snails, susceptibility was observed to decrease with age.

ii. Survival of infected and uninfected snails:

a) highest range of % survival = 75% for 7-8 day old snails and lowest range of % survival = 0% -14% for 33-39 day old snails refractile to infection = 40-60 day old snails;

b) 1 to 6 day old snails exhibited lowest % survival; further infections lowered survival.

iii. Sites of infection and routes of migration of *F. hepatica:*

a) infection resulted from penetration of anatomically exposed areas: foot, head, body wall and mantle;

b) sporocysts found in these parts of the snail appeared to migrate towards the mantle and

c) rediae were found in the hepatopancreatic tissues on day 28, where the development of them was completed.

iv. The number of cercariae which developed from 1-2 miracidia over a period of 30 days = 29-680. Death followed a day of shedding 196-210 cercariae.

v. Histopathological effects:

a) foot, head, body wall, and mantle where the sporocysts were found exhibited a localized type of tissue response: a layer of fibroblasts around a parasite which may or may not be separated by space from the parasite's body, and

b) destruction of hepatopancreatic tissue and abundance of amoebocytes in the hepatopancreas.

In Thailand, *L. (R.) a. rubiginosa* is an important intermediate host of several trematode species. It is known to harbour the larval stage of animal blood flukes, such as *Schistosoma incognitum, Orientobilharzia harinasutai, Trichobilharzia maegraithi* (Lee and Wykoff, 1965; Kruatrachue *et al.*, 1965; Kruatrachue *et al.*, 1968). They do not develop in man but may cause cercarial dermatitis. For this reason, the species is known in Thailand under the vernacular name "hoy kunn" or itchy snail. It is the first intermediate host of the liver fluke *Fasciola hepatica* and *F. gigantica* (Dissamarn, 1955). It has also been found to serve as the first intermediate host of *Echinostoma malayanum* and *E. revolutun* (Bhaibulaya *et al.*, 1964; 1966). *L. (R.) a. swinhoei* and *L. (R.) viridis* serve as intermediate host for the same trematode species as *L. (R.) a. rubiginosa* (Brandt, 1974).

Control

No serious consideration was made in control of lymnaeids in Southeast Asia. Indonesia has no problem with lymnaeids and therefore does not need to control the snails. In Malaysia, farmers in one state use copper sulphate to kill the snails when they are troubled by dermatitis while working in their fields. Sullivan and Palmieri (1979) studied the effect of copper sulphate on *Lymnaea* snails with *E. audyi* infection and found that snails with heavy infections were more susceptible to copper sulphate. Many biological studies have also been carried out using larval interspecific antagonism and microsporidians to control the trematode larvae that utilize lymnaeids as intermediate hosts.

In the Philippines, preliminary studies have been done on the use of microsporidians against *Radix quadrasi*. The specific objectives of the study are to determine and/or identify.

i. The capacity of the microsporidian parasite to develop in snails by experimentally infecting their haemocytes *in-vivo:*

a) haemocytes which phagocytosed the spores formed tight phagosomes containing one spore per phagosome and

b) most phagocytosed spores were digested intracellularly within loose phagosomes.

ii. The developmental stages in the life cycle of the microsporidian parasite that can develop in the snail are as follows:

a) schizonts which adhered tightly to the phagosome membrane.

b) sporozonts which matured in loose phagosomes.

iii. The potential of microsporidian spore as a biological control agent was assessed; the presence of early developmental stages of the parasite was taken as an indication of infection, on this basis, the snail host showed mild infection.

In Thailand, molluscicide trial of $CuSO_4$ and Frescon (N-trityl-morpholine) had been tested in the laboratory. The result of the tests showed that LC_{50} and LC_{90} of *L. (R.) a. (Radix) rubiginosa* after 24 hour of exposure of $CuSO_4$ were 0.39 and 0.77 mg/l, and of Frescon were 0.07 and 0.096 mg/l (Sornmani and Toungthong, pers. comm.). Sa Nguankul *et al.*, (1983) also tested Bayluscide and controlled release organotin compounds on the snails.

Recommendations

The taxonomic studies should be concentrated on: morphoanatomical basis of classification such as shell structure, reproductive organs and radula should be conducted to correlate with biochemical characterization and karyotyping methodologies.

Expertise in the area of biochemical characterization should be developed and/or expanded in the ASEAN by indepth training or advanced degree programmes for younger scientists.

Collaborative work of scientists in various areas should be encouraged to assure that methodology employed is uniform. It will also provide the necessary information for classification of the systematics of Lymnaeidae within the region.

Ecological and host-parasite relationship studies should have emphasis on: field assessment should be done together with laboratory cultivation. All experimental studies should make use of laboratory bred snails. Information on the reproductive biology, effects of varying conditions-physical, chemical, biological, susceptibility to infection and related phenomena as well as mechanics of transmission must use only laboratory bred snails. Host-parasite relation studies can also be undertaken using the same snails.

Control measures should be seriously studied for cercarial dermatitis which may turn out to be an important health hazard, and *Fasciola gigantica* infection in cattle if data show that economic losses are considerable.

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