

CHAPTER 2

LITERATURE REVIEW

2.1. Taxonomy of Genus *Rhiostoma*

All operculated gastropods were classified by using respiratory organ, radula, and operculum. Vaught (1989) classified *Rhiostoma* into a hierarchical taxa as follows;

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia
Order Mesogastropoda
Superfamily Cyclophoroidea
Family Cyclophoridae
Subfamily Pterocyclinae
Genus *Rhiostoma*

Land operculated snails are a gastropod group belonged to Subclass Prosobranchia, this name derived from the position of their respiratory organ, "proso" refers from Greek word "proso", means forward, onward, or in front, "branchia" refers from "branchos", means gill. (Brown, 1956). In land operculated snail, mantle cavity is developed into vascularized pulmonary sac or lung (Torre *et al.*, 1942; Ruppert and Barnes, 1994). The Superfamily Cyclophoroidea contains only land operculated snails, their forms are diversified, present in discoidal, turbinata, turret or pupiform shell shape. Operculum is corneous or calcareous. Radula is taenioglossa type, which contains 7 teeth in each row, mostly multispiral. Sex separated, male has tapering penis behind the right tentacle. The Family Cyclophoridae located in tropic region from western Pacific islands, Australia, Philippines, Southeast Asia, India, throughout Madagascar and Africa. The Subfamily Pterocyclinae is subdiscoidal shape, it contains cylindrical calcarocorneous operculum, with outside convex and inside concave. *Rhiostoma*

Benson, 1860 is one of the four genera in the Subfamily Pterocyclinae, (*Platyrrhaphe* Moellendorff, 1890, *Pearsonia* Kobelt, 1902, and *Pterocyclus* Benson, 1832).

It was described by Benson in 1860 with *Rhiostoma haughtoni* the original description for species. This name derived from 2 Greek words "rhino", means nose, snout, beak, or bill, and "stoma" means mouth (Brown, 1956). Rhiostomid snails are one of a few oriental shell which have air breathing tube for the way of the air pass to inside when the aperture closed by operculum (Tomlin, 1931). Several species of genus *Rhiostoma* were classified by their unique shell characters as follows; some part of last whorl disconnect to penultimate whorl, apertural margin free, peristome has notch above dorsal side, small projection or tube start at or near the peristome notch, tube direct backward, keel presents at the base of projection or tube along the disconnect part of last whorl up to the junction among the last whorl and penultimate whorl (Gude, 1921; Tomlin, 1931; Salisbury, 1949; Hemmen *et al.*, 1999)

Godwin-Austen (1989) described *Rhiostoma cavernae*, *R. gwendolena*, *R. hungerfordi* and *R. iris* in the paper "On a collection of land-shells made in Borneo by A. Everett, with Descriptions of supposed new species. Part I. Cyclostomacae", which contained 70 species of land operculated snail, 36 species were new to science.

Moellendorff (1891) revised the previous classification of land and freshwater shells of Perak, Malaysia, including 97 species. *Rhiostoma jousseaumei* were collected from Kinta valley. However the classification was still unclear because of small size specimens, lack of operculum, and the poor description of literatures.

Moellendorff (1894) described *Rhiostoma asiphon* from the collection of Mr. C. Roebelen collected from Samui Islands, in the Gulf of Thailand. It differs from other *Rhiostoma* by lacking an air breathing tube, but form tube-like at peristome edge which look very similar to the genus *Pterocyclus*.

Blanford (1902) described *Rhiostoma dalyi* from the collection of Mr. W. M. Daly. It was found only from one locality near Phitsanulok in very damp and dense forest. He explained that it is nearly allied to *R. hainesi* and *R. simplicilabre*, which *R. dalyi* is smaller than *R. hainesi*, diameter of its whorls and its mouth are proportion smaller too. *R. simplicilabre* is quite different by the simple peristome. *R. haughtoni* smaller than *R. dalyi*, has the free portion of the last whorl shorter, and has very small tube arising from the peristome.

Blanford (1903) identified 41 non-marine molluscs from the collection of Mr. W. M. Daly, which were collected from Lamphun and Phitsanulok, including his proposed and Mr. Daly's noted. *Rhiostoma bernardii* was collected from Lamphun and *R. dalyi* was collected from Phitsanulok, which he proposed that *R. dalyi* may be only a variety of *R. hainesi*

Sykes (1903) described *Rhiostoma jalorensis* from limestone hills and caves in Biserat, Jalor. This species was discovered from the collection of "Skeat Expedition" from Malay Peninsula in 1899-1900. *R. jalorensis* is nearly related to *R. housei* but larger, slightly more depressed, the whorls not so tightly coiled, the disconnected parts of the last whorl is much longer than *R. housei*.

Gude (1921) reported 280 species of the land operculated snails found in India, Ceylon and Burma, and reported *Rhiostoma houghtoni* and *R. strubelli* found in Burma.

Tomlin (1931) described *Rhiostoma spelaeotes* and *R. samuiense*. The Malay species, *R. spelaeotes* looks similar to *R. jousseumei*, but size is much larger, tube is smaller, peristome somewhat reflexed, space between the end of the tube and the penultimate whorl is narrower than *R. jousseumei*. The Thai species, *R. samuiense* allied to *R. asiphon*, which is similar in having a projection but no tube, differs from *R. asiphon* by its much flatter shell, much darker in color, and broader disconnected last whorl.

Laidlaw (1932) reported 24 species of land snails from Batu caves in Selangor, Malaysia. He found *Rhiostoma spelaeotes* outside the cave, some of them are almost completely mineralized, and called as semi-fossil. This species has not been reported from other places.

Tomlin (1938) described *Rhiostoma chupingense* from Bukit Chuping in Perlis, Malaysia. This species and other 4 new species of micro-snails received from Mr. M. W. F. Tweedie of the Raffle Museum, Singapore. It looks similar to *R. samuiense* in the presentation of disconnected part of last whorl without the tube, but differs in larger size, broader aperture, more solid shell, and more thick peristome.

Laidlaw (1939) collected and described *Rhiostoma macalpine-woodsii* from Sungei Siput in Perak, Malaysia. It is very allied to *R. jousseaumei*, but differs in smaller size, less solid, and more depressed.

Laidlaw (1941) reexamined Tomlin's specimen, *Rhiostoma macalpine-woodsii* with its operculum. From this operculum, he ensured that this species is true *Rhiostoma*, because it has the shape of rhiostomid operculum shape.

Salisbury (1949) described *Rhiostoma tomlini* from Khao Sabap, Thailand. It is similar to *R. hainesi* from Cambodia and *R. jalorensis* from Biserat, Jalor. It differs from *R. jalorensis* by its much greater size, and differs from *R. hainesi* by its darker and uniform color, lacking the pattern and mottled appearance of *R. hainesi*, disconnected part of last whorl longer and more depressed.

Bentham Jutting (1949) identified on the collection of non-marine mollusc of Malaysia, which deposit in the Raffle Museum, Singapore. 2 specimens of rhiostomid were identified to *Rhiostoma macalpine-woodsii*.

Bentham Jutting (1960) reported species list of non-marine mollusc of Peninsula Malaysia, including *Rhiostoma asiphon* from Perlis and *R. macalpine-woodsii* from Perak, both were collected from limestone hills in Malaysia.

Habe (1965) wrote about land operculated snails from Southeast Asia, which were collected by the members of Osaka University in the Biological Expedition to Southeast Asia. *Rhiostoma housei* were found from Saraburi and Chanthaburi. He suggested *R. haughtoni*, *R. simplicilabris*, and *R. hainesi* were synonyms to *R. housei* and proposed new subspecies name "*Rhiostoma housei kirai* for the specimens from Chanthaburi, which the size are larger and disconnected part of last whorl longer than the typical form of *R. housei* from Saraburi.

Solem (1966) studied 156 catalog numbers of non-marine mollusc from Thailand, which were collected during the first Thai-Danish expedition among 1958-1959. He reported 2 rhiostomids from Doi Chiang Dao, Chiang Mai at different altitude, *Rhiostoma dalyi* were found at 400 and 1,100 meters, but *R. housei* were found at 1,100-1,200 meters. *R. smithi* and *R. tomlini* look very identical, because paratypes of *R. tomlini* (catalog number FMNH 71338) have the form and siphon of *R. smithi*.

Abbott (1989) published a color guide book " Compendium of Landshells", which including 2 rhiostomids, *Rhiostoma housei* and *Rhiostoma smithi*, the pictures of *R. smithi* were taken from a paratype collected from Khao Sabap, Thailand.

Panha and Thanamitramanee (1997) surveyed land snails in Phliu National Park, Chanthaburi Province, Eastern part of Thailand found 15 pulmonates and 3 prosobraches which *R. smithi* was reported.

Hemmen *et al.* (1999) discussed that genus *Rhiostoma* distributes in Cambodia, Laos, Thailand, Malaysia. Sixteen species including *Rhiostoma housei* (Haines, 1855), *R. haughtoni* Benson, 1860, *R. simplicilabre* Pfeiffer, 1862, *R. bernardii* Pfeiffer, 1862, *R. hainesi* Pfeiffer, 1862, *R. jousseaumei* Morgan, 1885, *R. asiphon* Moellendorff, 1893, *R.*

strubelli Moellendorff, 1899, *R. dalyi* Blanford, 1902, *R. jalorensis* Sykes, 1903, *R. speleaeotes* Tomlin, 1931, *R. samuiense* Tomlin, 1931, *R. smithi* Bartsch, 1932, *R. chupingense* Tomlin, 1938, *R. macalpine-woodsii* Laidlaw, 1939, and *R. tomlini* Salisbury, 1949 were reported. Six unclassified species were judged and placed in genus *Pterocyclus*. They contain development of the double apertural margin, these species including *R. tenerum* (Menke, 1856), *R. cambodjense* (Morelet, 1875), *R. cavernae* Godwin-Austen, 1889, *R. gwendolena* Godwin-Austen, 1889, *R. hungerfordi* Godwin-Austen, 1889, and *R. iris* Godwin-Austen, 1889.

Patamakanthin (2001) reported and shown his rhiostomids' collection from Malay Peninsular including *R. asiphon*, *R. chupingense*, *R. jousseaumei*, *R. samuiense*, *R. speleaeotes*, and *R. smithi*.

In conclusion, so far 7 rhiostomid species were reported from Thailand, 5 species from Malaysia, 2 species from Myanmar, and 2 species from Cambodia.

2.2. Morphometric Analysis

Lindberg (1985) used a Discriminant Function Analysis to analyzed the shell sexual dimorphism in 16 known sex trochid gastropods *Margarites vorticifera* from field by used 4 shell parameters, and predict the sex of 7 type specimens in the museums by comparing these shell parameters to those of analyzed shells.

Aranyavalai (1996) study on the morphometry of Brown Tortoise *Manouria emys emys* and Burmese Black Tortoise *M. emys phayrei* in Thailand by measured 56 characters of shell and analyzed by T-test, Cluster Analysis, and Discriminant Function Analysis. Sexual Dimorphism were found the difference in some characters among both sexes which the equation for the predictions of sexes and subspecies were obtain.

2.2. Cladistic analysis

Gerlach (1999) determined the phylogeny of the land snail genus *Pachnodus* of Seychelles islands by used a cladistic analysis of 19 characters of shell and soft part anatomy. The analysis was performed using Hennig86, which finally *Pachnodus* was divided into 2 distinct subgenera.

Panha *et al.* (2001) determined the phylogeny of tree snail genus *Amphidromus* of Thailand by used 17 characters of shell and soft part anatomy were analyzed by used Hennig86, which divided into 2 distinct subgenera.

2.3. Anatomical study

Thompson (1969) revised taxonomy of some Mexican and Central American land operculated snail in family Cyclophoridae which later classify them to Megalomastomidae and Poteriidae (Vaught, 1989)). He used characteristics of reproductive system to separate them into 2 subfamilies including Megalomastominae which has penis located behind right tentacle, Neocyclotinae which has penis located on the dorsal side of the verge on the center of the nape, both subfamilies have the open seminal groove (Figure 2.1). He nominated 2 new genera, *Dicrista* and *Xenocyclus* which differ from old genus *Amphicyclotus* by its small vagina slit and lack of common duct. *Dicrista* has a saculate pouch of seminal receptacle discharge the uterus near the vaginal slit. *Xenocyclus* has segmented grandular seminal receptacle discharge the uterus near distal end (Figure 2.2).

Kumprataung (1988) studied on reproductive system of 3 land snails from North-eastern part of Thailand. One of them is land operculated snail *Cyclophorus auranticus* (*C. volvulus* follow habe(1964)). It has bursa copulatrix and lack albumin gland in female, seminal vesicle present in male. The illustration of both sexes shown in figure 2.3

Stanisic (1998) wrote about the Superfamily Cyclophoroidea of Australia, he referred to the work of Jonges (1980) which studied on some species of *Leptopoma*, females have albumin gland, capsule gland, bursa copulatrix, seminal receptacle, oviduct, uterus, and genital opening. Whereas males have open pallial sperm groove, and conoidal penis.



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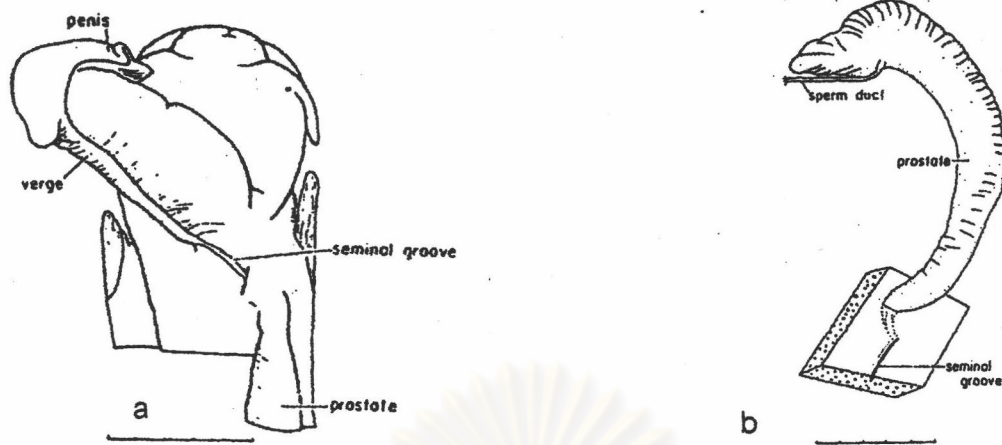


Figure 2.1 a. Dorsal view of head and nape of *Dicrista liobasis* with the verge bent forward to show the seminal groove. b. Prostate gland and associated organs of *Amphicyclotus texturatus spiralis* and seminal groove at scale bar 5 mm. (After Thompson, 1969)

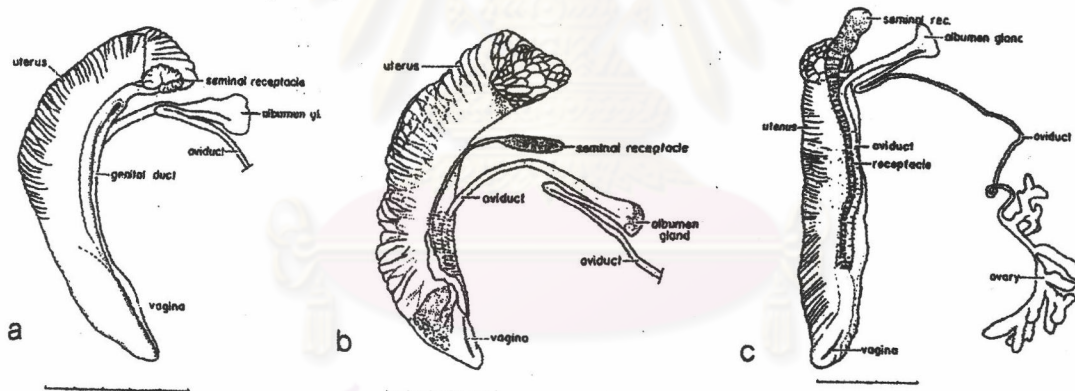


Figure 2.2 Ventral view of uterus and associated organs of a. *Amphicyclotus paulsonorum* b. *Dicrista liobasis* and c. *Xenocyclus patulus*. At scale bar 5 mm. (After Thompson, 1969)

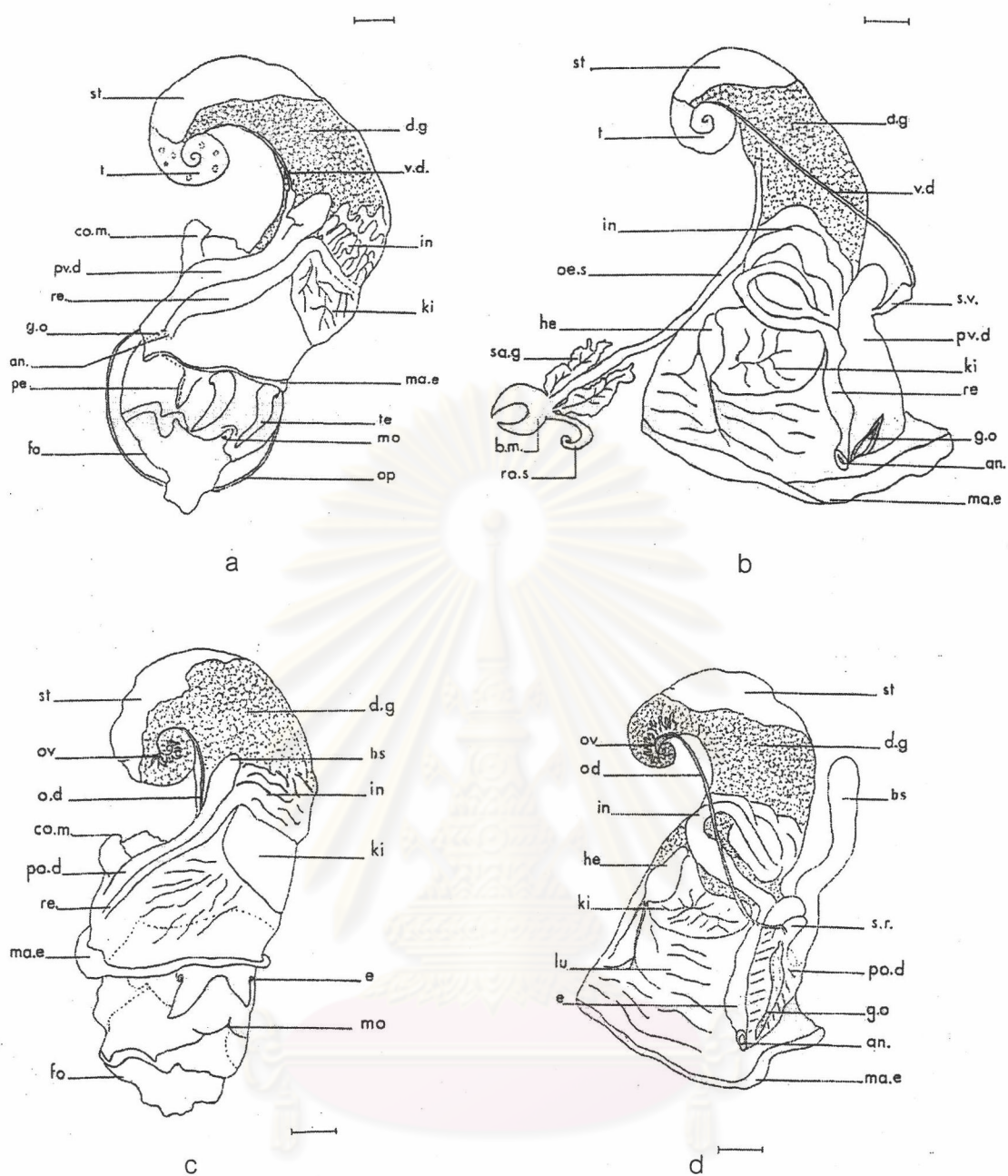


Figure 2.3 Male and female reproductive organ of *Cyclophorus volvulus*; Male a) soft part; b) reproductive organ; Female c) soft part; d) reproductive organ; at scale bar 10 mm. al.g=albumen gland, an=anus, bm=buccal mass, bs=bursa copulatrix, co.m.=columellar muscle, d.g=digestive gland, e=eye, fo=foot, g.o=genital opening, he=heart, in=intestine, ki=kidney, lu=lung, ma.e=mantle edge, mo=mouth, o.d=oviduct, oe.s=oesophagus, op=operculum, ov=ovary, pe=penis, po.d=pallial oviduct, pv.d=pallial vas deferens, ra.s=radular sac, re=rectum, sa. G=salivary gland, st=stomach, sr=seminal receptacle, sv=seminal vesicle, t=testis, te=tentacle, v.d=vas deferens (After Kumprataung, 1988).