การปรับปรุงการจัดจำแนกหอยทากลดเปลือกในประเทศไทยและบางส่วนของประเทศเพื่อนบ้าน

นางสาวชนิดาพร วรจักร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาสัตววิทยา ภาควิชาชีววิทยา
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2543
ISBN 974-347-249-5

TAXONOMIC REVISION OF SEMI-SLUGS IN THAILAND AND SOME PARTS OF NEIGHTBOURING COUNTRIES

MISS CHANIDAPORN VORAJUK

A Thesis Submitted in Partial Fulfillment of the Requirement
for the Degree of Master of Science in Zoology

Department of Biology
Faculty of Science
Chulalongkorn University

Academic year 2000
ISBN 974-347-249-5

Thesis Title	Taxonomic Revision of Semi-slugs in Thailand and some parts of Neighbouring Countries
By	Miss Chanidaporn Vorajuk
Department	Biology
Thesis Advisor	Associate Professor Dr. Somsak Panha

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.....Dean of Faculty of Science
(Associate Professor Dr. Wanchai Phothiphichitr)

THESIS COMMITTEE

.....Chairman
(Associate Professor Dr. Kingkaew Wattanasirmkit)

.....Thesis Advisor
(Associate Professor Dr. Somsak Panha)

.....Members
(Associate Professor Dr. Kumpol Isarankura)

.....Members
(Associate Professor Dr.Yaowaluk Chitramvong.)

นางสาวชนิดาพร วรจักร: การปรับปรุงการจัดจำแนกหอยทากลดเปลือกในประเทศไทยและบางส่วนของประเทศเพื่อนบ้าน (Taxonomic Revision of Semi-slugs in Thailand and some parts of Neighbouring Countries) อ. ที่ปรึกษา: รศ. ดร. สมศักดิ์ ปัญหา,119หน้า ISBN 974-347-249-5

หอยทากลดเปลือกที่สำรวจพบในประเทศไทยและบางส่วนของประเทศลาว มาเลเซีย และเวียดนาม มี 1 วงศ์ 2 วงศ์ย่อย 6 สกุล และ 12 ชนิด ซึ่งพบว่ามี 7 ชนิดคือ cf. ***Megaustenia*** sp., cf. ***Cryptaustenia*** sp.1., cf. ***Cryptaustenia*** sp.2, ***Parmarion*** sp.1, ***Parmarion*** sp.2, ***Durgella*** sp.1, และ ***Durgella*** sp.2 ที่เป็นการรายงานครั้งแรกว่าพบในประเทศไทย ในการศึกษาครั้งนี้ไม่พบหอยทากลดเปลือก 2 สกุลคือ ***Cryptaustenia*** และ ***Muangnua*** ที่รายงานโดย Solem ในปี ค.ศ.1966 จากการศึกษาครั้งนี้ลักษณะทางกายวิภาคศาสตร์ระบบสืบพันธุ์เป็นลักษณะสำคัญที่ใช้ในการจัดจำแนกชนิดประกอบกับลักษณะทางสัณฐานวิทยาของเปลือกและลักษณะภายนอกได้เป็นอย่างดี เช่นการมีหรือไม่มี dart apparatus พบว่าหอยสกุล cf. ***Cryptaustenia*** sp. 1 ไม่พบ dart apparatus ส่วน cf. ***Cryptaustenia*** sp. 2 พบ dart apparatus ขนาดเล็ก การมี dart apparatus ของหอยสกุล ***Parmarion*** ยังใช้จำแนกออกจาก ***Muangnua*** Solem, 1966 ซึ่งสิ่งแวดล้อมอาจทำให้หอยสกุล ***Muangnua*** สูญพันธุ์ไปจากประเทศไทย ในหอยสกุล ***Durgella libas***, ***Durgella*** sp.1 และ***Durgella*** sp. 2 มี dart apparatus ขนาดใหญ่ ซึ่งไม่พบใน ***Durgella*** sp.3 นอกจากนี้ยังพบว่าขนาด และรูปร่างของ penis สามารถใช้แยกหอยสกุล ***Parmarion*** ออกจาก ***Muangnua*** ได้เป็นอย่างดี ลักษณะการมี epiphallic retractor caecum และlime-sac ของ cf. ***Cryptaustenia*** สามารถใช้แยกออกจาก ***Cryptaustenia*** ได้อย่างสมบูรณ์ นอกจากนี้ยังพบว่าลักษณะสัณฐานวิทยาของแรดูลาสามารถเป็นข้อมูลที่ช่วยในการจัดจำแนกชนิดได้ พบว่าในหอยสกุล cf. ***Cryptaustenia*** มีฟันกลาง ฟันข้าง และฟันขอบแบบ tricuspid ส่วน ***Cryptaustenia*** มีฟันกลางเป็นแบบ tricuspid ส่วนฟันข้าง และฟันขอบแบบ bicuspid หอย ***Durgella libas*** และ ***Durgella*** sp. 1 มี แรดูลาขนาดเล็ก จำนวนมาก ฟันกลางเป็น unicuspid ส่วนฟันข้างและฟันขอบเป็น bicuspid ด้านข้างของฟันขอบด้านนอกมีซี่ฟันขนาดเล็ก ขณะที่แรดูลาของหอยสกุล ***Durgella*** sp. 2 มีลักษณะตรงกันข้ามทุกลักษณะ

ภาควิชา ชีววิทยา
สาขาวิชา สัตววิทยา
ปีการศึกษา 2543

ลายมือชื่อนิสิต.....
ลายมือชื่ออาจารย์ที่ปรึกษา.....
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

4172261523 : MAJOR ZOOLOGY
KEY WORD: PULMONATE/ SEMI-SLUGS/ ANATOMY/ THAILAND/ GENITAL SYSTEM

CHANIDAPORN VORAJUK: TAXONOMIC REVISION OF SEMI-SLUGS IN THAILAND AND SOME PARTS OF NEIGHBOURING COUNTRIES. THESIS ADVISOR: ASSOC. PROF. DR.SOMSAK PANHA, 119 pp. ISBN 974-347-249-5

Helicarionid semi-slugs from Thailand and some parts of Laos, Vietnam and Sabah, Malaysia were recorded of 1 Family, 2 Subfamlies, 6 genera and 12 species. Seven species are new record for Thailand i.e. cf. *Megaustenia* sp., cf. *Cryptaustenia* sp.1, cf. *Cryptaustenia* sp.2, cf. *Parmarion* sp.1, cf. *Parmarion* sp.2, *Durgella* sp.1, and *Durgella* sp.2. Two genera (*Cryptaustenia* and *Muangnua*) that reported by Solem in 1966 are absent in the present study. Genital system is an important character that can be combined with shell, soft parts and external morphology for identification. The absent of dart apparatus in cf. *Cryptaustenia* sp.1 and present small dart apparatus of cf. *Cryptaustenia* sp.2. *Parmarion* can be distinguished from *Muangnua* Solem, 1966 by the present of dart apparatus and suggested that *Muangnua* may not exist in Thai environment. In *Durgella libas*, *Durgella* sp. 1 and *Durgella* sp. 2 have a large dart apparatus, while absent in *Durgella* sp. 3. The present of epiphallic retractor caecum and lime-sac of cf. *Cryptaustenia* can be used to distinguish from *Cryptaustenia*. Radula morphology is an assistance information for classification, In cf. *Cryptaustenia* has tricuspid central tooth, lateral teeth and marginal teeth. While *Cryptaustenia* has tricuspid central tooth and bicuspid lateral teeth and marginal teeth, in *Durgella libas* and *Durgella* sp. 1 has an enormous number of teeth, unicuspid and very minute central tooth, with very numerous, bicuspid and serrated edge latero-maginal teeth while in *Durgella* sp. 2 shows totally different.

Department BIOLOGY
Field of study ZOOLOGY
Academic year 2000

Student's signature……
Advisor's signature ……..
Co-Advisor's signature ……

Acknowledgement

I wish to express my sincere gratitude to my thesis advisor, Associate Professor Dr. Somsak Panha, for his valuable suggestion, guidance, patience's, and strong encouragement throughout the study. I wish to extend my grateful thank to Associate Professor Dr. Kingkaew Wattanasirmkit, chairman of thesis committee for her precious advice. I am especially grateful to thesis committee, Associate Professor Dr. Kumpol Isarankura for his valuable advice, comment and suggestions. I also would like to express my appreciation to Associate Professor Dr.Yaowaluk Chitramvong for her kind suggestions and comments in several aspects of genital system. Very special thanks to Vorajuk family for a supported study grant, and assistance in several aspects. I wish to thank Biology Department for the use of facilities and to the staff members of Biology for their assistance in many ways. I am a very special thanks to Mr. Pornchai Uttaruk for his helping during the period of the thesis presentation and preparing. My special thanks for their helping hands to Mr. Satit Pripuk, Mr. Sakboworn Tumpeesuwan, Mr. Thanakhom Bundhitwongrat, Mr. Chirasak Sucharit, Mr. Pongrat Dhamrongrojwattana, Miss Piyorose Tongkird, Miss Anchira Maneewong, Miss Chatnaree Meesukkho, and students of the department of Biology, Faculty of Science, Chulalongkorn University. I am indebted to the grant of Mahasarakham University and very special thanks to the staff members of Department of Biology, for their invaluable suggestion and assistances. Finally, I would like to express my deep gratitude to all my teachers, for their guidances and trainings that leading me toward this success.

Contents

page

List of Tables

Table Page

List of Figures

Figure page

List of Figures (cont.)

Figure page

The following abbreviations are used:

abbreviations	characteristics
A	Atrium
AG	Albumen gland
D	Dart apparatus
E	Epiphallus
EF	Epiphallic flagellum or lime-sac
ERC	Epiphallic Retractor Caecum
HD	Hermaphroditic Duct
O	Ovotestis
P	Penis
PS	Penial Sheath
PRM	Penial Retractor Muscle
Pr	Prostate gland
UT	Uterus
S	Spermatheca
FO	Free Oviduct
V	Vagina
VD	Vas deferens
DM	Dart apparatus Muscle
CF	Caudal Foss
CH	Caudal Horn

Chapter 1

Introduction

Gastropods are the largest group amongst molluscs. They are soft-bodied invertebrate animals with their internal organ enclosed in a hard, usually spiraled shell, composed mainly of calcium carbonate. The naked molluscs called slugs and semi-slugs are exceptional cases. Their shells have been lost through a long evolutionary process by continually reduced the relative size and thickness of the shell. They are terrestrial pulmonate snails, comprising a large and very diverse groups of animals which distribute world-wide. (Burch, 1991). Slugs and semi-slugs are abundant in habitats with high rainfall and reduced availability of calcium (Burch, 1976).

Semi-slugs are snails in which shell reduction has proceeded so far, and with such drastic shortening of the oesophagus, that the crop (when it is not separated from the stomach by a section of oesophagus) is at least partly contained in the foot cavity and the animal cannot retract inside the shell (Tillier, 1984). Other particular characters recently reported in a semi-slug from Costa Rica, *Cryptostracon corcovadensis* are stomach retained in the upper visceral cavity, shortening of lung and development of secondary respiratory structures and reproductive system almost entirely located in the foot cavity (Cuezzo, 1997). These are delicated characters which have been added in semi-slug definition (Tiller, 1984).

The semi-slugs are in the process of evolution into slugs but still possessing a functional external shell. A word slug refers to a body type (a shell-less snail), and not to an overall taxonomic group, (Burch, 1976). A term “semi” refers from Latin word “semis”, means a half (Brown, 1956). The ancestors of slugs are snails with large well developed shells. In locomotion, the reduction and lost of shell in semi-slugs and slugs probably allowed somewhat greater speed. The initial stage in such shell size and reduction would involve compacting the pallial cavity space and thus shortening the visceral hump. Semi-

slugs evolve into a slug when the stomach sinks into the foot cavity, lower than the posterior edge of the foot cavity. In advanced, semi-slugs may have retained or lost hypertorsion of the digestive tract (Tillier, 1984). This is a kind of complete evolution in slug case and the evolution in progress in semi-slugs (Burch, 1976).

Taxonomy of semi-slugs in Thailand is poorly known. Most Thai semi-slugs belong to the Family Helicarionidae (Solem, 1966). Early description of semi-slugs were based largely on shell characters, but the shells of the helicarionid semi-slugs lack many of the characters present in typical helicoid shells and thus anatomical characters are of little use in species identification. Anatomical studies are necessary to elucidate relationships, within the Helicarionidae (Scott, 1995). In 1966, Solem studied malacofauna of India and Burma including some parts of Thailand. Most specimens were collected by Mrs. Birgit Degerbol Hansen in the northern and western Thailand. Five Genera and five species were identified, however there were some uncleared information for example two species, *Austenia doisutepensis* and *Muangnua limax* were too young for identification because of imprecise descriptions in previous literatures and limitation of collecting sites.

The helicarionid semi-slug in this region is diverse, there are 11 genera found in Burma and India, *Cryptogirasia, Pseudoaustenia* are extinct genera (Godwin-Austen, 1908). Many species of Thai semi-slugs should be reported after the more careful studies have been done.

Objectives

The main purpose of this research is to revise taxonomy of semi-slugs in Thailand and some parts of Laos, Malaysia and Vietnam by using shell and soft parts morphology.

Chapter 2

Literature Review

2.1 Semi-slugs Taxonomic Review

The classification of semi-slugs in general

Phylum Mollusca Cuvier, 1795

Class Gastropoda Cuvier, 1797

Subclass Pulmonata Cuvier, 1817

Order Stylommatophora Schmidt, 1856

Family Helicarionidae Ferussac, 1821

Family Xanthonychidae Strebel & Pfeiffer, 1880

Family Humboldtianidae Pilsbry, 1939

(after Kershaw, 1979; Miller, 1987; Vaught, 1989; Burch and Pearce, 1990; Naranjo, 2000)

Most semi-slugs in Asia and Australia belong to the Family Helicarionidae. While semi-slugs in Central America belong to the Family Xanthonychidae and Family Humboldtianidae Pilsbry, 1939.

Semi-slugs are terrestrial pulmonate stylommathophoran in which shell started reduction. There is a form in a process of evolution into slug condition but still possesing external shell (Burch, 1976). The animal cannot retract inside the shell (Tillier,1984). Some helicarionid semi-slugs possess, shell reduction to a cap-like structure enclosed by shell laps (Solem, 1966). The edges of mantle cavity sealed to the back of animal except respiratory pore (Morton et al,1998).

Semi-slugs evolve into a slug whice stomach sink into the foot cavity, lower than the posterior edge of the foot cavity. When this process occurs, the edge of foot cavity may located in front or behind the posterior end of the digestive tract and visceral cavity.

As an advanced semi-slug may have retained or lost hypertorsion of the digestive tract, four situations are possible (Tiller, 1984), depending on which ancestral type of semi-slug; 1) a partly detorted semi-slug having the posterior edge of the foot cavity in front of the stomach; 2) a partly detorted semi-slug having the posterior edge of the foot cavity behind the stomach; 3) a hypertorted semi-slug having the posterior edge of the foot cavity in front of the stomach; 4) a hypertorted semi-slug having the posterior edge of the foot cavity behind the stomach; When the posterior edge of the foot cavity located in front of the stomach, the tail becomes progressively hollow posteriorly and digestive tract turns down into the enlarged foot cavity. When the posterior edge of the foot cavity located behind the stomach, the foot becomes more hollow ventrally and the digestive tract may sink directly into it without any change in its disposition (Tellier, 1984). In the limacisation of semi-slugs the crop and stomach are progressively uncoiled and become parallel to foot length, but may or may not retain hypertorsion. The reduction in number of visceral mass whorls results the reduction of the foot and visceral cavities. The lung reduced and the kidney either shortened or becomes transverse folds.

Alterations in the kidney, heart, and hindgut relationships are equally varied. In the Thai helicarionid semi-slugs, for example *Durgella libas* has a perfectly normal pallial cavity in a shell of 3.5-4 whorls, *Megaustenia siamensis* has the pallial cavity shortened with the shell reduced to 2.25 whorls and the kidney bent downwards by the intruding intestinal loop, *Cryptaustenia gadinodromica* has the kidney not only bent downwards but actually reflected forwards into a partial “U” pattern, while in both the “close affinity” *Austenia doisutepensis* and *Muangnua limax*, the kidney is completely “U” -shaped with the reflected lobe longer than the pallial roof section (Solem, 1978).

Early description of semi-slugs were based largely on external morphology of shell, shape and size of tail, caudal horn, caudal foss, foot, mantle, radula and reproductive morphology such as the present or absent of dart apparatus, size and shape of epiphallic caecum (Tillier, 1989; Solem, 1966). However most of the shells of the helicarionid semi-slugs lack of many characters present in typical helicoid shell, most shell are look alike without generic or specific recognition. Anatomical study would be

necessary procedure to elucidate the relationships within the Helicarionidae (Scott, 1995).

Members of the Helicarionidae are both ground-dweller and arboreal. The shell in many genera are very thin and reduced, compare to size of the animal, with few whorls and wide aperture. As from the said characters the term “semi-slugs” was firstly nominated by Solem in 1974. They are tripartite sole, well-developed caudal foss and overhung horn, they have multicuspid marginal radula teeth. In advanced groups, shell perforated, rarely umbilicated and well development of amatorial organs or dart apparatus are observed.

The subfamily Ariophantinae, they have long cylindrical dart sac with muscular or calcareous papilla; epiphallus varying from large and sac-like; penial retractor is simple, usually with large coiled retractor caecum or large straight caecum. They are classified into 2 Tribes; Tribe Girasii, dart apparatus present or absent; shell reduced drastically; penial retractor caecum small and straight or absent; tail usually triangular in cross section, caudal horn and foss are very large; epiphallus folded with lime-sac lying bound to penis and prominent *Megaustenia* and *Austenia* are only two genera in this tribe.

Tribe Durgelli, dart apparatus present or absent; shell reduced; tail elongated with greatly overhung caudal horn; lime-sac reduced to a small bump just lateral to insertion of penial retractor that has at almost a small straight caecum. There are 3 genera i.e. *Durgella, Cryptaustenia* and *Muangnua*.

Genital system of some Australian semi-slugs are represented in helicarionid semi-slugs, subfamily Helicarioninae. The spermatheca is shaft short, spermathecal head swollen and rounded, epiphallus is thin and long, approximately 150% length of penis. Penis is thin, long surrounded by collar-like penis sheath, dart apparatus absent (Fig.2.1). The absent of dart apparatus is a dominant character of subfamily Helicarioninae.

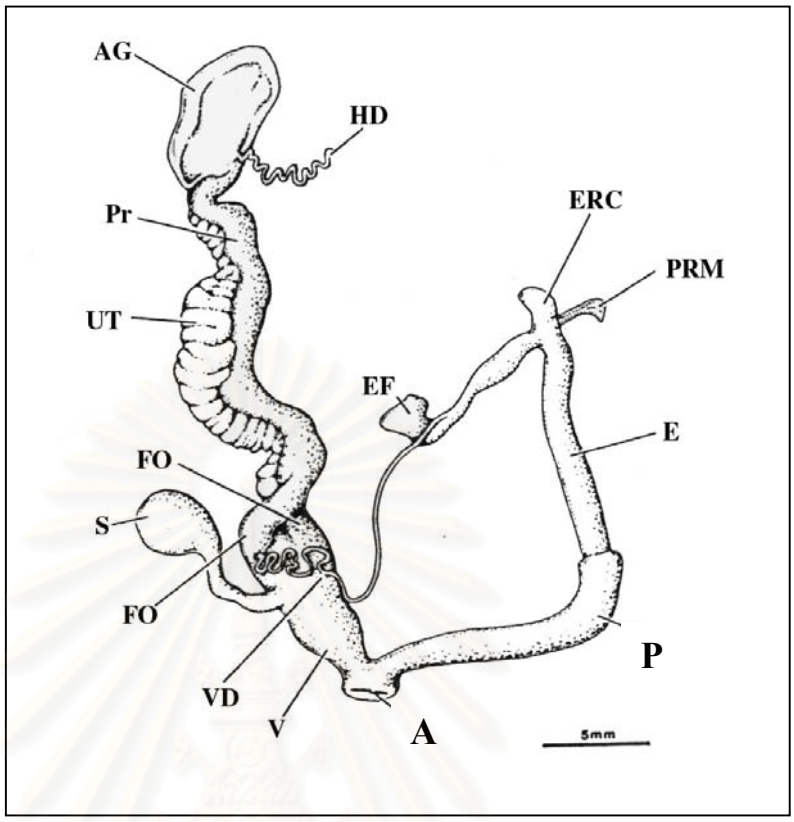


Figure. 2.1. Genital system of Australian helicarionid semi-slugs Genus *Fastosarion superbra* (Scott, 1995) (abbreviation on pages XI)

2.2 Semi-slugs hypothesis

The ancestors of slugs were snails with large well developed shell (Fig.2.2). A snail's shell is protection from periods of unfavorable climate and predators. Snails have four basics needs: moisture, food, calcium, and shelter (Burch, 1976). Calcium is needed for the construction of their shell and the shell helps to conserve body moisture, In their evolutionary history, snails with a rather constant supply of moisture but little calcium could still survive quite well, assuming food was available and predation not too severe. Under such favorable moisture conditions, the protective value of the shell for preserving water would be reduced. In fact, the bulky, heavy shell, which also requires a considerable amount of metabolic energy to construct, might prove to be advantage. Therefore, under such circumstances, small mutations reducing the shell would be

selected for rather than against. A protective device exhibited by slugs and semi-slugs is mucus noxious to their predators.

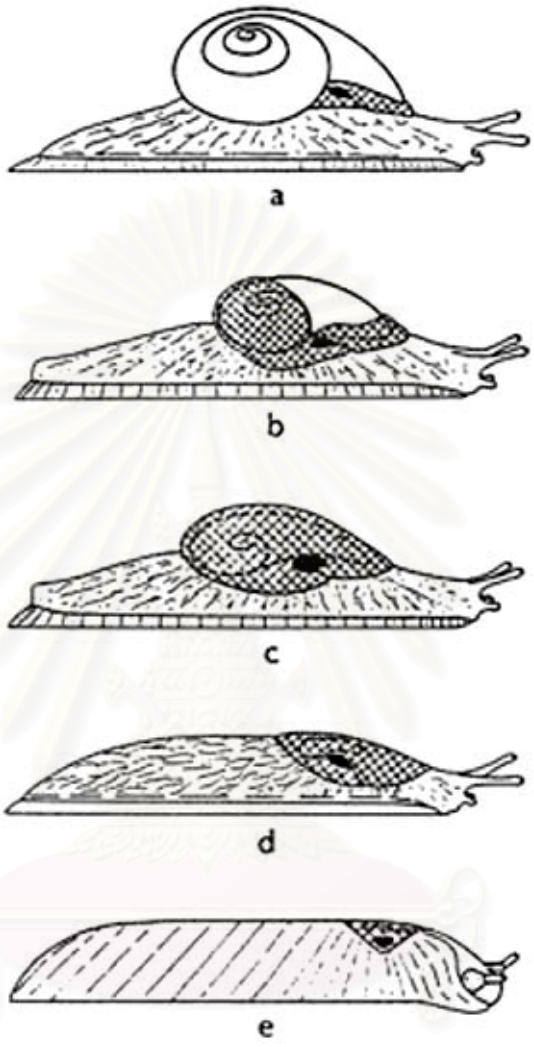


Figure 2.2. Evolutionary stage in slug development; a. Ancestral snails with well developed shell, b. semi-slugs with reduced shell, c. slug with coiled shell d. advanced slug form e. advanced slug form, with almost reduced mantle. (after Burch, 1976)

2.3 Internal morphological study review

Godwin-Austen (1908) investigated taxonomy of Testacellidae and Zonitidae of British India, including Ceylon and Burma. Eleven genera of semi-slugs such as *Cryptaustenia, Girasia, Austenia, Cryptozoma, Pseudoaustenia, Helicarion, Durgella*, *Cryptogirasia, Mariaella, Ibycus* and *Eurychlamys* were reported. The external morphology; shell, mantle, tail, radular and reproductive anatomy are main characters for diagnosis.

Kozloff (1958) studied genital system in a slug, *Hemiphillia malonei* collected from Larch Mountain described reproductive system that the sperm duct opens into the penis at one side of the base of the attachment of the verge appear to be a significant difference. The insertion of the retractor muscle of the penis jointed upon the penis and the epiphallus is a unique characteristic of this species.

Hubricht (1962) studied of genital system of some *Mesomphix* slug species, The length of penial appendix, free oviduct, epiphallus, and the size of penial retractor muscle are key characteristics.

Poster (1965) studied and compared the genital system of two sympatric species slugs, *Haplotrema* from the northwest Pacific Islands. The comparative location of the muscular collar on the vagina, the size of the vas deferens, and the shape and size of the talon are distinct characteristics for each species

Miller (1969) reported a new *Sonorella* from the salt river Mountain of Phoenix, Arizona, by using the lenght of the penial sheath, penial retractor muscle, and epiphallus, the size of muscular collars and vagina, the size and shape of free oviduct, and the present or absent of verge are the key characteristics.

Miller (1971) studied the genital system of *Tryonigens remondi*, and concluded the distinct characteristics for classification from other congeneric species. They are the

absent of a dart apparatus, the present of a large verge, the mode of insertion of the penial retractor muscle, and the absent of epiphallic caecum.

Branson (1972) studied two slugs species, *Hemiphilla dromedarius*, a new a*rionid* slug from Washington differs from *H. danielsi* by coloration and possessing of the inflated penis and lacking an accessory stimulator.

Kershaw (1979) redescribed a semi-slug, *Helicarion cuvieri* from southern Tasmania and *H. freycineli* from New South Wales. The shell and anatomy of *H. cuvieri* are described a neotype was designated, lectotype was also designated for *H. freycineli* by description of the external mophology i.e. shell, mantle, tail, caudal horn and caudal foss.

Tillier (1984) studied on patterns of digestive tract morphology in the limacisation of helicarionid, succineid and athroracophorid snails and slugs (Mollusca: Pulmonata). In Family Helicarionidae, hypertorsion is retained during the initial steps of limacisation, and may be retained or lost in semi-slugs and slugs. In succineids, the digestive tract is detorted in the course of limacisation. Detorsion may be related to their bulimoid shell shape. Athoracophorids have more exaggerated hypertortion of the digestive tract than other slugs. The anatomical characters may result from advanced limacisation. In the conclusion, the athoracophorids are more closely related to other Aulacopoda than to succineids.

Hoffman (1987) reported a new species of *Rabotus* (Gastropoda: Pulmonata: Bulimulidae) from Sonora, Mexico, with a description of the distinct genitalia system of *R.nigromotanus* which differs from other congeneric species by the penial sheath shape and penial retractor muscle insertion to the end of the epiphallic caecum.

Hoffman (1987) reported a new species of *Drymaeus* (Gastropoda: Pulmonata: Bulimulidae) from Sonora and Sinaloa, Mexico. The present and absent of epiphallic caecum is a distinct characteristic for classification from other congeneric species.

Miller (1987) reported a new species of semi-slug, genus *Bynnya* (Gastropoda: Pulmonata: Humboldtianidae) from western Mexico.By using reproductive system, the numbers of mucus gland, the present and absent dart apparatus, and spermathecal diverticulum mophology.

Ueshima (1988) described anatomical and radula features of a helicarionid species, *Hirasea diplomphalus* and taxonomic position of the genus *Hirasea*, the genus *Hirasea* is transfered from family Endodontidae to the family Helicarionidae, subfamily Euconulinae with the following characteristics; fused gonoduct (spermoviduct), triangular kidney, complete secondary ureter, elongated marginal teeth with only one ectocone, short bursa copulatrix not reaching carrefour, well developed glandular region in free oviduct, well developed penial appendix, the absent of anatomical organ or dart apparatus, lacking of flagellum or lime sac on the epiphallus, and small bursa copulatrix as long as free oviduct. Caudal horn and foss found in *Hirasea* are characters common in Helicarionidae.

Ueshima (1989) studied generic position of *Kaliella yaeyamensis* (Pulmonata: Helicarionidae) by using genital system as follows; separated gonoduct, bursa copulatrix on male side, ovoviviparity, present of penial appendix and horny stimulator inside the penis.

Fairbanks (1989) studied the genital system and taxonomic status of two slug species, *Philomycus venustus* and *P.bisdosus* (Pulmonata: Philomycidae) by using the penial anatomy comparison.

Fairbanks (1990) studied reproductive morphology of genus *Megapalisfea* (Gastropoda: Philomycidae). Size and shape of the penis and the shape of the upper atrial lobes are distinct characteristics from the other congeneric species.

Fairbanks (1993) studied the genital system of two slug species, *Philomycus sellatus* and *P. virginicus* (Gastropoda: Philomycidae) and described penial internal mophology. Their genital systems are also distinct the shape of the penis and their internal anatomy are clearly different.

Scott (1995) redescribed a semi-slug, *Fastosarion superba* and described two new species of *Fastosarion* from northern Queensland (Pulmonata: Helicarionidae). *Fastosarion* is difficult to identified from *Helicarion* and other genera of semi-slugs by external characters. Two features of the reproductive tract separated *Helicarion* and *Fastosarion*; *Fastosarion* has a well-developed vagina and a caecum near the retractor muscle. Both are absent in *Helicarion* (Kershaw, 1979, 1981)(Table 2.1).Two new species, *F. helenkingae* and *F. aquavitae* can be separated from *F. superba* by penial sculpture.

Table 2.1 comparative reproductive anatomy of genera of northeastern Queensland helicarionid (after Scott, 1995)

	Fastosarion	*Helicarion*	*Thularion*	*Eungarion*	*Malandena*	*Sitala*
vagina	present	absent	present	present	present	present
spermatheca	short	short	medium	short	-	short
flagellum	sinuate	small	long, straight	sinuate	long, straight	absent
caecum	present	absent	present	present	absent	absent
dart sac	absent	absent	absent	absent	present	present

Cuezzo (1997) reported of *Cryptostrakon corcovadensis*, a new species of semi-slug from Costa Rica (Helicoidea: Xanthonychidae) and commented on the systematics position of the genus, base on new internal anatomical evidence, especially the present of mucus gland and a dart apparatus are homologous (by position). The systematic position of the genus with in the Xanthonychidae is reconfirmed. Comparisons among the

semi-slug genera of the Xanthonychidae are provided. Morphologically; body shape, tail, middorsal groove, shell, body cavity, jaw, buccal mass, and reproductive anatomy; verge, mucus gland, dart apparatus, albumen gland , *Cryptostrakon* appears to be more related to *Xanthonyx* and *Metrostracon* than other Xanthonychid genera.

Naranjo et al. (2000) reported a new genus and species of semi-slugs from southern Chipas, Mexico (Gastropoda: Pulmonata: Xanthonychidae), They described and compared the genital system i.e. the length of penis, the located of verge, numbers of mucus glands, atrial sac, and the present or absent dart apparatus. The species was found to differ considerably from *Xanthonyx* is having the penis is short, conical, and swollen at the apical and the located of verge. Accordingly, they propose a new genus to accommodate this new species. *Semiconchula custepecana* has two mucus glands that enter into the atrial sac near the dart apparatus. In comparision with *Xanthonyx sumichrasti* (type species of *Xanthonyx*), which has one mucus gland that enters low on the vagina but without dart apparatus.

2.4 Helicarionid semi-slugs study in Thailand

.

Taxonomy of semi-slugs in Thailand is very poor. In 1966 Solem studied malacofauna of India and Burma including some parts of Thailand. Most specimens were collected by Mrs. Birgit Degerbol Hansen in northern and western Thailand. Five Genera and five species (Table 2.2), there are *Durgella libas, Cryptaustenia gadinodromica, Muangnua limax, Megaustenia siamensis and Austenia doisutepensis* were identified. By using morphological characters, such as shell, foot, mantle, jaw, radula and internal anatomy are main digestive tract and genital system characters, however there are some uncleared information for example two juvenile species, *A. doisutepensis* and *M. limax* were too young for identification, some species also have limited numbers and limitation of collecting sites.

Table 2.2 Comparative Thai helicarionid semi-slug (after Solem, 1966)

Characters	*Durgella*	*Cryptaustenia*	*Muangnua*	*Megaustenia*	*Austenia*
body shape	semi-slug	semi-slug	More slug-like	semi-slug	More slug-like
shell	with 4+whorls depressed	with 4 whorls depressed	reduced to a cap-like	with 2.5-3 whorls depressed	with 1.25-2 whorls
tail	short	very elongated	narrow, very elongated	medium, triangular	short elevated, triangular
flagellum	present	absent	absent	present	present
spermatheca	broad collared base, narrow stalk, bulbous head	broad collared base, narrow stalk, bulbous head	long finger-like	short finger-like	long finger-like
caecum	present	absent	present	present	present
dart apparatus	present	present/absent	absent	present	present

The helicarionid semi-slug in this region is diverse, eleven genera found in Burma and India (Godwin-Austen, 1908). Many species of Thai semi-slugs should be reported after the more careful studies have been done.

Chapter 3

Materials and Methods

Materials

1. Specimens in this study are taken from two sorts, one from Chulalongkorn University Museum of Zoology and the other were collected from various localities in Thailand and some parts of Laos, Sabah (Malaysia) and Vietnam (Fig. 3.1)

2. Materials

- 2.1. Dissected tools
- 2.2. Stereo Microscope
- 2.3. Camera and Film
- 2.4. Paper for drawn
- 2.5. Pencil
- 2.6. Bottles are various size
- 2.7. Slide and cover slide
- 2.8. Scanning Electron Microscope
- 2.9. Beaker
- 2.10. Testube
- 2.11. Vernier Calipper
- 2.12. Rack
- 2.13. Petri disc
- 2.14. Light Microscope
- 2.15. Vial 4 ,10ml. Scintillation 20 ml.
- 2.16. Hot plate

3. Chemicals

3.1. Ethanol 30, 50,70 and 95%
3.2. NaOH 10%
3.3. Water
3.4. Canada Balsum
3.5. Lactophenal Blue

Methods

The specimens were collected from various localities in Thailand and some parts of Laos and Vietnam, shown in Fig. 3.1.

Living specimens were killed by suffocation. The specimens were relaxed and killed by suffocation in bottles for 24 hrs and were divided into 2 groups, one preserved in 70% and the other in 95% ethanol for future molecular studies.

Specimens were then labelled, the collection number, scientific name, locality, collected date, collector, number of specimens and habitats. Some specimens were firstly identified by comparing with paratypes from Zoologisk Museum Kobenhavn (*Austenia doisutepensis*; Leg: 2089; Solem 1570 m.; 10/1/1959; the north Thailand) and using the according main literatures, Solem, 1966 and Godwin-Austen, 1908 for basic taxonomy.

Shell morphology of semi-slugs including shell width, (SW), shell height (SH), body length (BL), and tail length (TL) were measured in millimeters by vernier calipper. These parameters are illustrated in figure 3.2.

- Shell width is measured from widest part of shell,
- Shell height is measured from apex to base of shell,
- Body length is measured from the tip of tail to tip of head,
- Tail length is measured from the tip of tail to visceral hump.

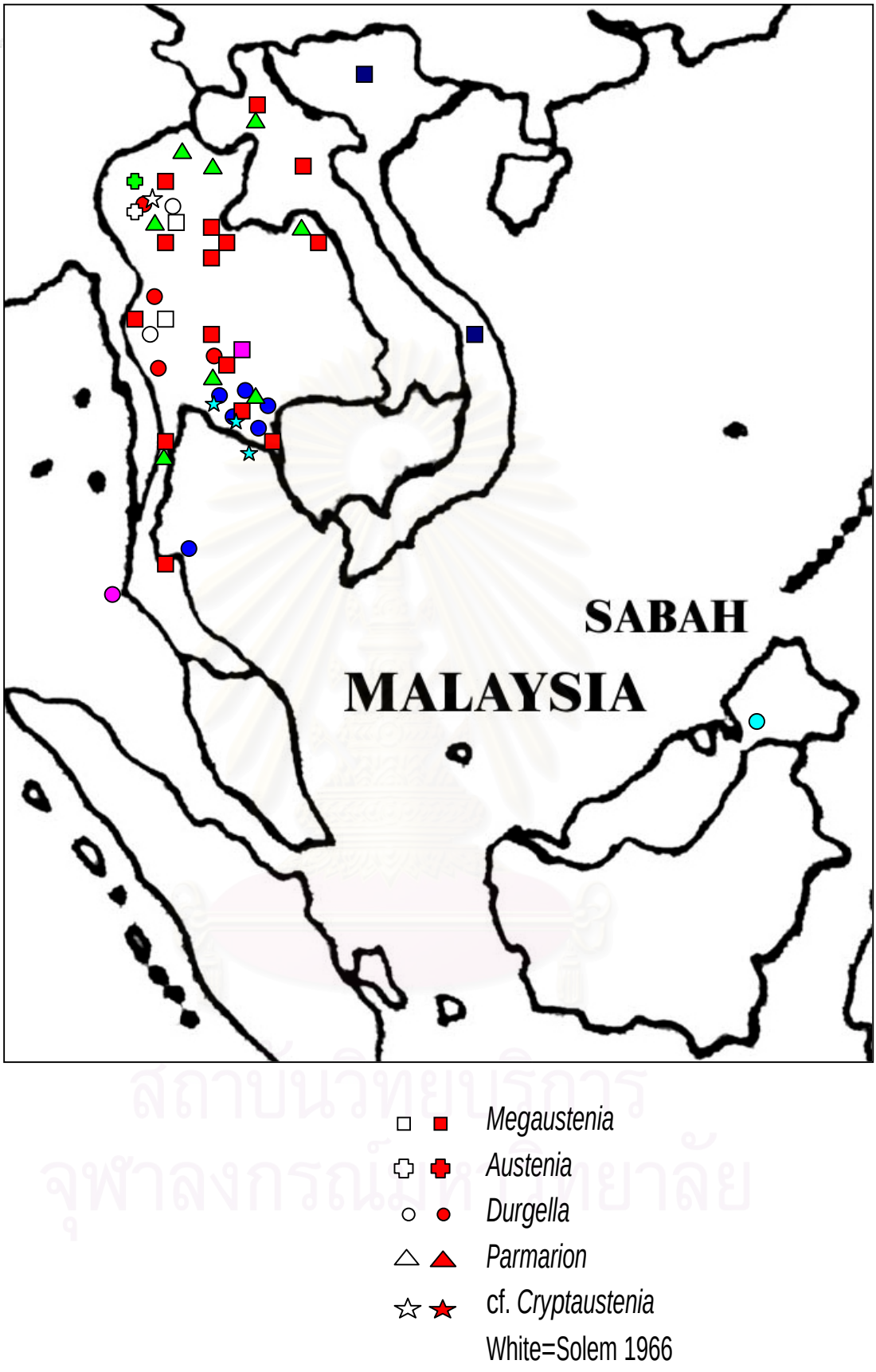


Figure 3.1 Collecting site of semi-slugs in the present study and a report from Solem (1966).

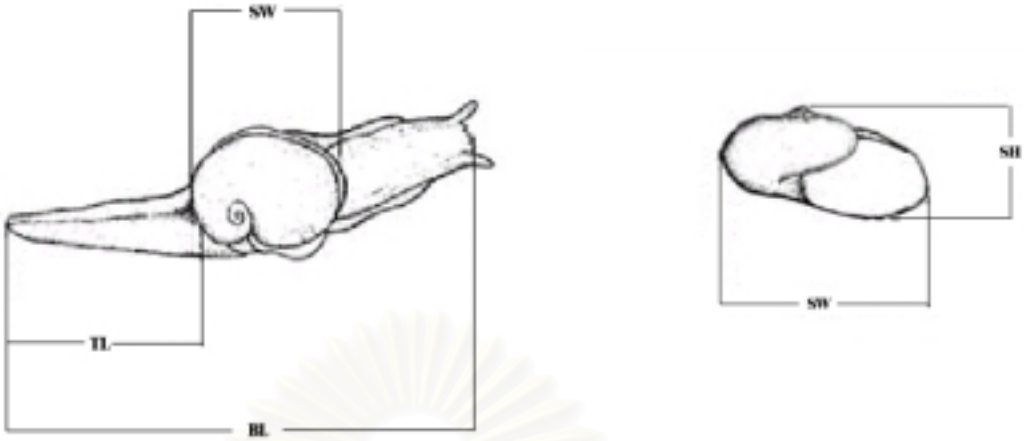


Figure 3.2. Terminology of shell and body measurements in semi-slugs.

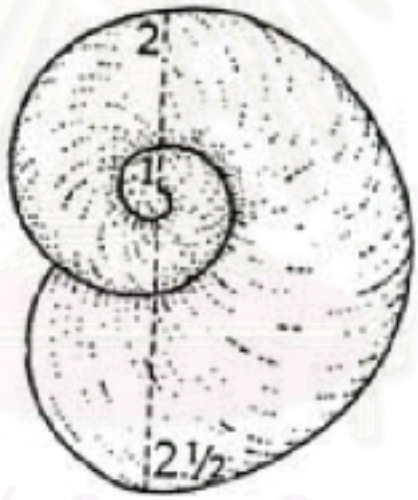


Figure 3.3. Method of whorl counting (after Burch, 1990)

The whole animals were dissected under light microscope for separation of reproductive system. The specimens were dissected to allow examination of the terminal genitalia. The terminal genitalia were examined under a dissecting microscope and drawing for description. (Fig. 3.4)

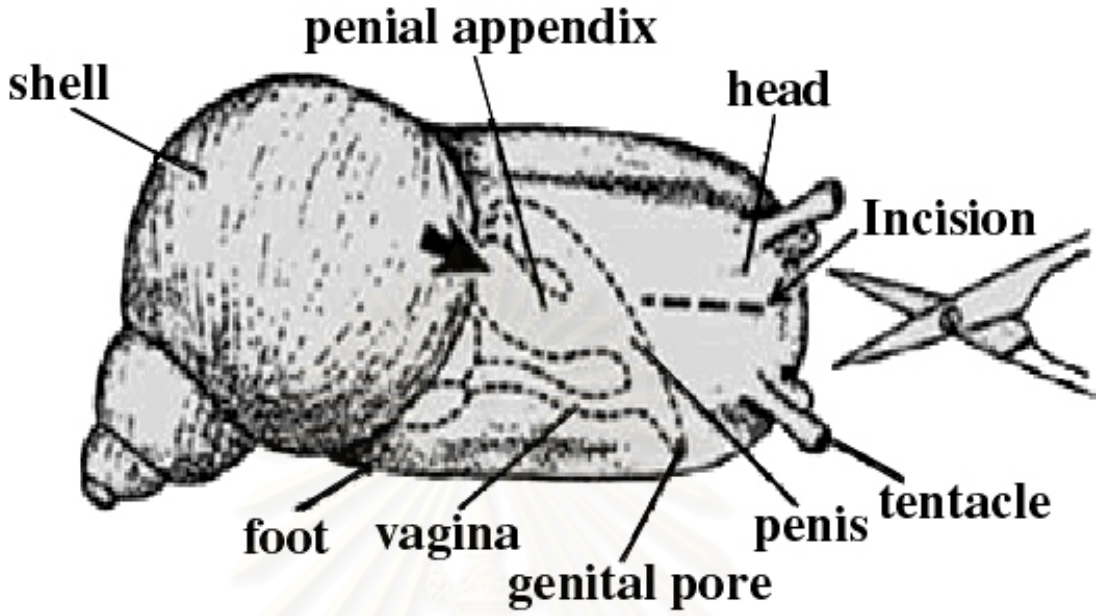


Figure 3.4. The position of dissecting in land snails (after Burch, 1990)

The radula was removed from buccal mass and placed in warm 10% NaOH. They were washed in water and dehydrated in 50, 70, 90, 95% ethanol, stained with lactophenol blue and washed in 95%, and absolute ethanol before clearing in xylene and mount by Canada Balsum. Radula teeth types were investigated and counted each rows under light microscope, some were kept in 95% ethanol and then proceed to the process for Scanning Electron Microscope (SEM).

Chapter 4

Results

The present study, 1 Family, 2 subfamilies, 6 genera and 12 species were classified and identified. The list is shown in Table 4.1

Table 4.10. The list of helicarionid semi-slugs found in Thailand and some parts of neighboring countries.

Family	Subfamily	Genus	species
Helicarionidae	Ariophantinae	*Austenia*	1. *A.doisutepensis*
		Megaustenia	2. *M. siamensis*
			3. cf. *M. siamensis*
		Durgella	4. *D. libas*
			5. *Durgella* sp.1
			6. *Durgella* sp.2
			7. *Durgella* sp.3
		Parmarion	8. *Parmarion* sp.1
			9 *Parmarion* sp.2
	Helicarioninae	cf. *Megaustenia* sp.	10. cf. *Megaustenia* sp.
		cf. *Cryptaustenia*	11. cf. *Cryptaustenia* sp.1
			12. cf. *Cryptaustenia* sp.2

The descriptions of each species are presented belows;

Genus *Austenia* Nevill, 1878

Description: Shell is ovate and ear-shape, with 1-2 whorls, apex flat, very thin, aperture very large. Animal large, tail and foot are broad and high, non-retractable within the shell. A cylindrical dart apparatus exist with very long spermatheca.

Distribution: Himalaya, Siliguri, The north of Bengal, Cachar and Silchar, Naga Hills, Assam, Northeast India, Arbor Hills, Damd, Siyom Valley, Arbor Hills Burma, and Thailand.

Austenia doisutepensis Solem, 1966

(Fig.4.1)

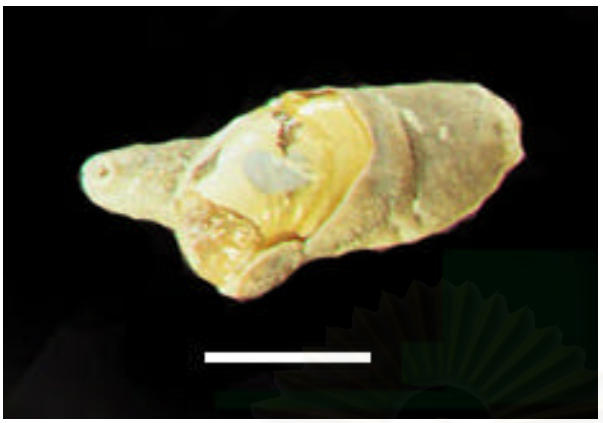
Shell is small, there are about 1 ¾ to 2 whorls, apex is very slightly raised or flat, surface without sculpture, smooth and shining. Shell and visceral hump not enclosed by shell laps and mantle lobes. Foot and tail are small, body length in 70% ethanol ranges 20-28 mm., foot is broad and short, tails is very short, high, triangular in cross section. No part of caudal horn performs overhang, caudal foss is a long vertical slit in tail. Mantle lobe and shell laps are very dark and gray above. Right mantle lobe is small and thick, left mantle lobe greatly expanded and completely fused with shell lap.

Genital system: Ovotestis and part of hermaphroditic duct are embedded in mid-gut gland. Uterus and prostate gland are long, and slender. Vas deferens is long and slender, simple tube, passing along free oviduct, vagina and penis, entering the apex of epiphallus beside the lime-sac. Epiphallus is slender, slightly broader than vas deferens, with a prominent epiphallic retractor caecum. Penis is very long and slender, thick-walled. Free oviduct and vagina are short, spermatheca is long and finger-like, reaching two-thirds of way to albumen gland. Dart apparatus is long and slender. Atrium is rather long.

Radula: radula formula 48:11:1:11:48. Central tooth is a typical tricuspid slightly smaller than lateral teeth, with broad basal plate, mesocone is very large, and long, ectocone are small and prominent, rather symmetrical. Lateral teeth are also tricuspid, with broader mesocone than central tooth, with broad basal plate. First to fifth lateral teeth with ectocone larger than endocone. Endocone is small and located near mesoconal tip. After ninth lateral tooth, endocones gradually reduced and nearer mesoconal tip, mesocone increasing in size. Marginal teeth are bicuspid, elongate, with a large mesocone, a prominent ectocone and reduced narrow basal plate, on the outer marginals, ectocone and mesocone becomes smaller (Fig.4.2).

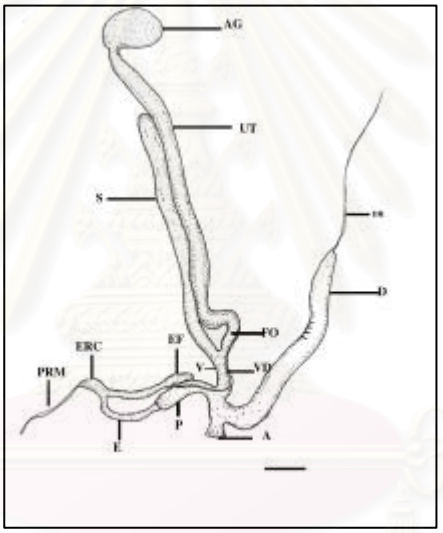
Localities: Doi sutep and Doi Chiang Dao (Chiangmai Province).

Diagnosis: shell ear-shape, with 1-2 whorls, foot and tail very short and high, shell laps covering less than half of shell with distinct spiral coiling, long finger-like spermatheca.



a

b



c

Figure 4.1 *Austenia doisutepensis*; a) preserved specimens; b) distribution; Doi sutep and Doi Chiang Dao (Chiangmai Province); c) genitalia scale bar 1 cm (Abbreviations are shown in page xi).

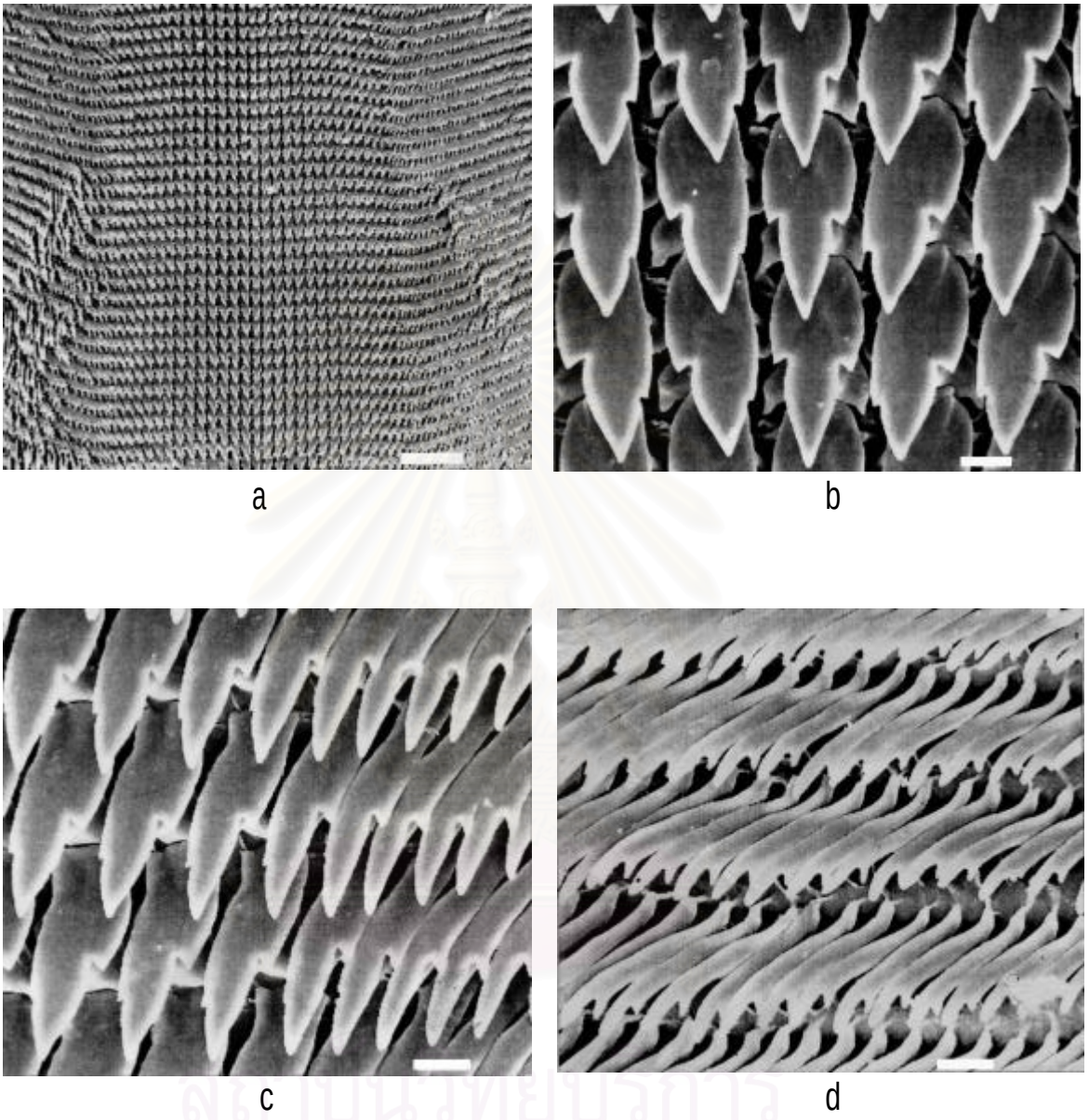


Figure 4.2 Radula of *Austenia doisutepensis*.; a) radula rows at scale bar 100 μm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d scale bars 10 μm.

Genus *Megaustenia* Cockerell, 1912

Description: Shell is very large with diameter ranges 11.32-33.18 mm, about 2 ½ -4 ½ whorls, the last whorl is very large. The animal can retract within the shell and secretes an epiphragm during the dry season. A large dart apparatus exist with small straight retractor caecum, Tail large with caudal foss. Caudal horn performs overhang.

Distribution: southern China to Hongkong and upper Burma; Mergui; Malaya; Shan Hills, eastern Burma and Thailand.

Megaustenia siamensis Haines, 1858

(Fig.4.3)

1858 *Vitrina siamensis*, Ann. Lyceum Nat. Hist. New York 6, p. 158. Siam (Haines)
1867 *Vitrina siamensis* Preuss. Exped. Ost. Asian, Zool. 2, pp. 68-69 (Martens)
1898 *Vitrina siamensis* Moll.India, 2: 52, 53, pl. 71 (Godwin-Austen)
1922 *Vitrina siamensis* Sitz. Ber. Naturf. Ges. Leipzig 45-48, pp. 4-8 (Ehrmann)
1929 *Vitrina siamensis* Nautilus 43, (2), pp. 51-54. (Cockerell)

Shell diameter ranges 11.2-33.18 mm, in adult specimens, with pale yellow color; about 2 ½ -3 ¼ whorls, body whorls depressed and rapidly increased, spire depressed; aperture very large roundly ovate. Foot and tail are elongated, body color is yellow and middorsal stripes is yellow. Caudal foss very large with slightly overhang caudal horn. Opening occupies full height of tail. Lateral edges of mantle extended into left and right pallial lappets which cover shell; right body lappet locates superior to pneumostome. Mantle collars narrow with large lobe and laps.

Genital system. Ovotestis with small alveoli and embedded in mid-gut gland. Hermaphroditic duct is small, short, and weakly convoluted. Albumen gland is large and triangular shape. Prostate gland and uterus are well developed, extremely swollen by pregnancy. Vas deferens is slender tube, short and entering the apex of epiphallus besides the lime-sac; epiphallus is slender slightly broader than vas deferens with a prominent epiphallic retractor caecum, epiphallic retractor caecum is small and short.

Penis is large and long, thick-walled. Free oviduct is cylindrical and slender, short tube with a large papillose glandular collar, vagina is swollen and short, spermatheca has short stalk with rounded bulb at terminal. Dart apparatus is large. Atrium is very short and thick walled.

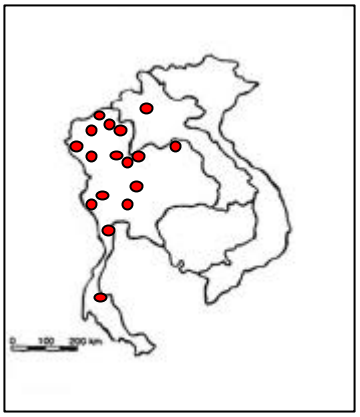
Radula: Central tooth is large tricuspid, with broad basal plate; mesocone is large and long, ectocone are prominent, extending far past edge of basal plate, lateral teeth are also tricuspid with elongated and broad basal plate; ectocone more prominent, endocone indistinctly appeared. Marginal teeth are bicuspid, narrowly, lack endocone, mesocone reduced, basal plate is very elongate, with large ectocone. Outermost marginal teeth the mesocone and ectocone are equal in size. (Fig.4.4).

Habitat notes: *M. siamensis* usually found and under rocks. Sometimes they appear crawling on the log and tree trunk.

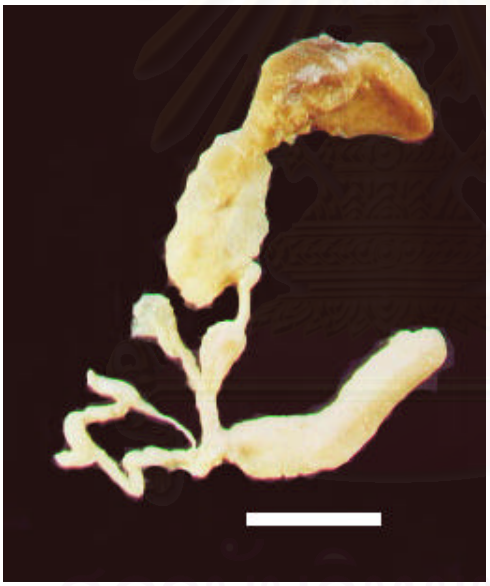
Localities: Chiangmai, Phetchaburi, Nongkai, Khonkaen, Loei, Chaiyaphum, Nakhonratchasima, Kanchanaburi, Nan, Phrae, Chantaburi, Suratthani, Maehongson, Phayao, Tak, and Laos (Wang vieng and Laung Phra bang)

Diagnosis: Shell large, foot and tail are elongated, with weak mid-dorsal groove, caudal foss is large, caudal horn is overhang. A large dart apparatus appeared.

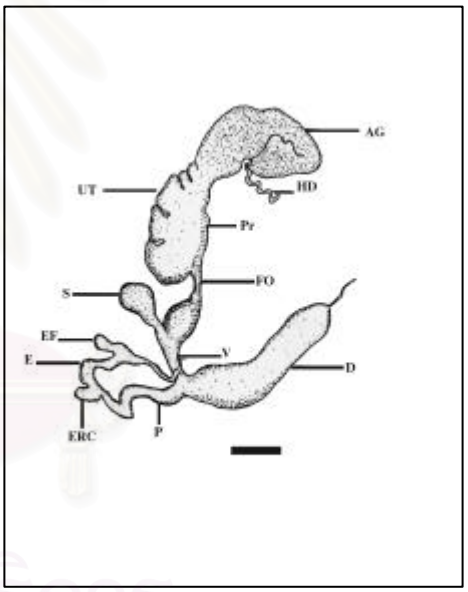
a



b



c



d

Figure. 4.3 *Megaustenia siamensis*; a) live specimen; b) distribution; Chiangmai, Phetchaburi, Nongkai, Khonkaen, Loei, Chaiyaphum, Nakhonratchasima, Kanchanaburi, Nan, Phrae, Chantaburi, Suratthani, Maehongson, Phayao, Tak Provinces, and Laos (Wang vieng and Laung Phra bang); c) and d) genitalia at scale bar 1 cm. (Abbreviations are shown in page xi).

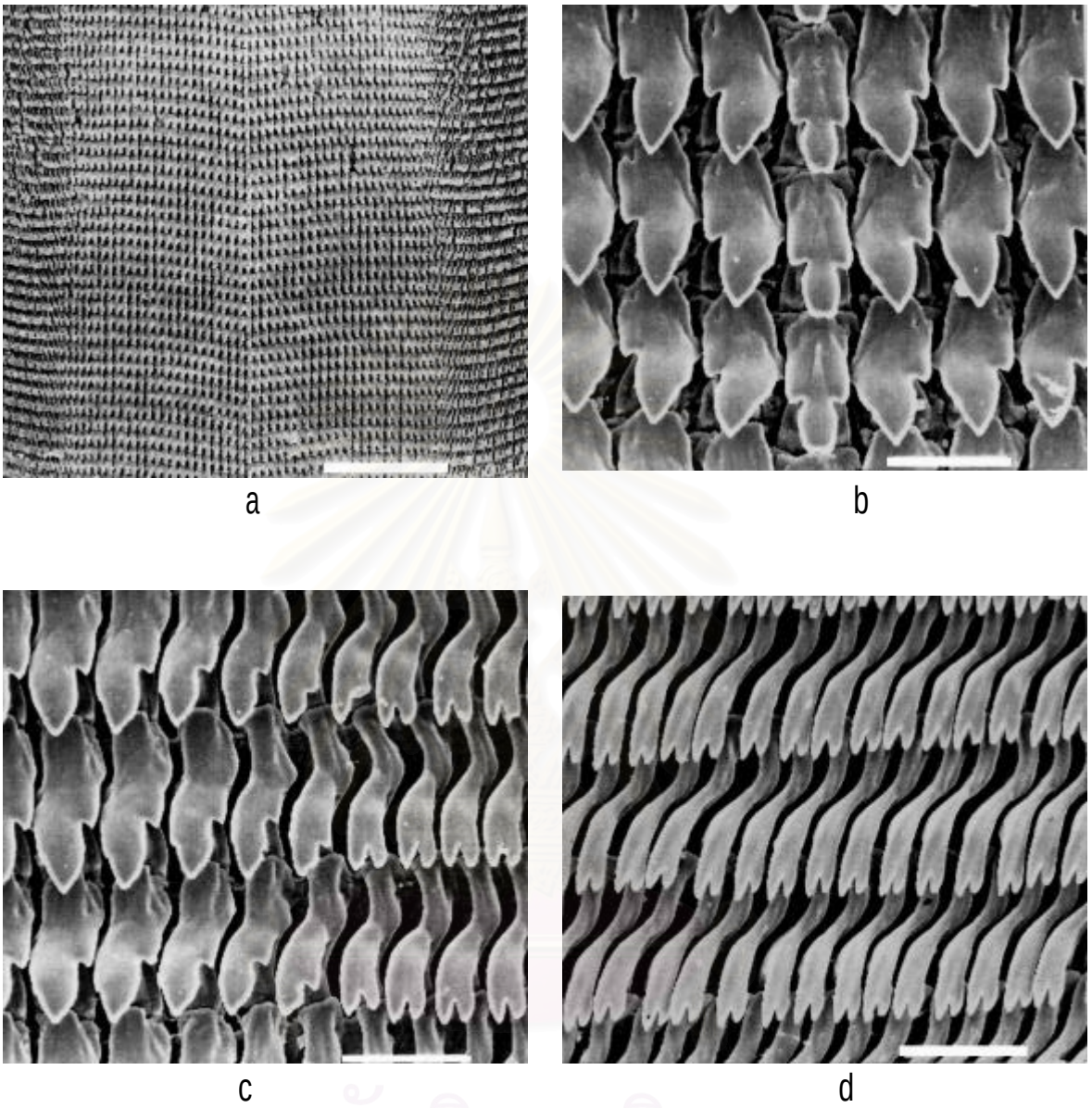


Figure 4.4 Radula of *Megaustenia siamensis*; a) radula rows at scale bar 1 mm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d at scale bars 50 μm.

cf. *Megaustenia siamensis* Haines (1858) Viet nam variety

(Fig. 4.5)

shell diameter ranges 23.12-35.30 mm, in adult specimens. Shell has brown color, there are about 3 ¼- 3 ½ whorls, body whorls depressed and rapidly increased, spire depressed, aperture very large, roundly ovate. Foot and tail are elongated; body color is gray. Caudal foss is very large with slightly overhang caudal horn. Opening occupies full height of tail. Lateral edges of mantle extended into left and right pallial lappets which cover shell; right body lappet locates superior to pneumostome. Mantle collar narrow with large lobe.

Genital system: Ovotestis embedded in mid-gut gland. Hermaphroditic duct is a small simple tube with convoluted. Albumen gland is very large.and triangular shape. Prostate gland and uterus are well developed extremely swollen by pregnancy. Vas deferens is a slender tube, long and entering the apex of epiphallus besides the lime-sac; lime-sac is large and short. Epiphallus is large, long slightly broader than vas deferens with prominent epiphallic retractor caecum. Epiphallic retractor caecum is large and short. Free oviduct is small, has a large papillose glandular collar, vagina is swollen and short, spermatheca is short stalk with swollen head and rounded. Penis is short and large. Free oviduct very large. Dart apparatus locating on male side is very large enters into base of penis. Atrium is large and thick walled.

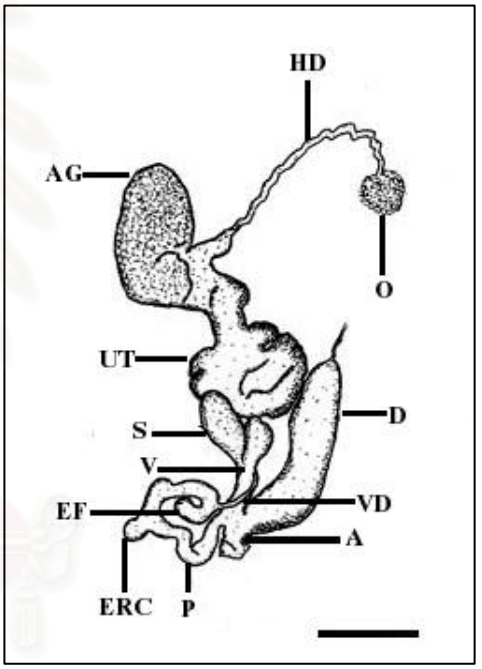
Radula: Central tooth is large tricuspid, with broad basal plate; mesocone is large and long; ectocone are prominent extending far past edge of basal plate; lateral teeth are also tricuspid, with basal plate elongated and broad, ectocone more prominent; endocone only slightly less prominent and near mesoconal tip. Marginal teeth are bicuspid, narrowly, lack endocone; mesocone reduced, basal plate is very elongate, with large ectocone. Outermost marginal teeth the mesocone and ectocone are equal in size. (Fig.4.6).

Localities: Cuc phaung National Park and Catba National Park in Viet nam

a

b

c



d

Figure 4.5 cf. *Megaustenia siamensis;* a) preserved specimen; b) distribution; Cuc phaung National Park and Catba National Park in Viet nam; c) and d) genitalia at scale bars 1 cm. (Abbreviations are shown in page xi).

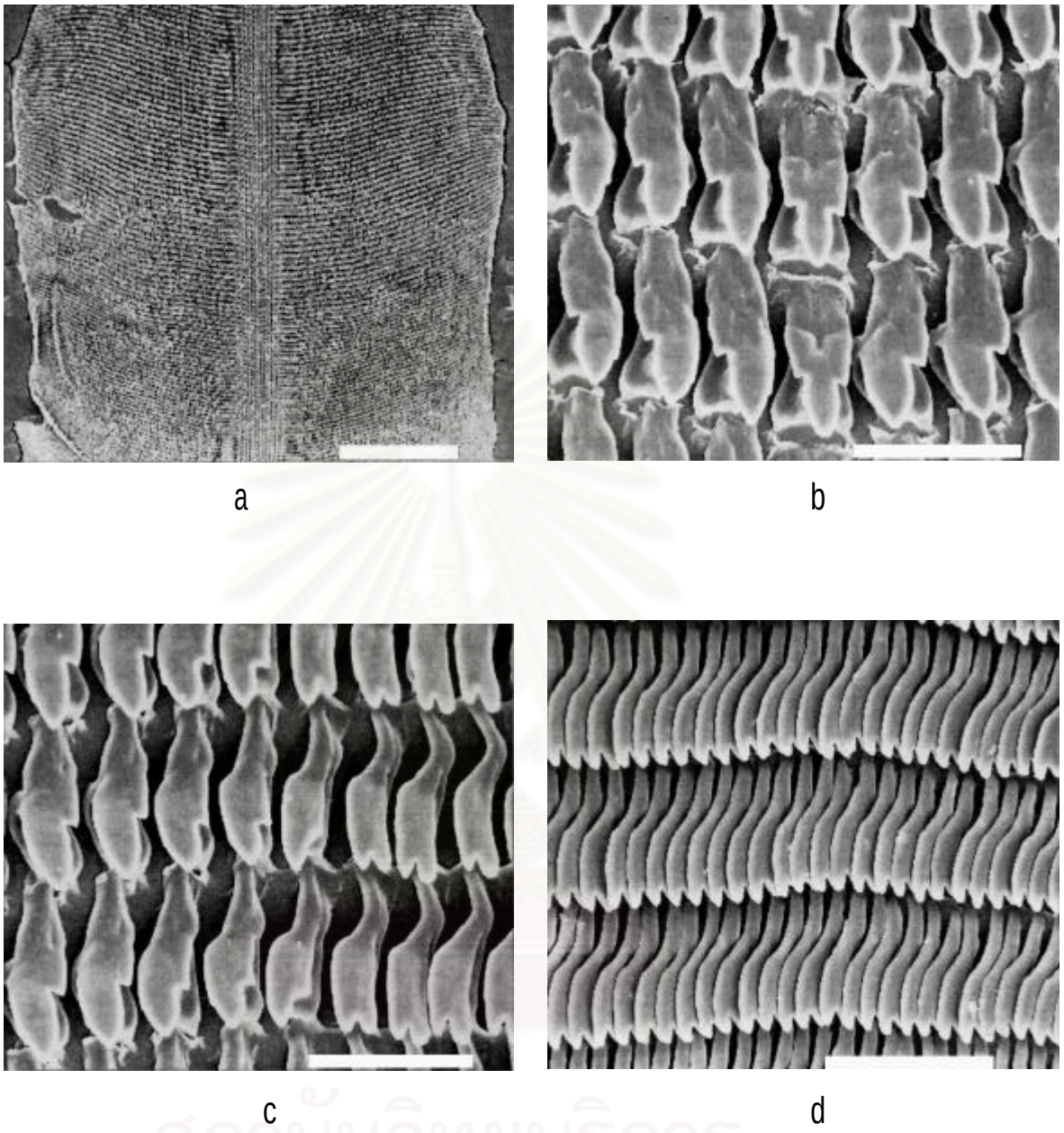


Figure 4.6 Radula of cf. *Megaustenia siamensis* a) radula rows scale bar 1 mm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c and d scale bars 50 μm.

cf. *Megaustenia* sp.

(Fig. 4.7)

shell is 23.12-29.30 mm diameter in adult specimens. Shell has brown color; there are about 3 ½ - 4 ½ whorls, body whorls depressed and increasing rapidly; spire depressed; aperture very large and roundly ovate. Foot and tail are elongated. Body color is gray. Caudal foss is very large with slightly overhung caudal horn. Opening occupies full height of tail. Lateral edges of mantle extended into left and right pallial lappets which cover shell; right body lappet locates superior to pneumostome. Mantle collars narrow with large lobe.

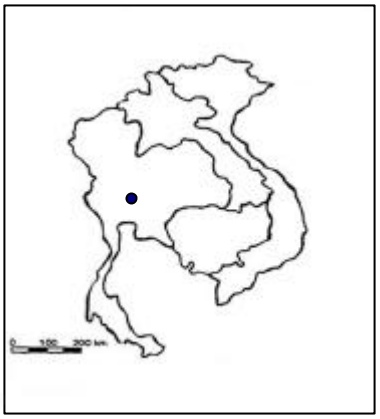
Genital system: Ovotestis embedded in mid-gut gland. Hermaphroditic duct is a small simple tube and convoluted. Albumen gland is very large.and triangular. Prostate gland and uterus are well developed extremely swollen by pregnancy. Vas deferens is a slender tube, long and entering the apex of epiphallus besides the lime-sac. Epiphallus is large, long slightly broader than vas deferens with prominent epiphallic retractor caecum. Epiphallic retractor caecum is large and short. Free oviduct is small, has a large papillose glandular collar; vagina is swollen and short; spermatheca is short stalk with swollen head and rounded. Penis is short and large. Free oviduct. Dart apparatus is absent. Atrium is large and thick walled.

Radula: Central tooth is large tricuspid, with broad basal plate; mesocone is large and long, ectocone are prominent extending far past edge of basal plate; lateral teeth are also tricuspid with elongated and broad basal plate; ectocone more prominent, endocone only slightly less prominent and near mesoconal tip. Marginal teeth are bicuspid, narrowly, lack endocone, mesocone reduced, basal plate is very elongate with large ectocone. Outermost marginal teeth the mesocone and ectocone are equal in size. (Fig.4.8).

Locality: chaiyaphum Province.

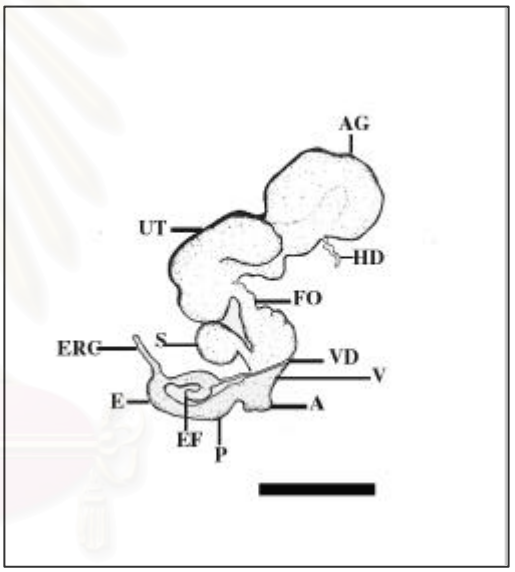
Diagnosis: shell large, foot and tail are elongated, with weak mid-dorsal groove, caudal foss is large, caudal horn is very hanging. Dart apparatus is absent.

a



b

c



d

Figure. 4.7 cf. *Megaustenia* sp.; a) Shell; b) Distribution; chaiyaphum Province. c) and d) genitalia at scale bar 1 cm. (Abbreviations are shown in page xi).

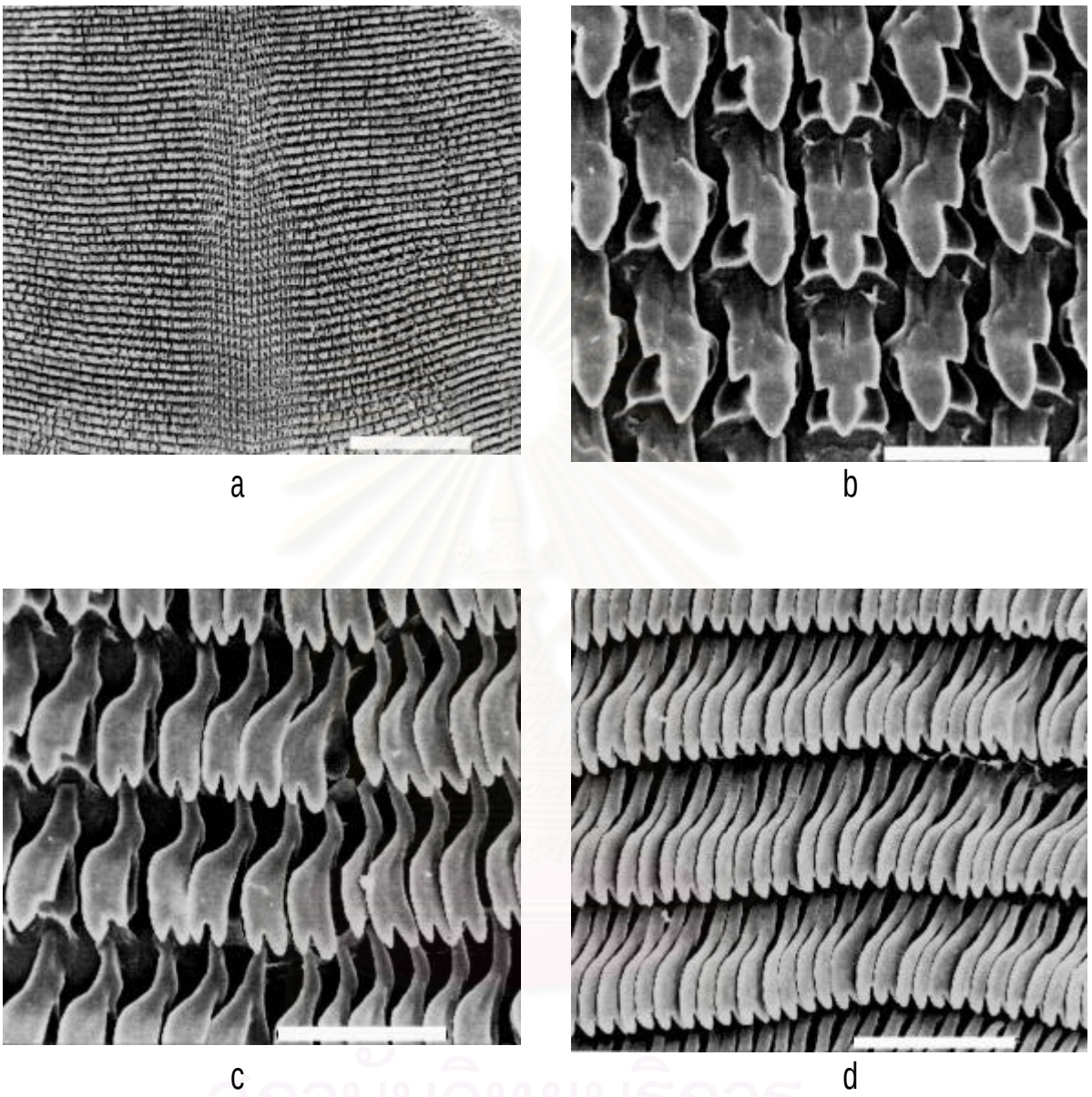


Figure 4.8 Radula of cf. *Megaustenia* sp.; a) radula rows at scale bar 1 mm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d at scale bars 50 μm.

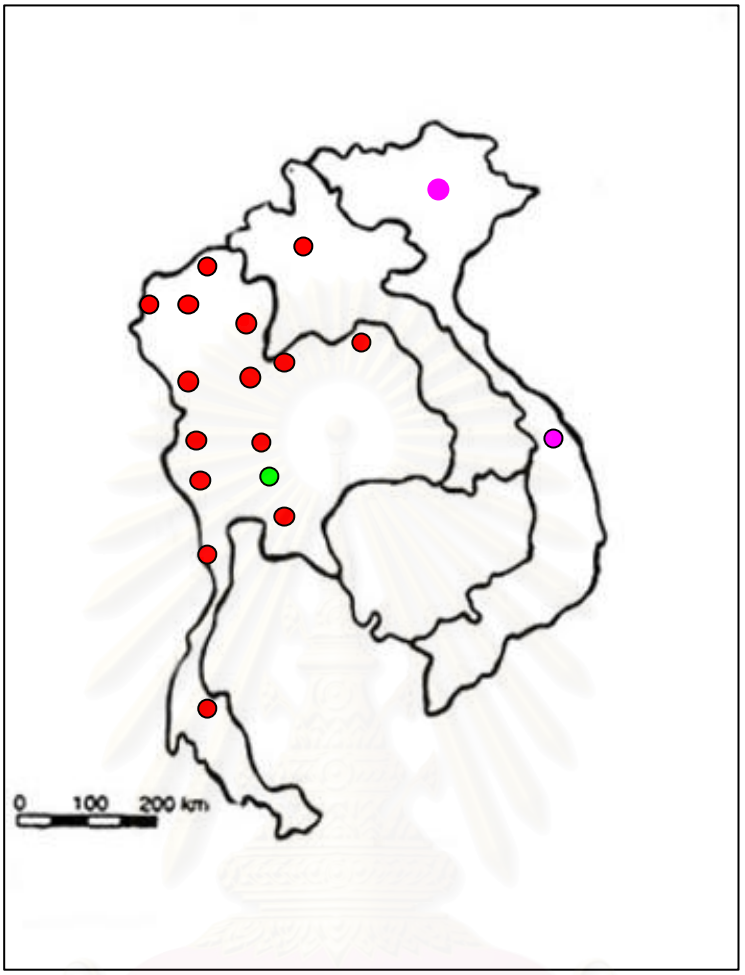


Figure 4.9 Distribution of *Megaustenia siamensis*, cf. *Megaustenia* sp. and cf. *Megaustenia siamensis*.

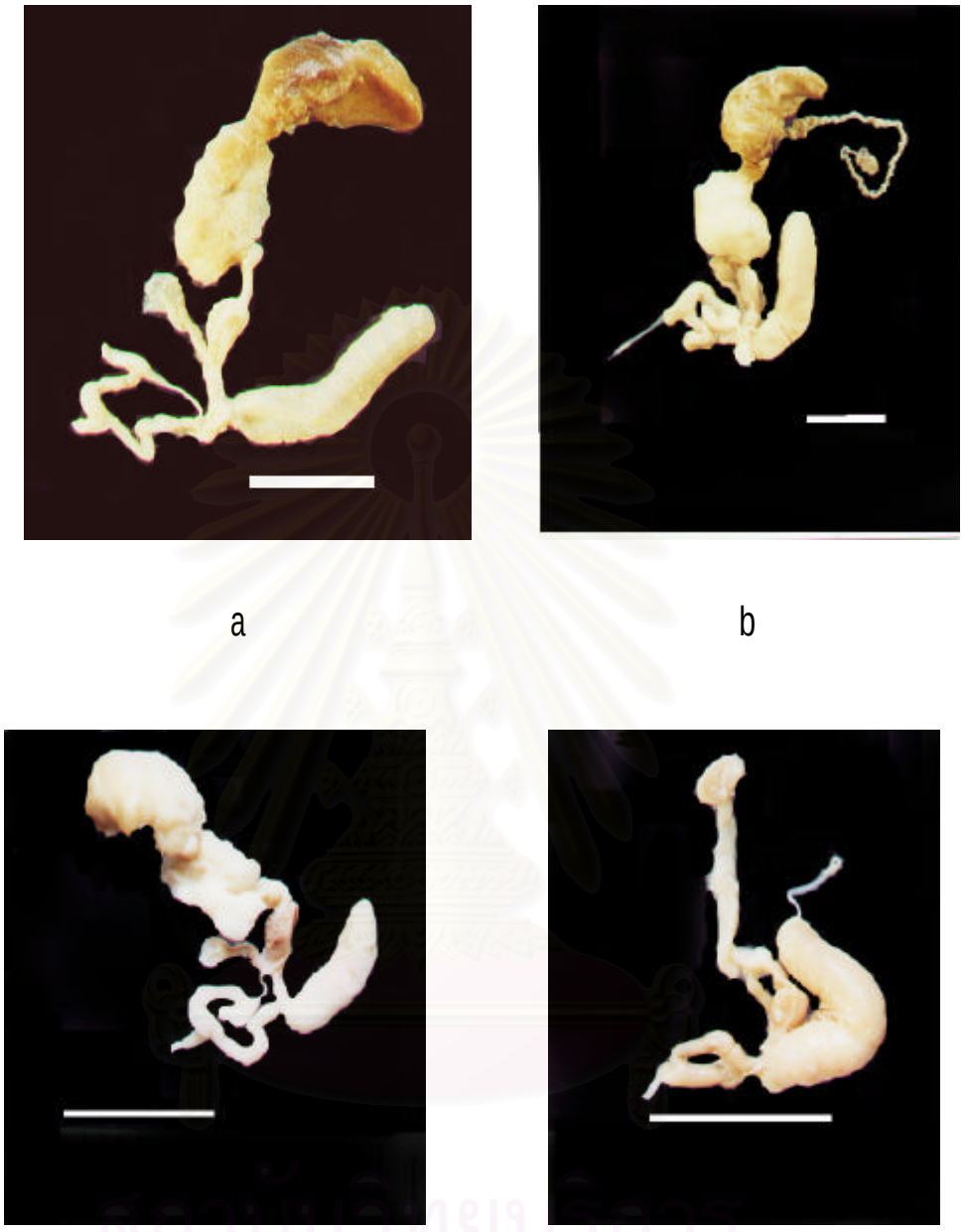


Figure 4.10 Comparative genital system of *M. siamenis* from different localities; a) Khonkean; b) Cuc Phuang National park North Vietnam; c) Chaiyaphum; d) Loei. a) and b) at scale bars 1 cm, c) and d) at scale bars 0.25 cm.

Genus *Cryptaustenia* Cockerell, 1898

Description: Shell depressed, with about 3-3 ¼ whorls. Body length is about 52.5 mm in adult specimens; body color is yellow, black; visceral hump and shell is small. Tail is very elongated with prominently protruded caudal horn. Umbilicus closed. Dart apparatus is short and small or absent.

Distribution: Bengal, Calcutta, Jessore, Sikhim, Bhutan, Assam, Cachar, Rajmahal, Khasi Hills, Tavoy, Tenasserim, Sadiya, Eastern Assam, Upper Rotung, Arbor Hills, Dajiling, south Syllhet Hills, and Thailand.

cf. *Cryptaustenia* sp.1

(Fig. 4.11)

Shell diameter ranges 11.5-20 mm, thin, pale yellow color; about 3.0-3 ¼ whorls, body whorls depressed and increasing rapidly; a shell lappet covering body surface; spire depressed; aperture very large roundly ovate. Umbilicus closed. Foot and tail are very long and slender about 50-60 mm.; body color is yellow. Visceral hump large, located just behind the head; tail over twice as long as head and visceral hump. Caudal foss is absent, caudal horn is very large and overhang. Lateral edges of mantle extended into left and right pallial lappets which cover shell, right body lappet superior to pneumostome, mantle collar is narrow; shell laps with large pebbling, scattered black markings on the surface.

Genital system: Ovotestis embedded in the mid-gut gland; hermaphroditic duct is small, convoluted in middle portion and straight on surface of albumen gland. Albumen gland is small, triangular shape. Uterus is well developed, extremely swollen by pregnancy; lower region of uterus which attaches to prostate gland is small and slender. Vas deferens is slender tube, entering the apex of epiphallus, epiphallus is slender, small ,well developed, lacking epiphallic retractor caecum and lime-sac. Free oviduct is long and slender; vagina is large; spermatheca is long and slender; penis is large and long; genital atrium below and slightly posterior to right ocular tentacle. Dart apparatus is absent.

Radula: radula formula (45-53):1:(45-53). Central tooth is tricuspid, with broad basal plate, mesocone very large and slender, ectocone are prominent. Lateral teeth are tricuspid. First laterals are closely similar to central in size and shape, each having a prominent endocone and ectocone, ectocone almost equal to endocone in size and shape, mesocone is very large and broad, entocone prominent nearer mesoconal tip. Marginal teeth are tricuspid, elongate with large mesocone. Endocone and ectocone. reduced narrow basal plate. Outer marginal, mesocone, endocone and ectocone are equal in size (Fig. 4.12)

Habitat note: cf. *Cryptaustenia* sp.1 frequently found on surface of tree trunk and log.

Locality: Chiangrai Province

Diagnosis: Dart apparatus, lime-sac, and epiphallic retractor caecum are absent. Radula with tricuspid central tooth; laterals teeth and marginal teeth.

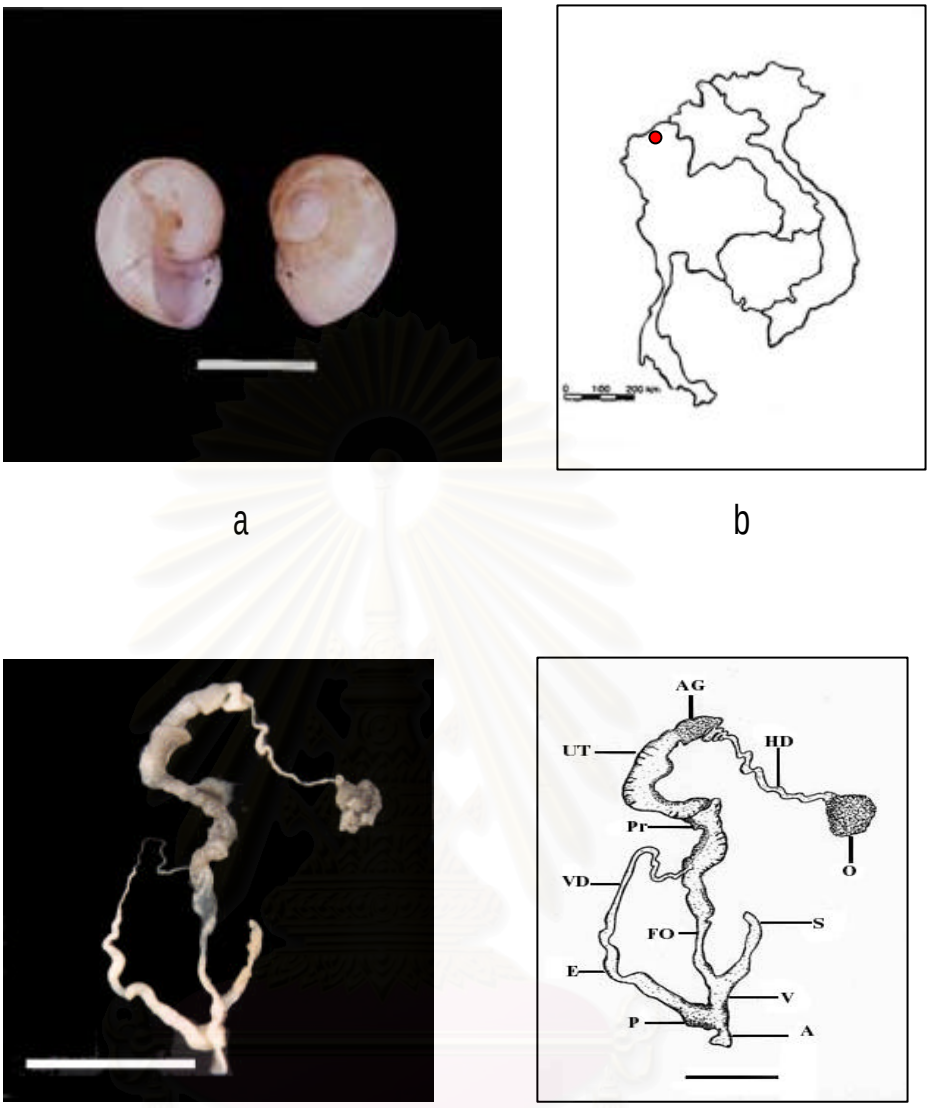


Figure 4.11 cf. *Cryptaustenia* sp.1; a) shell morphology; b) distribution; Chiangrai Province; c) and d) genitalia at scale bar 1 cm. (abbreviations are shown in page xi).

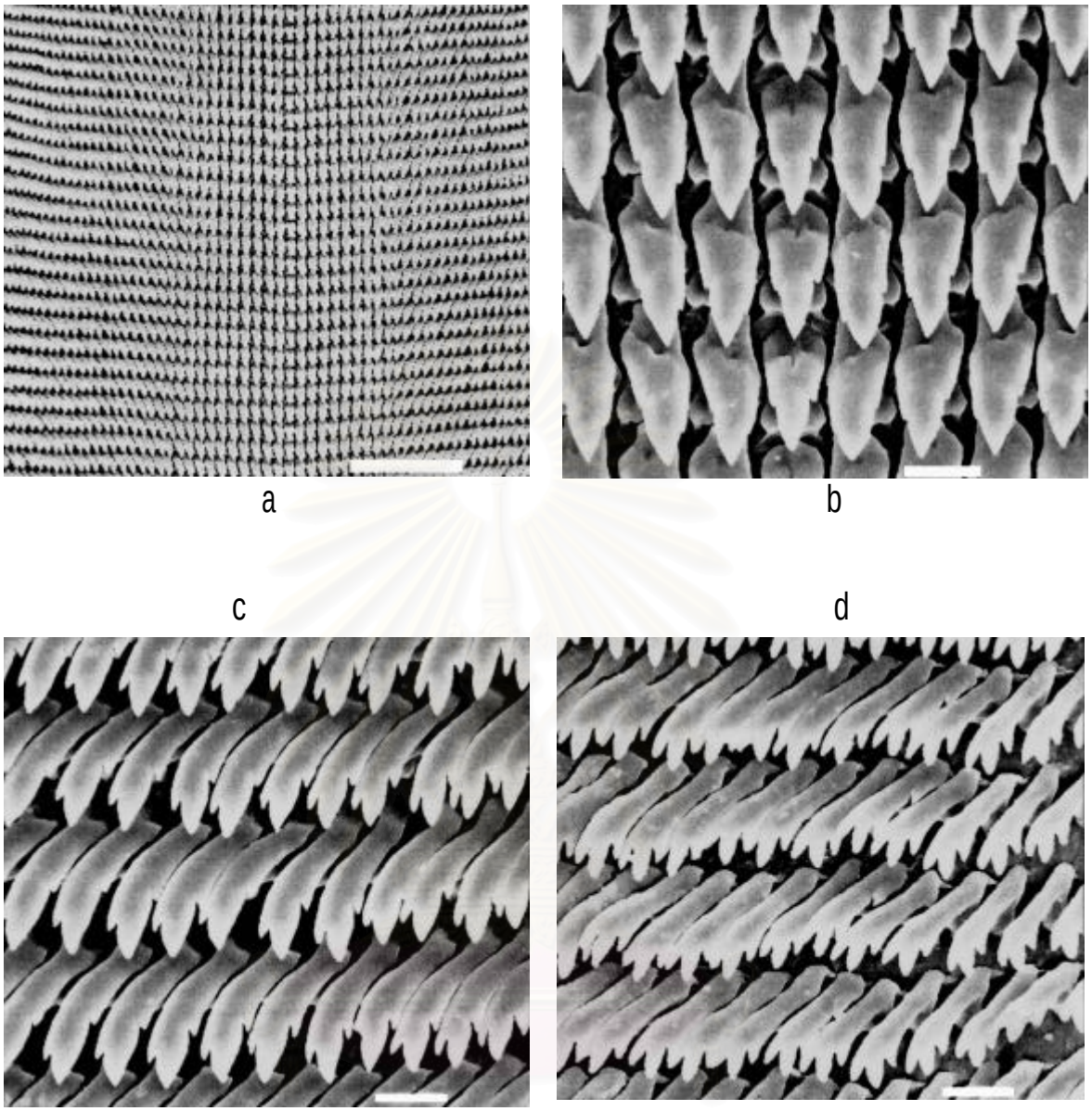


Figure 4.12 Radula of cf. *Cryptaustenia* sp.1; a) radula rows at scale bar 100 μm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d scale bars 10 μm.

cf. *Cryptaustenia* sp. 2

(Fig. 4.13)

Shell diameter ranges 11.5-17.5 mm., thin, pale yellow color; there are about 3.0-3½ whorls; body whorls depressed and increasing rapidly, a lappets covering body surface; spire depressed ,aperture very large and roundly ovate. Umbilicus closed. Foot and tail are very long and slender about 45-60 mm., Body color is very black. Visceral hump large, located just behind the head. Tail over twice as long as head and visceral hump. Caudal foss is absent, caudal horn is very large and overhung. Lateral edges of the mantle extended into left and right pallial lappets which cover the shell. Right body lappet superior to pneumostome, mantle collar is narrow. Shell lap with large pebbling, scattered black markings on the surface.

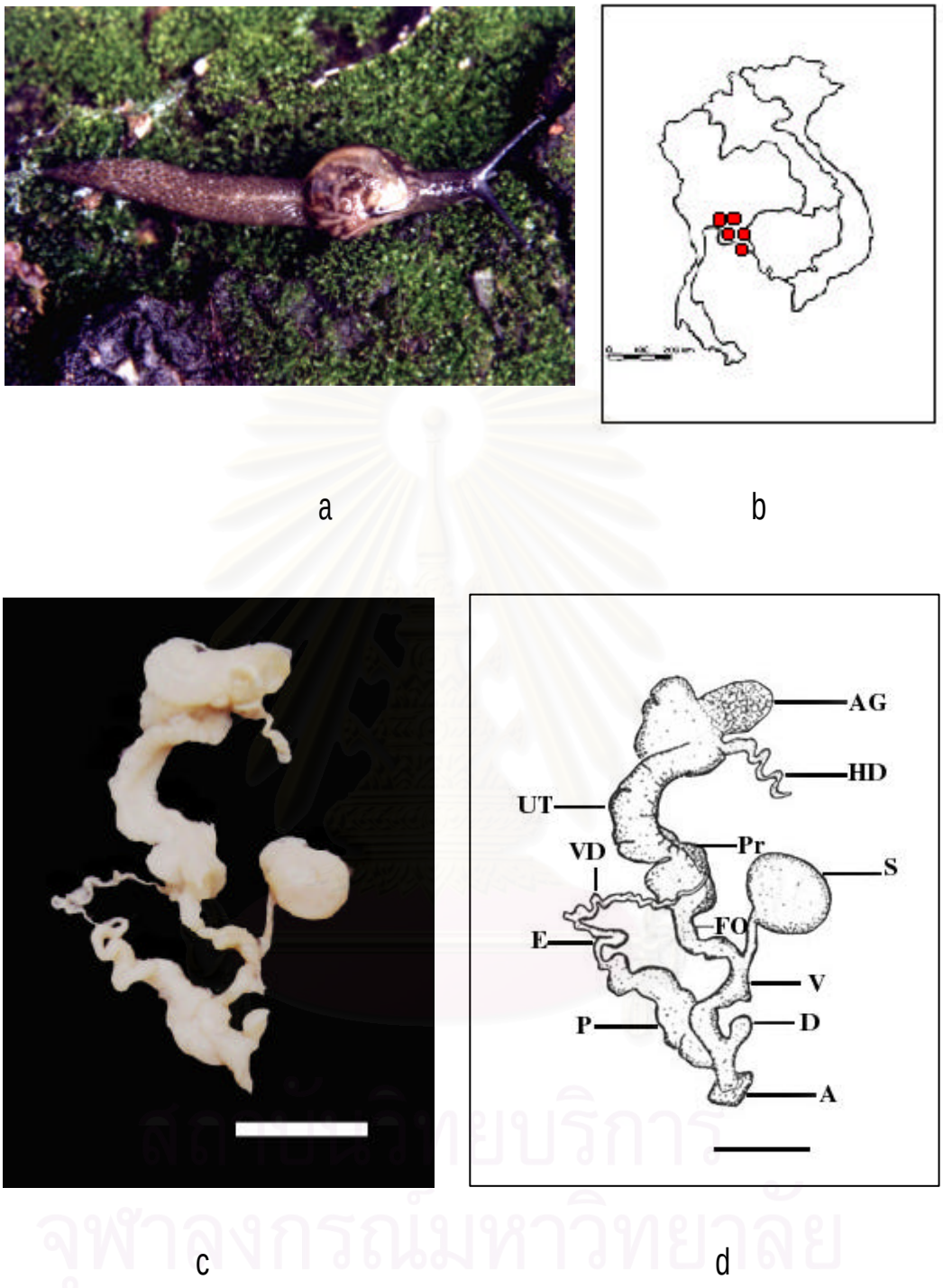
Genital system: Ovotestis embedded in the mid-gut gland, hermaphroditic duct is small, sinuated in middle portion and straight on surface of albumen gland. Albumen gland is large triangular. Uterus is well developed, extremely swollen by pregnancy; prostate is small and slender. Vas deferens is slender tube, entering the apex of epiphallus. Epiphallus is rather long, well developed, without caecum (EF) or lime-sac and epiphallic retractor caecum; penis is very large and long, free oviduct is short, thin walled. Vagina is large and short. Spermatheca is long stalk with swollen head and rounded. Genital atrium below slightly posterior to right ocular tentacle. Dart apparatus locating in male side is very small, thin walled, and enters into the base of penis. Atrium is short and thin walled.

Radula: radula formula (55-59):1:(55-59). Central tooth is tricuspid, with broad basal plate, mesocone very large and slender, ectocone are prominent. Lateral teeth are tricuspid. First laterals are closely similar to central in size and shape, each having a prominent endocone and ectocone; ectocone almost equal to endocone in size and shape, mesocone is very large and broad, endocone prominent nearer mesoconal tip. marginal teeth are tricuspid, elongate with large mesocone, endocone and ectocone, reduced narrow basal plate. Outer marginal the mesocone, endocone and ectocone are equal in size (Fig. 4.14)

Habitat note: cf. *Cryptaustenia* sp. 2 is often found on surface of trunk and log.

Localities: Chachoengsao, Chonburi, Trad, and Chanthaburi Province

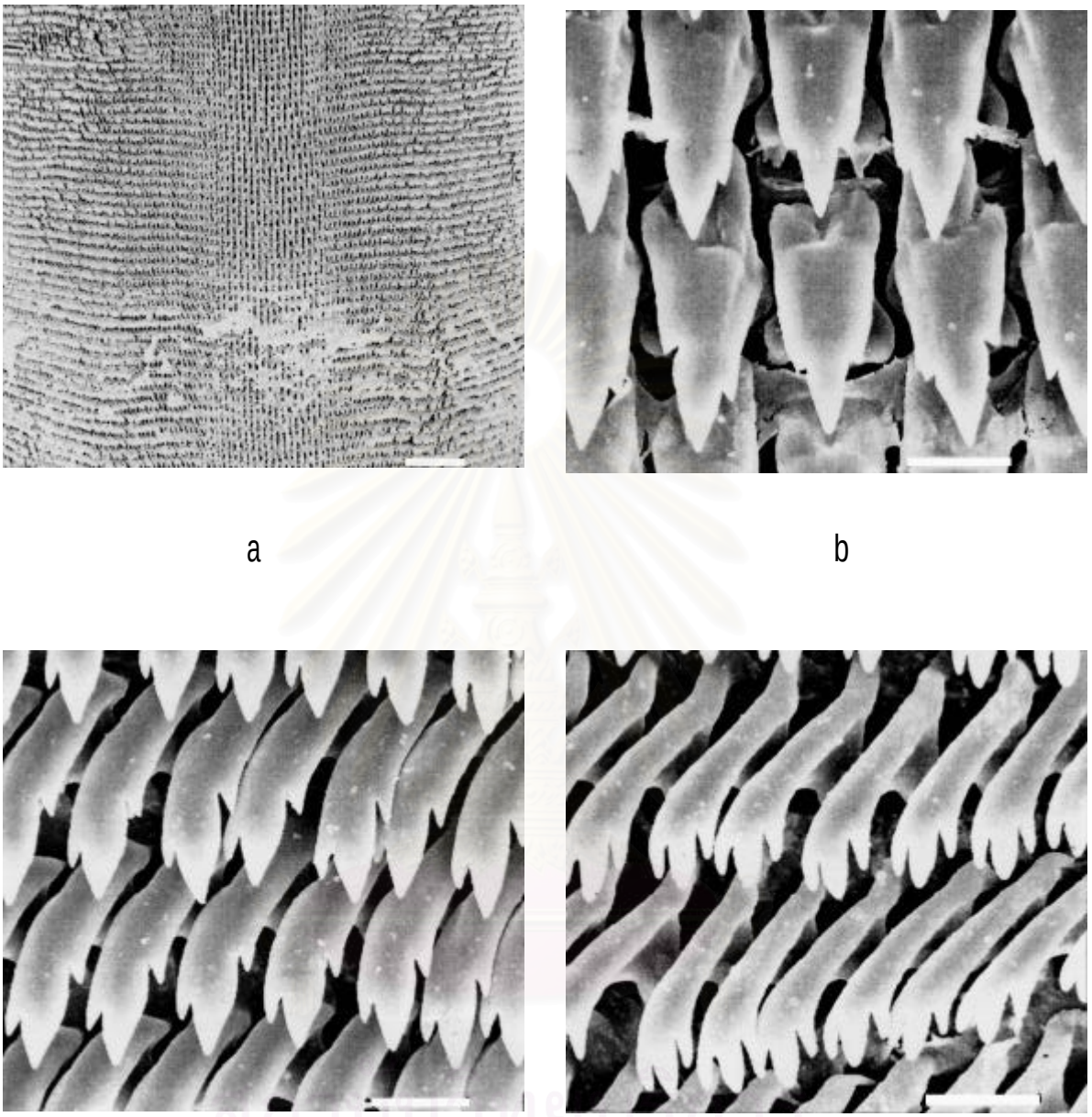
Diagnosis: Tail very elongated with prominently protruding caudal horn; caudal absent, with 4 ¼ to 4 ½ whorls. Body length about 52.5 mm in adult specimens; body color is very dark; umbilicus closed, dart apparatus is very small. Lime-sac and epiphallic retractor caecum are absent. Radula with tricuspid central, laterals and marginal teeth.



a b

c d

Figure 4.13 cf. *Cryptaustenia* sp.2; a) live specimen; b) distribution; Chachoengsao, Chonburi, Rayong, Trad, and Chanthaburi Provinces; c) and d) genitalia at scale bar 1 cm. (abbreviations are shown in page xi).



a b

c d

Figure 4.14 Radula of cf. *Cryptaustenia* sp. 2; a) radula rows at scale bar 100 μm; b) central tooth and lateral teeth; c) latero- marginal teeth and d) marginal teeth. b, c and d scale bars 10 μm.

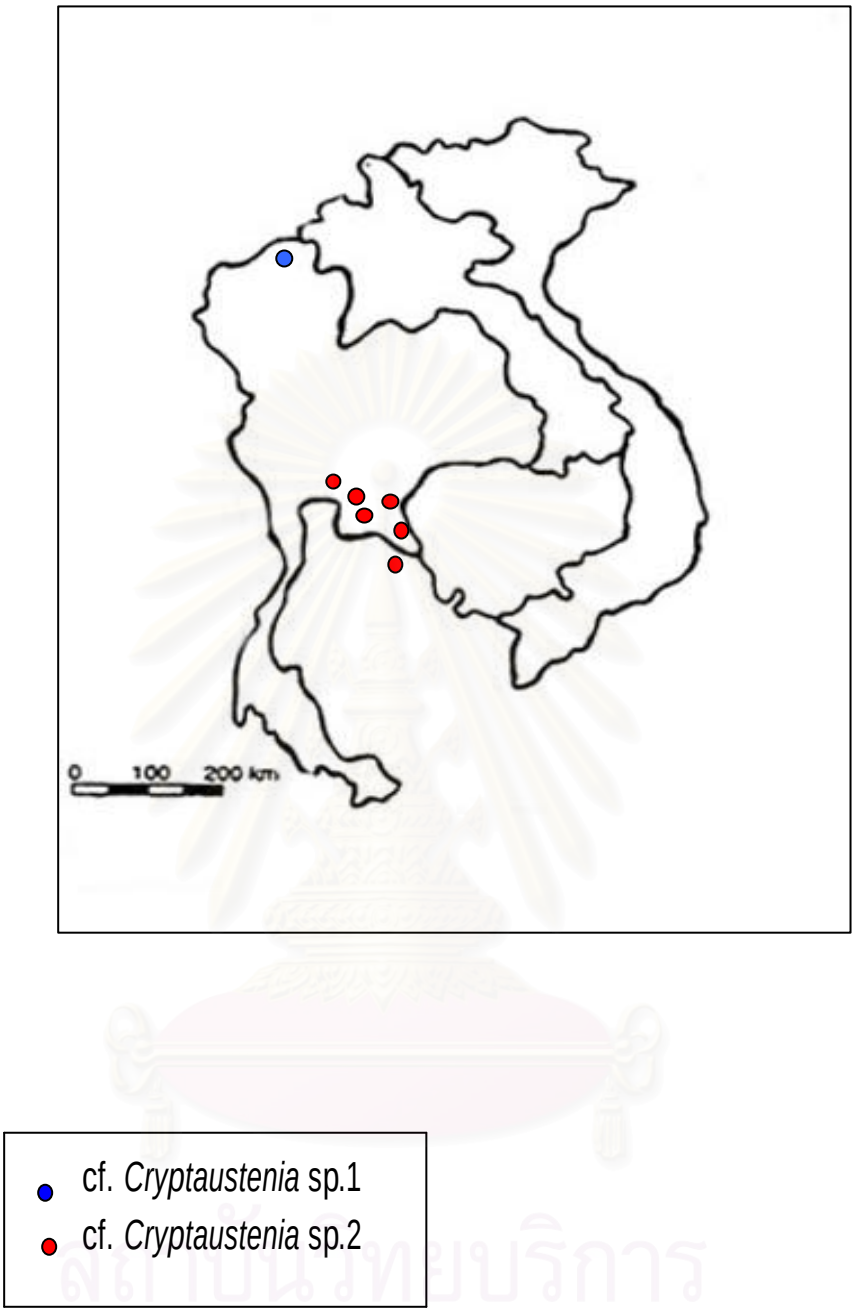
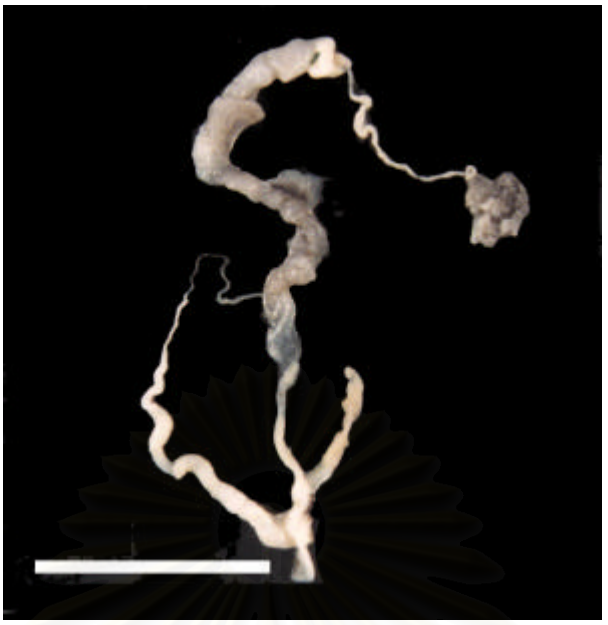


Figure 4.15 Distribution of cf. *Cryptaustenia*.



a

b

Figure 4.16 Comparative genital system of cf. *Cryptaustenia*; a) cf. *Cryptaustenia* sp.1; b) cf. *Cryptaustenia* sp.2. At scale bars 1 cm.

Genus *Durgella* Blandford, 1863

Description: shell is depressed and thin, with 4 ¼-4 ½ whorls; lobes of the mantle partially covering the shell when expanded. Foot and tail are very short, caudal horn is very hanging, caudal foss indented in tail. In generative organs, a dart apparatus is large, spermatheca is of moderate in size, wide at the base, constrict and broader again at the end. Radula is pectiniform.

Distribution: Indo-Malay region, Tenasserim Burma, Assam, south Andamans, India, upper Pegu, Burma and Thailand.

Durgella libas Solem, 1966

(Fig.4.17)

Shell diameter ranges 7.00-9.84 mm, in adult specimens; thin, with color yellow. There are about 3 ¼-4 ½ whorls, body whorls depressed and increasing rapidly. Spire is not depressed. Foot and tail are elongated. Caudal horn greatly overhung. Caudal foss indented with opening occupying middle of the tail. Mantle collar is narrow, shell laps is very large. Body color is yellow and gray.

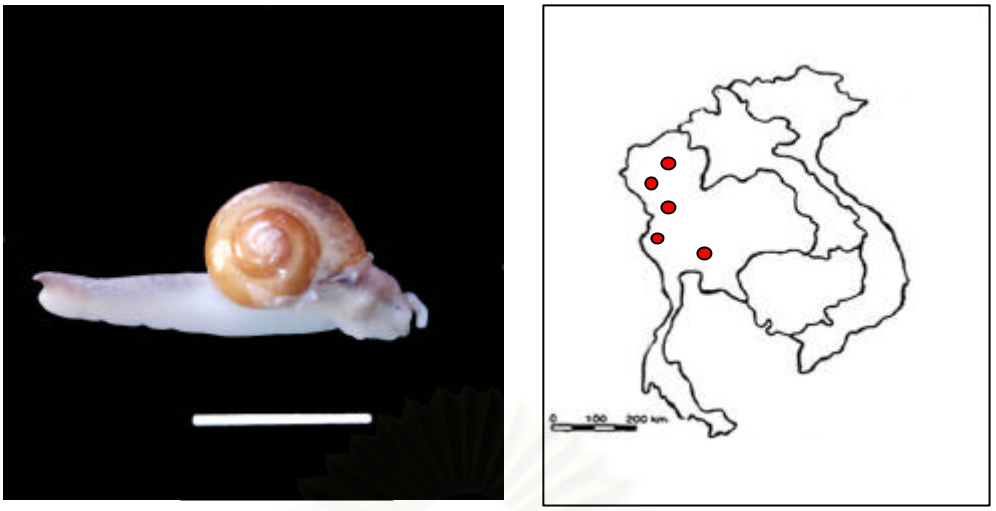
Genital system: Ovotestis embedded in the mid-gut gland at the second apical shell whorl and consist of three clusters alveoli; hermaphroditic duct is small, slightly convoluted. Albumen gland is small and triangular shape. Prostate gland and uterus are well developed, extremely swollen by pregnancy. Vas deferens is small, slender tube, entering the apex of epiphallus. Epiphallus with enlarge tip, containing an expanded terminal pilaster insertion of penial retractor. Penis is s-shape, large and long. Free oviduct is rather long and slender, vagina is large, short, and thick walled. Spermatheca is large at basal stalk, an extremely narrow neck, and an upper thin-walled sac that lies bound to “s” loop. Dart apparatus is very large and thick walled. Atrium is very short.

Radula: radula teeth very small and pectiniform. Radula formula 400+:1: 400+. central tooth reduced. Latero-marginal teeth are very small, bicuspid with several tiny accessory ectoconal cusps. Marginal teeth are bicuspid. (Fig.4.18)

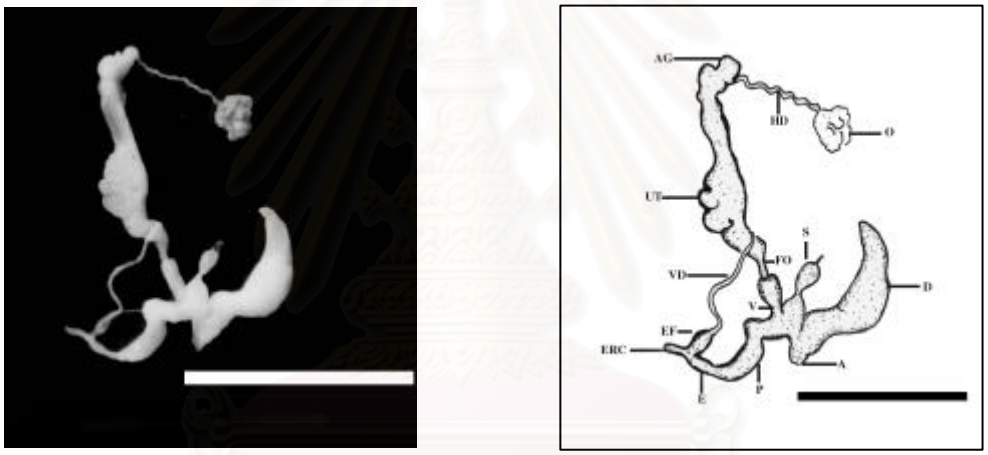
Habitat notes: *D. libas* usually found crawling on the leaf surface of bamboo.

Localities: Sai Yok Kanchanaburi Province, Khao Yai National Park in Nakhonrhatchasima Province. Inthanon National Park (Chiangmai Province) and Tak Province.

Diagnosis: shell small, foot and tail are small, short, caudal horn is distinctly hanging. Dart apparatus is large, spermatheca is s-shape, large and long. Radula is pectiniform.



a b



c d

Figure 4.17 *Durgella libas*; a) external morphology; b) distribution; Sai Yok (Kanchanaburi Province), Khao Yai National Park (Nakhonrhatchasima Province), Doi Inthanon National Park (Chiangmai Province) and Tak Province; a), c) and d) genitalia at scale bar 1 cm. (Abbreviations are shown in page xi).

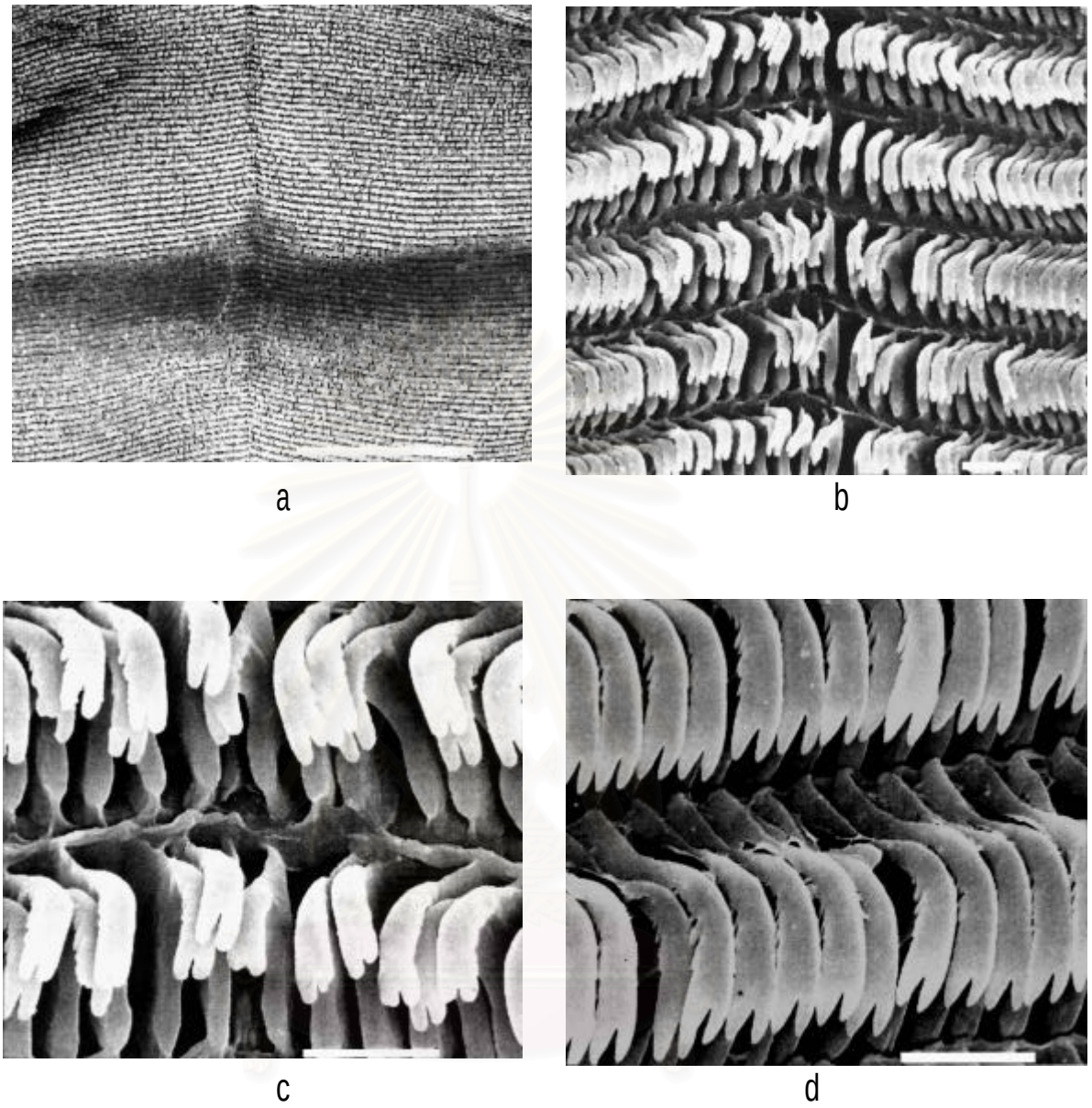


Figure 4.18 Radula of *Durgella libas*.; a) radula rows at scale bar 500 μm; b) central tooth and lateral teeth; c) latero-marginal teeth; d) marginal teeth.b, c,and d at scale bars 10 μm.

Durgella sp.1

(Fig. 4.19)

Shell diameter ranges 6.50-8.44 mm., in adult specimens, thin, depressed, color is yellow. There are about 3 1/4-4 ¼ whorls, body whorls depressed and increasing rapidly, spire depressed. Foot and tail are very elongated. Caudal horn greatly overhung. Caudal foss indent with opening occupying middle of the tail. Mantle collar is narrow, shell laps is very large. Body color is yellow and gray.

Genital system: Ovotestis embedded in the mid-gut gland, second apical whorl and consist of three clusters of alveoli; hermaphroditic duct is small, slightly convulated. Albumen gland is very large and triangular. Prostate and uterus are well developed, extremely swollen by pregnancy. Vas deference is a small, slender tube, entering the apex of epiphallus. Epiphallus with enlarge tip, containing an expanded terminal pilaster tapering towards insertion of penial retractor. Penis is very large and long. Free oviduct is rather long and slender. Vagina is large, short, and thick walled. Spermatheca is large with basal stalk, an extremely narrow neck, and an upper thin-walled sac that lies bound to “s” loop. Dart apparatus locating on male side is large, thick walled, and enters into base of penis. Atrium is very short.

Radula: radula teeth very minute and pectiniform. Radula formula 400+:1:400+. central tooth reduced or absent. Latero-marginal teeth very small, bicuspid with several tiny accessory ectoconal cusps. First lateromarginal with base opposite elevate portion of central tooth. Outer most teeth is shorter than inner lateromarginal (Fig.4.18)

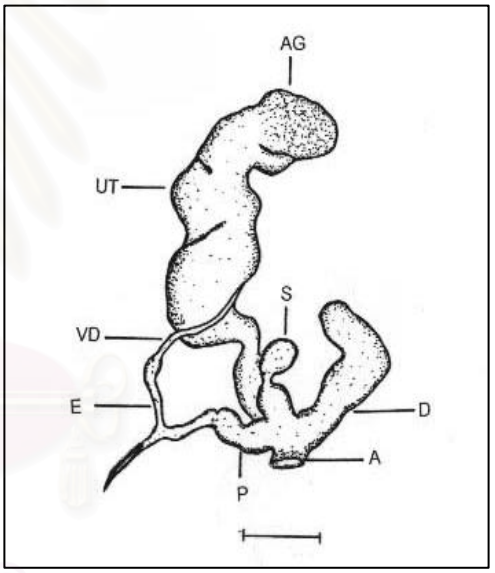
Habitat notes: *Durgella* sp1 is often found on leaf surface of tree.

Localities: Ko Samui Suratthani Province, Chachoengsao, Chonburi, Srakaew, and Chanthaburi Provinces.

a

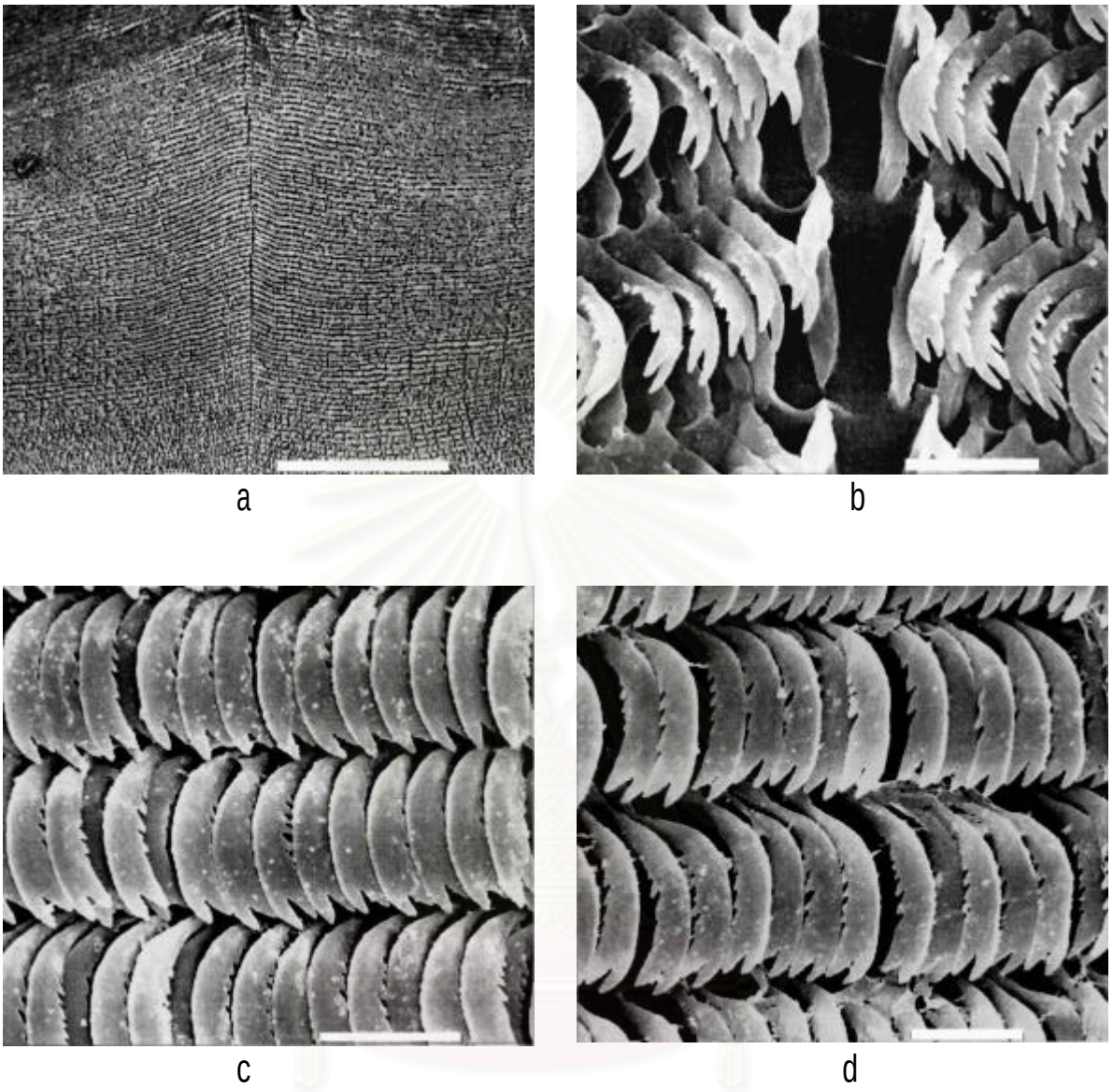
b

c



d

Figure 4.19 *Durgella* sp.1; a) live specimens; b) distribution; Ko Samui Suratthani Province, Chachoengsao, Chonburi, Srakaew, and Chanthaburi Provinces; c) and d) genitalia at scale bar 1 cm. (Abbreviations are shown in pages xi).



a b

c d

Figure 4.20 Radula of *Dugella* sp.1; a) radula rows at scale bar 500 μm; b) central tooth and lateral teeth; c) latero-marginal teeth, d) marginal teeth b, c, and d at scale bars 10 μm.

Durgella sp. 2

(Fig. 4.21)

Shell diameter ranges 7.25-8.50 mm., in adult specimens, thin, depressed, color is yellow. There are about 3.0-3 ¼ whorls; body whorls depressed and increasing rapidly. Foot and tail are very elongated. Caudal horn greatly overhang. Caudal foss indent with opening occupying middle of the tail. Mantle collar is narrow, shell laps is very large and cover shell more than ½of shell, body color is yellow.

Genital system: Ovotestis is embedded in the mid-gut gland, and consist of three clusters of alveoli; hermaphroditic duct is small, slightly sinuate at first, then tightly folded until reaching surface of albumen gland. Albumen gland is very large and triangular. Prostate and uterus are well developed, extremely swollen by pregnancy. Vas deference is a small, slender tube, entering the apex of epiphallus. Epiphallus with small tip, containing an expanded terminal pilaster tapering towards insertion of penial retractor. Penis is very small, slender and long. Free oviduct is rather long and slender. Vagina is long, slender and thin walled. Spermatheca is slender with basal stalk, an extremely narrow neck, and an upper thin-walled sac that lies bound to “s” loop. Dart apparatus locating on male side is very long and slender, thin walled, and enters into base of penis. Atrium is very short and thin walled.

Radula: radula teeth very large and pectiniform. Radula formula 375+:1: 375+. Central tooth is reduced and narrow. Lateromarginal teeth are very large, bicuspid with several large accessory ectoconal cusps. First lateromarginal with base opposite elevate portion of central tooth. Outermost teeth and inner lateromarginal teeth are equal in size and shape. (Fig.4.22).

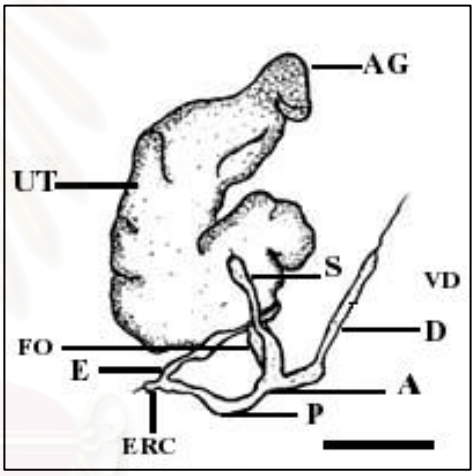
Habitat notes: *Durgella* sp.2 usually found on leaf surface of tree.

Locality: Ko Tachai Phang-nga Province.

a

b

c



d

Figure 4.21 *Durgella* sp.2; a) external morphology at scale bar 1 cm.; b) distribution; Ko Tachai Phang-nga Province; c) and d) genitalia at scale bars 1 cm. (Abbreviations are shown in page xi).

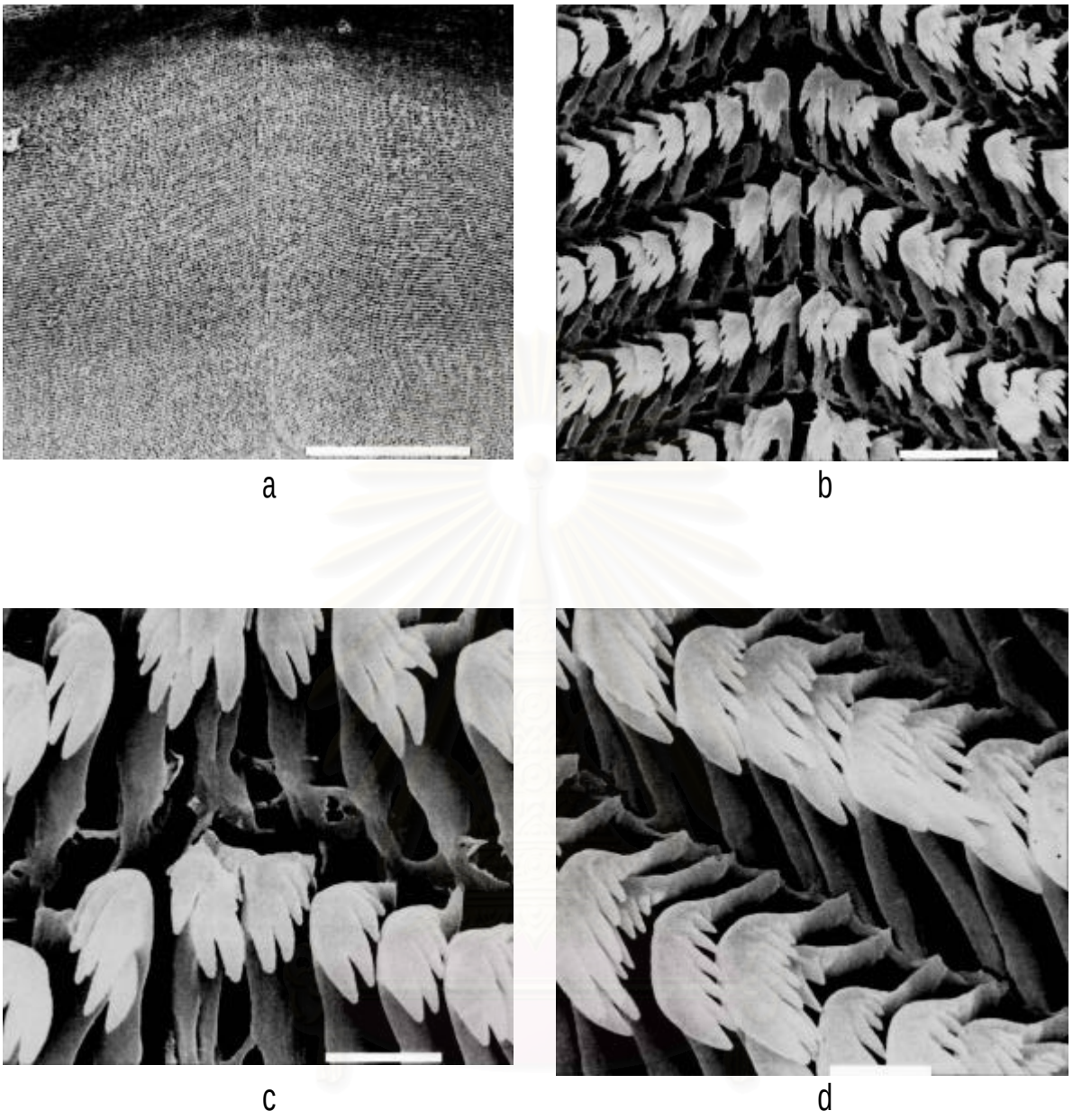


Figure 4.22 Radula of *Durgella* sp.2; a) radula rows at scale bar 500 μm; b)central tooth and lateral teeth at scale bar 10 μm; c)central-lateral teeth at scale bar 5 μm; d) latero-marginal teeth at scale bar 5 μm.

Durgella sp. 3

(Fig. 4.23)

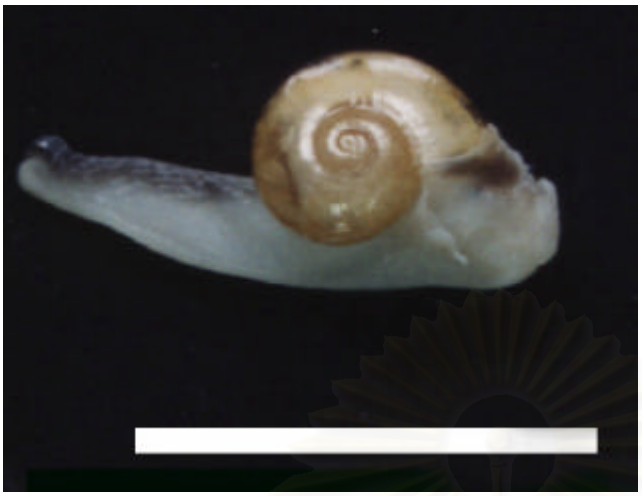
Shell diameter ranges 4.55-6.4 2 mm., in adult specimens, thin, depressed, color is yellow and shinning. There are about 3 ¼ -3 ½ whorls; body whorls depressed and increasing rapidly. Foot and tail are very elongated. Caudal horn greatly overhang. Caudal foss indented with opening occupying middle of the tail. Mantle collar is narrow, shell laps is very large and cover shell more than ½of shell, body color is yellow.

Genital system: Ovotestis is embedded in the mid-gut gland, and consist of three clusters of alveoli; hermaphroditic duct is small, slightly sinuate at first, then tightly folded until reaching surface of albumen gland. Albumen gland pear-shape and well developed. Prostate and uterus are well developed, extremely swollen by pregnancy. Vas deference is a small, slender tube, entering the apex of epiphallus. Epiphallus with small tip, containing an expanded terminal pilaster tapering towards insertion of penial retractor. Penis is very small, slender and long. Free oviduct is greatly swollen and enlarged. Vagina is long, slender and thin walled. Spermatheca with very long basal stalk, an extremely narrow neck then constricted and broader again at the end. Dart apparatus absent. Atrium is very short and thin walled.

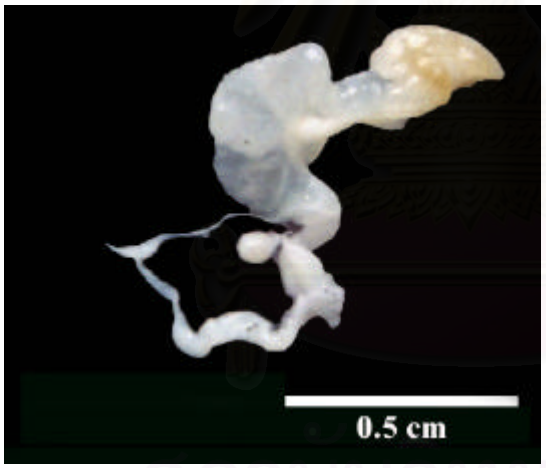
Radula: radula teeth very large and pectiniform. Central tooth is reduced and narrow. Latero-marginal teeth are very large, bicuspid with several large accessory ectoconal cusps. First latero-marginal with base opposite elevate portion of central tooth. Outermost teeth and inner latero-marginal teeth are equal in size and shape. (Fig.4.24).

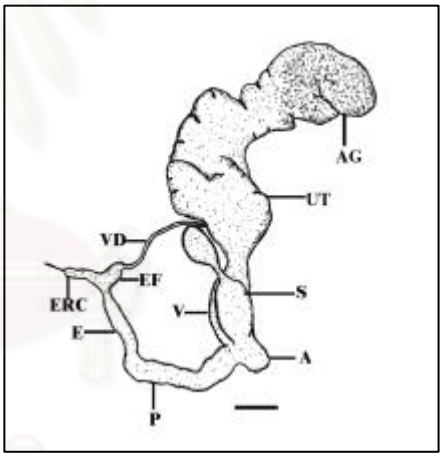
Habitat notes: *Durgella* sp.3 usually found on leaf surface of tree.

Locality: Sabah, Malaysia.



a b





c d

Figure 4.23 *Durgella* sp.3; a) external morphology at scale bars 1 cm.; b) distribution; Sabah, Malaysia; c) and d) genitalia at scale bars 0.5 cm. (Abbreviations are shown in page xi).

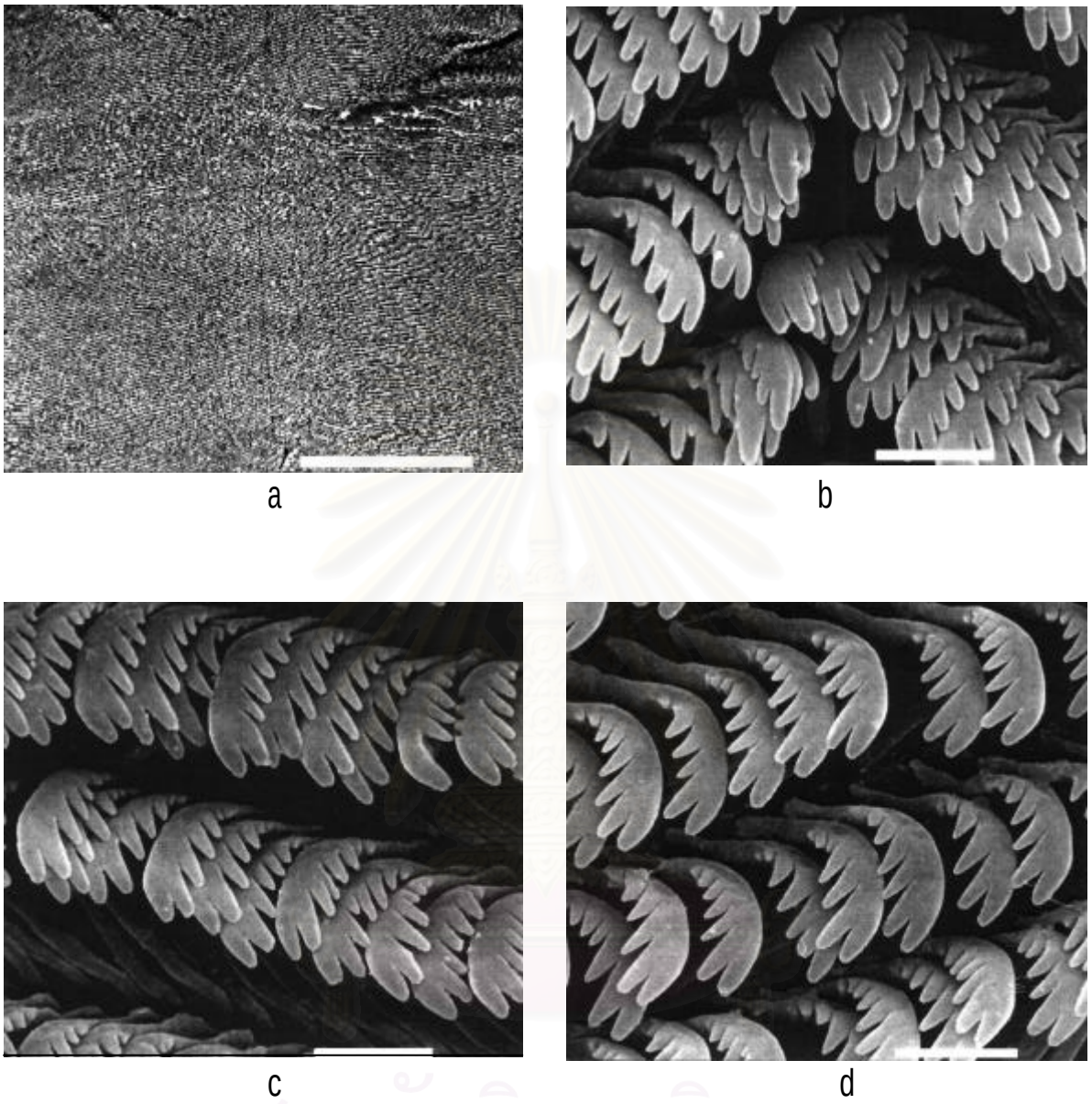


Figure 4.24 Radula of *Durgella* sp.3; a) radula rows at scale bar 500 μm; b) central tooth and lateral teeth at scale bar 10 μm; c)central-lateral teeth at scale bar 5 μm; d) latero-marginal teeth at scale bar 5 μm.

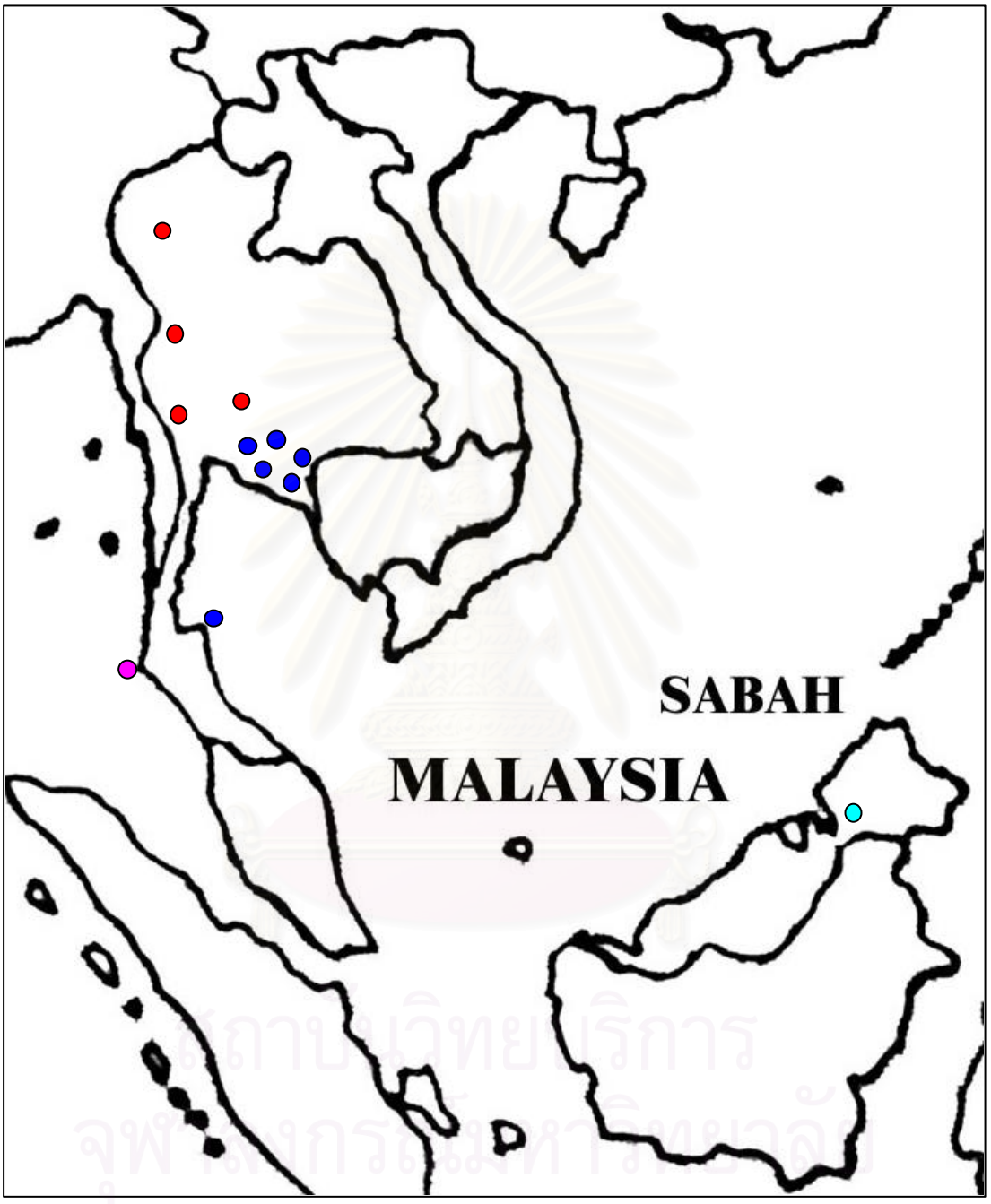


Figure 4.25 Distribution of *Durgella*.

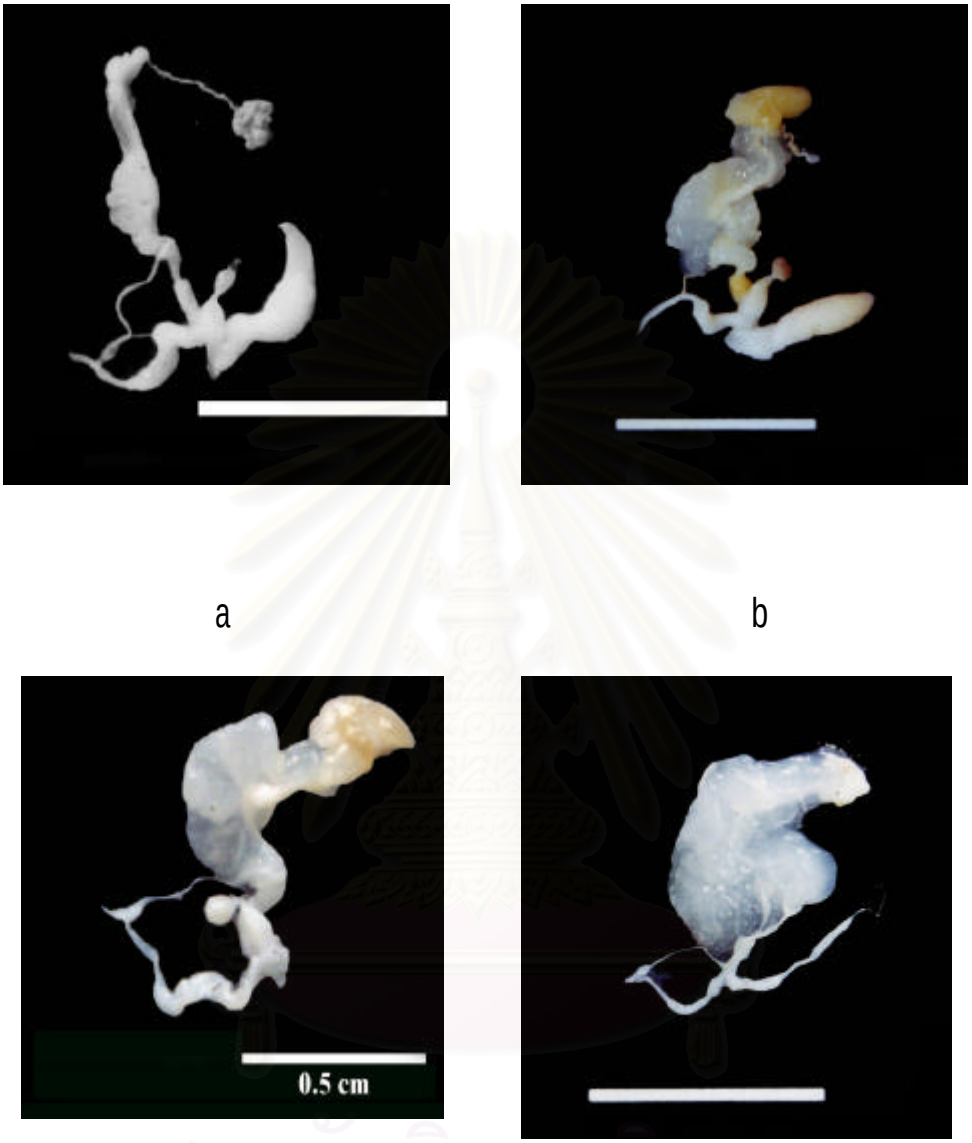


Figure 4.26 Comparative genital system of *Durgella*; a) *Durgella libas*; b) *Durgella* sp.1; c) *Durgella* sp.3 at scale bar 0.5 cm.; d) *Durgella* sp.2. a), b) and d) at scale bars 1 cm.

Parmarion Heude, 1885

Description: Shell reduced to a calcified cap-like, having only single remnant of coiling and completely covered by fused shell laps. Mantle lobes forming large cephalic shield reaching near the eyes. Tail is very long and slender, sharp keeled mid-dorsally, with hooked caudal horn, color yellow with black stripes. With large dart apparatus, spermatheca is ver short, The penis complex is also similar to that of *Mariella* but with a much reduced epiphallic flagellum.
Distribution: Malaysia

Parmarion sp.1
(Fig.4.27)

Shell reduced to a cap like. Slug-like snail. Mantle lobes is large cephalic shield reaching near the eyes. Tail is very long and large sharp mid-dorsally keeled , with large caudal foss and caudal horn. Caudal horn is prominent, slightly overhang. Caudal foss a transverse slit up under caudal horn. Body color yellow. Pallial region compressed with organ distorted. Mantle lobe and shell laps are fused completely covering shell and visceral hump.

Genital system: Ovotestis embedded in mid-gut gland. Hermaphroditic duct is small, a simple tube, convoluted at first and straight to surface of albumen gland. Albumen gland is very large and triangular shape. Prostate gland and uterus are well developed, extremely swollen by pregnancy. Vas deferens is very long and slender, entering the apex of epiphallus besides lime-sac; lime-sac is small and prominent. Epiphallus is very short and small, slightly broader than vas deferens, with prominent epiphallic retractor caecum. Penis is very large, thick walled and short; free oviduct is rather short and large, vagina is small and long. Spermatheca is bulb shape. Dart apparatus is very large, consists of long and slender basal stalk, narrow stalk and cylindrical large head. Atrium is very short and thick walled.

Radula: radula formula (65-71):7:1:7:(65-71) with 85 rows, and central tooth is tricuspid, large and long with broad basal plate. Mesocone is very long and slender, ectocones are prominent, extending far past edge of basal plate. Lateral teeth are

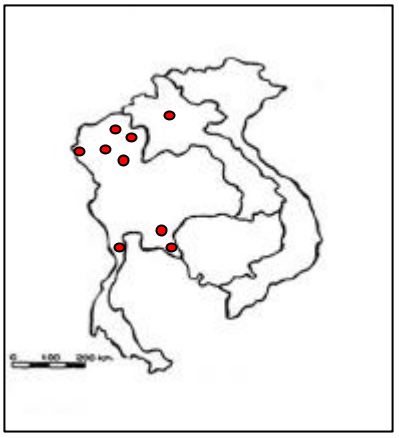
tricuspid. First lateral with small endocone near mesoconol tip, ectocone is large; after tenth lateral, ectocone increasing, endocone reduced and lost in marginal teeth. Marginal teeth are bicuspid, ectocone and mesocone are equal in size (4.26).

Habitat notes: *Parmarion* sp 1 frequently found on leaf surface of tree. Sometimes live on the rock..

Localities: Prachinburi, Phayao, Nan, Chiangmai, Rayong, Phetchaburi, Maehongson Provinces and Laos (Wang vieng and Laung Phra bang).

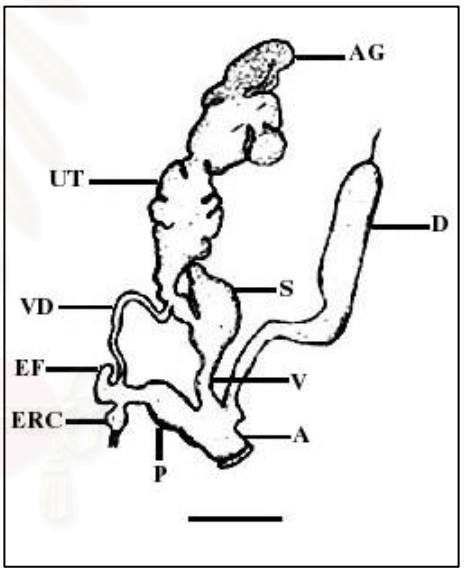
Diagnosis: shell reduced to a cap-like, slug-like snails, tail is long, caudal foss is large, caudal horn is overhang, visceral hump nearer to the eyes than the tail, Genitalia with a large dart apparatus, penis is very large, epiphallus is very short. Spermatheca is very large and short.

a



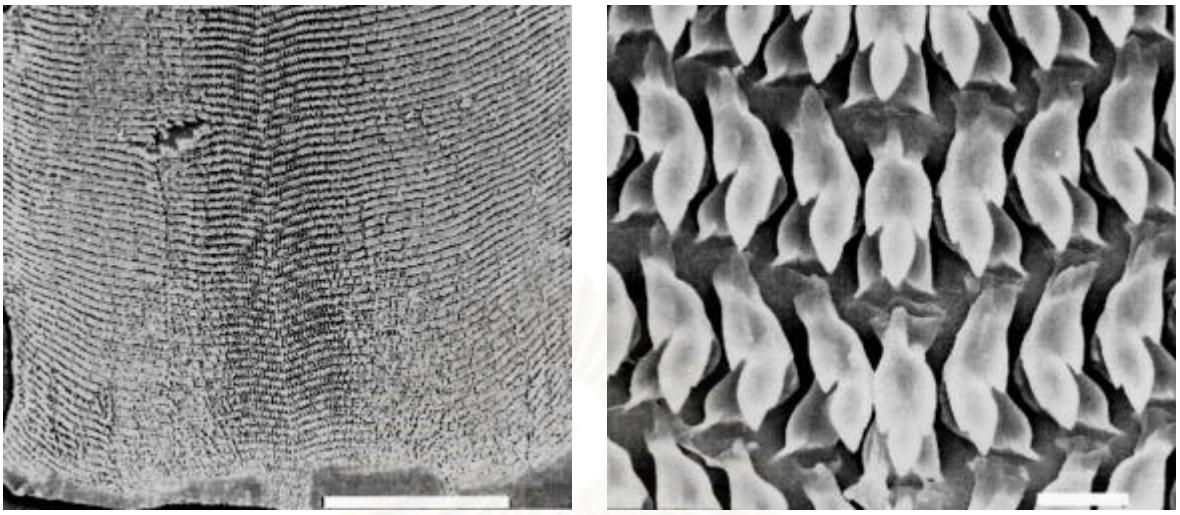
b

c

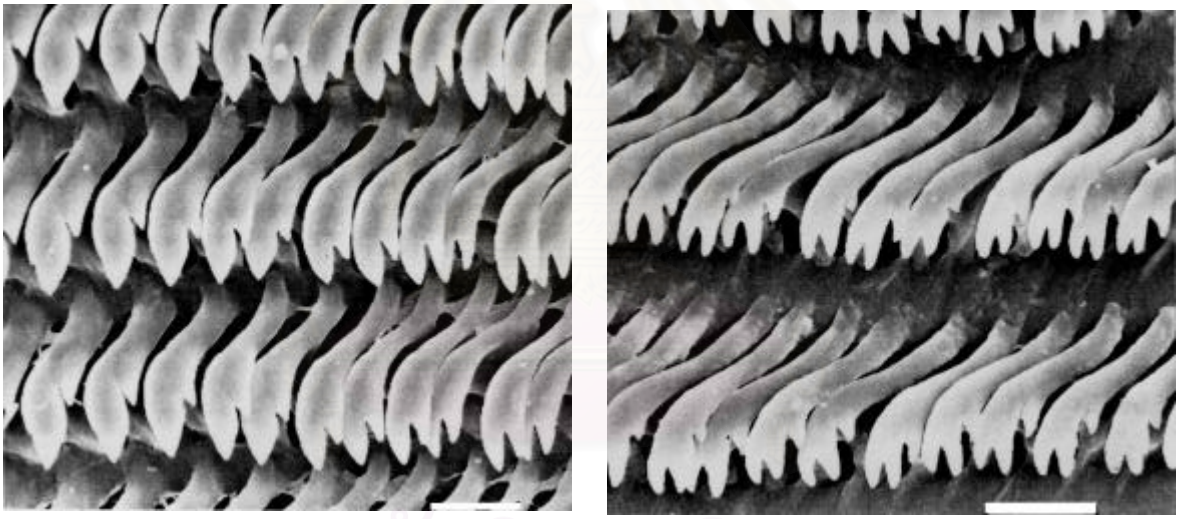


d

Figure 4.27 *Parmarion* sp.1; a) live specimens; b) distribution; Prachinburi, Phayao, Nan, Chiangmai, Rayong, Phetchaburi, Maehongson Provinces and Laos (Wang vieng and Laung Phra bang); c) and d) genitalia at scale bar 1 cm. (Abbreviations are shown in page xi).



a b



c d

Figure 4.28 Radula of *Parmarion* sp.1.; a) radula rows at scale bar 500 μm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d at scale bars 50 μm.

Parmarion sp.2

(Fig.4.29)

Shell reduced to a cap like. Slug-like snail. Mantle lobes forming large cephalic shield reaching near the eyes. Tail is very long and slender with large caudal foss and caudal horn. caudal horn is prominent, slightly overhang. Caudal foss a transverse slit up under caudal horn. Body color yellow and black. Pallial region compressed and organ distorted. Mantle lobe and shell laps are fused completely covering the shell.

Genital system: Ovotestis embedded in mid-gut gland. Hermaphroditic duct is small, a simple tube, convoluted at first and straight to surface of albumen gland. Albumen gland is very small and triangular shape. Prostate gland and uterus are rather small and slender, possibly seasonally undeveloped. Vas deferens is very long, small and slender tube, entering the apex of lime-sac. Epiphallus is very large and short. Epiphallic retractor caecum is small. Penis is large and long. Free oviduct is rather short, vagina is small and short. Spermatheca is bulb shape. Dart apparatus is very long, cylindrical shape. Atrium is very short and thick walled.

Radula: Central tooth is tricuspid, large and long with broad basal plate, mesocone very long and slender, ectocones are prominent, extending far past edge of basal plate. Lateral tooth are tricuspid, first lateral with small endocone near mesoconal tip; ectocone is large, laterals have elongated basal plate, endocone more prominent, ectocone only slightly less prominent. Marginal teeth are bicuspid, lack endocone that are almost equal to mesocone in size (Fig.4.30).

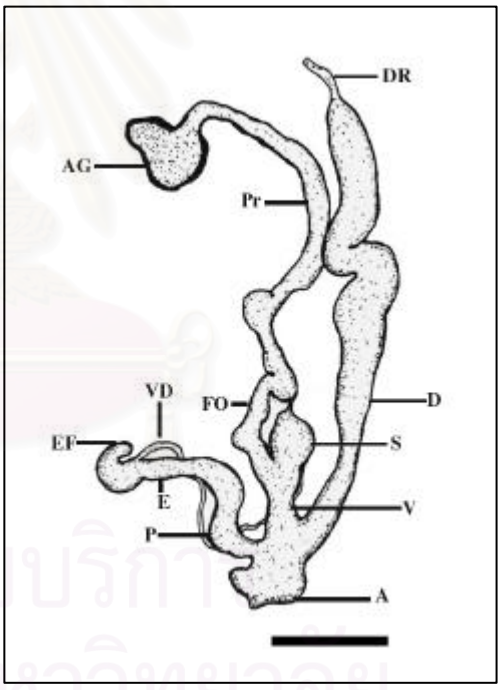
Habitat notes: cf. *Muangnua* sp. 2 is often found on leaf surface of tree, sometimes live on the rock.

Localities: Chiang Rai and Nong Kai Provinces

a

b

c



d

Figure 4.29 *Parmarion* sp.2; a) shell morphology; b) distribution; Chiang Rai and Nong Kai Provinces; c) and d) genitalia; at scale bar 1 mm (Abbreviations are shown in page xi).

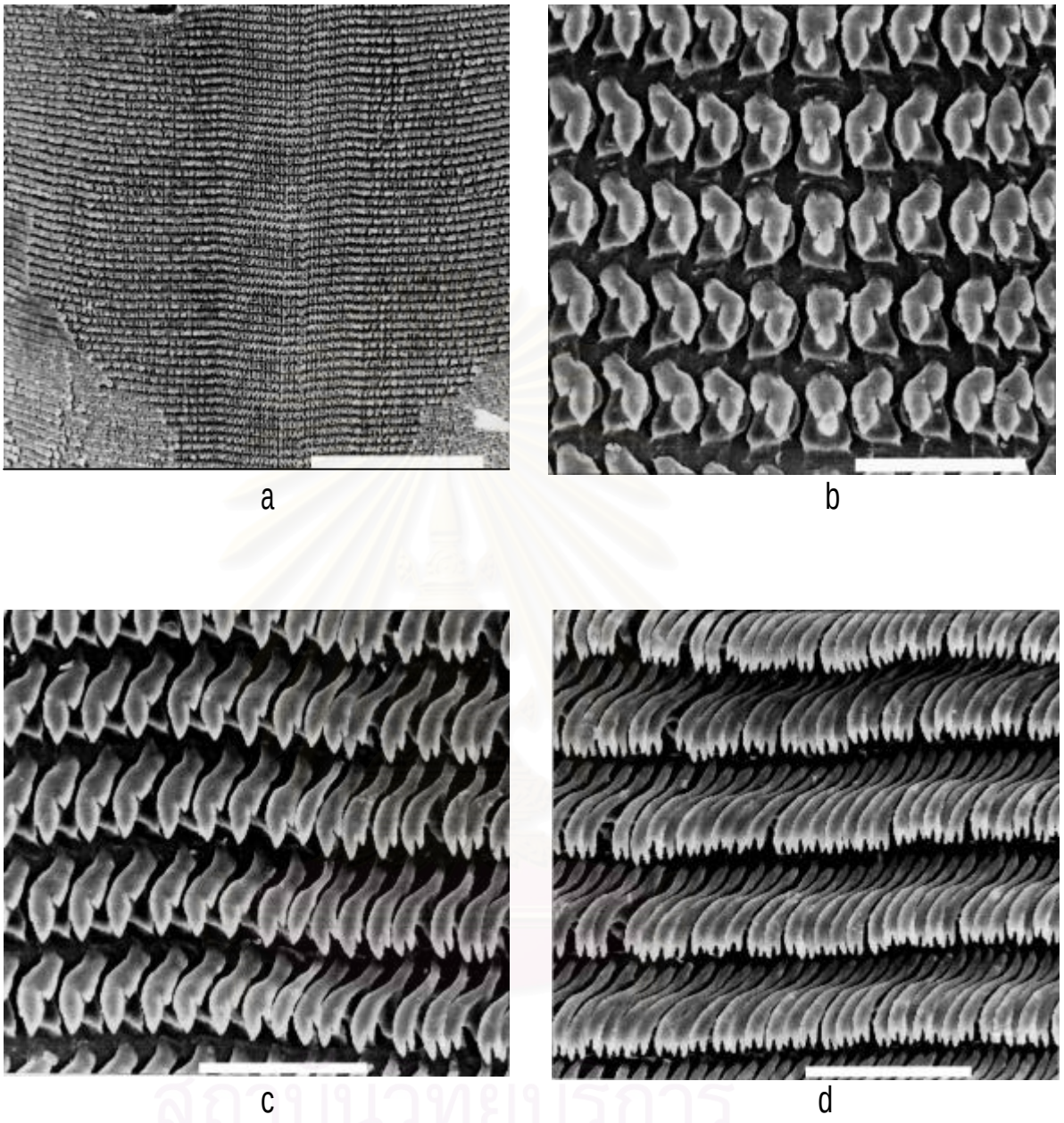


Figure 4.30 Radula of *Parmarion* sp.2; a) radula rows at scale bar 500 μm; b) central tooth and lateral teeth; c) latero-marginal teeth and d) marginal teeth. b, c, and d at scale bars 10 μm.

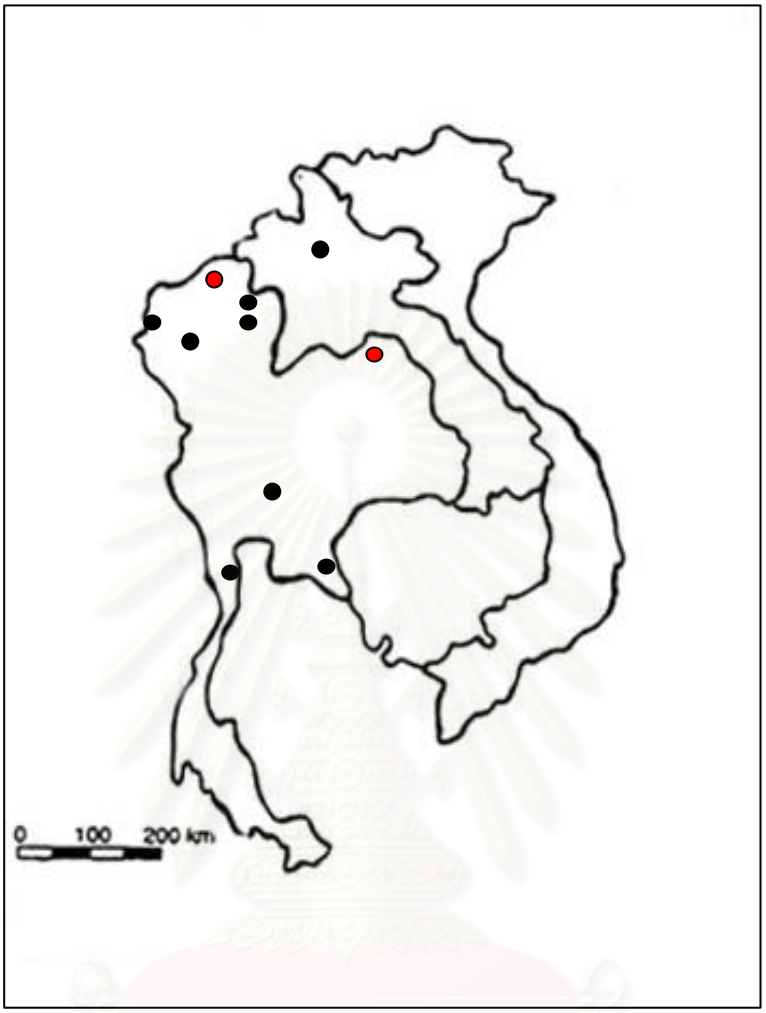


Figure 4.31 Distribution of *Parmarion*.

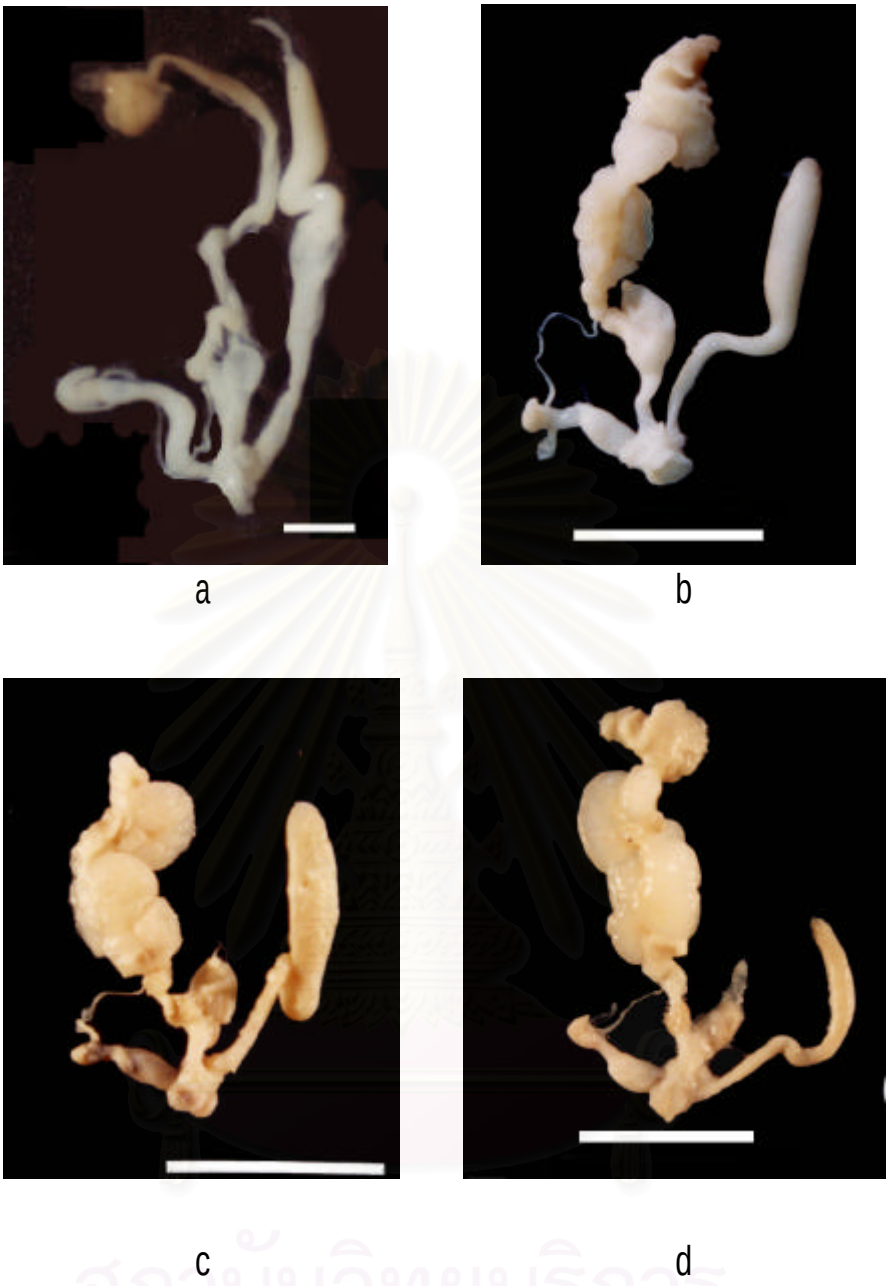


Figure 4.32 Comparative genital system of *Parmarion* from various localities; a) Nongkai Province; b) Phayao Province; c) Laos; and d) Chiangmai Province. At scale bars 1 cm.

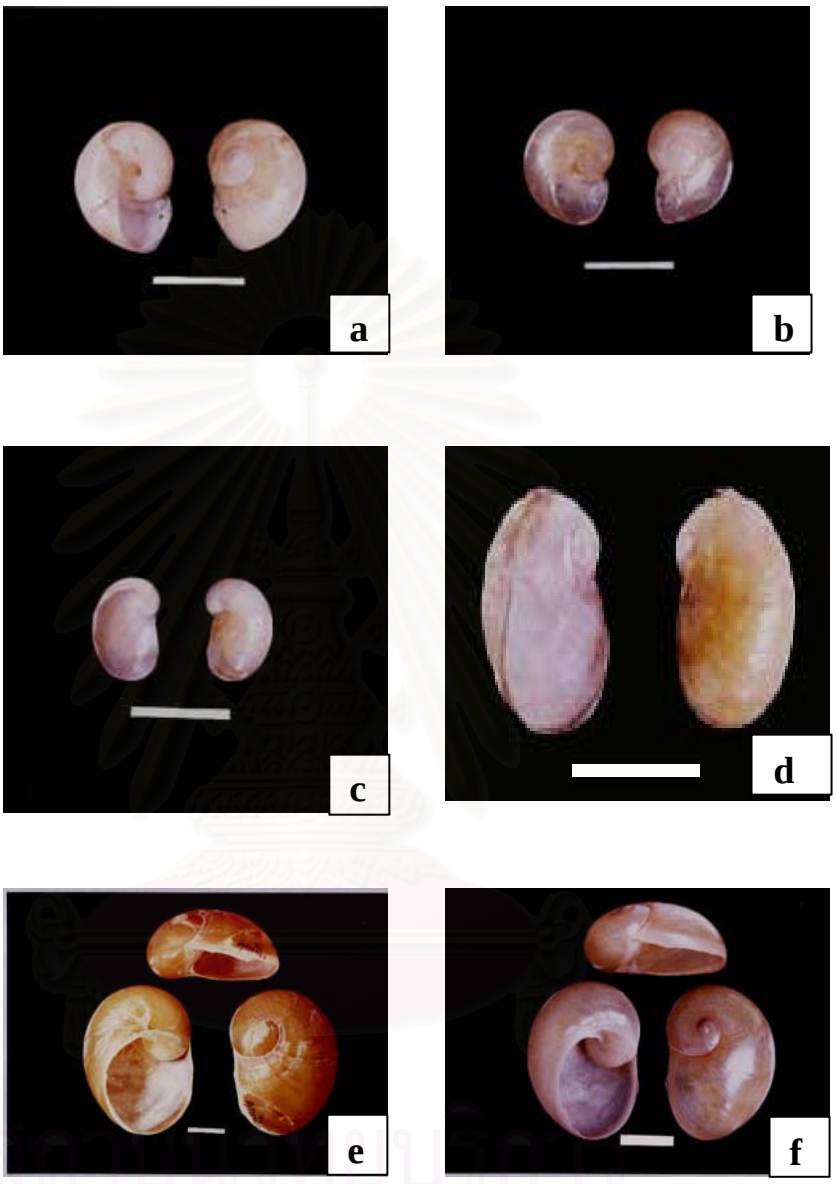


Figure 4.33 Comparative shell of six helicarionid semi-slugs in Thailand and some parts of neighbouring countries. a) cf. *Cryptaustenia* sp.2; b) *Durgella libas*; c) *Austenia doisutepensis*; d) *Parmarion* sp. 2 ; e) *Megaustenia siamensis*; f) cf. *Megaustenia* sp. At scale bars 1 cm.

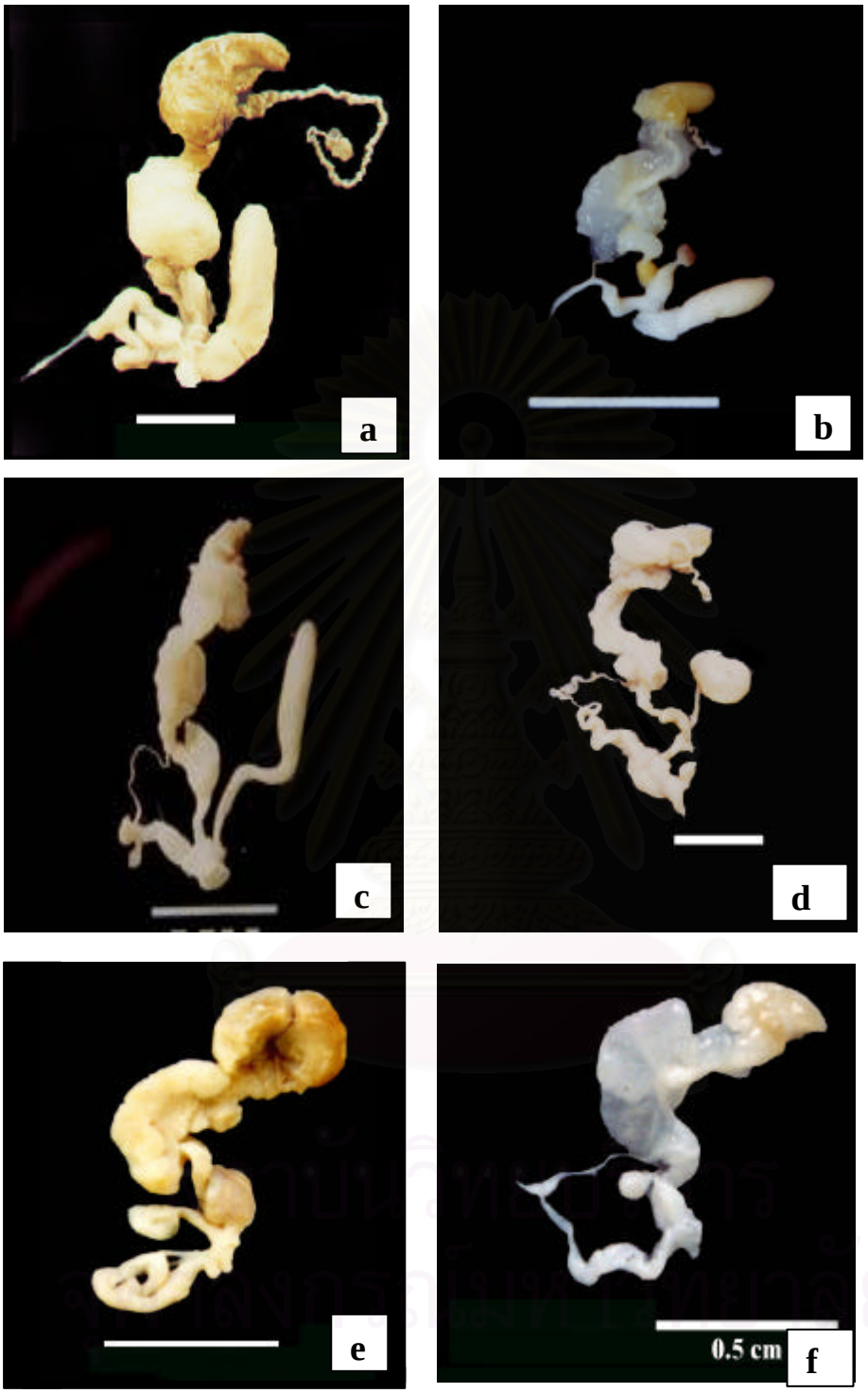


Figure 4.34 Comparative genital system of six helicarionid semi-slugs in Thailand and some parts of neighbouring countries. a) cf. *Megaustenia siamensis*; b) *Durgella* sp. 1; c) *Parmarion* sp.1; d) cf. *Cryptaustenia* sp. 2; e) cf. *Megaustenia* sp.; f) *Durgella* sp. 3; a-e scale bars 1 cm. and f scale bars 0.5 cm.

Table 4.2 Comparative radula morphology of helicarionid semi-slug.

Species	Central tooth	Lateral teeth	Marginal teeth
Austenia doisutepensis	Tricuspid, large and broad	Tricuspids, mesocone very large, ectocone near mesoconal tip	Bicuspids, mesocone and ectocone equal in size
Megaustenia siamensis	Tricuspid, large, broad, ectocone prominent	Tricuspids, mesocone large, ectocone promonent	Bicuspids, mesocone and ectocone small equal in size
Durgella libas	Unicuspid	Bicuspids, pectiniform small several tiny	Bicuspids, pectiniform small several tiny
Durgella sp.1	Reduced to absent	Bicuspids, pectiniform small several tiny	Bicuspids, pectiniform small several tiny
Durgella sp.2	Unicuspid	Bicuspids, pectiniform large several tiny	Bicuspids, pectiniform large several tiny
cf. *Cryptaustenia* sp.1	Tricuspid, mesocone large and broad, ectocone prominent	Tricuspids, mesocone large and broad, ectocone prominent	Tricuspids, mesocone, ectocone and endocone are equal in size
cf. *Cryptaustenia* sp.2	Tricuspid, mesocone large and broad, ectocone prominent	Tricuspids, mesocone large and broad, ectocone prominent	Tricuspids, mesocone, ectocone and endocone are equal in size
Parmarion sp.1	Tricuspid, mesocone large and broad, ectocone prominent	Tricuspids, mesocone large and broad, ectocone prominent	Bicuspids, mesocone, and ectocone are equal in size
Parmarion sp.2	Tricuspid, mesocone large and broad, ectocone prominent	Tricuspids, mesocone large and broad, ectocone prominent	Bicuspids, mesocone, and ectocone are equal in size and several tiny
cf. *Megaustenia*	Tricuspid, large, broad, ectocone prominent	Tricuspids, mesocone large, ectocone promonent	Bicuspids, mesocone and ectocone small equal in size

Table 4.3 Comparative genital system of helicarionid semi-slug in Thailand and some parts of neighboring countries.

Species	Dart apparatus	Penis	Epiphallus	Epiphallic retractor ceacum	Lime-sac	Spermatheca	Muscular collar on free oviduct
Austenia doisutepensis	Long and slender	Long and slender	Long and slender	Small and prominent	Small and prominent	Long and fingerlike	absent
Megaustenia siamensis	Large and broad	Large and long	Long and slender	Large and prominent	Small and prominent	Long stalk and head swollen	present
Durgella libas	Large and broad	Very large, thick-walled and "s"-shape	Short and long, slender	Longer than epiphallus	Absent	Short basal stalk, narrow neck, head swollen	present
Durgella sp.1	Large and broad	Small and cylindrical, thick-walled	Short and slender	Long equal epiphallus	Absent	Short basal stalk, narrow neck, head swollen	present
Durgella sp.2	Small and slender	small, thin-walled and "s"-shape	Long and slender	Short equal epiphallus	absent	Very long and slender	Present
cf. *Cryptaustenia* sp.1	Absent	Large, and swollen	Long and slender	Absent	Absent	Long and slender	Absent
cf. *Cryptaustenia* sp.2	Small	Large, and swollen	Long and slender	Absent	Absent	Long stalk and head swollen	absent
Parmarion sp.1	Small, slender	Large, swollen	Very short	Absent	Prominent and short	Short, large and swollen	Absent

Species	Dart apparatus	Penis	Epiphallus	Epiphallic retractor ceacum	Lime-sac	Spermatheca	Muscular collar on free oviduct
Parmarion sp.2	Long stalk, cylindrical head	Large, and swollen	Short and slender	Absent	Prominent and short	Short, large and swollen	absent
cf. *Megaustenia*	Absent	Large and long	Long and slender	Large and prominent	Small and prominent	Long stalk and head swollen	present

Key to genera of Thai semi-slugs.

1. a. shell coiled……2
   b. shell reduced to cap-shape……3
2. a. genitalia with a large dart apparatus……4
   b. genitalia with a small dart apparatus or absent……5
3. a. tail long, slender, caudal horn overhang, dart apparatus have long stalk and large cylindrical head, spermatheca is short……*Parmarion*
   b. tail and foot are broad and high, caudal horn not overhang, dart apparatus is very long, spermatheca long and finger-like……*Austenia*
4. a. shell is small, radula with very numerous pectiniform latero-marginal teeth……*Durgella*
   b. shell is very large, radula not pectiniform, caudal foss and caudal horn distinctly hanging epiphallic retractor caecum, lime-sac are prominent……*Megaustenia*
5. a genitalia without dart apparatus, shell very large caudal foss and caudal horn distinctly hanging. epiphallic retractor caecum, lime-sac are prominent……cf. *Megaustenia*

b. genitalia with small dart apparatus, tail very long, caudal foss, epiphallic retractor caecum, lime-sac are absent ……cf. *Cryptaustenia*

Morphological and anatomical characteristics of helicarionid semi-slug in Thailand and some parts of neighboring countries can be used to construct dichotomous key.

6. a. shell coiled……2
   b. shell reduced to cap-shape……3
7. a. genitalia with a large dart apparatus……4
   b. genitalia with a small dart apparatus or absent……5
8. a. tail long, slender, caudal horn overhanging……6
   b. tail and foot are broad and high, caudal horn not overhung, dart apparatus is very long, spermatheca long and fingerlike……*A. doisutepensis*
9. a. shell is small, radula pectiniform……7
   b. shell is very large, radula v-shape tricuspid or bicuspid, caudal foss and caudal horn very hanging epiphallic retractor caecum, and epiphallic flagellum are prominent, muscular collar on free oviduct……. *M. siamensis*
10. a genitalia without dart apparatus, body color yellow……9
    b. genitalia with dart apparatus, body color very dark, tail is very long, shell small, caudal foss, epiphallic retractor caecum, and epiphallic flagellum are absent ……cf. *Cryptaustenia*.sp.2
11. a. dart apparatus long and slender, penis is long, body color relative pale yellow, marginal teeth have several tiny…… *Parmarion* sp.1
    b. dart apparatus long stalk and large cylindrical head, penis is large and short, large epiphallic flagellum, body color is yellow and dark, marginal

teeth are bicuspid ..... *Parmarion* sp.2

12. a. dart apparatus is very large and broad, spermatheca is short basal stalk, narrow neck, head swollen, radula have several tiny 8

    b. dart apparatus is very long and slender spermatheca long and slender, epiphallus is very long, radula; lateromarginal is very large.....*Durgella* sp.2

13. a. penis is very large, thick-walled and s-shape.....*Durgella libas*

    b. penis is small, short, and cylindrical, epiphallus is long..... *Durgella* sp.1

14. a. tail is very long, shell small, caudal foss, epiphallic retractor caecum, and epiphallic flagellum are absent.....cf. *Cryptaustenia* sp.1

    b. tail and foot are elongated, triangular, caudal foss and caudal horn very hanging epiphallic retractor caecum, and epiphallic flagellum are prominent, muscular collar on free oviduct.....cf. *Megaustenia*

The present study used six external morphometry i.e. Shell Width / Body length ratio, Shell Width / Tail Length ratio, Shell Width / Shell Height ratio, Shell Height / Body length ratio, Shell Height / Tail Length ratio and Body length / Tail Length ratio. Only Shell Width / Shell Height ratio can be used to identified to species (Appendix III).

In *Parmarion* sp.1 could be completely separated *Parmarion* sp.2 by Shell Width / Shell Height ratio. In cf. *Cryptaustenia*, it may not be easily identified to species by shell morphometry but they posses other distinct different by genital system. In *Durgella* sp.1 could be separate from *Durgella* sp.2 by Shell Height / Tail Length ratio. In *Megaustenia* and cf. *Megaustenia* could not be separated by shell morphometry but they posses other distinct different by genital system.

The ratios are significant different ($p < 0.05$) among species. Body length / Tail Length ratio could be separated 3 groups of 9 helicarionid semi-slugs. Shell Height /

Body length ratio could be separated 2 groups of 9 helicarionid semi-slugs. Shell Height / Tail Length could be separated 3 groups of 9 helicarionid semi-slugs. Shell Width / Body length ratio could be separated 3 groups of 9 helicarionid semi-slugs. Shell Width / Shell Height ratio could be separated 5 groups of 9 helicarionid semi-slugs. Shell Width / Tail Length ratio could be separated 4 groups of 9 helicarionid semi-slugs.

Shell Width / Shell Height ratio could bring to test with Duncan's multiple range test, it is seem to be the best ratio for identification in this study.

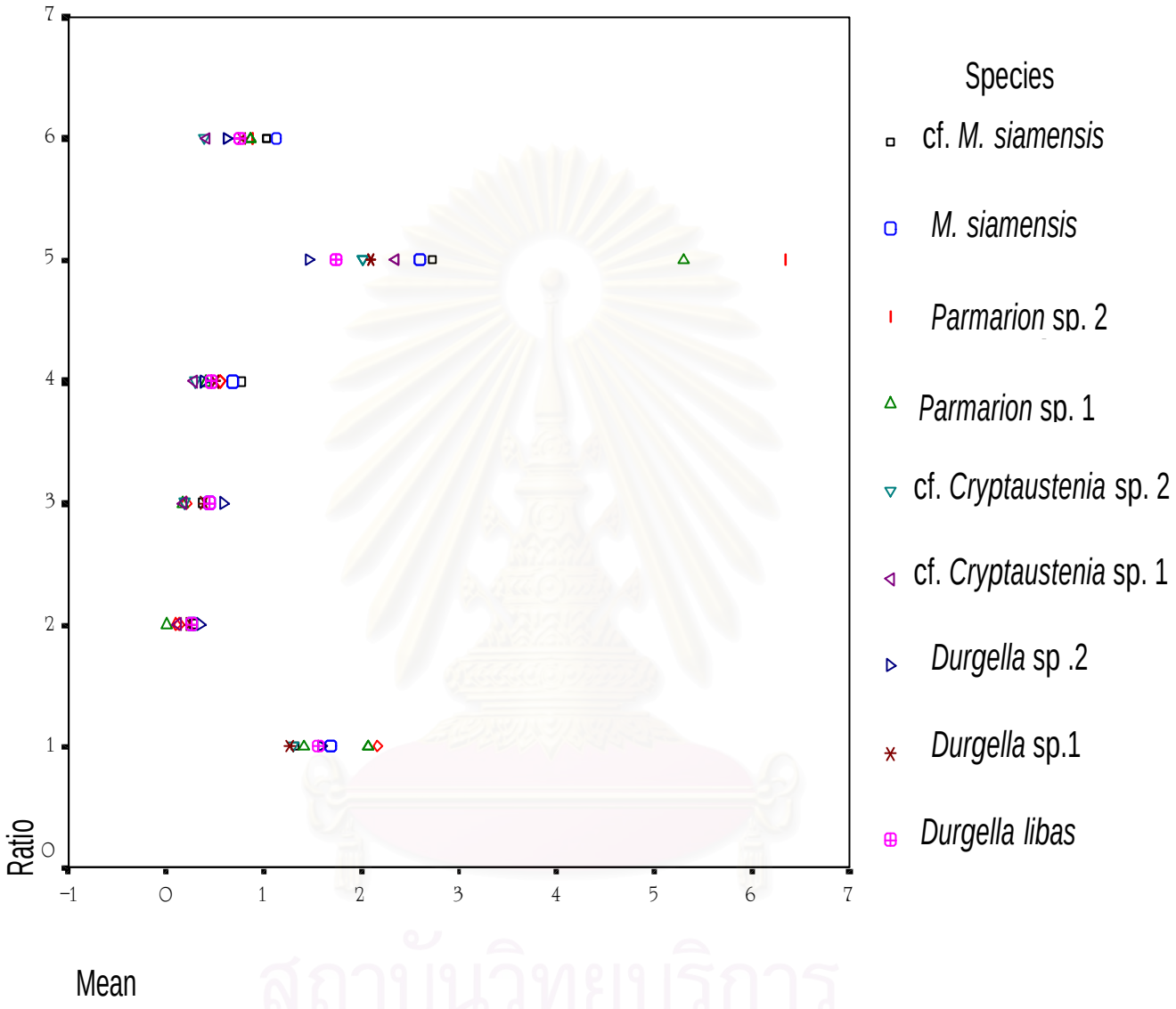


Figure 4.35 Scatter plot of result from Duncan' multiple range test. (Ratio 1=BL/TL, 2= SH/BL, 3= SH/TL, 4=SW/BL, 5=SW/SH and 6= SW/TL).

Chapter 5

Discussion

Helicarionid semi-slugs found in Thailand and some parts of Laos, Vietnam and Malaysia were recorded of Twelve species in the present study. They are *Austenia doisutepensis*, *Megaustenia siamensis,* cf. *Megaustenia siamensis*, cf. *Megaustenia* sp. *Durgella libas, Durgella* sp. 1, *Durgella* sp. 2, *Durgella* sp. 3, cf .*Cryptaustenia* sp.1, cf. *Cryptaustenia* sp.2, *Parmarion* sp. 1, and *Parmarion* sp. 2. Two genera reported in Thailand by Solem in 1966 i.e. *Cryptaustenia* and *Muangnua* are not notified in this study and seem to be a bit confusing in the present classification because of the limited specimen numbers and almost all juveniles were investigated. Seven species seem to be new record, new genera or new species i.e. cf. *Megaustenia* sp., *Durgella* sp.1, *Durgella* sp.2, cf. *Cryptaustenia* sp.1, cf. *Cryptaustenia* sp.2, *Parmarion* sp.1, and *Parmarion* sp.2.

It is clear that shell and soft parts and external morphology can be used to distinguish helicarionid semi-slugs at generic level (*Austenia*, *Parmarion*; *Durgella*, *Cryptaustenia*) and the present study, for example shell laps, tail characteristics and spiral coiling completely separated *Austenia* from *Parmarion*; *Parmarion* has the shell completely covered by the shell laps. *Austenia* has the shell laps covering less than half of the shell with distinct spiral coiling. Tail, head, and visceral hump ratios are good for cf. *Cryptaustenia* and *Durgella* discrimination. In cf. *Cryptaustenia* has tail over twice as long as head and visceral hump, in *Durgella* has less elongated and shorter than cf. *Cryptaustenia*. In *Megaustenia* and cf. *Megaustenia* morphology of genitalia is the only character to be employed in classified animals.

Genital system is an important character that can be combined with shell, soft parts and external morphology for identification. They are distinctly different within the genus, for example in *Durgella*; the spermatheca is not finger-like but consists of a broad, thick and wide at the base, with a narrow stalk and a swollen rounded terminal

portion, the vas deferens enters laterally at the epiphallic head. In the present study they were difference in size and shape of penis, spermatheca, epiphallus, vagina, atrium and dart apparatus (Table 5.2). *D. libas* has s-shape of penis and very large, *Durgella* sp.1 has cylindrical penis and small, short, *Durgella* sp.2 has cylindrical penis, small, long and very thin. *Durgella* sp.2 an isolated species collectd from Tachai Island, the Andaman sea, looks distinctly different from other mainland species and shows sign of morphological transformation from *Durgella* sp. 1. This species should be nominated as new species. In *Durgella libas*, *Durgella* sp. 1 and *Durgella* sp. 2 have a large dart apparatus, while absent in *Durgella* sp. 3. Genital system in *Durgella* sp. 3 is similar to *Durgella assamica* (found in Paniputer tea-garden, near Tezpur, Assam), both species are lack dart apparatus.

In cf. *Cryptaustenia*, genital system is a unique character i.e. epiphallus without lime-sac and epiphallic retractor ceacum. They were separated by dart apparatus, The absent of dart apparatus in cf. *Cryptaustenia* sp.1 and present small dart apparatus of cf. *Cryptaustenia* sp.2. The present of epiphallic retractor caecum and lime-sac of cf. *Cryptaustenia* can be used to distinguish from *Cryptaustenia*. In 1966 Solem reported, *C. gadinodromica* has distinct epiphallic flagellum or lime-sac and epiphallic retractor caecum . In cf. *Cryptaustenia* the two characters are absent (Table 5.2).

Parmarion can be distinguished from *Muangnua* Solem, 1966 by the present of dart apparatus and suggested that *Muangnua* may not exist in Thai environment. *Muangnua* is another genus that still be problem. In this study I finally separated *Parmarion* from *Muangnua* because *Muangnua* prefers the absent of dart apparatus but in the genitalia present study the observed specimens contain a large dart apparatus, cylindrical penis and very short epiphallus (Table 5.1). *Parmarion* should later be clarified and re-describe because *Muangnua limax* is the only one type species described by Solem in 1966 using small number of juvenile specimens.

In *Austenia*, genitalia of all dissected individuals immature. The specimens comparing with paratypes from Zoologisk Museum Kobenhavn (*Austenia doisutepensis*; Leg: 2089; Solem 1570 m.; 10/1/1959; the north Thailand). The present study *Austenia*

doisutepensis were found at Doi Sutep National Park and Doi Chiangdao in Chiangmai Province.

cf. *Megaustenia* were found in Chaiyaphum Province areas. There are 4 specimens, distinctly separated from *Megaustenia* by Dart apparatus. cf. *Megaustenia* never contains dart apparatus but *Megaustenia* has a large apparatus. In *Megaustenia* and cf. *M. siamensis*. They are different in size and shape of Dart apparatus, penis, epiphallus, and free oviduct. cf. *M. siamensis* were found in Cuc Pheung, and Catba National Park in north Vietnam. Genital system of cf. *M. siamensis* is larger than *M. siamensis*. Epiphallic retractor caecum and lime-sac in cf. *M. siamensis* is longer than *M. siamensis*, and muscular collar on free oviduct in cf. *M. siamensis* is larger than *M. siamensis*.

Radula morphology is an assistance information for classification. It can be used to identify at the species level in some genera. In cf. *Cryptaustenia* sp.1 and cf. *Cryptaustenia* sp.1 have tricuspid central tooth, lateral teeth and marginal teeth, while *Cryptaustenia* (Solem reported in 1966 and Godwin-Austen in 1908) has tricuspid central tooth and bicuspid lateral teeth and marginal teeth (table 5.2). In genus *Durgella*, radula with very numerous unique pectiniform, bicuspid latero-marginal teeth and a minute unicuspid central tooth. In *Durgella* sp.1 is similar to *D. libas*, they have an enormous number of teeth, unicuspid and very minute central tooth, with very numerous, bicuspid and serrated edge latero-maginal teeth. While in *Durgella* sp. 2 and *Durgella* sp. 3 show totally different each other. In *Durgella* sp. 2, It is an isolated species collected from Tachai Island, the Andaman sea, looks distinctly different from other mainland species and shows size and shape of radula transformation from *Durgella* sp. 1. Radula of *Parmarion* is different from *Muangnua limax* Solem reported in 1966 (Table 5.1). Radula of *Muangnua limax* has tricuspid central tooth, lateral teeth and marginal teeth. While *Parmarion* sp.1 and *Parmarion* sp. 2 have tricuspid central tooth and lateral teeth but bicuspid marginal teeth.

Table 5.1 Comparative characteristics of *Muangnua* (Solem, 1966) and *Parmarion* (The present study).

Genus Characteristics	*Muangnua* (Solem, 1966)	*Parmarion* (The present study)
Shell	reduced to cap-like	reduced to cap-like
Tail	slender with three black stripes	broad, sharp mid-dorsal line, body yellow or black
Caudal horn	overhang	overhang
Caudal foss	present	present
Radula		
central tooth	tricuspid	tricuspid
lateral teeth	tricuspid	tricuspid
marginal teeth	tricuspid	bicuspid, serrated
Genitalia		
dart apparatus	absent	present, long basal stalk and cylindrical head
spermatheca	very long and finger-like	very short, head bulbous
epiphallus	absent	very short
epiphallic retractor	small	small, prominent
caecum		
lime-sac	absent	short, prominent
penis	very long, slender	short and broad

Table 5.2 Comparative characteristics of *Cryptaustenia* (Solem,1966) and cf. *Cryptaustenia* (The present study).

Genus Characteristic	*Cryptaustenia* (Solem, 1966)	cf. *Cryptaustenia* (The present study)
Shell	globose, helicoid	depressed, helicoid
Tail	body yellow, black mid-dorsal tail stripe, tail slender, long	body very black, tail slender, long
Body length	17.6 0 mm	50-60 mm
Caudal horn	very long and overhang	very long and overhang
Caudal foss	Openning at base of caudal horn	absent
Radula		
central tooth	tricuspid	tricuspid
lateral teeth	tricuspid, bicuspid	tricuspid
marginal teeth	bicuspid	tricuspid
Genitalia		
dart apparatus	absent	absent, present
spermatheca	basal conical, thick-walled, head swollen	long stalk, head bulbous
epiphallus	with enlarge head	very long, slender
epiphallic retractor	absent	absent
caecum		
lime-sac	prominent	absent
penis	short and large	large and very long
penial retracter	present	absent

External morphometry

The Shell Width / Shell Height ratio and Shell Height / Tail Length ratio are very important morphometric discrimination of *Parmarion*. However it is still difficult in other genera. They may be small ratios could be of good characteristics to be added in future studies.

The ratios are significant different ($p < 0.05$) among species. Shell Width / Shell Height ratio could bring to test with Duncan's multiple range test, it is seem to be the best ratio for identified in this study.

In *Parmarion* sp.1 could be completely separated *Parmarion* sp.2 by Shell Width / Shell Height ratio. In cf. *Cryptaustenia*, it may not be easily identified to species by shell morphometry but they posses other distinct different by genital system. In *Durgella* sp.1 could be separate from *Durgella* sp.2 by Shell Height / Tail Length ratio. In *Megaustenia* and cf. *Megaustenia* could not be separated by shell morphometry but they posses other distinct different by genital system.

Shell Width / Body length ratio, Shell Width / Tail Length ratio, Shell Height / Body length ratio, and Body length / Tail Length ratio could not bring to identified to species level in helicarionid semi-slugs.

Chapter 6

Conclusions and Suggestions

Helicarionid semi-slugs in Thailand and some parts of neighbouring countries were recorded that twelve species in the present study, there are *Austenia doisutepensis*, *Megaustenia siamensis,* cf. *Megaustenia siamensis*, cf. *Megaustenia* sp. *Durgella libas, Durgella* sp. 1, *Durgella* sp. 2, cf .*Cryptaustenia* sp.1, cf. *Cryptaustenia* sp.2, *Parmarion* sp. 1, and *Parmarion* sp. 2.

Two genera reported by Solem in 1966 were not found in the present study i.e. genus *Cryptaustenia* and *Muangnua*.

Seven species of helicarionid semi-slugs are first record in Thailand i.e. cf. *Megaustenia* sp., *Durgella* sp.1, *Durgella* sp.2, cf. *Cryptaustenia* sp.1, cf. *Cryptaustenia* sp.2, *Parmarion* sp. 1, and *Parmarion* sp. 2.

Genital system may be character for identification helicarionid semi-slugs in Thailand and some parts of neighbouring countries. Dart apparatus present or absent, the size and shape of penis, epiphallus, lime-sac, epiphallic retractor caecum, vagina and free oviduct are considered.

The present study that external morphometry of helicarionid semi-slugs can be used to identified at the species level in only genus i.e., *Parmarion* sp.

References

Aparicio, M. T., 1982. Observation on the anatomy of some Helicidae from central Spain. Malacologia 22(1-2):621-626.

Barnes, R. D., 1987. Invertebrate Zoology. Fifth edition. USA:Saunders College Publishing.

Binney, W.G.,1897. On the jaw and lingual dentition of certain Costa Rica land shell collect by Dr.William M. Gabb. Annals of the New York Academy of science 1 (9) : 257-262 .

Blanford, W. T., and Godwin-Austen, H. H., 1908. The Fauna of British India including Ceylon and Burma. London :Taylor and Fracis, Red Lion Court,Fleet Street,122-236.

Branson, B. A., 1968. Two new slugs (Pulmonata: Philomycidae:Philomycus) from Kentucky and Virginia. Nautilus, 81(4). 127-133.

Branson, B. A., 1972. *Hemiphilla dromedarius*, A new Arionid slug from Washing. Nautilus 85(3).100-106.

Brown, R. W., 1956. Composition of scientific Words. Baltimore, Typography by Monotype Composition.

Burch, J. B., 1976. Slug. Australian Natural history 18(9).

Burch, J. B., and Pearce, T.A. 1990. Terestrial gastropoda In L. Dindal. (ed.), Soil Biology Guide, pp. 201-309. USA: John Wiley & Sons.

Cuezzo, M. G., 1997. *Cryptostrakon eoreovadensis,* a new species from Costa Rica (Helicoidea :Xanthonychidea) with comment on systematic position of the genus. American Malacological Bulletin 14(1): 1-8.

Fairbanks, H. L., 1989. The reproductive anatomy and taxonomic status of *Philomycus venustus* Hubricht, 1953 and *P. bisdosus* Branson, 1968. The Nautilus 103(1) 20-23.

Fairbanks, H. L., 1990. Morphological comparison of the species of *Megapallifera.* (Gastropoda: Philomycidae). The Nautilus 104(2): 71-75.

Fairbanks, H. L., 1993. The reproductive anatomy of *Philomycus sellatus* Hubricht, 1972 and *P. virginicus* Hubricht, 1953.(Gastropoda: Philomycidae) The Nautilus 107(1). 9-13.

Hoffman, J. E., 1987. A new species of Rabdotus (Gastropoda: Bulimulidae) from Sorana, with description of reproductive anatomy of *Rabdotus nigromontanus*. The Veliger 29(4). 419-423.

Hoffman, J. E., 1987. A new species of *Drymaeus* (Gastropoda: Bulimulidae) from Sonara and Sinaloa, Mexico. The Veliger 29(4). 424-427.

Hubrict, L., 1962. *Mesomphix vulgatus* and its allies. The Nautilus 76(1). 1-7.

Kershaw R. C., 1979. Reproduction of *Helicarion cuvieri* from southern Tasmania and *Helicarion freycineti* from new south Wales (Pulmonata: Helicarionidae) J. Malac.
Soc. Aust 4(3): 145-156.

Kozloff, E. N., V. Joann., 1958. Systematic status of *Hemiphillia malonei*. Nautilus 72 (2). 42-49.

Miller, W. B., 1967. Two new *Sonorella* from Rincon mountains of Arizona. Nautilus 81 (2). 54-61.

Miller, W. B., 1969. A new *Sonorella* from the salt river of phoenix, Arizona. Nautilus 82 (3). 87-93.

Miller, W. B., 1971. The reproductive anatomy of *Tryonigens remondi*, Tryon 1863. Helminthoglyptidae. Nautilus 85(2). 61-64.

Miller, W. B., 1987. A new species of *Bunnay* (Gastropoda: Pulmonata: Humboldtianidae)from western Mexico, with notes on its life cycle and familial relationships. The Veliger 29(3). 308-312.

Morton, B., Prezant, RS &Wilson, B.,1998. Mollusca: The southern synthesis. Fauna of Australia. Vol. 5. CSIRO publishing: Melbourne, Part B. 563-1234 pp.

Naranjo, E, T. A. Pearce and O.J, Polaco., 2000. A new genus and species of semislug from southern Chaipas, Mexico. (Gastropoda: Pulmonata: Xanthonycidae). Arch. Molluskenkunde 128(1/2). 153-161.

Panha, S., 1995-1996.A Checklist and Classification of the Terrestrial Pulmonate Snails Of Thailand. Walkerana 8 (19); 31-40.

Porter, C. A., 1965. Comparison of genitalia of two sympatric species of *Haplotrema*. Nautilus 79(1). 19-23.

Prieto, C.E., A. I. Puenta., K. Altonage and B. J. Gomez, 1993. Genital morphology of Caracollina lenicula (Michaud, 1831), with a new proposal of classification of *Helicodontoid* genera (Pulmonata: Hygromioidae). Malacologia 35(1). 63-77.

Scott, B., 1998. Anatomy and relationships of the papuininae land snail *Melibba Shaferyi* Iredale, 1940 (Pulmonata: Stylommatophora: Camaenidae). Mollucan Research. 19(1). 59-68.

Solem, A., 1966 . Some non-marine mollusks from Thailand with notes on classification of the Helicarionidae . Spolia Zool .Mus .Hauniensis 24:1-110.

Solem, A.,1978, Classification of the land Mollusca. In FRETTER, V. & PEAKE. J. (eds.), Pulmonates 2A Academic Press: 49-97.

Takeda, N., 1989.Hormonal Control of Reproduction in Land Snail. Venus. 48 (2):99-139.

Tillier, S., 1984. Patterns of digestive tract morphology in the Limacisation of the Helicarionid, Succunid and Athoracophorid snails and slugs (Mollusca : Pulmonata). Malacologia 25(1): 173 -192.

Thomson, F. G., 1958. The land snail genus *Microconus*. Nautilus 72(1). 5-11.

Ueshima, R. and Kurozumi, T., 1988. Anatomical Features of *Hirasea* (s.s.) *diplomphalus* and Taxonomic Position of the Genus *Hirasea* (Pulmonate: Sigmurethra). Venus 47(4): 261-270.

Ueshima, R., 1989. Generic position of *Kaliella yaeyamensis* Pilsbry, 1901 (Pulmonata : Helicarionidae) . Venus 48(2): 85-95.

Vaught, K. C., 1989. A classification of the living mollusca. R. T. Abbott, and K. J. Boss (eds.). Florida: American Malacologist.

Appendices

Appendix I
Specimens collection

Collection

Scientific name	COLL. NO.	Locality	Date
Megaustenia siamensis	122	Chiangmai	25-26 May 1997
cf. *Cryptaustenia* sp.2	181	Plieu N. P.Chanthaburi	Oct-96
cf. *Cryptaustenia* sp.2	211	Pa Roi To; Chachoengsao	May-94
Austenia doisutepensis	217	Doi Chiang Dao; Chiangmai	28-May-97
Megaustenia siamensis	250	Phetchaburi	18-Dec-95
Megaustenia siamensis	255	Chiangmai	28-May-97
Megaustenia siamensis	283	Chiangmai	24-27 Oct 1997
Megaustenia siamensis	285	Nongkai	20-21 Oct 1996
cf. *Megaustenia siamensis*	287	Catba , Vietnam	1-May-97
Megaustenia siamensis	288	Nongkai	20-21 Oct 1996
Megaustenia siamensis	290	Nongkai	20-21 Oct 1997
Durgella libas	291	Sai Yok; Kanchanaburi	23-Jul-96
Megaustenia siamensis	292	Mae Yom, Nan	10-15 October 1996
Megaustenia siamensis	293	Doi phunang; Phayao	10-Nov-96
Parmarion sp.2	296	Nongkai	20-22 October 1996
Parmarion sp.2	297	Nongkai	20-22 October 1997
Parmarion sp.2	320	Nongkai	20-22 October 1998
Megaustenia siamensis	321	Doi Chiang Dao, Chiangmai	
Austenia doisutepensis	322	Doi Chiang Dao, Chiangmai	
Megaustenia siamensis	323	Doi Chiang Dao, Chiangmai	
Parmarion sp.2	329	Nongkai	Aug-96
Durgella libas	339	Kanchanaburi	9 February 1996
Megaustenia siamensis	363	Plieu N. P. Chanthaburi	October 1996
Megaustenia siamensis	387	Loei	July-94
Megaustenia siamensis	573	Kanchanaburi	3 Septober 1994
Megaustenia siamensis	574	Klong sang ; Suratthani	27 Aug'1995
Megaustenia siamensis	578	Kanchanaburi	21 March'1996
Durgella libas.	579	Kanchanaburi	Dec'1961
Megaustenia siamensis	583	Loei	10 Aug'1996

Scientific name	COLL. NO.	Locality	Date
Austenia doisutepensis	586	Chiangmai	10 Jan '1959
cf. *Cryptaustenia* sp. 2	588	Pa Roi To; Chachoengsao	4 Sep'1994
Megaustenia siamensis	589	Loei	10 Aug'1996
Megaustenia siamensis	591	Kanchanaburi	9 Oct'1994
Megaustenia siamensis	592	Loei	Sep'1994
cf. *Cryptaustenia* sp. 2	593	Pa Roi To; Chachoengsao	24 Sep'1994
cf. *Cryptaustenia* sp. 2	595	Pa Roi To; Chachoengsao	25 Sep'1994
cf. *Cryptaustenia* sp. 2	596	Pa Roi To; Chachoengsao	26 Sep'1994
Megaustenia siamensis	597	Klong sang, Suratthani	7 June'1995
Megaustenia siamensis	598	Klong sang, Suratthani	4 June'1995
Megaustenia siamensis	601	Mae hong son	9 Sep'1995
Megaustenia siamensis	602	Klong sang, Suratthani	4 June'1995
Megaustenia siamensis	603	Klong sang, Suratthani	4 June'1995
Megaustenia siamensis	604	Klong sang, Suratthani	4 June'1995
Megaustenia siamensis	610	Panthong	10-11 Sep'1995
Megaustenia siamensis	615	Chiangmai	13 Sep'1995
Megaustenia siamensis	616	Chiangmai	5 Dec'1995
Megaustenia siamensis	627	Placave	18 May'1995
cf. *Cryptaustenia* sp.2	628*	Plieu N.P. Chanthaburi	15 Aug'1998
Parmarion sp.2	629	Phetchaburi	22 Sep'1998
Megaustenia siamensis	630	Vang Vieng Laos	17 Sep'1998
Megaustenia siamensis	631	Phetchaburi	22 Sep'1998
Megaustenia siamensis	664	Laos	20 July'1999
cf. *Megaustenia siamensis*	666	Vietnam	15-17 May'1999
Megaustenia siamensis	668	Laos	20 July'1999
Megaustenia siamensis	670	Phayao	
Megaustenia siamensis	671	Loei	1999
Megaustenia siamensis	672*	Nakon rhatchasima	1999
Megaustenia siamensis	673	Kanchanaburi	
cf. *Megaustenia siamensis*	674	Vietnam	18-21 May'1999
Megaustenia siamensis	675*	Doi Chiang dao; Chiangmai	20 Oct'1999
Scientific name	COLL. NO.	Locality	Date

Megaustenia siamensis	676*	Doi Chiang dao; Chiangmai	21 Oct'1999
Megaustenia siamensis	677	Tak	22 Oct'1999
Megaustenia siamensis	678	Chaiyaphum	2 April'1999
Parmarion sp.2	679*	Chiangrai	Oct'1999
cf. *Cryptaustenia* sp.1	680*	Chiangrai	Oct'2000
Parmarion sp.1	681	Nan	Oct'1999
Parmarion sp.1	682	Prachinburi	28 Aug'1999
Megaustenia siamensis	683	Nan	Oct'1999
Durgella sp.1	687*	Ko Sa Mui; Suratthani	Feb'2000
Parmarion sp.1	697	Phayao	15 April'2000
Durgella libas	698*	Nakon rhatchasima	9 April'2000
Durgella libas	700*	Kanchanaburi	7 May'2000
Megaustenia siamensis	701*	Kanchanaburi	8 May'2000
Durgella sp.2	705*	Ko Ta Chai; Phang Nga	14 May'2000
Durgella sp.1	706*	Pa Roi To; Chachoengsao	19 May'2000
cf. *Cryptaustenia* sp.2	707*	Pa Roi To; Chachoengsao	20 May'2000
cf. *Cryptaustenia* sp.2	710*	Chonburi	7-9July'2000
Megaustenia siamensis	712*	Phetchaburi	July'2000
Durgella libas	713	Lod cave	12 May'2000
cf. *Cryptaustenia* sp.2	714	Plieu N. P. Chanthaburi	
Megaustenia siamensis	715	Lod cave	12 May'1998
Megaustenia siamensis	716*	Tak	22 Dec'1997
Megaustenia siamensis	717*	Kanchanaburi	22 July'2000
Durgella sp.1	721*	Chonburi	27 July'2000
Durgella sp.1	722*	Srakaew	27 July'2000
Durgella sp.1	723*	Plieu N. P. Chanthaburi	28 July'2000
Durgella sp.1	724	Nakon nayok	May'2000
cf.*Cryptaustenia* sp.2	725*	Chonburi	Aug'2000
cf. *Cryptaustenia* sp.2	726*	Plieu N. P. Chanthaburi	25 July'2000
Megaustenia siamensis	727*	Doi Inthanon; Chiangmai	25 Sept"2000
Durgella libas	728*	Doi Inthanon; Chiangmai	25 Sept"2000
Scientific name	COLL. NO.	Locality	Date
Durgella libas	729 *	Doi Inthanon; Chiangmai	28 sept"2000

Cryptaustenia sp.2	732	Trat	20.26 oct"2000
Megaustenia siamensis	733	Khonkean	Nov"2000
Parmarion sp.1	734	Prachinburi	-
Parmarion sp.1	735	Rayong	2-3 Dec"2000
cf. *Cryptaustenia* sp. 2	736	Phitsanulok	13 Oct"2000
Megaustenia siamensis	737	Phitsanulok	13 Oct"2000
Durgella sp. 1	738	Phetchaburi	20 Jan" 2000
Durgella sp. 3	739	Sabah, Malaysia	13-16 Feb"2001

COLL. NO. refers Collection numbers

* Refers Chanidaporn Vorajuk

Appendix II
Measurement

Morphology measurement of cf. *Cryptaustenia* .

Scientific Name	NO.	No. of whorls	Shell Width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Cryptaustenia sp.1	1	4	1.474	0.522	4.41	3.122
Cryptaustenia sp.1	2	4 1/2	1.198	0.568	4.219	3.052
Cryptaustenia sp.1	3	4 1/2	1.038	0.431	3.77	2.57
Cryptaustenia sp.1	4	3 3/4	1.11	0.418	4.032	2.64
Cryptaustenia sp.2	5	4 1/2	0.88	0.36	3.46	2.864
Cryptaustenia sp.2	6	4 1/2	1.068	0.48	3.612	3.024
Cryptaustenia sp.2	7	33/4	1.328	0.638	3.168	2.342
Cryptaustenia sp.2	8	33/4	0.795	0.31	3.242	2.562
Cryptaustenia sp.2	9	41/4	0.67	0.342	2.344	1.7
Cryptaustenia sp.2	10	4+	0.608	0.318	2.233	1.788
Cryptaustenia sp.2	11	4+	0.61	0.312	1.976	1.488
Cryptaustenia sp.2	12	41/4	0.694	0.224	2.158	2.11
Cryptaustenia sp.2	13	41/4	0.618	0.27	1.918	1.35
Cryptaustenia sp.2	14	41/4	0.61	0.346	2.036	1.474
Cryptaustenia sp.2	15	4+	0.554	0.318	1.714	1.298
Cryptaustenia sp.2	16	4+	0.478	0.256	1.566	1.124
Cryptaustenia sp.2	17	41/4	0.8	0.424	2.612	2.068
Cryptaustenia sp.2	18	41/2	0.798	0.406	2.542	1.998
Cryptaustenia sp.2	19	4+	0.714	0.346	2.364	1.998
Cryptaustenia sp.2	20	41/2	0.744	0.394	2.284	1.82
Cryptaustenia sp.2	21	41/2	0.764	0.494	2.07	1.064
Cryptaustenia sp.2	22	4+	0.716	0.374	2.046	1.502
Cryptaustenia sp.2	23	41/2	0.762	0.358	2.674	1.932
Cryptaustenia sp.2	24	4+	0.678	0.36	2.422	1.93
Cryptaustenia sp.2	25	41/2	0.822	0.446	3.128	2.442
Cryptaustenia sp.2	26	4+	0.695	0.336	2.54	1.956
Cryptaustenia sp.2	27	41/2	0.73	0.382	2.394	1.736

Morphology measurement of cf. *Cryptaustenia* .(continue)

Scientific Name	NO.	No. of whorls	Shell Width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Cryptaustenia sp.2	28	4 ½	0.648	0.314	2.368	1.726
Cryptaustenia sp.2	29	4+	0.628	0.346	2.326	1.806
Cryptaustenia sp.2	30	4+	0.636	0.302	2.086	1.51
Cryptaustenia sp.2	31	41/2	0.363	0.328	2.336	1.83
Cryptaustenia sp.2	32	4 1/2	0.664	0.34	2.098	1.918
Cryptaustenia sp.2	33	4+	0.542	0.3	2.03	1.554
Cryptaustenia sp.2	34	4+	0.582	0.278	2.076	1.63
Cryptaustenia sp.2	35	41/2	1.1	0.566	2.385	1.626
Cryptaustenia sp.2	36	4+	0.996	0.446	2.388	2.322
Cryptaustenia sp.2	37	4+	0.928	0.41	3.492	2.534
Cryptaustenia sp.2	38	41/2	0.76	0.372	2.978	2.204
Cryptaustenia sp.2	39	41/2	0.732	0.342	2.632	2.074
Cryptaustenia sp.2	40	41/2	0.758	0.4	2.584	2.026
Cryptaustenia sp.2	41	4 1/2	0.708	0.348	2.466	1.956
Cryptaustenia sp.2	42	4 1/2	0.614	0.33	2.284	1.982
Cryptaustenia sp.2	43	41/2	0.712	0.416	2.712	2.12
Cryptaustenia sp.2	44	4+	0.692	0.328	2.378	1.74
Cryptaustenia sp.2	45	4+	0.722	0.344	3.024	2.278
Cryptaustenia sp.2	46	4+	0.682	0.364	2.368	2.27
Cryptaustenia sp.2	47	4+	0.638	0.322	2.57	1.938
Cryptaustenia sp.2	48	4+	0.702	0.316	2.282	1.76
Cryptaustenia sp.2	49	4 1/2	0.798	0.35	1.628	1.078
Cryptaustenia sp.2	50	3 1/4	1.26	0.612	4.708	3.473
Cryptaustenia sp.2	51	3 1/4	1.228	0.578	4.638	3.632
Cryptaustenia sp.2	52	3 1/2	1.178	0.554	4.494	3.224
Cryptaustenia sp.2	53	3 1/4	1.112	0.542	4.158	2.99
Cryptaustenia sp.2	54	3 1/2	1.113	0.55	4.278	3.1

Morphology measurement of cf. *Cryptaustenia.* (continue)

Scientific Name	NO.	No. of	Shell Width	Shell High	Body Length	Tail Length

		whorls	(cm.)	(cm.)	(cm.)	(cm.)
Cryptaustenia sp.2	55	3 1/2	1.112	0.562	3.982	2.994
Cryptaustenia sp.2	56	3 1/4	1.072	0.468	3.67	2.974
Cryptaustenia sp.2	57	3 1/4	1.024	0.533	3.99	3.187
Cryptaustenia sp.2	58	3 1/2	1.082	0.58	3.976	3.16
Cryptaustenia sp.2	59	3 1/4	1.026	0.488	2.963	1.977
Cryptaustenia sp.2	60	3 1/2	1.332	0.635	4.678	3.432
Cryptaustenia sp.2	61	3 1/2	1.322	0.623	4.568	3.383
Cryptaustenia sp.2	62	3 1/2	1.166	0.586	4.385	3.186
Cryptaustenia sp.2	63	3 1/2	1.354	0.713	4.534	3.417
Cryptaustenia sp.2	64	3 1/2	1.232	0.641	4.574	3.66
Cryptaustenia sp.2	65	3 1/2	1.24	0.63	4.356	3.244
Cryptaustenia sp.2	66	3 1/2	1.332	0.614	5.6	3.994
Cryptaustenia sp.2	67	3 1/2	1.106	0.53	3.744	2.528
Cryptaustenia sp.2	68	3 1/2	1.126	0.58	3.632	2.647
Cryptaustenia sp.2	69	3 1/2	1.102	0.562	4.004	2.771
Cryptaustenia sp.2	70	3 1/2	1.154	0.58	4.012	2.958
Cryptaustenia sp.2	71	3 1/2	1.108	0.605	1.187	3.084
Cryptaustenia sp.2	72	3 1/2	1.004	0.45	3.348	2.508
Cryptaustenia sp.2	73	3 1/2	1.264	0.618	5.249	4.11
Cryptaustenia sp.2	74	3 1/2	1.226	0.584	3.982	2.98
Cryptaustenia sp.2	75	3 1/2	1.326	0.682	3.842	2.938
Cryptaustenia sp.2	76	3+	0.702	0.434	1.802	1.29
Cryptaustenia sp.2	77	3+	0.642	0.384	1.986	1.41
Cryptaustenia sp.2	78	3 1/2	1.042	0.468	4.022	3.282
Cryptaustenia sp.1	79	3 3/4	1.234	0.66	4.45	3.502
Cryptaustenia sp.1	80	3 1/2	1.566	0.602	4.642	3.298
Cryptaustenia sp.1	81	3 1/2	1.082	0.534	3.765	2.516

Morphology measurement of *Durgella*

Scientific Name	NO.	No. of	Shell width	Shell High	Body Length	Tail Length

		whorls	(cm.)	(cm.)	(cm.)	(cm.)
Durgella sp.1	1	4 1/4	1.022	0.494	1.53	1.038
Durgella sp.1	2	3 3/4	0.72	0.3		
Durgella sp.1	3	4 1/4	1.028	0.424	1.438	0.942
Durgella sp.1	4	3 1/2	0.964	0.424	1.722	0.958
Durgella sp.1	5	3 3/4	0.956	0.428	1.428	1.102
Durgella sp.1	6	3 1/2	0.986	0.394	1.358	0.942
Durgella sp.1	7	3 1/4	0.998	0.436	1.432	0.994
Durgella sp.1	8	3 1/4	0.988	0.337	1.148	0.923
Durgella sp.1	9	4 1/4	0.924	0.376		
Durgella sp.1	10	4 1/4	0.936	0.393	1.281	0.84
Durgella sp.1	11	3 1/4	0.886	0.306	1.008	0.913
Durgella sp.1	12	3 1/4	0.998	0.336		
Durgella sp.1	13	3 1/2	0.618	0.303		
Durgella sp.1	14	3 1/4	0.508	0.168		
Durgella sp.1	15	3 1/2	0.984	0.484		
Durgella sp.1	16	4 1/4	1.026	0.36	1.508	0.984
Durgella sp.1	17	4 1/4	0.924	0.366	1.188	0.902
Durgella sp.1	18	3 1/2	0.974	0.364	1.65	1.104
Durgella sp.1	19	3 1/2	0.834	0.308	1.624	0.996
Durgella sp.1	20	3 3/4	0.778	0.288	1.478	0.845
Durgella sp.1	21	3 3/4	0.918	0.328	1.694	1.038
Durgella sp.1	22	3 1/2	0.948	0.324	1.134	0.928
Durgella sp.1	23	3 1/4	0.956	0.43	1.028	0.764
Durgella sp.1	24	3 1/3	1.021	0.39		
Durgella sp.1	25	3 2/3	0.978	0.382	0.988	0.738
Durgella sp.1	26	3 1/2	0.978	0.392		

Morphology measurement of *Durgella* (continue)

Scientific Name	NO.	No. of whorls	Shell width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Durgella sp.1	27	31/4	0.998	0.378	1.412	0.906

Durgella sp.1	28	4 1/4	0.986	0.424	1.416	0.976
Durgella sp.1	29	3 1/2	0.864	0.446	1.134	0.882
Durgella sp.1	30	3 3/4	0.914	0.332	1.124	0.734
Durgella sp.1	31	3 3/4	0.902	0.358		
Durgella sp.1	32	3 3/4	0.842	0.42		
Durgella sp.1	33	3 1/2	0.836	0.498		
Durgella libas	34	4 1/2	0.936	0.402	1.978	1.062
Durgella libas	35	41/2	0.888	0.474	1.902	1.022
Durgella libas	36	4 1/2	0.984	0.346	2.076	1.29
Durgella libas	37	4 1/4	0.848	0.406	1.718	0.96
Durgella libas	38	4 1/2	0.808	0.45	1.958	0.918
Durgella libas	39	41/2	0.95	0.426	1.982	1.11
Durgella libas	40	4 1/2	0.876	0.402	2.04	1.158
Durgella libas	41	4 1/2	0.864	0.428	1.976	1.082
Durgella libas	42	4 1/2	0.768	0.344	1.97	1.074
Durgella libas	43	41/4	0.84	0.378	1.634	0.91
Durgella libas	44	4 1/4	0.858	0.368	1.694	0.998
Durgella libas	45	4 1/4	0.75	0.276	1.468	0.91
Durgella libas	46	31/2	0.758	0.348	0.908	0.488
Durgella sp.2	47	31/4	0.864	1.364	1.978	1.178
Durgella sp.2	48	3 1/4	0.81	0.313	1.606	1.024
Durgella sp.2	49	3 1/4	0.4	0.33	1.63	1.06
Durgella sp.1	50	41/2	1.042	0.474	2.074	1.268
Durgella sp.1	51	4 1/2	1.16	0.68	2.298	1.0426
Durgella libas	52	4 1/4	0.876	0.478	2.158	1.4
Durgella libas	53	41/2	0.882	0.532	2.21	1.208

Morphology measurement of *Durgella* (continue)

Scientific Name	NO.	No. of whorls	Shell width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Durgella libas	54	4 1/2	0.878	0.548	2.048	1.238
Durgella libas	55	4 1/2	0.938	0.53	2.388	1.438

Durgella libas	56	41/2	0.95	0.482	1.972	1.038
Durgella libas	57	4 1/4	0.931	0.511	2.072	1.202
Durgella libas	58	4 1/2	0.822	0.514	2.082	1.212
Durgella libas	59	4 1/2	0.862	0.534	2.01	1.284
Durgella libas	60	4 1/4	0.83	0.512	0.996	1.18
Durgella libas	61	4 1/4	0.88	0.482	2.118	1.438
Durgella libas	62	4 1/2	0.886	0.534		
Durgella libas	63	4 1/4	0.772	0.518	1.604	1.124
Durgella libas	64	4 1/2	0.882	0.512	1.998	1.204
Durgella libas	65	4 1/4	0.798	0.514	1.952	1.884
Durgella libas	66	4 1/4	0.942	0.522	2.132	1.04
Durgella libas	67	4 1/2	0.946	0.574	2.279	1.478
Durgella libas	68	4 1/4	0.78	0.482	1.982	1.082
Durgella libas	69	4 1/4	0.882	0.572	2.0152	1.348
Durgella libas	70	41/2	0.838	0.5	2.04	1.382
Durgella libas	71	4 1/2	0.834	0.514	1.932	1.348
Durgella libas	72	4 1/2	0.782	0.524	2.074	1.38
Durgella libas	73	4 1/4	0.738	0.43	2.018	1.122
Durgella libas	74	4 1/4	0.788	0.412	1.724	1.158
Durgella libas	75	4 1/2	0.838	0.522	1.988	1.294
Durgella libas	76	4 1/2	0.878	0.536	1.934	1.238
Durgella libas	77	3 1/2	0.834	0.474	1.718	1.14
Durgella libas	78	4 1/4	0.852	0.532	1.75	1.198
Durgella libas	79	41/2	0.724	0.452	1.28	0.84
Durgella libas	80	4 1/2	0.836	0.57	1.678	1.288

Morphology measurement of *Durgella* (continue)

Scientific Name	NO.	No. of whorls	Shell width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Durgella libas	81	4 1/4	0.79	0.49	1.962	1.258
Durgella libas	82	4 1/2	0.832	0.524	1.78	1.082
Durgella libas	83	4 1/2	0.766	0.522	1.624	1.194

Durgella libas	84	4 1/2	0.82	0.434	1.55	0.934
Durgella libas	85	4 1/2	0.874	0.53	1.708	1.07
Durgella libas	86	4 1/2	0.802	0.5	1.23	0.87
Durgella libas	87	4 1/2	0.732	0.434	1.48	1.038
Durgella libas	88	41/2	0.728	0.424	1.572	1.128
Durgella libas	89	4 1/2	0.736	0.448	1.472	0.858
Durgella libas	90	4 1/4	0.738	0.434	1.778	1.148
Durgella libas	91	41/4	0.926	0.578	1.826	1.274
Durgella libas	92	4 1/2	0.912	0.538	1.92	1.194
Durgella libas	93	4 1/2	0.84	0.47	1.678	1.124
Durgella libas	94	4 1/4	0.834	0.502	1.61	1.19
Durgella libas	95	41/2	0.926	0.558	1.702	1.078
Durgella libas	96	4 1/2	0.89	0.512	1.778	1.138
Durgella libas	97	3 3/4	0.88	0.504	1.81	1.104
Durgella libas	98	4 1/2	0.862	0.52	1.7	1.03
Durgella libas	99	4 1/2	0.782	0.548	1.762	0.986
Durgella libas	100	4 1/2	0.806	0.554		
Durgella libas	101	4 1/2	0.79	0.504	1.412	0.958
Durgella libas	102	4 3/4	0.784	0.414	1.728	1.284
Durgella libas	103	4 1/2	0.734	0.47	1.632	1.04
Durgella libas	104	4 1/4	0.75	0.472	1.662	1.072
Durgella libas	105	4 1/2	0.792	0.482	1.55	0.94
Durgella libas	106	4 1/2	0.78	0.486	1.54	0.89
Durgella libas	107	4 1/2	0.78	0.486	1.702	0.978

Morphology measurement of *Durgella* (continue)

Scientific Name	NO.	No. of whorls	Shell width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Durgella libas	108	41/2	0.958	0.508	1.702	0.978
Durgella libas	109	4 1/2	0.902	0.542	1.64	0.964
Durgella libas	110	41/2	0.894	0.574	1.672	1.078
Durgella libas	111	4 1/2	0.92	0.6	1.53	0.952

Durgella libas	112	4 1/2	0.926	0.556	1.582	1.068
Durgella libas	113	4 1/2	0.814	0.528	1.45	1.01
Durgella libas	114	4 1/2	0.832	0.528	1.426	0.828
Durgella libas	115	4 1/4	0.734	0.46	1.528	0.754
Durgella libas	116	4 1/2	0.782	0.534	1.562	1.064
Durgella libas	117	4 1/2	0.818	0.542	1.334	0.924
Durgella libas	118	4 1/2	0.85	0.508	1.586	1.056
Durgella libas	119	41/4	0.768	0.446	1.636	1.14
Durgella libas	120	4 1/4	0.786	0.48	1.546	0.938
Durgella libas	121	4 1/4	0.652	0.48	1.088	0.638
Durgella libas	122	4 1/2	0.932	0.626	1.486	0.946
Durgella sp.1	123	4 1/2	0.892	0.554	1.352	1.05
Durgella sp.1	124	4 1/2	0.95	0.512	1.43	0.996
Durgella sp.1	125	4 1/2	0.966	0.656	1.4	0.984
Durgella sp.1	126	4 1/2	1.032	0.612	1.678	1.09
Durgella sp.1	127	4 1/2	1.036	0.436	2.03	1.396
Durgella sp.1	128	4 1/2	0.962	0.636	1.98	1.282
Durgella sp.1	129	4 1/2	1.004	0.676	1.83	1.156
Durgella sp.1	130	4 1/2	0.896	0.51	1.688	1.064
Durgella sp.1	131	4 1/2	0.994	0.528	1.738	1.138
Durgella sp.1	132	4 1/2	0.938	0.584	1.19	0.32
Durgella sp.1	133	4 1/2	0.988	0.606	1.588	0.91
Durgella sp.1	134	4 1/2	1.02	0.646	2.13	1.334
Scientific Name	NO.	No. of whorls	Shell width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Durgella sp.1	135	4 1/2	0.91	0.564	1.23	0.79
Durgella sp.1	136	4 1/2	1.016	0.598	2.288	1.448
Durgella sp.1	137	4 1/2	0.962	0.544	2.074	1.284
Durgella sp.1	138	4 1/2	0.934	0.602	1.902	1.284
Durgella sp.1	139	4 1/2	0.978	0.632	2.188	1.472
Durgella sp.1	140	4 1/2	0.918	0.6	2.03	1.348

Durgella sp.1	141	4 1/2	1.046	0.684	2.18	1.336
Durgella sp.1	142	4 1/2	0.884	0.634	2.202	1.432
Durgella sp.1	143	4 1/2	0.974	0.564	1.992	1.338
Durgella sp.1	144	4 1/2	0.932	0.626	2.14	1.408
Durgella sp.1	145	4 1/2	0.922	0.594	1.97	1.302
Durgella sp.1	146	4 1/2	0.982	0.508	2.001	1.248
Durgella sp.1	147	4 1/2	0.846	0.524	1.774	1.052
Durgella sp.1	148	4 ½	1.684	1.644	1.97	1.884
Durgella sp.3	149	3 ¼	0.525	0.258	1.242	0.808
Durgella sp.3	150	3 ½	0.562	0.284	1.242	0.786
Durgella sp.3	151	3 ½	0.455	0.234	1.002	0.751
Durgella sp.3	152	3 ½	0.604	0.334	1.314	0.880
Durgella sp.3	153	3 ½	0.537	0.284	1.126	0.765
Durgella sp.3	154	3 ½	0.531	0.288	0.956	0.623
Durgella sp.3	155	3 ½	0.484	0.288	1.082	0.708
Durgella sp.3	156	3 ½	0.500	0.274	1.231	0.847
Durgella sp.3	157	3 ½	0.482	0.265	1.044	0.711
Durgella sp.3	158	3 ½	0.534	0.328	0.962	0.722
Durgella sp.3	159	3 ½	0.530	0.280	1.187	1.239
Durgella sp.3	160	3 ½	0.642	0.340	1.280	0.817

Morphology measurement of *Meguatenia*

Species	NO.	No. of Whorls	Shell width (cm.)	Shell High (cm.)	Body length (cm.)	Tail length (cm.)
M. siamensis	1	3	2.3	0.842	2.841	2.181
M. siamensis	2	3 1/4	2.83	1.28	3.662	2.286
M. siamensis	3	2 1/2	1.463	0.532	3.224	2.21
M. siamensis	4	2 1/2	2.081	0.99	4.046	2.626
cf.*M.siamensis.*	5	3 1/4	3.53	1.198	4.208	3.096

cf.*M.siamensis.*	6	3 2/3	3.225	1.458	4.026	3.158
cf.*M.siamensis.*	7	3 1/4	2.312	0.76	3.298	2.39
M. siamensis	8	4 1/2	2.808	1.201	3.884	2.321
M. siamensis	9	3 1/2	2.77	0.91	2.426	1.63
M. siamensis	10	3 1/2	3.02	0.9	2.338	1.596
M. siamensis	11	3 1/2	2.66	1.046	2.514	1.612
M. siamensis	12	3 1/3	2.682	0.968	2.432	1.61
M. siamensis	13	3 1/2	2.544	0.88	2.306	1.48
M. siamensis	14	3 1/2	2.438	0.846	2.26	1.36
M. siamensis	15	3 3/4	2.234	0.706	2.334	1.596
M. siamensis	16	3 3/4	2.44	1.08	2.482	1.634
M. siamensis	17	3 3/4	2.322	0.792	2.254	1.24
M. siamensis	18	3 3/4	2.31	0.788	2.048	1.076
M. siamensis	19	3 1/4	2.584	1.068	4.99	2.612
M. siamensis	20	3 1/4	2.438	0.754	4.98	3.414
M. siamensis	21	3 1/2	2.754	1.08	5.023	3.462
M. siamensis	22	3 1/2	2 5/8	0.92	3.615	2.152
M. siamensis	23	3 3/4	2.321	0.922	1.946	1.392
M. siamensis	24	4 1/4	2.998	1.194	2.648	2.052
M. siamensis	25	4 1/4	2.998	1.126	4.462	2.65
M. siamensis	26	3 1/2	2.052	0.692	2.228	1.292

Morphology measurement of *Meguatenia* (continue)

Species	NO.	No. of Whorls	Shell width (cm.)	Shell High (cm.)	Body length (cm.)	Tail length (cm.)
M. siamensis	27	2 3/4	1.436	0.678	2.64	1.815
M. siamensis	28	3 1/2	1.97	0.832	3.541	2.152
M. siamensis	29	3 3/4	1.97	0.738	2.312	1.798
M. siamensis	30	2 3/4	1.482	0.512	1.36	1.974
M. siamensis	31	3 1/4	2.244	0.654	4.88	3.06

M. siamensis	32	3 1/2	1.824	0.664	2.6	1.792
M. siamensis	33	3 1/2	0.808	0.658	2.44	1.632
M. siamensis	34	2 3/4	2.06	0.802	4.84	2.24
M. siamensis	35	3	1.574	0.578	3.64	1.86
M. siamensis	36	3 1/4	1.984	0.784	3.337	1.442
M. siamensis	37	3 1/4	1.768	0.684	3.28	1.514
M. siamensis	38	3 1/4	1.978	1.71	3.462	1.742
M. siamensis	39	3 1/4	2.044	0.698	3.48	1.922
M. siamensis	40	2 3/4	1.424	0.508	2.25	0.932
M. siamensis	41	2 1/2	1.998	0.614	2.532	1.782
M. siamensis	42	3 1/4	1.424	0.656	2.036	1.342
M. siamensis	43	3 1/4	1.484	0.684	2.074	1.092
M. siamensis	44	3 1/2	1.674	0.716	2.242	1.398
M. siamensis	45	3 1/3	1.194	0.428	1.292	0.944
M. siamensis	46	3 1/2	2.95	0.906	5.05	2.58
M. siamensis	47	3 1/2	2.506	0.918	5.014	2.98
M. siamensis	48	2 1/2	2.524	0.782	3.724	2.206
M. siamensis	49	3	2.788	1.24	3.61	2.09
M. siamensis	50	3 1/4	3.318	0.934	3.358	1.734
M. siamensis	51	2 3/4	1.132	0.432	2.35	1.298
M. siamensis	52	3 1/4	2.45	1.09	5.14	2.366

Morphology measurement of *Meguatenia* (continue)

Species	NO.	No. of Whorls	Shell width (cm.)	Shell High (cm.)	Body length (cm.)	Tail length (cm.)
M. siamensis	53	3 1/4	2.12	1.314	3.562	1.7
M. siamensis	54	3 1/4	2.65	1.17	4.192	2.192
M. siamensis	55	31/4	2.43	1.026	5.042	2.968
M. siamensis	56	*3 1/4*	2.328	*1.038*	4.274	2.274
M. siamensis	57	31/4	2.36	1.02	4.422	2.426

M. siamensis	58	31/4	2.228	0.721	4.496	2.946
M. siamensis	59	31/4	2.044	0.79	5.166	3.145
M. siamensis	60	3 1/4	2.224	0.798	4.526	2.22
M. siamensis	61	3 1/4	2.508	0.936	4.726	2.696
M. siamensis	62	31/2	2.258	0.746	4.972	2.696
M. siamensis	63	3 1/2	2.27	0.79	4.2	2.496
M. siamensis	64	3 1/2	2.398	0.708	4.41	2.748
M. siamensis	65	3 1/2	2.464	0.904	4.566	2.956
M. siamensis	66	3 1/4	2.14	0.67	3.43	1.998

Morphology measurement of *Parmarion*

Species	NO.	Shell Width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Parmarion sp.1	1	1.482	0.374	2.992	1.474
Parmarion sp.1	2	1.436	0.402	2.492	1.12
Parmarion sp.1	3	1.488	0.98	2.342	1.174
Parmarion sp.1	4	1.59	0.359	2.986	1.732
Parmarion sp.1	5	1.362	0.212	2.158	1.128

Parmarion sp.1	6	1.314	0.136	3.038	1.562
Parmarion sp.1	7	1.641	0.218	2.94	1.032
Parmarion sp.1	8	1.124	0.206	3.446	1.626
Parmarion sp.1	9	1.224	0.232	3.326	1.73
Parmarion sp.1	10	1.082	0.328	3.304	1.82
Parmarion sp.1	11	1.072	0.223	3.212	1.82
Parmarion sp.1	12	1.288	0.442	3.548	1.62
Parmarion sp.1	13	1.124	0.284	2.826	1.768
Parmarion sp.1	14	0.934	0.204	2.86	1.208
Parmarion sp.1	15	0.958	0.264	2.94	1.462
Parmarion sp.1	16	0.864	0.212	3.374	1.782
Parmarion sp.1	17	0.748	0.164	2.388	1.296
Parmarion sp.1	18	0.638	0.158	2.508	1.044
Parmarion sp.1	19	0.788	0.148	2.378	1.162
Parmarion sp.1	20	1.6	0.232	3.62	1.5
Parmarion sp.1	21	0.954	0.228	2.557	0.884
Parmarion sp.1	22	1.412	0.304	3.652	1.838
Parmarion sp.1	23	1.49	0.204	3.528	1.846
Parmarion sp.1	24	1.422	0.188	3.544	1.948
Parmarion sp.1	25	0.93	0.1	2.756	1.246
Parmarion sp.1	26	1.504	0.24	2.584	1.116
Parmarion sp.1	27	1.336	0.234	2.18	1.096

Morphology measurement of cf. *Muangnua* (continue)

Species	NO.	Shell Width (cm.)	Shell High (cm.)	Body Length (cm.)	Tail Length (cm.)
Parmarion sp.1	29	1.256	0.294	3.448	1.798
Parmarion sp.1	30	1.39	0.166	2.778	1.349
Parmarion sp.1	31	1.104	0.154	3.432	1.868
Parmarion sp.2	32	1.514	0.288	3.094	1.322
Parmarion sp.2	33	1.198	0.142	3.238	1.49

Parmarion sp.2	34	0.972	0.186	2.782	1.256
Parmarion sp.2	35	1.51	0.318	3.128	1.722
Parmarion sp.2	36	0.987	0.23	2.17	1.042
Parmarion sp.2	37	0.966	0.182	3.733	1.62
Parmarion sp.2	38	0.862	0.144	3.162	1.384
Parmarion sp.2	39	1.13	0.142	3.192	1.738
Parmarion sp.2	40	0.908	0.15	0.1984	0.778
Parmarion sp.2	41	1.024	0.144	2.54	0.922
Parmarion sp.2	42	1.028	0.134	2.72	1.238
Parmarion sp.2	43	1.452	0.238	3.732	1.468
Parmarion sp.2	44	1.314	0.344	5.074	2.624
Parmarion sp.2	45	1.536	0.196	3.458	1.628
Parmarion sp.2	46	1.2	0.184	2.89	1.37
Parmarion sp.2	47	1.39	0.16	3.248	1.208
Parmarion sp.2	48	1.742	0.302	3.236	1.264
Parmarion sp.2	49	1.732	0.194	3.52	1.798
Parmarion sp.2	50	1.414	0.134	3.014	1.524
Parmarion sp.2	51	1.232	0.16	3.372	1.448
Parmarion sp.2	52	1.604	0.265	3.348	1.524
Parmarion sp.2	53	1.212	2.278	2.85	1.156
Parmarion sp.2	54	0.58	0.142	2.686	1.286
Parmarion sp.2	55	0.71	0.15	2.39	0.834

Appendix III
Morphometry Analysis

Result of external morphometry by One-way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
BL_TL	Between Groups	28.48981	8	3.561226	23.73649	0
	Within	51.46088	343	0.150032		

	Groups					
	Total	79.95069	351			
SH_BL	Between Groups	1.803368	8	0.225421	20.13795	0
	Within Groups	3.839488	343	0.011194		
	Total	5.642856	351			
SH_TL	Between Groups	4.909149	8	0.613644	18.14486	0
	Within Groups	11.59997	343	0.033819		
	Total	16.50911	351			
SW_BL	Between Groups	6.077271	8	0.759659	9.360462	0
	Within Groups	27.83655	343	0.081156		
	Total	33.91382	351			
SW_SH	Between Groups	682.5709	8	85.32137	110.5304	0
	Within Groups	264.7709	343	0.771927		
	Total	947.3418	351			
SW_TL	Between Groups	21.19659	8	2.649574	30.07909	0
	Within Groups	30.2138	343	0.088087		
	Total	51.41039	351			

Result of external morphometry by Duncan' s multiple analysis.

BL_TL

		N	Subset for alpha = .05		
	SPECIES		1	2	3
Duncan	*Durgella* sp.1	61	1.270004		
	Cryptaustenia sp.2	75	1.310427	1.310427	

	Megaustenia sp.1	3	1.337982	1.337982	
	Cryptaustenia sp.1	7	1.423396	1.423396	
	Durgella libas	84	1.565407	1.565407	
	Durgella sp.2	3	1.595071	1.595071	
	Megaustenia siamensis	63		1.684008	
	Parmarion sp.1	32			2.074388
	Parmarion sp.2	24			2.171488
	Sig.		0.110204	0.064049	0.583342

SH_BL

		N	Subset for alpha = .05	
	SPECIES		1	2
Duncan	*Parmarion* sp.1	32	0.091503	
	Parmarion sp.2	24	0.120661	
	Cryptaustenia sp.1	7	0.12726	
	Cryptaustenia sp.2	75	0.153077	
	Durgella sp.1	61		0.26086
	Megaustenia siamensis	63		0.270886
	Durgella libas	84		0.279993
	Megaustenia sp.1	3		0.292428
	Durgella sp.2	3		0.362311
	Sig.		0.25107	0.060461

SH_TL

		N	Subset for alpha = .05		
	SPECIES		1	2	3
Duncan	*Cryptaustenia* sp.1	7	0.180369		
	Parmarion sp.1	32	0.189081		
	Cryptaustenia sp.2	75	0.197479		
	Parmarion sp.2	24	0.214908		

	Megaustenia sp.1	3		0.388876	
	Durgella sp.1	61		0.40401	
	Durgella libas	84		0.44414	0.44414
	Megaustenia siamensis	63		0.448863	0.448863
	Durgella sp.2	3			0.591627
	Sig.		0.713954	0.523337	0.097257

SW_BL

		N	Subset for alpha = .05		
	SPECIES		1	2	3
Duncan	*Cryptaustenia* sp.1	7	0.295838		
	Cryptaustenia sp.2	75	0.303602		
	Durgella sp.2	3	0.395521		
	Parmarion sp.1	32	0.417178	0.417178	
	Durgella libas	84	0.477611	0.477611	
	Durgella sp.1	61	0.5111	0.5111	0.5111
	Parmarion sp.2	24	0.561114	0.561114	0.561114
	Megaustenia siamensis	63		0.693612	0.693612
	Megaustenia sp.1	3			0.780317
	Sig.		0.079281	0.057258	0.057861

SW_SH

		N	Subset for alpha = .05				
	SPECIES		1	2	3	4	5
Duncan	*Durgella* sp.2	3	1.477804				

	Durgella libas	84	1.735827	1.735827			
	Cryptaustenia sp.2	75	2.01042	2.01042	2.01042		
	Durgella sp.1	61	2.101564	2.101564	2.101564		
	Cryptaustenia sp.1	7		2.356287	2.356287		
	Megaustenia siamensis	63		2.607529	2.607529		
	Megaustenia sp.1	3			2.733539		
	Parmarion sp.1	32				5.318987	
	Parmarion sp.2	24					6.362178
	Sig.		0.159186	0.051543	0.110145	1	1

SW_TL

		N	Subset for alpha = .05			
	SPECIES		1	2	3	4

Duncan	*Cryptaustenia* sp.2	75	0.39128			
	Cryptaustenia sp.1	7	0.420894			
	Durgella sp.2	3	0.63394	0.63394		
	Durgella libas	84		0.762094	0.762094	
	Durgella sp.1	61		0.784667	0.784667	
	Parmarion sp.1	32		0.86899	0.86899	0.86899
	Parmarion sp.2	24		0.881824	0.881824	0.881824
	Megaustenia sp.1	3			1.04292	1.04292
	Megaustenia siamensis	63				1.14114
	Sig.		0.090745	0.10473	0.064168	0.066123

Result of external morphometry by Duncan' s multiple analysis.

Species	Ratio	Group	Mean
Durgella sp.1	BL_TL	1	1.270004
cf. *Cryptaustenia* sp.2	BL_TL	1	1.310427
cf. *Megaustenia siamensis*	BL_TL	1	1.337982

cf. *Muangnua* sp.1	BL_TL	1	1.423396
Durgella libas	BL_TL	1	1.565407
Durgella sp.2	BL_TL	1	1.595071
Durgella sp.2	BL_TL	1	1.595071
Megaustenia siamensis	BL_TL	1	1.684008
Megaustenia siamensis	BL_TL	1	1.684008
Parmarion sp.1	BL_TL	2	2.074388
Parmarion sp.1	BL_TL	3	2.074388
Parmarion sp.2	BL_TL	3	2.171488
Parmarion sp.1	SH_BL	1	0.00095
Parmarion sp.2	SH_BL	1	0.120661
cf. *Cryptaustenia* sp.1	SH_BL	1	0.12726
Parmarion sp.2	SH_BL	1	0.153077
Durgella sp.1	SH_BL	2	0.26086
Megaustenia siamensis	SH_BL	2	0.270886
Durgella libas	SH_BL	2	0.279993
cf. *Megaustenia siamensis*	SH_BL	2	0.292428
Durgella sp.2	SH_BL	2	0.362311
cf. *Cryptaustenia* sp.1	SH_TL	1	0.180369
Parmarion sp.1	SH_TL	1	0.189369
cf. *Cryptaustenia* sp.2	SH_TL	1	0.197479
Parmarion sp.2	SH_TL	1	0.214908
cf. *Megaustenia siamensis*	SH_TL	2	0.388876
Durgella sp.1	SH_TL	2	0.40401
Durgella libas	SH_TL	2	0.44414
Durgella libas	SH_TL	3	0.44414
Megaustenia siamensis	SH_TL	2	0.448863
Megaustenia siamensis	SH_TL	3	0.448863
Durgella sp.2	SH_TL	3	0.591627
cf. *Cryptaustenia* sp.1	SW_BL	1	0.295838
cf. *Cryptaustenia* sp.2	SW_BL	1	0.303602
Durgella sp.2	SW_BL	1	0.395521
Parmarion sp.1	SW_BL	1	0.417178

Parmarion sp.1	SW_BL	2	0.417478
Durgella libas	SW_BL	1	0.477611
Durgella libas	SW_BL	2	0.477611
Durgella sp.1	SW_BL	1	0.5111
Durgella sp.1	SW_BL	2	0.5111
Durgella sp.1	SW_BL	3	0.5111
Parmarion sp.2	SW_BL	1	0.561114
Parmarion sp.2	SW_BL	2	0.561114
Parmarion sp.2	SW_BL	3	0.561114
Megaustenia siamensis	SW_BL	2	0.693612
Megaustenia siamensis	SW_BL	3	0.693612
cf. *Megaustenia siamensis*	SW_BL	3	0.780317
Durgella sp.2	SW_SH	1	1.477804
Durgella libas	SW_SH	1	1.735827
Durgella libas	SW_SH	2	1.735827
cf. *Cryptaustenia* sp.2	SW_SH	1	2.01042
cf. *Cryptaustenia* sp.2	SW_SH	2	2.01042
cf. *Cryptaustenia* sp.2	SW_SH	3	2.01042
Durgella sp.1	SW_SH	1	2.101564
Durgella sp.1	SW_SH	2	2.101564
Durgella sp.1	SW_SH	3	2.101564
cf. *Cryptaustenia* sp.1	SW_SH	2	2.356287
cf. *Cryptaustenia* sp.1	SW_SH	3	2.356287
Megaustenia siamensis	SW_SH	2	2.607529
Megaustenia siamensis	SW_SH	3	2.607529
cf. *Megaustenia siamensis*	SW_SH	3	2.733539
Parmarion sp.1	SW_SH	4	5.318987
Parmarion sp.2	SW_SH	5	6.362178
cf. *Cryptaustenia* sp.2	SW_TL	1	0.39128
cf. *Cryptaustenia* sp.1	SW_TL	1	0.420894
Durgella sp.2	SW_TL	1	0.63394
Durgella sp.2	SW_TL	2	0.63394

Durgella libas	SW_TL	2	0.762094
Durgella libas	SW_TL	3	0.762094
Durgella sp.1	SW_TL	2	0.784667
Durgella sp.1	SW_TL	3	0.784667
Parmarion sp.1	SW_TL	2	0.86899
Parmarion sp.1	SW_TL	3	0.86899
Parmarion sp.1	SW_TL	4	0.86899
Parmarion sp.2	SW_TL	2	0.881824
Parmarion sp.2	SW_TL	3	0.881824
Parmarion sp.2	SW_TL	4	0.881824
cf. *Megaustenia siamensis*	SW_TL	3	1.02492
cf. *Megaustenia siamensis*	SW_TL	4	1.02492
Megaustenia siamensis	SW_TL	4	1.14114

Biography

Miss Chanidaporn Vorajuk was born on the 24th January 1974. Waritchaphum District, in Sakonnakhon Province. She obtained hers bachelor's of Science in Biology in 1997 from the department of Biology, Faculty of Science, Mahasarakham University. She continued her graduated study for Master's degree of Science in Zoology at the Chulalongkorn University (1998-2000). She was awarded a two-year scholarship by the University Development Committee (UDC), Ministry of University Affairs in 1994. After her graduation, she works as a full-time lecturer at the Department of Biology, Faculty of Science, Mahasarakham University.