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タイ中央部における淡水二枚貝の棲息地調査及び繁殖に関する研究

ソムサク・パナ

The Site Survey and the Study on Reproductive Cycles of Freshwater Pearl Mussels in the Central Part of Thailand

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Abstract: Eight species of freshwater pearl mussels were collected in the general canals and irrigation canals at Nakornsawan, Chainat, Lopburi, Saraburi, Singburi, Ayutthaya and Pathumthani Provinces, from September 1988 to September 1989. *Pilsbryochoncha exilis* was the most abundant and distributed in all provinces surveyed. *Ensidens ingallsianus*, *Uniandra contradens* and *Scabies crispata* were the second. *Pseudodon vondembuschianus* was found at only Lopburi Province. The largest species which found in the deepest water was *Hyriopsis* (*Limnoscapha*) *myersiana*. The females with marsupia were observed from September 1988 to September 1989. The patterns were quite different from each other in eight species of mussels. Fourteen species of fish were found as hosts of glochidium from mid-October 1988 to March 1989 which corresponded with the gestation and elimination of glochidium of female mussels.

Introduction

Freshwater mussels are common inhabitants of lakes, rivers, canal, stream and also swamp. Although there have been a number of studies on their distribution, biomass, reproductive biology particularly in Europe and U.S.A. (Bauer, 1987b, c; Bauer and Vogel, 1987; Jones et al., 1986; Kondo and Yamashita, 1980; Morton and Dudgeon, 1984; Tedla and Fernando, 1969; Zale and Neves, 1982), very few works has been done on Thai freshwater mussels.

Brandt (1974) reported 3 families (Margaritiferidae, Amblemidae, Unionidae) of freshwater mussels found in Thailand. Panha (1985) studied on some ecological aspects of freshwater mussels in Thailand, and showed the zonation pattern of 7 amblemid species in the canal at Ubolrachathani Province.

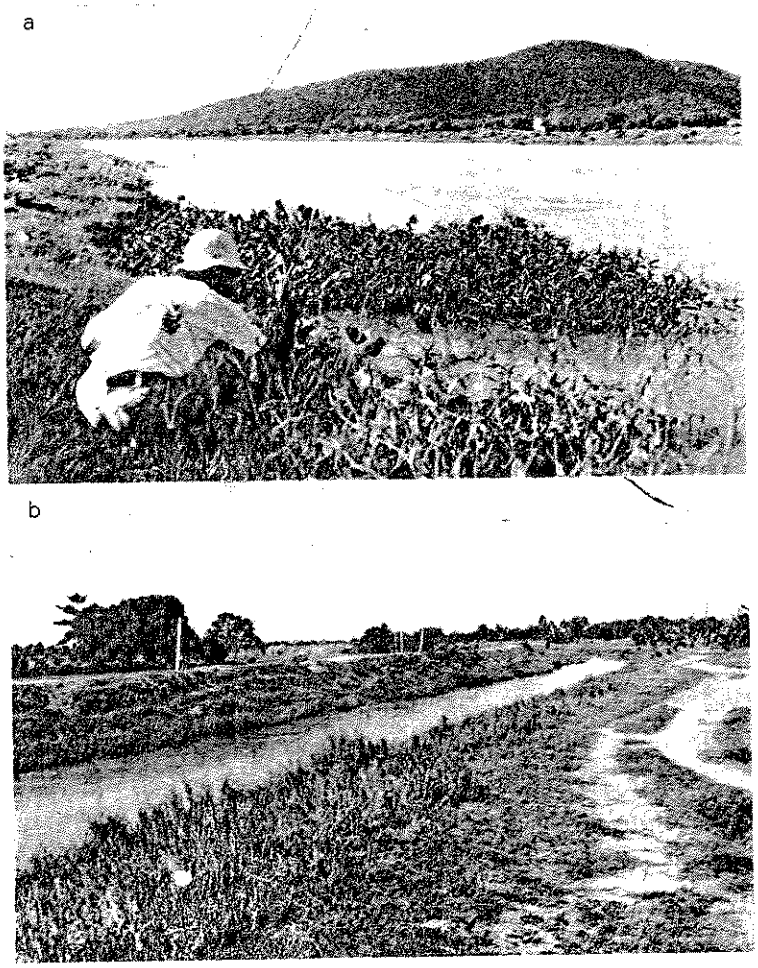

Fig. 1. a. Irrigation canal at Takli District, Nakornsawan Province.
b. A small irrigation canal, Inburi District, Singburi Province.

In this study eight species of amblemid freshwater mussels were found in the irrigation canals and canals near the rice fields at Chinat, Nakornsawan, Singburi, Ayutthaya and Pathumthani Provinces. *Pilsbryochoncha exilis*, *Physunio superbus*, *Uniandra contradens*, *Pseudodon cambodjensis*, and *Ensidens ingallsianus* were the most abundant, and *Scabies crispata*, and *Hyriopsis* (*Limnoscapha*) *myersiana* were less numerous, while *Pseudodon vondembuschianus* was rarely found.

The amblemid freshwater mussels have highly specialized life cycles. Of the Amblemidae the eggs are moved into specialized portions of the outer gills or both inner and outer gills (marsupia) where they develop into hooked or hookless larval stage (glochidium) (Brandt, 1974; Panha, 1989). Mature glochidia are released into the water where they spend some time attached to

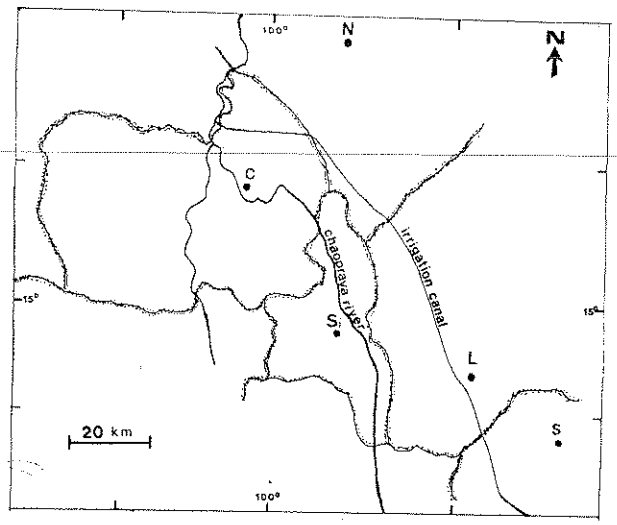

Fig. 2. The map of the irrigation canal, a man-made tributary of Chaophraya River (C ,Chainat; N, Nakornsawan; L, Lopburi, S, Saraburi).

mostly a fish (Lefever and Curtis, 1910; Atkins, 1979; Kraemer and Swanson, 1985; Jones et al., 1986), but glochidia are also found infected tadpoles (Seshaiya, 1941; Walker, 1981), a salamander (Howard, 1951) and a palemonid shrimp (Panha, unpublished), as well.

Materials and Methods

The irrigation canal (Fig. 1) has a length of 170 km, and extends (Fig. 2) from Chainat Province to Saraburi Province. It is a man-made tributary of the Chaophraya River under the Lower Chaophraya River Agricultural Project.

From September 1988 to September 1989, a field study was carried out in two types of habitat. One was in the canal which the depth was deeper than 2 metres around the paddy field in Pathumthani, Ayutthaya, Lopburi, Saraburi, Chainat and Nakornsawan Provinces. About 30 individuals of *Pilsbryochoncha exilis*, *Physunio superbus*, *Scabies crispata*, *Ensidens ingallsianus*, *Uniandra contradens*, *Pseudodon cambodjensis*, *Pseudodon vondembuschianus*, were collected by hand. The other habitat was in the irrigation canal of which the depth was deeper than 2 metres in one sampling site of Chainat Province, 3 of Nakornsawan Province, 3 of Lopburi Province, and 2 of Saraburi Province. About 25 individuals of *Physunio superbus* and 5–10 of *Hyriopsis* (*Limnoscapha*) *myersiana* were collected by hand and dredging.

Mussels collected were dissected and determined their sexes. Shell length of each mussel and incidence of females incubating eggs or glochidia in the

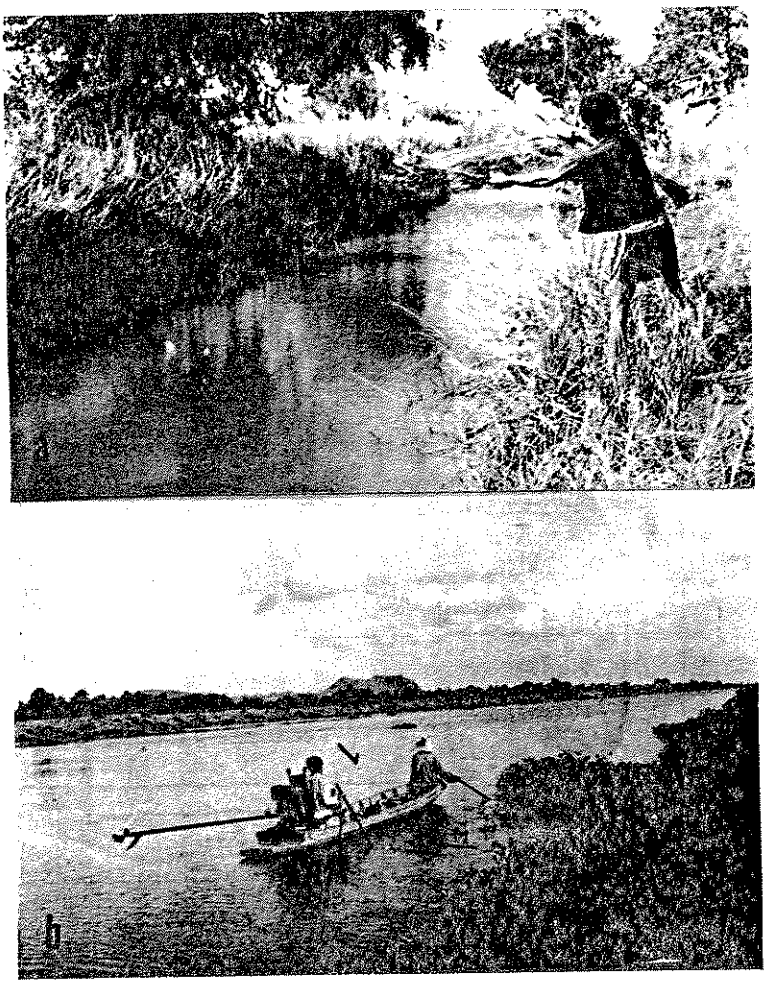

Fig. 3. Trawling net (a) and floating net (b) used for fish collection.

marsupium were also recorded. Some were reared for the further observations and experiments in aquaria. Histological study of gonads was also done in some species.

The observation of glochidium was done both on the living materials and those preserved in a 10% formalin. Shell length and height were measured with an ocular micrometer on the glochidium preserved in 10% formalin.

The fish were also caught monthly at almost all collecting sites by trawling net, floating net (Fig. 3) as well as by hand. They were at once preserved in 10% formalin, and the species, position, number and size of attached glochidia were examined under the binocular in the laboratory. Species identifications of mussels were based on Brandt (1974) and fish identifications were based on Smith (1945) and Department of Fisheries (1987).

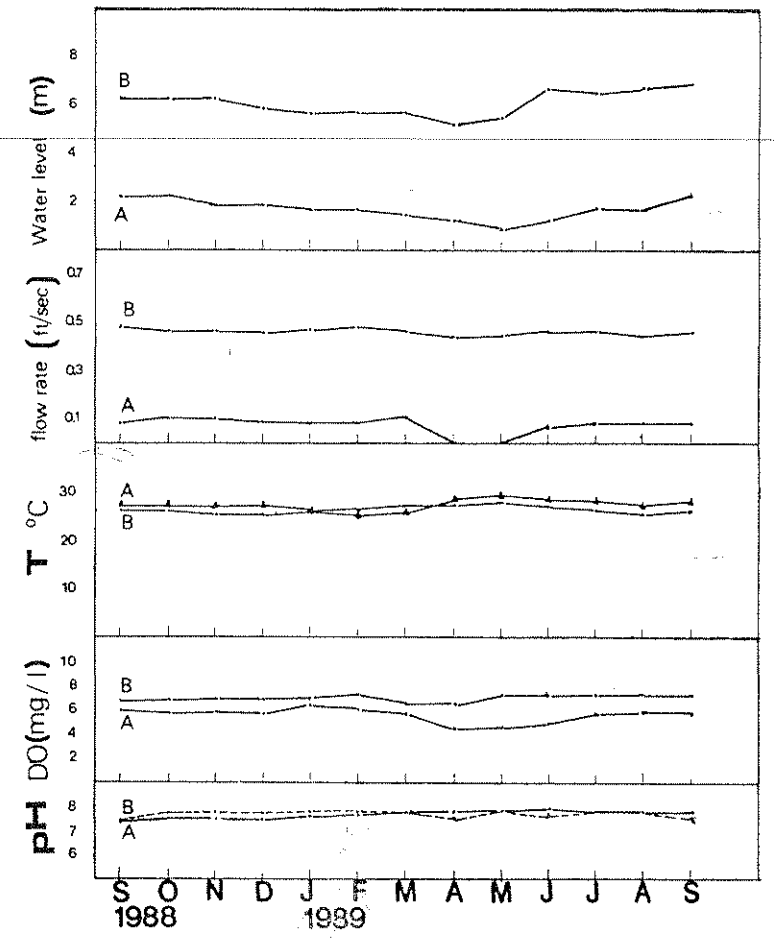

Fig. 4. The hydrological data of: A, 193 km canal at Nakornsawan Province; B, irrigation canal at Thakae, Lopburi Province from September, 1988 to September, 1989 with water level, flow rate, temperature, dissolved oxygen, and pH.

Results

Seasonal fluctuations in temperature, dissolved oxygen, pH, flow rate and water level were measured (Fig. 4).

The distribution over different depths of bottom of each species by area were represented in Fig. 5 and a series of monthly length frequency histograms was constructed in Fig. 6. These will give an assessment of the time of larval metamorphosis and settlement as well as period of growth and reproduction.

The abundances of the six species occurred in small irrigation canals or canals near rice fields which are shallower than 2 m with muddy bottom.

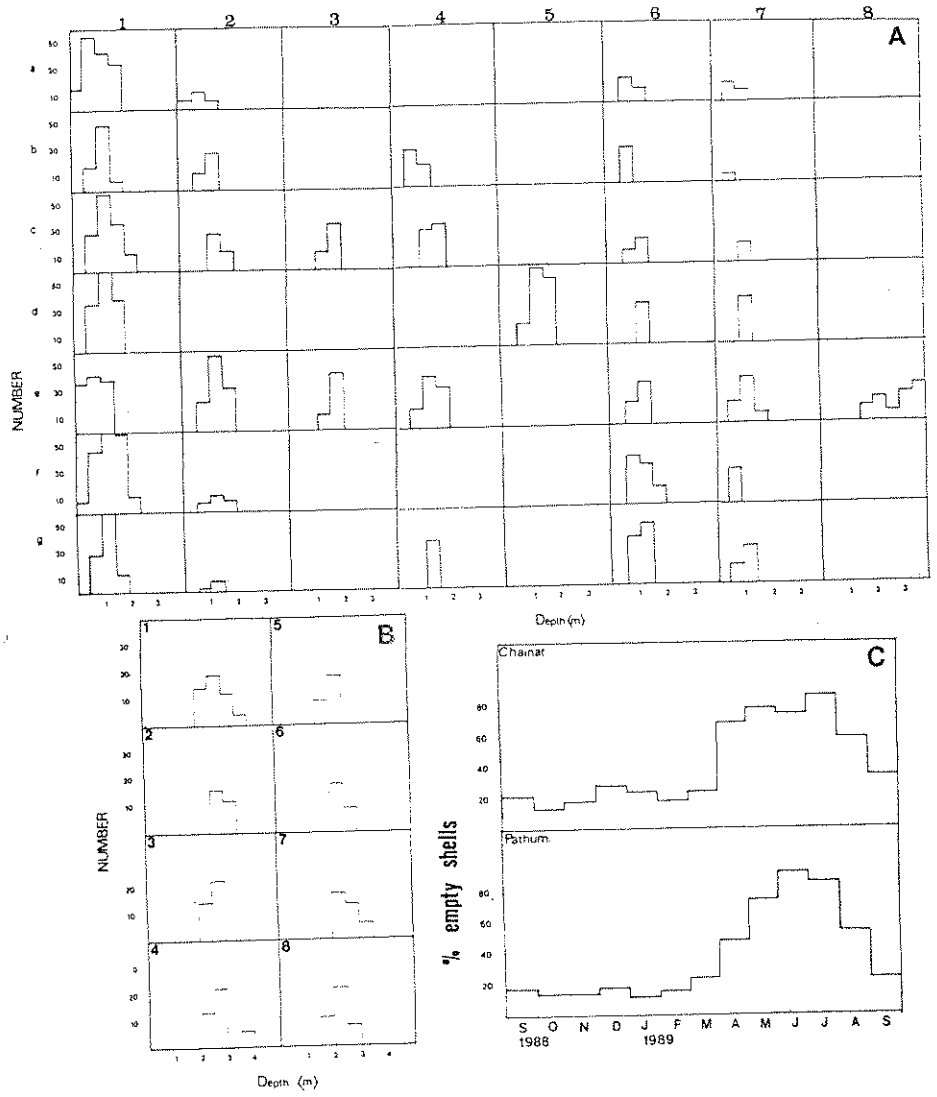

Fig. 5. **A.** The distribution upon different depths of bottom of eight species of amblemid mussels from sample areas between November, 1988 and January 1989. (Species 1–8 are ordered as in Table 1; a, 193 km canal Nakornsawan Province; b, Chainat Province; c, Inburi, Sigburi Provnce; d. Lopubri Province; e. Banmoh, Saraburi Province; f, Ayutthaya Province; g, Pathumtani Province) **B.** The distribution of *Hyriopsis* (*Limnoscapha*) *myersiana* in a big irrigation canal at 1, Chainat; 2, Takli; 3, Chongkae; 4, Nongmuang; 5, Banmi; 6, Thakae; 7, Lopburi; 8, Banmoh. **C.** Percentage of empty valves of *Pilsbryochoncha exilis* found at Chainat Province and Pathumtani Province (quadrat 25 m^2) from September 1988 to September 1989.

Table 1. Monthly mean numbers of eight species of amblemid mussels at different areas (per 25 m^2 area)
Area—A, Chainat Province; B, Nakornsawan Province; C, Lopburi Province; D, Saraburi Provincce; E, Ayutthaya Province.
Species—1. *Pilsbryochoncha exilis*, 2. *Uniandra contradens*, 3. *Physunio superbus*, 4. *Pseudodon cambodjensis*, 5. *P. vondembuschianus*, 6. *Ensidens ingallsianus*, 7. *Scabies crispata*, 8. *Hyriopsis* (*Limnoscapha*) *myersiana*

		1988				1989								
Species		S	O	N	D	J	F	M	A	M	J	J	A	S
1	A	152.0	131.8	112.0	90.8	98.0	86.3	69.8	54.8	48.8	41.0	34.0	49.0	96.3
	B	138.0	95.2	87.5	110.5	108.8	92.8	65.5	63.3	73.0	84.0	77.8	94.3	95.3
	C	100.3	97.3	101.0	98.8	86.8	60.0	60.3	54.0	64.6	69.8	97.8	86.3	92.3
	D	155.3	110.2	78.5	132.3	109.0	115.0	113.8	105.8	108.5	108.8	113.8	96.0	108.0
	E	117.2	99.2	115.2	108.0	110.5	103.5	92.5	89.0	81.5	96.5	101.3	109.0	98.3
2	A	55.6	64.1	58.3	63.3	58.0	48.6	62.0	48.3	49.3	41.5	32.4	52.6	49.4
	B	42.7	36.6	42.3	66.0	54.0	48.0	38.3	46.0	32.0	38.3	28.3	34.4	41.0
	C	66.5	42.0	43.6	46.6	46.0	47.3	54.0	46.6	44.0	41.4	48.2	41.3	49.5
	D	71.1	58.6	58.0	53.3	43.6	45.0	41.3	37.6	39.0	52.0	51.0	43.2	41.5
	E	48.2	57.4	42.6	39.6	28.5	31.2	35.0	27.0	32.1	31.2	38.4	48.4	39.0
3	A	17.4	13.2	9.3	11.0	12.6	16.1	8.4	9.6	7.4	9.0	12.3	10.0	14.0
	B	11.0	12.8	12.6	15.3	9.4	9.0	13.7	9.0	11.3	3.8	10.0	12.3	10.3
	C	—	—	—	—	—	—	—	—	—	—	—	—	—
	D	16.2	18.4	13.2	12.0	11.8	14.3	8.6	13.6	12.7	9.8	11.8	10.8	10.5
	F	—	—	—	—	—	—	—	—	—	—	—	—	—
4	A	16.0	13.2	9.4	11.7	7.3	12.1	13.0	11.8	11.3	13.0	11.5	12.3	10.0
	B	—	—	—	—	—	—	—	—	—	—	—	—	—
	C	17.6	14.3	19.0	16.4	13.6	14.8	17.0	13.2	13.6	12.4	14.0	13.0	12.3
	D	21.2	19.6	13.2	17.6	17.0	15.7	18.4	11.2	11.6	15.0	17.3	17.3	16.2
	E	—	—	—	—	—	—	—	—	—	—	—	—	—
5	A	—	—	—	—	—	—	—	—	—	—	—	—	—
	B	—	—	—	—	—	—	—	—	—	—	—	—	—
	C	66.2	71.4	83.5	76.1	65.0	49.2	67.3	58.6	51.3	47.3	56.5	52.3	57.0
	D	—	—	—	—	—	—	—	—	—	—	—	—	—
	E	—	—	—	—	—	—	—	—	—	—	—	—	—
6	A	18.0	15.6	12.1	16.2	15.6	16.6	14.8	15.0	17.4	16.0	17.2	15.3	17.3
	B	17.4	17.3	18.2	19.2	17.4	17.2	24.2	21.2	16.6	18.2	16.0	17.3	18.3
	C	11.8	14.6	13.6	9.6	14.1	18.3	15.2	14.1	12.3	15.7	13.3	11.5	14.0
	D	12.0	13.8	11.0	14.2	12.6	11.6	12.0	11.3	14.2	13.0	12.0	13.0	12.5
	E	14.7	15.6	11.8	12.8	13.0	14.2	15.1	11.4	10.2	11.3	16.8	12.5	15.0
7	A	13.0	15.6	12.3	8.0	11.0	13.7	13.2	9.7	12.1	13.0	14.5	11.3	13.7
	B	11.6	14.2	13.6	15.3	9.0	11.6	16.3	14.0	14.2	11.5	14.0	13.3	13.0
	C	22.3	19.0	28.4	19.0	17.8	19.3	16.5	15.0	17.2	21.3	15.5	16.8	16.3
	D	18.0	17.3	21.6	17.0	12.0	13.6	14.0	19.6	15.0	15.0	14.0	14.8	15.0
	E	7.0	11.2	13.0	9.2	14.6	21.2	13.2	9.6	11.3	14.8	13.5	13.8	13.0
8	A	7.0	13.6	7.0	10.0	12.0	11.6	7.3	10.0	8.4	10.3	10.0	9.8	11.3
	B	7.6	10.0	9.0	10.6	7.6	10.3	12.0	8.3	6.7	9.0	9.5	9.3	9.3
	C	7.0	11.4	7.6	14.3	11.2	13.0	9.0	11.4	9.6	10.3	11.3	9.0	10.3
	D	8.6	9.0	11.0	7.6	6.6	8.0	7.0	14.1	11.3	9.5	11.5	10.0	11.8
	E	—	—	—	—	—	—	—	—	—	—	—	—	—

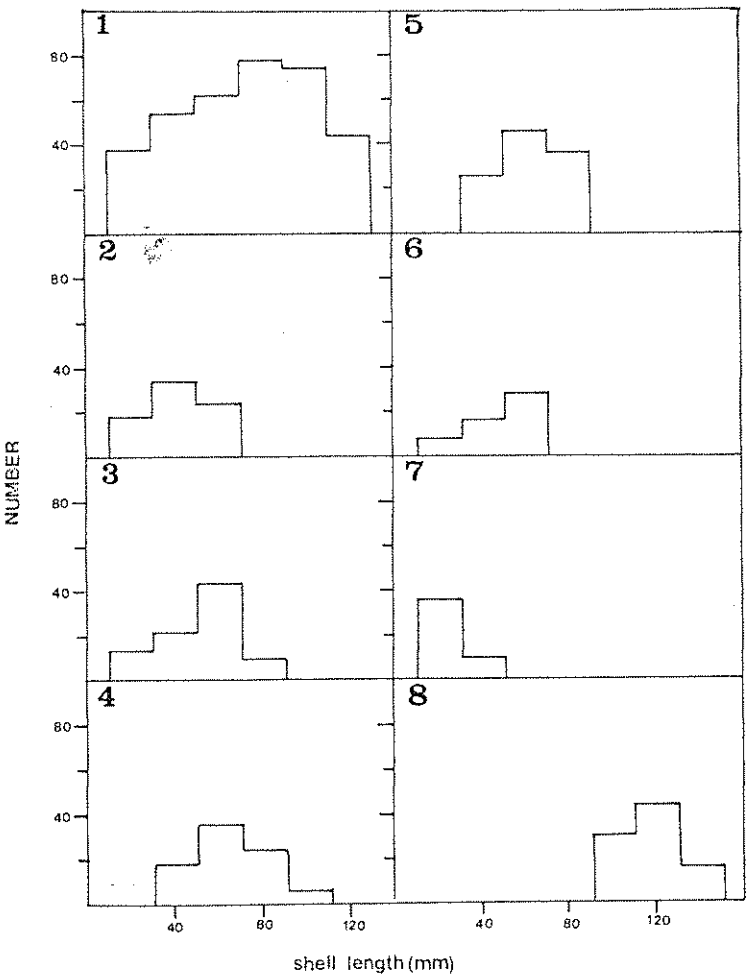

Fig. 6. Size frequency histograms of the population structure of eight species of amblemid mussels from November 1988 to March 1989. (Species 1-8 are ordered as in Table 1). The areas selected are Saraburi Province (Species 1-4, 7, 8), Lopuri Province (Species 5), Ayutthaya Province (Species 6).

The other two species, *Hyriopsis (Limnoscapha) myersiana* and *Physunio superbus*, were usually found from deeper than 2 m in the biggest irrigation canal. However, *Pseudodon vondembuschianus ellipticus* was rarely found at only Lopburi Province in a canal near rice field and some small irrigation canals of which the depth ranged between 1.40 m and 1.95 m with muddy bottom.

The monthly mean population of 8 species was estimated as shown in Table 1. Shell length varied between 7 mm and 140 mm. The biggest species was *Hyriopsis (Limnoscapha) myersiana*, the smallest one was *Scabies crispata*.

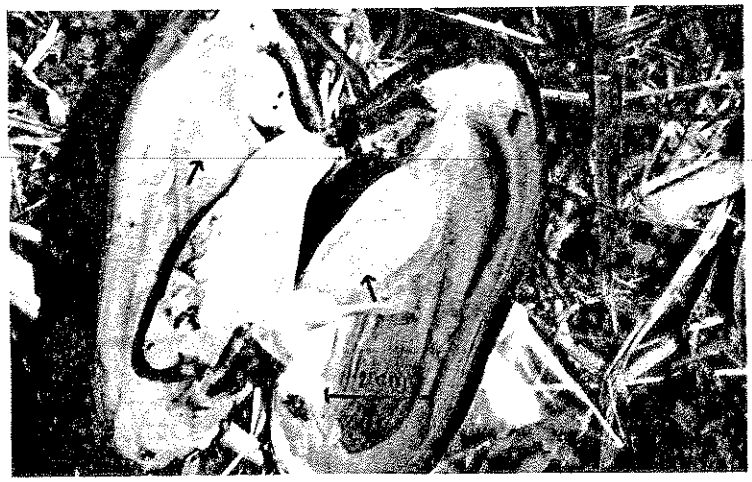

Fig. 7. The marsupia of *Pilsbryochoncha exilis* (arrows) collected from Banmoh, Saraburi Province, 14 November 1988.

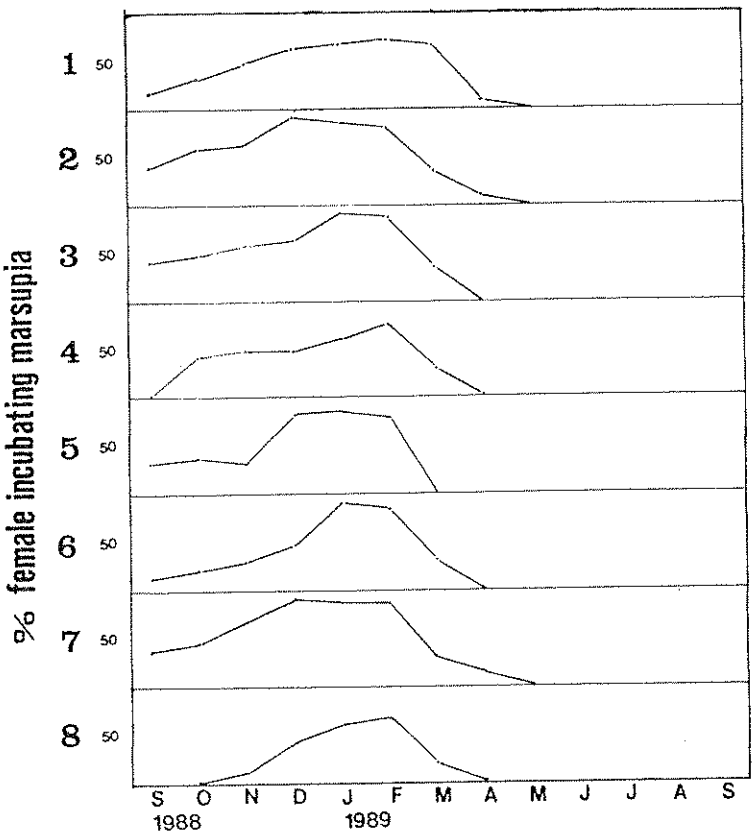

Fig. 8. The percentage frequency of females incubatin larvaeg within the outer or both inner and outer demibranchs from September 1988 to September 1989.

Table 2. Size range of female carrying marsupium in eight species of amblemid mussels.

Species	Size range (mm)
1. *Pilsbryochoncha exilis*	63—136
2. *Physunio superbus*	48— 89
3. *Uniandra contradens*	28— 62
4. *Pseudodon cambodjensis*	67— 86
5. *Pseudodon vondembuschianus*	59— 83
6. *Ensidens ingallsianus*	34— 66
7. *Scabies crispata*	9— 31
8. *Hyriopsis (Limnoscapha) myersiana*	78—160

Table 3. Fourteen species of fish and percentage in infection by amblemid glochidia, based on collections from canals at Saraburi Province and Ayutthaya Province, December 1988 to February 1989.

Fish species	No. examined	% infection
Cyprinidae		
A. *Puntius schwannenfeldi*	42	53.8
B. *Puntius gonionotus*	26	26.9
C. *Puntioplites proctozysron*	17	47.0
D. *Cirrhinus jullieni*	61	45.9
E. *Rasbora heteromorpha*	40	44.4
Bagridae		
F. *Mystus nemurus*	18	63.6
G. *Mystus vittatus*	134	69.4
Eleotris marmoratus		
H. *Oxyeleotris marmoratus*	22	45.4
Centropomidae		
I. *Chanda siamensis*	83	67.4
Notopteridae		
J. *Notopterus notopterus*	40	60.0
Nandidae		
K. *Pristolepis fasciatus*	71	71.9
Ophicephalidae		
L. *Channa striatus*	14	35.7
Belonidae		
M. *Xenentodon cancila*	9	33.3
Anabantidae		
N. *Trichogaster microlepis*	67	43.3

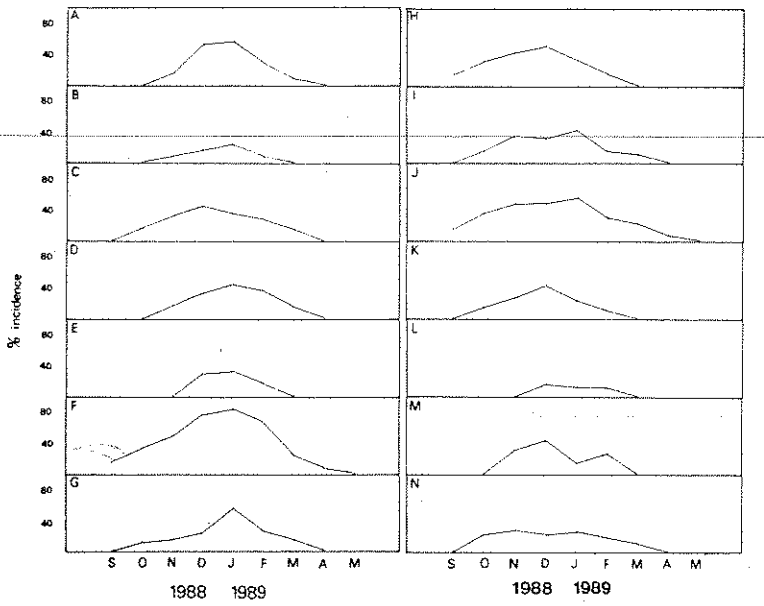

Fig. 9. Incidence of infection of fourteen species of fish by glochidia of freshwater mussels from September 1988 to September 1989. Species A to N are ordered as in Table 3.

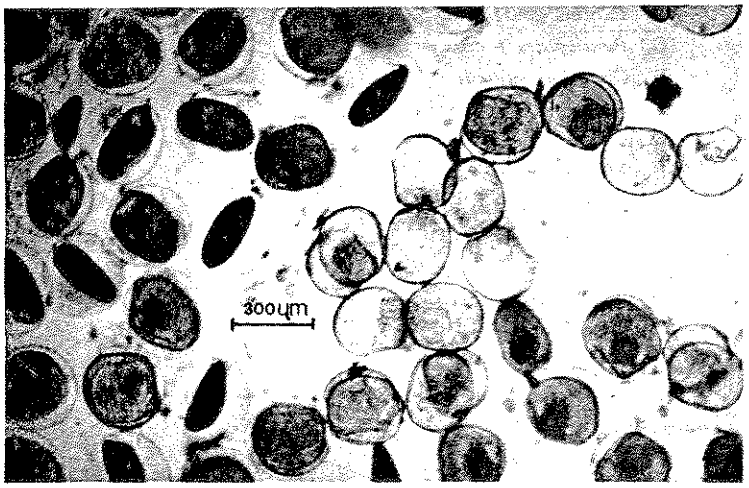

Fig. 10. Glochidia of *Uniandra contradens*.

Juveniles and small individuals of mussels (less than 15 mm shell length) were obtained in November, December, January and February, but the frequency of occurrence was low in November and they are absent from March and May.

Sexual cycle, female gravidity and glochidial settlement:

The ratio of males to females by each species are: *Pilsbryochoncha exilis*

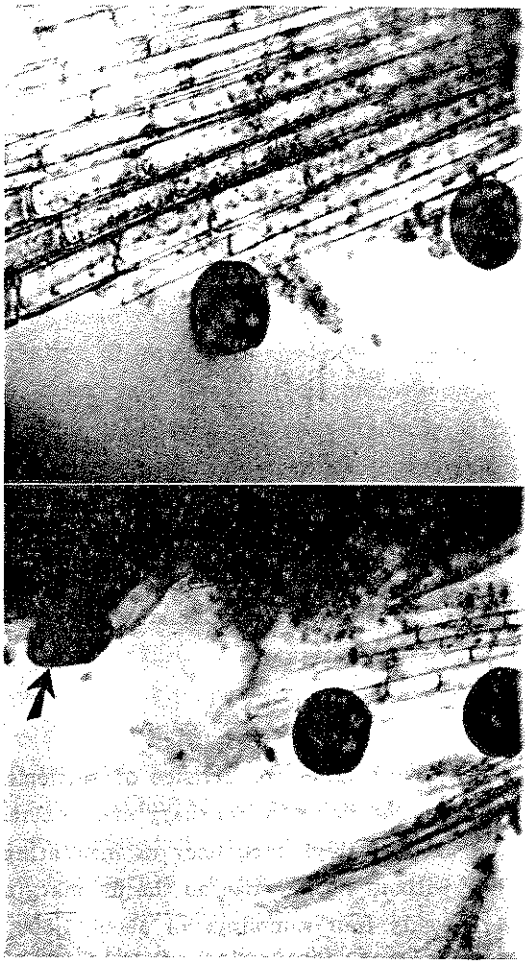

Fig. 11. The glochidia of *Uniandra contradens* small cyprinid fish *Cirrhina jullieni* (a fin, and abdomen (arrow) (b).

exilis 1.5 : 1, *Physunio superbus* 1 : 1.1, *Uniandra co* *'seudodon* *cambodjensis* 1 : 1.6, *Ensidens ingallsianus* 1 : 1.1 ι 1.2 : 1, *Hyriopsis* (*Limnoscapha*) *myersiana* 1 : 1.3, and *Ps* *ιschianus* 1 : 1.

The outer or inner and outer demibranchs of ified for marsupium to incubate fertilized eggs in the suprab (Fig. 7). Brooding occurs in females of 9–10 mm shell length ι to 140–150 mm in *Hyriopsis* (*Limnoscapha*) *myersiana* (Tab nal basis, the occurrence of incubating females of 8 species) ecember, January and February (Fig. 8), while lowest or a \pril and May.

Glochidial settlement on fish of mussels is observ rom mid-

Table 4. The numbers of glochidia collected in plankton nets from September 1988 to August 1989 at Ayutthaya Province.

Month	No. of glochidia collected nearest mussel bed
1988	
September	—
October	32,700
November	69,000
December	120,300
1989	
January	264,000
February	167,000
March	2,250
April	—
May	—
June	—
July	—
August	—

October to late March (Fig. 9). The highest occurrence of settlement varied by species, for example, *Pilsbryochoncha exilis* in February and *Scabies crispata* in January. This corresponded with the high frequency of incubating femaels.

The glochidia, with hooks or without hook, settle on the fin margins or gills of fish and encyst (Fig. 10). Twenty four samplings of about 1,500 fish were made from September, 1988 to August, 1989 (Table 3). Of 29 fish species collected, only 14 species were infected with glochidia at various parts of fish body (Fig. 11). However, glochidial identification was not still established in almost all species. Only a special observation on glochidium and host relationship of *Physunio superbus* in yellow mystus *Mystus nemurus* were made. However, it can be concluded that smaller fish are more heavily infected with glochidia than larger ones and the peak of infection started from November, 1988 till January, 1989 (Panha, 1989). Almost all of fish in the family Cyprinidae, Bagridae, and Eleotridae are found to be infected by glochidia (Table 3).

Discussion

Considering the data obtained through this research, the mussels of the family Amblemidae are well represented in the freshwaters of surveyed area. This study found eight species of mussels in various habitats. In the canals near rice fields of all Provinces in the Central Thailand under study, the dominant species were *Pilsbryochoncha exilis, Ensidens ingallsianus, Uniandra*

contradens, *Pseudodon cambodjensis* and *Scabies crispata*, that were found almost together at the same habitat. *Hyriopsis myersiana* and *Physunio superbus* were found at deeper than 2 m in irrigation canals. However, *Pseudodon vondembuschianus* was rarely found at only Lopburi Province in some canals near rice fields and some small irrigation canals of which the depth ranged between 1.40 m to 1.95 m with muddy bottom, with pH ranged between 7.7 and 8.4.

The quantitative distribution of amblemid mussels was modified in time and space by modifications of its habitat. One of the factors affecting density and distribution of mussels in the same place was the stretch and depth of the water. In water with large strech, mussels were more widely dispersed over the pool and as the water subsides mussels withdraw as well. The zonation pattern of many species of freshwater mussels was observed (Hanex and Fernando, 1978; Panha, 1985). The average density variations of each Amblemidae population was investigated in the irrigation canals and canals near rice fields was related to the depth of water from September, 1988 to September, 1989 (Fig. 5). The biggest species which is also the most valuable for pearl farming, *Hyriopsis myersiana* can live only in the large and deep irrigation canal, as this species was found at the depth ranged from 2 to 7 m (Fig. 5B).

In periods with shallow water, thus with less extensive surface, mussel density was greater and vice versa. However, the low density of *Pilsbryochoncha exilis* at Chinat and Pathumthani Provinces in April, May, June, and July 1989, when the water reached its minimal depth level and covered with rich vegetation, particularly water hyacinth, was accounted by an intense degree of silting. Thus, the canals became stagnant which led to an intense mortality of molluscs. In samples collected in May, June, and July 1989, a high percentage of empty valves was found (Table 1 and Fig. 5C).

Other factors affecting the distribution of mussels in the canals were the nature of the bottom and the presence or absence of vegetation. In places where the bottom surface was covered by a thick layer of bare mud, the richest fauna of mussels were found. In places with silty bottom covered with vegetation (water hyacinth and others), the mussel population was extremely poor. Of the Amblemidae, *Pilsbryochoncha exilis* became a dominant species while *Uniandra contradens* and *Ensidens ingallsianus* ranked the second. In place with sandy, deep, well-aerated bottoms, only *Hyriopsis myersiana* dominated.

Reproductive cycles:

The amblemid mussels spread their reproductive cycle over a long period of time, from rainy season until early of summer. Females approach maturity during the cold season, namely, in November, December, January and Febraury, as water temperature lowers. The patterns were little different from each

other among eight species of mussels (Fig. 9). Release of the ova into suprabranchial chamber of gills takes place from September in almost all species, except *Pseudodon cambodjensis* and *Hyriopsis myersiana*. Fertilization occurs there and developing larvae are incubated in the marsupium. Temperature may give an effect for female maturity or for the growth and development of some plankton which is the food for both juvenile and adult mussels.

The release of glochidia follows a period of incubation of which the peak varies by species. In the observation of glochidial release in *Pilsbryochoncha exilis*, *Ensidens ingallsianus*, *Uniandra contradens* and *Scabies crispata* by plankton net sampling glochidia was found in the short incubation period about 1 month. The first individuals of mussels incubating glochidia was observed in September, and glochidia were released in October (Fig. 8 and Table 4), and the host attachment began in the same month (Fig. 9). The incubation period seems to be rather short in all species, and the further studies should be done in the near future for confirmation. Most temperate zone species have long incubation periods spanning during autumn and winter (Heard, 1975; Dudgeon and Morton, 1923). From the data of this study, high and low temperatures may accelerate larval development and subsequent release.

A series of observations carried out in nature and in the laboratory showed that, although the reproductive cycle of Amblemidae involved unfolds within wide temperature limits, thermal shocks, even within these limits, induce a mass elimination of larvae from mussels and simultaneously the destruction of the branchial tissue. As a rule, release of larvae in the natural habitat will take place gradually and not suddenly, as temperature shocks are uncommon. The successive release of larvae is an advantage for the survival of the adults, because in the case of massive release, destruction of the branchial tissue might inflict severe injury. Moreover, the gradual deposition and release of the larvae offers an advantage by increasing the chance of the released glochidia to reach the host fish for its development and maintaining the population.

From September, 1988 through September, 1989, released glochidia were found attached to the fins and gills of fish. The peak of incidence is in December or January which depended on mussel species (Fig. 9). The frequency of infection to fish hosts corresponded with the high frequency of incubating females. Fourteen species of fish were found infected by glochidia, particularly the families Cyprinidae, Bagridae and Eleotridae.

In this study, both laboratory and field observations demonstrated that some amblemid mussels exhibited a high degree of host specificity. Hosts of *Physunio superbus* were limited to two bagrid fish, *Mystus nemurus* and *Mystus vittatus* (Panha, 1989), whereas the only host of *Pilsbryochoncha exilis* was a cyprinid fish.

Host specificity of glochidia has been observed by several authors (Lefevre

and Curtis, 1912; Arey, 1921; Murphey, 1942; Tedla and Fernando, 1969; Wile, 1975; Zale and Neves, 1982 and Bauer, 1987). They showed the data of laboratory and field in details such as the susceptibility to attachment by the glochidia, host specificity, and glochidial metamorphosis in hosts. Murphey (1942) observed that in nature the glochidia of *Margaritifera margaritifera* attach on the gill filament of rainbow and brown trouts. Bauer (1987b) presented the same results in the laboratory works.

The relationship of fish and freshwater mussel was very interesting, although only 2 cases were crudely observed in this study. The changes of the species composition and relative abundance of fish fauna may result in the reproductive failure of mussel populations through loss of required fish hosts. River systems inhabited by mussels, particularly endangered species, should therefore be managed to retain their existing fish fauna.

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要　約

1988年9月～1989年9月，タイ国中央部のナコルンサワン，チャイナット，ロブブリ，サラブリ，シングブリ，アユチャヤ及びパツムサニ地方の灌漑用水や他の運河の淡水二枚貝の調査を行った結果8種同定された．中では *Pilsbryochoncha exilis* が最も多く，調査の全域に分布していた．*Ensidens ingallsianus*, *Uniandra contradens* 及び *Scabies crispata* がこれに次ぐ．*Psudodon vondembuschianus* はロブブリにのみ分布した．最大種で真珠養殖上最重要種の *Hyriopsis myersiana* は最も深いところ（水深2～7 m）にすむ．保育嚢をもつ雌貝は種によって季節が若干異なる．グロキヂウムが寄生する魚類は14種に達し，1988年の10月中旬から1989年3月まで見られたがそのピークは種によって12～1月であった．宿主の選択性も示唆され，魚類相が変化すると二枚貝類の繁殖もおびやかされる恐れが生ずるであろう．

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