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ความหลากชนิดของหอยน้ำจืดในพื้นที่แอ่งเกษตรแม่ลาว จังหวัดเชียงราย และความสัมพันธ์กับปัจจัยกายภาพ-เคมีบางประการ

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บทคัดย่อ: แอ่งเกษตรแม่ลาวตั้งอยู่ในพื้นที่ลุ่มน้ำย่อยแม่ลาวของลุ่มน้ำกก จังหวัดเชียงราย โดยพื้นที่นี้ยังไม่มีรายงานความหลากชนิดของหอยน้ำจืดมาก่อน ดังนั้นวัตถุประสงค์ของการศึกษาครั้งนี้ เพื่อประเมินความหลากชนิดและศึกษาปัจจัยทางกายภาพ-เคมีบางประการของแหล่งน้ำที่สัมพันธ์กับความชุกชุมของหอยน้ำจืด โดยดำเนินการเก็บตัวอย่างหอยน้ำจืดด้วยวิธี Quadrat sampling และศึกษาคุณสมบัติทางกายภาพ-เคมีบางประการของแหล่งน้ำในพื้นที่แอ่งเกษตรของอำเภอแม่ลาว จังหวัดเชียงราย และศึกษาความหลากชนิดโดยใช้ดัชนีความมากชนิด (Species richness) ดัชนีความหลากหลาย (Shannon's diversity index) และดัชนีความสม่ำเสมอ (Evenness index) และวิเคราะห์ความสัมพันธ์ระหว่างความชุกชุมของหอยน้ำจืดกับปัจจัยทางกายภาพ-เคมีของแหล่งน้ำในแต่ละถิ่นอาศัยของหอยร่วมด้วย ผลการศึกษาพบหอยทั้งหมด 3,725 ตัว จัดจำแนกได้ 12 ชนิด คือ *Bithynia funiculata*, *B. siamensis goniomphalos*, *B. s. siamensis*, *Clea helena*, *Trochotaia trochoides*, *Filopaludina doliaris*, *F. martensi martensi, F. sumatrensis polygramma*, *Lymnaea auricularia*, *Melanoides tuberculata*, *Pomacea canaliculata* และ *Corbicula* sp. ซึ่งจากหอยทั้ง 12 ชนิดนี้ พบหอย 9 ชนิดที่มีความสำคัญทางการแพทย์และสัตวแพทย์ โดยหอยที่พบจำนวนมากจากการศึกษาครั้งนี้ คือ ชนิด *B. s. siamensis* และ *M. tuberculata* ผลจากการวิเคราะห์ข้อมูลคุณสมบัติทางกายภาพ-เคมีของแหล่งน้ำระหว่างถิ่นอาศัย (ลำธารและนาข้าว) ของหอยน้ำจืดพบว่าไม่แตกต่างกันอย่างมีนัยสำคัญ อย่างไรก็ตาม ปัจจัยทางกายภาพ-เคมีบางประการของแหล่งน้ำที่สัมพันธ์กับความชุกชุมของหอยน้ำจืดอย่างมีนัยสำคัญนั้น ได้แก่ ค่าออกซิเจนละลายน้ำและค่าความเป็นกรด-ด่าง ($p<0.05$) โดยพบในถิ่นที่อยู่ที่เป็นลำธาร นอกจากนี้พบว่าความหลากชนิดและความชุกชุมของหอยน้ำจืดในถิ่นอาศัยที่เป็นลำธารนั้น มีความหลากชนิดและความชุกชุมสูงกว่านาข้าว ซึ่งการศึกษาครั้งนี้เป็นรายงานความหลากชนิดของหอยน้ำจืดครั้งแรกจากแอ่งเกษตรแม่ลาวในพื้นที่ลุ่มน้ำย่อยแม่ลาว

คำสำคัญ: ความหลากชนิด หอยน้ำจืด แอ่งเกษตรแม่ลาว ปัจจัยทางกายภาพ-เคมี

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Species Diversity of Freshwater Snails in Mae Lao Agricultural Basin (Chiang Rai, Thailand) and its Relationship with some Physio-chemical Parameters

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Abstract: Mae Lao agricultural basin is located in the Mae Lao sub-river basin of Kok River basin, Chiang Rai province, Thailand. There is a scarcity of information on the diversity of freshwater snails in this area. Herein, the aim of this study was to assessing the freshwater snail diversity and the abundance in relation to the physio-chemical properties in different watercourse. Physio-chemical properties and snails were sampled in 10 sites in Mae Lao district to characterize the snail habitats. Species richness, Shannon's diversity and evenness indices were employed to describe snail diversity and diversity across the habitat types. Statistical analyses were conducted to examine the extent to which the physio-chemical properties and abundance of snails. Among 3,725 collected snails, 12 snail species namely *Bithynia funiculata*, *B. siamensis goniomphalos*, *B. s. siamensis*, *Clea helena*, *Trochotaia trochoides*, *Filopaludina doliaris*, *F. martensi martensi, F. sumatrensis polygramma*, *Lymnaea auricularia*, *Melanoides tuberculata*, *Pomacea canaliculata* and *Corbicula* sp. were identified. 9 out of these 12 snail species are of medical and veterinary importance. *B. s. siamensis* and *M. tuberculata* were the most enumeration of snail species. Analysis of the data revealed that the physio-chemical properties no significant difference across the stream and rice paddy habitats. However, freshwater snail abundance was significant correlated with dissolved oxygen and pH in stream habitat ($p<0.05$). In addition, different habitats had different species diversity and snail abundance with high snail abundance at stream habitats. The present study is the first research on the freshwater snail fauna in Mae Lao agricultural basin and all snail species were recorded for the first time from this area.

Keywords: Species diversity, Freshwater snail, Mae Lao agricultural basin, Physio-chemical parameters

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Introduction

The Mae Lao agricultural basin is located in the Mae Lao sub-river basin of Mae Kok River basin and covers Mae Lao district, Chiang Rai province, northern Thailand. It's an area under watershed class 1 and 2. Land use of Mae Lao district comprises mainly rice production, vegetables and fruit trees-perennial crops. Agricultural land comprises 58,421 ha (18% of the total area) (Janekarnkij, 2014). There were not any studies on the species diversity of freshwater snails in the region and or information on the habitat distribution of the freshwater snails there.

Previously, 16 species of freshwater snails were reported from other areas of Chiang Rai province, which focused on the studies of larval trematode infection in snails (Mard-arhin *et al*., 2001; Dechruksa, 2006; Sri-aroon *et al*., 2007; Chontananarth and Wongsawad, 2017). Fresh water snails are an important ecological community; thus they are very important consumers of primary production and secondary producers, such as *Sulcospira hainanensis.* They have been reported is an abundant secondary consumer in Hong Kong streams (Yeung and Dudgeon, 2014). Moreover, freshwater snails play significant role in public and veterinary health (Dillon, 2000). Many species of freshwater snails are important intermediated hosts of helminthes (i.e., trematode and nematode) and parasites of human and animal disease (Woodruff and Upatham, 1992; Sri-aroon, 2011; Madsen and Hung, 2014). Several environmental factors are considered as affecting the ecology of freshwater snails. Physio-chemical properties of water, such as temperature, dissolved oxygen, salinity and acidity, are key abiotic modulators that can affect organisms' composition, distribution and abundance in freshwater environment (Abdulkadir *et al*., 2013; Sharma *et al*., 2013; Salawu and Odaibo, 2014; El-deeb *et al*., 2017).

This gap in knowledge has hindered our understanding of the species distribution of freshwater snails in this area, and its relationship between their abundance and some physio-chemical properties of water bodies. Hence, the study was aimed at providing baseline data on the species diversity of freshwater snails and the influence of some physio-chemical parameters on the abundance of freshwater snails, to the represent the area of Mae Lao agricultural basin.

Materials and Methods

Study area

The study area is in Mae Lao district, Chiang Rai province, north Thailand (Figure 1). This area, located in the Mae Lao sub-river basin of Kok River basin, has a tropical

monsoon climate with distinctive seasons. Sampling sites were selected in consideration of the potential freshwater snail habitats and site accessibility. A total of 10 sampling sites in Mae Lao district feasible for sampling were identified along the edges of the two habitat types, including streams and rice paddies. Sampling of freshwater snails was conducted in July, September and November 2017. Sampling in three periods was to capture the habitat conditions of the rainy season. According to to Brockelman *et al.* (1986) who reported this time period corresponded to the peak in snail reproduction. The habitat types and geographical positions of the sites were recorded and given in Table 1.

Sample collection

Physio-chemical properties of water: Water temperature, electrical conductivity, dissolved oxygen (DO), pH, total dissolved solid (TDS) and salinity were measured directly in the selected watercourses using multi-probe water quality meters (EUTECH CyberScan PCD650). All the physio-chemical parameters were measured and recorded between 10:00 am to 3:00 pm. These parameters have been considered as possible abiotic factors influencing freshwater snail distributions (Salawu and Odaibo, 2014; Sharma *et al.*, 2013; Marie *et al.*, 2015; El-deeb *et al.*, 2017).

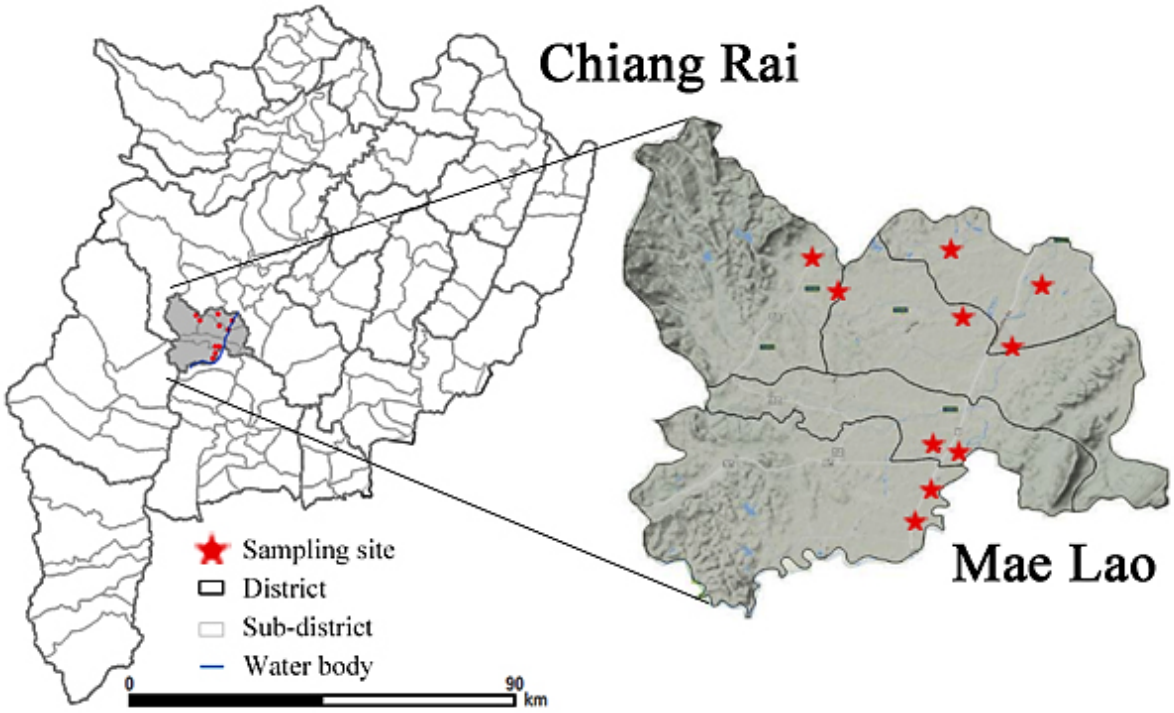

Figure 1. Map of the study area, showing the sub-districts of sampling sites, indicated by the gray polygons, in Chiang Rai province, Thailand.

Table 1. List of sampling sites where snails were collected.

Habitat types	Sampling site	Coordinates (UTM)
Stream	1. Sri Wang Moon village, Bou Sali Sub-district	47Q 0579971, 2190137
	2. Mae Tak village, Bou Sali Sub-district	47Q 0576564, 2191577
	3. Rong Sala village, Dong Mada Sub-district	47Q 0575837, 2182466
	4. Pa Sang village, Pong Phrae Sub-district	47Q 0571279, 2191158
Rice paddy	1. Pa Ko Dam Mai village, Pa Ko Dam Sub-district	47Q 0578894, 2187948
	2. Nong Bou village, Pa Ko Dam Sub-district	47Q 0576866, 2188841
	3. San Pa Sak village (1), Chom Mok Keaw Sub-district	47Q 0576893, 2183806
	4. San Pa Sak village (2), Chom Mok Keaw Sub-district	47Q 0576074, 2184078
	5. Pa Tung village, Dong Mada Sub-district	47Q 0575252, 2181352
	6. Mae Mon village, Pong Phrae Sub-district	47Q 0572223, 2189898

Snail sampling and Identification: The freshwater snails were sampled by quadrat method. Along the shallow edge of the watercourse of sampling site, a 1 m square quadrat measuring 1 m^2 in area was placed three times at every meter interval along a transect to measure a total quadrat area of 3 m^2 (Krebs, 1989). All snail species found within the quadrat were collected and then preserved in 70% ethyl alcohol solution. The specimens were classified by conchology using taxonomic key (Brandt, 1974; Upatham *et al*., 1983).

Data analysis

The following indices were used to describe species abundance and diversity. First, richness index is defined by the Margalef's richness index (*D*), was computed with the following formula:

$$D = \frac{S - 1}{\ln n}$$

where *S* was the total number of species and *n* was the total number of individuals (Washington, 1984; Clarke and Warwick, 1994).

Second, Shannon's diversity index (*H*) was computed to measure snail diversity across different habitat types with the following formula:

$$H = -\sum_{i=1}^{n} p_i \ln p_i$$

where p_i was the proportion of the total count arising from the *i*-th species. A higher value indicated a large number of species with similar abundances, whereas a lower value indicated low diversity that was dominated by one or a few species

(Washington, 1984; Clarke and Warwick, 1994; Hill *et al*., 2005).

Third, species evenness (*J'*), this expresses how evenly the individuals are distributed among the different species, and is often expressed as Pielou's evenness index with the following formula:

$$J' = \frac{H}{\ln S}$$

where *H* referred to Shannon's diversity index. Its values between 0 and 1; values closer to zero represented uneven populations that were dominated by one species, while values closer to 1 represented even populations that were comprised of several species with similar abundances (Brewer, 1994; Clarke and Warwick, 1994; Hillebrand, 2008).

Statistical analysis

To examine the influence of physio-chemical parameters on the abundance of freshwater snails, two sets of statistical analyses were conducted. The first set of analysis used basic descriptive statistics to summarize the physio-chemical properties of the two habitat types (i.e., streams and rice paddies). The data was statistically analyzed for the significance. The difference was demonstrated at $p<0.05$ by using T-test and values were expressed as means±S.D. The second set of analysis consisted of correlation analyses to explore the relationship between physio-chemical parameters with freshwater snails abundance were determined by Pearson's correlation. The significant level was set at $p<0.05$. All the statistical analyses were performed using R version 3.4.3 (R Development Core Team, 2017).

Results

Physio-chemical properties of water

There was no significantly difference between sampling site of physio-chemical properties, but stream habitats tend to had higher mean temperature, DO, pH and salinity compared to rice paddies. Conversely, rice paddies had the higher mean for electrical conductivity and TDS than stream habitats. The details of the physio-chemical parameters with range and standard deviation are shown in Table 2. It was noticed that the streams and rice paddy habitats have the same properties of water. There were no significant differences among stream and rice habitats ($p>0.05$).

Composition and diversity of freshwater snail species

A total of 3,725 freshwater snails were collected from the ten sites of investigation during the study period (Table 3 and Figure 2), consisting of 7 families, 8 genera and 12 snail species namely *Bithynia funiculata* (1.77%), *B. siamensis goniomphalos* (0.08%),

B. s. siamensis (58.50%), *Clea helena* (2.71%), *Trochotaia trochoides* (2.66%), *Filopaludina doliaris* (0.27%), *F. martensi martensi* (1.21%), *F. sumatrensis polygramma* (0.99%), *Lymnaea auricularia* (0.13%), *Melanoides tuberculata* (30.50%), *Pomacea canaliculata* (0.94%) and *Corbicula* sp. (0.24%). All freshwater snails were found in two habitat types, i.e. streams and rice paddies, except the species *Corbicula* sp. which was not found in rice paddies. The two most abundant species in the stream habitats were *M. tuberculata* (1,118) and *B. s. siamensis* (825). For rice paddies, *B. s. siamensis* was the most abundant species, accounting for 1,354 of the 1,585 snails collected. The abundance of individuals per 1 m^2 was <1-93.17 in stream habitats and <1-75.22 in rice paddy.

Index of species diversity and equitability

The species richness, diversity and evenness showed that the stream habitats had the higher than rice paddy habitats, with a species richness of 12 (D = 1.434±0.793). For the rice paddy habitats, were not found snail species *Corbicula* sp. in any their of sampling sites, resulting in a species richness of 11 (D = 1.357±0.961) (Table 4). In addition, the stream habitats had the largest snail abundance than rice paddy habitats, with an average of 178.33 snails per m^2, which was about double of that for the rice paddies (88.05 snails per m^2). The highest diversity index was recorded in the streams (H = 1.060±0.372) where all species in the stream were sampled, and the diversity index of rice paddy habitats was 0.720±0.543The evenness index was also higher in stream habitats (J' = 0.426±0.481), whereas the rice paddy habitats were 0.300±0.343.

Table 2. The physio-chemical properties of the sampling sites in two habitat types of Mae Lao district, Chiang Rai province.

Parameters	Mean±S.D. (Range)				*P* value
	Stream (*n = 12*)		Rice paddy (*n = 18*)		
Water temperature (°C)	30.45±1.71	(28.6-32.0)	28.52±3.24	(24.5-32.4)	0.310
Electrical conductivity (µS/cm)	149.65±27.01	(120.9-184.4)	158.65±48.37	(102.1-221.0)	0.746
Dissolved oxygen (mg/l)	4.88±1.82	(2.41-6.77)	4.66±2.33	(2.39-8.02)	0.875
pH	6.85±0.24	(6.5-7.0)	6.58±0.33	(6.1-7.0)	0.205
Total dissolved solid (mg/l)	4.46±1.33	(2.570-5.570)	5.22±2.09	(3.060-8.450)	0.540
Salinity (ppt)	0.0135±0.0005	(0.013-0.014)	0.0128±0.0012	(0.011-0.014)	0.327

Table 3. Species and number of freshwater snail collected in Mae Lao district, Chiang Rai province.

Family	Species	No. of individuals		Total	% of total individuals	Abundance (indiv./m^2)	
		Stream	Rice paddy			Stream	Rice paddy
Bithyniidae	*Bithynia funiculata*	54	12	66	1.77	4.5	0.67
	Bithynia siamensis goniomphalos	2	1	3	0.08	0.17	0.05
	Bithynia siamensis siamensis	825	1,354	2,179	58.50	68.75	75.22
Buccinidae	*Clea helena*	7	94	101	2.71	0.58	5.22
Viviparidae	*Trochotaia trochoides*	98	1	99	2.66	8.17	0.05
	Filopaludina doliaris	2	8	10	0.27	0.17	0.44
	Filopaludina martensi martensi	15	30	45	1.21	1.25	1.67
	Filopaludina sumatrensis polygramma	5	32	37	0.99	0.1	1.78
Lymneidae	*Lymnaea auricularia*	1	4	5	0.13	0.08	0.22
Thiaridae	*Melanoides tuberculata*	1,118	18	1,136	30.50	93.17	1.0
Ampullariidae	*Pomacea canaliculata*	4	31	35	0.94	0.33	1.72
Corbiculidae	*Corbicula* sp.	9	0	9	0.24	0.75	0
	Total	2,140	1,585	3,725	100	178.33	88.05

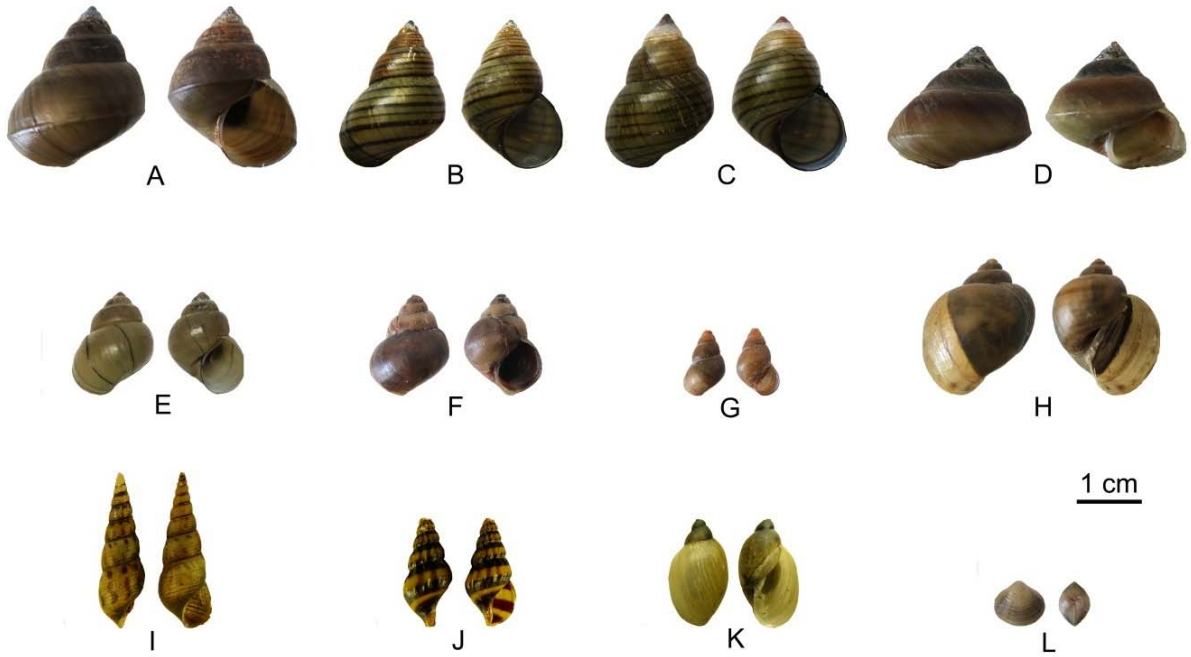

Figure 2. The shells morphology of freshwater snails collected from sampling sites (A) *Filopaludina martensi martensi;* (B) *F. doliaris;* (C) *F. sumatrensis polygramma;* (D) *Trochotaia trochoides;* (E) *Bithynia funiculata;* (F) *B. siamensis goniomphalos;* (G) *B. s. siamensis;* (H) *Pomacea canaliculata;* (I) *Melanoides tuberculata;* (J) *Clea helena;* (K) *Lymnaea auricularia;* (L) *Corbicula* sp.

Table 4. The diversity indices of freshwater snails across two habitat types.

	Habitat types	
	Stream	**Rice paddy**
Total number of snail species	12	11
Total number of snails collected	2,140	1,585
Abundance (indiv./m^2)	178.33±167.37	88.05±110.67
Margalef's richness index (*D*)	1.434±0.793	1.357±0.961
Shannon's diversity index (*H*)	1.060±0.372	0.720±0.543
Pielou's evenness index (*J'*)	0.426±0.481	0.300±0.343

Discussion

Water temperature showed a positive correlation in two habitat types, i.e. steams and rice paddies (Table 5). Ikpeze and Obikwelu (2016) also recorded a positive correlation between freshwater snails and temperature. The present study revealed that snails can tolerate a range of temperature

between 24.5-32.4°C. Hofkin *et al.* (1991) reported the snail species is highly sensitive to an elevation in temperature that may cause thermal stress on snails and which may also reduce the dissolved oxygen content of the water body. According to Marshall *et al.* (2015), whose study on thermal tolerance in tropical snails, suggested that heat coma temperatures and upper lethal temperatures exhibit limited adaptive genetic variation across habitats (i.e., mangroves and rocky shores). Meanwhile, our study has not found a significant link between freshwater snail abundance and water temperature. This finding echoes the results of previous studies by Abdulkadir *et al.* (2013) who reported that no significant relationship between the abundance of fresh water snails and water temperature. In contrast, Wang *et al.* (2015) reported the water temperature was significantly associated with the relative abundance and diversity of *Bithynia* snails. However, Salawu and Odaibo (2014) showed that the relationships between water temperature and snail abundance varied with different species of snails.

From the field work, it was found that the freshwater snails were collected at electrical conductivity range of 102.1-221.0 µS/cm. The results revealed that freshwater snail abundance were positively correlated with conductivity of water (Table 5). However, a significant relationship was not observed in this study and these results were supported by Mohamed *et al.* (2011), who noted that conductivity did not have impact on snail distribution in the water bodies. Abdulkadir *et al*. (2013) also reported insignificant relationship between freshwater snail abundance and conductivity.

Table 5. Correlation coefficient between physio-chemical parameters and freshwater snail abundance across two habitat types.

Parameters	Habitat types	
	Stream	Rice paddy
Water temperature	0.422	0.384
Electrical conductivity	0.246	0.323
Dissolved oxygen	0.956*	0.173
pH	0.964*	0.768
Total dissolved solid	0.661	0.317
Salinity	0.389	0.105

*Marked correlation was significant (p<0.05)

As shown by the results (Table 2), variations of DO range between 2.39-8.02 mg/l. DO was almost within the range mentioned by Njoku-Tony (2011) who suggested that the desired concentration of DO for snails ranged between 2.2-8.5 mg/l. Yirenya-Tawiah *et al*. (2011), who also reported the mean DO of 4.6 mg/l, which is favorable for the snail. The DO recorded in the rice paddy ranged from 2.39-8.02 mg/l

and furnished a weakly positive relationship with freshwater snails abundance, whereas a strongly significant correlation with freshwater snails abundance in stream habitats as depicted in Table 3 (p<0.05). Similar positive relationship between DO and freshwater snail abundance was recorded by Wang *et al.* (2015) for the *Bithynia* snails in Northeast Thailand. This is harmony with Mohamed *et al*. (2011) and Abdulkadir *et al*. (2013), who claimed that DO is the main factor influencing freshwater snail distribution in the water body. Likewise, the pH recorded in the rice paddy ranged from slightly acidic to slightly alkaline (6.1-7.0) and furnished a strongly positive relationship with abundance of freshwater snails, while a strongly significant correlation was found between pH and freshwater snails abundance in stream habitats as shown in Table 5 (p<0.05). The present pH range was found to be nearly similar to that of the finding, reported by Wang *et al*. (2015) who stated that pH range for all the sites that harbored snails was 6.2-8.6. This result is in agreement with Mäkelä and Oikari (1992) who declared that a slightly alkaline environment was favorable the occurrence of molluscs (*Physella cubensis*, *M. tuberculata*, *Biomphalaria straminea* and *Pisidium* sp.). Similarly, Agi and Okwuosa (2001) and Abdulkadir *et al*. (2013) also recorded that pH on alkaline side was more favorable for the survival of snails.

In addition, the freshwater snail abundance was found to exhibit a positive correlation with TDS in both stream and rice paddy habitats as shown in Table 5 which finds support from Abdulkadir *et al*. (2013) report. This is further substantiated by Mohamed *et al.* (2011) who report that TDS is the main factor influencing freshwater snail distribution. Nevertheless, filed study showed that the low value of TDS (2.574-8.450 mg/l). Hairson *et al*. (1958), however, reported that snails are not found in waters with low concentrations of TDS.

Regarding the salinity, the result of this study for the positive correlation between the abundance of freshwater snail and salinity in all habitat types supported the finding from Wang *et al*. (2015) that the salinity was positive correlation with abundance of *B. s. goniomphalos*. Furthermore, the finding of Suwannatrai *et al.* (2011) revealed that *B. s. goniomphalos* were exclusively found in water with salinity levels ranging between 0.05 to 2.11 ppt, which supports the notion that *B. s. goniomphalos* prefers water with some saline content over pure, freshwater.

Several studies on the diversity of freshwater snails have been reported from Thailand. The studies revealed many

described and undescribed snail species. The present study was carried out to observe the species diversity of freshwater snails in Chiang Rai province, Thailand. We detected a total 12 species of freshwater snails along with their distribution in the different region sites, which were identified for the first time in Mae Lao district, Chiang Rai province. Previously, limited work has been done on freshwater snails of some area of Chiang Rai province. However, 16 species of freshwater snails were reported from Chiang Rai province, which focus on the studies of larval trematode infection in snails (Mard-arhin *et al*., 2001; Dechruksa, 2006; Sri-aroon *et al.,* 2007; Chontananarth and Wongsawad, 2017). On the other hand, the diversity of freshwater snail fauna of the Chiang Rai province seems to be considerably lower, according to the number of species as compare to other provinces of Thailand. The present study has identified a total of 11 snail species and 1 species of clam in ten selected sites, including streams and rice paddies from Mae Lao district during the survey period. This gives an indication of stable coexistence found in habitat types. Our surveys showed that some freshwater snails have been found in all habitat types, while *Corbicula* sp. had limited in the stream habitats.

In addition, 9 out of these 12 snail species are of medical and veterinary importance in Thailand, i.e. *B. funiculata*, *B. s. goniomphalos*, *B. s. siamensis*, *C. helena*, *F. doliaris*, *F. m. martensi, F. s. polygramma*, *M. tuberculata* and *P. canaliculata* (Woodruff and Upatham, 1992; Petney *et al*., 2012; Chantima *et al.*, 2013; Krailas *et al.,* 2014; Yutemsuk *et al.,* 2017). The field survey detected that the *B. s. siamensis* and *M. tuberculata* were the most abundance of snail species. It was noted that *B. s. siamensis* invested in stream and rice paddy. This notice is in accordance with Upatham and Sukhapanth (1980) and Petney *et al*. (2012), who reported that *B. s. siamensis* was most abundant in paddy fields. A prior study showed that the almost exclusive presence of *B. funiculata* in the north of Thailand, *B. s. siamensis* in the central area and *B. s. goniomphalos* in the northeast (Petney *et al*., 2012). Though the surveys found all 3 species of *Bithynia* spp. that are snail intermediate hosts of *Opisthorchis viverrini* in Thailand (Upatham and Sukhapanth, 1980; Harinasuta and Harinasuta, 1984; Petney *et al*., 2012; Wang *et al*., 2015). Supian and Ikhwanuddin (2002) reported that *M. tuberculata* is the most common and most wide ranging member of the family Thiaridae, found in almost any kind of freshwater. Nevertheless, in this study the *M. tuberculata* occurred most frequently in stream habitats. *M. tuberculata* is considered to be of medical

significance, as the finding of Krailas *et al.* (2014) revealed that nine types and eighteen species of cercariae were infected in this snail in Thailand. Pinto and De Melo (2011) also recorded that *M. tuberculata* could be host for trematodes, identified as belonging to 17 families, 25 genera and 37 species. The presence of a high number of snail species of medical importance indicates that the animals and/or people participating in various activities in this area are predisposed to infections harbored by these organisms. Moreover, *P. canaliculata* is also found in this study. This species is an alien species, it was imported from South America in 1988 (Chanyapeth and Achawakhom, 1998), and is now a serious agricultural pests causing significant damage to newly planted rice fields (Greene, 2008).

Conclusions

The present study sheds some light on the diversity of freshwater snail fauna in Mae Lao agricultural basin, where no studies have been done before in this area. This study identified 12 freshwater snail species and 9 out of these snail species are of medical and veterinary importance. All taxa identified for the region have been recorded for the first time. Furthermore, there have been determined physio-chemical parameters that influence freshwater snail abundance, the most important being DO and pH which significant correlated in stream environments. Further studies would be carried out to investigate the extent of which parasitic infections found in their snail fauna. Our findings shall be utilized by future researchers and ecologists as supplementary information in public and veterinary health sciences as well as in water quality assessment.

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