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Diversity and abundance of gastropods in relation to physio-chemical parameters in rice paddies, Chiang Rai province, Thailand

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Abstract

Species diversity and abundance of gastropods were investigated in the rice paddy ecosystem in Chiang Rai province, Thailand during October 2018. Gastropod samples were collected at five stations using five sampling sites and the quadrat method; *in-situ* measurements of the physio-chemical characteristics of water were conducted using field meters. All data were analyzed to determine gastropod abundance and ecological indices. Statistical analyses were conducted to examine the physio-chemical properties and abundance of gastropods. In total, 943 gastropods were collected and classified into eight species belonging to six families and six genera: *Filopaludina sumatrensis polygramma* (Martens, 1860); *F. martensi martensi* (Frauenfeld, 1865); *Bithynia funiculata* Walker, 1927; *B. siamensis siamensis* Lea, 1856; *Lymnaea* sp., *Melanoides tuberculata* (Müller, 1774); *Pomacea canaliculata* (Lamarck, 1819); and *Indoplanorbis* sp. The abundance of gastropods was 104.75 individuals/m^2. The most dominant and widely distributed species was *B. siamensis siamensis*, which was found at all sampling stations. The mean (± SD) ecological indices of richness, diversity and evenness were 0.591 ± 0.14, 0.618 ± 0.27 and 0.474 ± 0.22, respectively. Data analysis revealed that some physio-chemical parameters of water (electrical conductivity and total dissolved solids) had negative correlations with gastropod abundance of *F. martensi martensi* ($p < 0.05$), while *P. canaliculata* was positively correlated with water temperature ($p < 0.05$).

Introduction

The paddy field area for this study was located in the Kok River basin in Mueang Chiang Rai district, Chiang Rai province, North Thailand. The Kok River basin is a part of the 795,000 km^2 Mekong River basin. The sampling station in this study was located in two sub-basins of the Kok River basin, namely the lower Kok River sub-basin (11% of basin area) and the lower Lao River sub-basin (6% of basin area). The lower Kok River and lower Lao River sub-basins cover an area of 1,823 km^2 and have an agricultural area of 1,180 km^2. Land use in the two sub-basins comprises mainly rice production, vegetables and perennial fruit tree crops. About 49.6% of the total agricultural area is utilized for rice paddies, which are located on the floodplain and on low terraces along the rivers. (Mekong River Commission, 2005).

Environmental changes following agricultural activities and irrigation development are likely to modify the pattern of aquatic fauna distribution. Agricultural activities can change in the ecology

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of the water that cause alteration in the distribution of the vector of water-borne diseases (Dale and Polasky, 2007; Sri-aroon et al., 2007). Malacologists have conducted studies on the correlation between gastropod distribution and physio-chemical factors and to discover the ranges of these factors within which the gastropods thrive (World Health Organization, 1994). Several physio-chemical properties of water are considered to affect the ecology of gastropods, with pH, water temperature, dissolved oxygen, and salinity being key abiotic factors that can affect the composition, distribution and abundance of organisms in a freshwater environment (Salawu and Odaibo, 2014; Wang et al., 2015).

Many species of gastropod play a significant role in public health; thus, they are important intermediated hosts of trematodes and nematodes that cause human and animal parasitic disease (Sri-aroon, 2011; Madsen and Hung, 2014). In previous reports, which focused on the studies of larval trematode infections, 16 species of gastropods were recovered from Chiang Rai province. (Mard-arhin et al., 2001; Dechruksa, 2006; Sri-aroon et al., 2007; Chontananarth and Wongsawad, 2017; Chantima et al., 2018). Recently, Chantima and Thesarin (2018) reported on the species diversity and abundance of freshwater snails and their relation to physio-chemical properties of water bodies across habitat types (stream and rice paddy) in the Mae Lao agricultural basin, which is located in the upper Lao River sub-basin of the Kok River basin and covers Mae Lao district, Chiang Rai province. However, no studies have been reported on the diversity of gastropods in the lower Kok River and lower Lao River sub-basin and nor is there any information on the environmental factors on gastropods distribution there. Therefore, the current study aimed to conduct a comprehensive gastropod survey in the rice paddies of some parts of the Kok River basin to assess the malacological diversity and abundance in relation to some physio-chemical properties of water.

Materials and Methods

Study area and sampling localities

The study area was in two sub-basins of the Kok River basin (lower Kok River and lower Lao River sub-basin) of Mueang Chiang Rai district, Chiang Rai province, North Thailand. The study was carried out in October 2018 at five stations with five sampling sites, all of which were selected based on the site accessibility of rice paddies (Fig. 1). Sampling during this period corresponded with the main rice season (wet rice season) in Thailand. The sampling stations and geographical positions are shown in Table 1.

Sample collection and laboratory procedures

The gastropods were randomly sampled using the quadrat method along the shallow edge of the rice paddies (Krebs, 1989). A sample was collected in a 1 × 1 m quadrat from a bottom area of 9 m^2 at each sampling station. Each quadrat was thoroughly searched, and all live specimens were kept in pre-labeled containers and were taken to the laboratory where they were washed, identified and counted. The complete samples were fixed in 4% buffered formaldehyde and later transferred into 70% ethanol. All specimens were identified using keys by Brandt (1974) and Upatham et al. (1983).

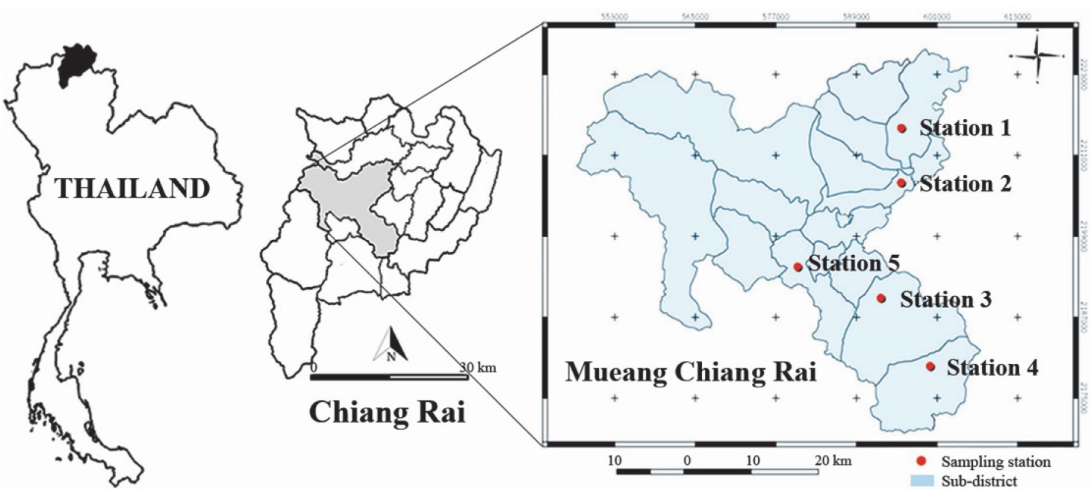

Fig. 1 Map of study area, showing sampling stations. (Source: GISTDA, 2012; QGIS Development Team, 2018)

Table 1 List of sampling stations where gastropods were collected in Chiang Rai province, Thailand

Sampling station	Coordinates (UTM)
1. Mae Khao Tom sub-district, Mueang Chiang Rai district	47Q 5959445 221286
2. Rim Kok sub-district, Mueang Chiang Rai district	47Q 5921579 220445
3. Huai Sak sub-district, Mueang Chiang Rai district	47Q 5929923 219040
4. Doi Lan sub-district, Mueang Chiang Rai district	47Q 5967139 217719
5. Pa O Don Chai sub-district, Mueang Chiang Rai district	47Q 5906081 219072

Measurement of physio-chemical parameters

In-situ determinations of water temperature (Temp), electrical conductivity (Cond), dissolved oxygen (DO), pH, total dissolved solid (TDS) and salinity (Sal) were carried out using multi-probe water quality meters (EUTECH CyberScan PCD650). All the physio-chemical parameters were measured and recorded between 1000 hours to 1500 hours (American Public Health Association, 2005). These parameters have been considered as possible abiotic factors influencing freshwater gastropod distributions (Salawu and Odaibo, 2014; Wang et al., 2015).

Data analysis

Ecological species richness was determined using Margalef's diversity index (D) and Shannon's diversity index (H) was used to measure gastropod diversity across different sampling sites (Washington, 1984; Clarke and Warwick, 1994). Species evenness (J') was expressed using Pielou's evenness index (Brewer, 1994; Clarke and Warwick, 1994). Gastropod abundance was represented as abundance and relative abundance. Abundance was expressed as individuals/m^2, and as a percentage of total gastropods present for each species. The relationship of the abundance of gastropod species with the physio-chemical parameters of the water at the various sampling stations was determined using Pearson's correlation and $p < 0.05$ was considered statistically significant.

Ethics statements

There was no use of animals for experimentation, only for surveyed research. The study was conducted under license number U1-03137-2559 issued by the Institute of Animals for Scientific Purpose Development (IAD), Thailand. However, this research with regard to animal use complied with all the relevant national regulations and institutional policies for the care and use of animals.

Results and Discussion

Composition and diversity of gastropods

In total, 943 gastropods were recovered from the five stations of investigation. Of these, eight species of gastropods belonging to six families and six genera were recovered from the rice paddies (Fig. 2 and Table 2). The gastropod species, total number (in bold) and relative abundance were: *Filopaludina sumatrensis polygramma* (Martens, 1860), **9**, (0.95%); *F. martensi martensi* (Frauenfeld, 1865), **33**, (3.50%); *Bithynia funiculata* Walker, 1927, **12**, (1.27%); *B. siamensis siamensis* Lea, 1856, **776**, (82.30%); *Lymnaea* sp., **7**, (0.74%); *Melanoides tuberculata* (Müller, 1774), **8**, (0.85%); *Pomacea canaliculata* (Lamarck, 1819), **95**, (10.07%); and *Indoplanorbis* sp., **3**, (0.32%). The abundance of gastropods was 104.75 individuals/m^2. The most dominant and widely distributed species was *B. siamensis siamensis* which was found at all sampling stations, accounting for 776 (86.20 /m^2) of the 943 gastropods collected. This was in accordance with Upatham and Sukhapanth (1980) and Petney et al. (2012), who reported that *B. siamensis siamensis* was most abundant in rice paddies. With regard to the recent distribution records of the Bithynia intermediate hosts of the liver fluke (*Opisthorchis viverrini*) in Thailand, Petney et al. (2012) reported the almost exclusive presence of *B. funiculata* in the north, with *B. siamensis siamensis* found in the central part and *B. siamensis goniomphalos* in the northeast; in contrast the current study found two species of *Bithynia* (*B. siamensis siamensis* and *B. funiculata*), which are snail intermediate hosts of *O. viverrini* (Petney et al., 2012; Wang et al., 2015). However, it was similarly reported by Brandt (1974) that the distribution of *B. siamensis siamensis* in Thailand is much broader, including the northern, western and southern parts of the country. The current field survey detected *B. siamensis siamensis* as the most abundant of the gastropod species. The presence of a high number of this species of medical importance indicates that the people participating in various activities in the rice paddy are predisposed to infections harbored by this organism.

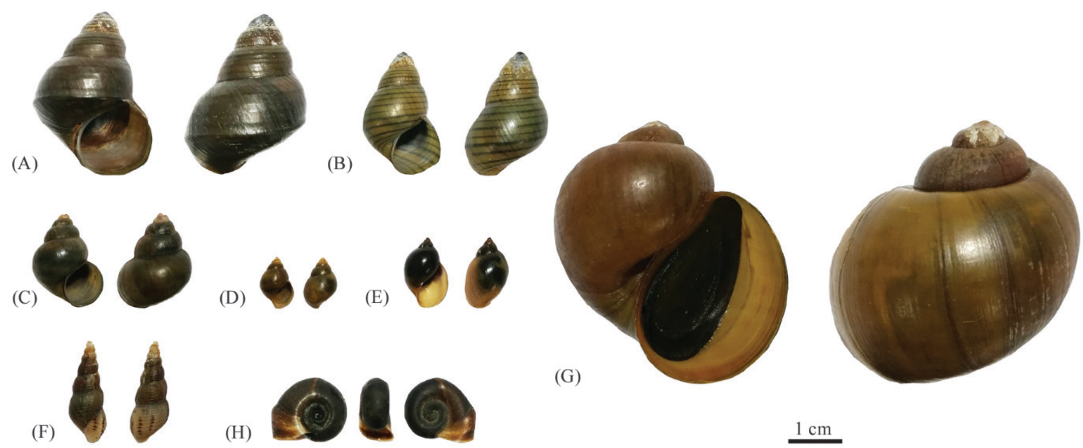

Fig. 2 Shell morphology of gastropods recovered from selected rice paddies in Chiang Rai province: (A) *Filopaludina martensi martensi*; (B) *F. sumatrensis polygramma*; (C) *Bithynia funiculata*; (D) *B. siamensis siamensis*; (E) *Lymnaea* sp.; (F) *Melanoides tuberculata*; (G) *Pomacea canaliculata*; (H) *Indoplanorbis* sp.

Table 2 Species and abundance of gastropods collected in rice paddies in Chiang Rai province, Thailand

Family	Species	Number of individuals at sampling station					Total	Relative abundance (%)	Abundance (individuals/m^2)
		1	2	3	4	5			
Viviparidae	*Filopaludina sumatrensis polygramma*	2	0	7	0	0	9	0.95	1.00
	Filopaludina martensi martensi	15	0	16	0	2	33	3.50	3.67
Bithyniidae	*Bithynia funiculata*	12	0	0	0	0	12	1.27	1.33
	Bithynia siamensis siamensis	359	177	2	206	32	776	82.30	86.20
Lymnaeidae	*Lymnaea sp.*	0	0	0	7	0	7	0.74	0.78
Thiaridae	*Melanoides tuberculata*	0	7	0	0	1	8	0.85	0.89
Ampullariidae	*Pomacea canaliculata*	52	3	0	18	22	95	10.07	10.55
Planorbidae	*Indoplanorbis sp.*	0	0	0	3	0	3	0.32	0.33
Number of species		5	3	3	4	4	8		
Total		440	187	25	234	57	943	100.00	104.75

Additionally, five out of these eight gastropod species are of medical and veterinary importance in Thailand, namely *F. sumatrensis polygramma*, *F. martensi martensi, B. funiculata*, *B. siamensis siamensis* and *M. tuberculata*, which are intermediate hosts of animal and human parasitic diseases (Petney et al., 2012; Chantima et al., 2013; Krailas et al., 2014). *Filopaludina sumatrensis polygramma* and *F. martensi martensi* are intermediate hosts of the intestinal fluke, *Echinostoma revolutum* (Chantima et al., 2013); *M. tuberculata* is also medically important because it can serve as the first intermediate host for human minute intestinal flukes (Pinto and Melo, 2010). Krailas et al. (2014) reported that 9 types in 18 species of cercariae were infecting *M. tuberculata* in Thailand. Moreover, *P. canaliculata* or the apple snail was also found in the current study, with a relative abundance of 10.07%. *Pomacea canaliculata* is an alien species that has been widely found. However, where this species has been found, native gastropods have declined, suggesting that the species may potentially impact range-restricted native species in the future (Köhler et al., 2012). Furthermore, *P. canaliculata* is now a serious agricultural pest causing significant damage to newly planted rice fields (Greene, 2008). Besides its importance as a crop pest, the apple snail can cause significant changes in the diversity and functioning of invaded natural wetlands (Horgan et al., 2014).

The total number of taxa varied between sampling stations (Table 2). The diversity index varied from 0.241 to 0.880, with a mean (± SD) of 0.618 ± 0.267, which is a low value (Table 3). The diversity of gastropods in the lower Kok River and lower Lao River sub-basins seemed to be considerably lower, according to the number of species, compared to the Mae Lao agricultural basin (upper Lao River sub-basin of Kok River basin) in Chiang Rai province (Chantima and Thesarin, 2018; Chantima et al., 2018). The evenness index varied from 0.220 to 0.768 with a mean (± SD) of 0.474 ± 0.223. These average values indicated that the community condition was unstable (Hillebrand, 2008). However, the gastropod community at station 3 was relatively stable compared to the other stations.

Relationships between physio-chemical parameters and gastropod abundance

There was variation in the recorded physio-chemical parameters of water among the sampling stations. Water temperatures ranged from 23.87°C to 27.27°C, with conductivity varying between 57.27 and 134.33 µS/cm. Dissolved oxygen varied between 3.58 and 5.41 mg/L, pH between 6.43 and 7.10 and total dissolved solids between 2.28 and 5.30 mg/L. The salinity varied from 10.61 to 11.49 parts per trillion. The details of the physio-chemical parameters are shown in Table 4, while correlation between gastropod abundance and these physio-chemical parameters of water are presented in Table 5.

Water temperature varied across sampling stations, with values ranging from 23.87°C to 27.27°C. The relationships between water temperature and gastropod abundance varied with different species of gastropods. An increase in temperature had a positive correlation with *P. canaliculata* ($r = 0.916$; $p < 0.05$). Several studies have reported the influence of temperature on certain stages of aquatic gastropods. A temperature of around 25°C has usually been considered to be optimal for rearing *P. canaliculata* (Seuffert and Martín, 2013; 2017). Therefore, in the current study, the temperature range of 23.87–27.27°C recorded in all sampling stations appears to be favorable for *P. canaliculata*. However, temperatures above 25°C would not result in an increase in the population of *P. canaliculata*, especially when high temperatures persist for long periods (Seuffert and Martín, 2017). Nonetheless, no correlations were found between the abundance of other gastropods and the water temperature of the study sites. In addition, the most abundant species was *B. siamensis siamensis,* which was found at all sampling stations in this study. For *Bithynia* snails, water quality has been suggested as an important determinant influencing gastropod distributions (Wang, 2012). Suwannatrai et al. (2011) reported that the presence of live *Bithynia* (*B. siamensis goniomphalos*) is dependent on various physical properties of the water habitat, including temperature, DO, pH and turbidity. Conversely, the current study failed to discern any effect of these factors on the abundance of *Bithynia* species (*B. siamensis siamensis* and *B. funiculates*). Clearly, this needs further investigation.

Table 3 Ecological indices of gastropods at selected rice paddies in Chiang Rai province, Thailand

Index	Sampling station					Mean±SD
	1	2	3	4	5	
Margalef's richness index (*D*)	0.657	0.382	0.621	0.550	0.742	0.591±0.135
Shannon's diversity index (*H*)	0.656	0.241	0.844	0.470	0.880	0.618±0.267
Pielou's evenness index (*J′*)	0.408	0.220	0.768	0.339	0.635	0.474±0.223

Table 4 Variations in physio-chemical parameters (mean±SD and range) of selected sampling stations

Physio-chemical parameter	Sampling station				
	1	2	3	4	5
Water temperature (°C)	27.27±0.46	23.87±0.47	24.43±0.31	25.77±0.21	26.53±0.25
	(27.00–27.80)	(23.50–24.40)	(24.10–24.70)	(25.60–26.00)	(26.30–26.80)
Conductivity (µS/cm)	58.27±0.15	99.77±0.81	57.27±0.23	134.33±0.95	102.867±0.51
	(58.10–58.40)	(98.90 –101.50)	(57.00–57.40)	(133.40 –135.30)	(102.30–103.30)
Dissolved oxygen (mg/L)	3.87±0.11	5.41±0.7	3.90±0.05	3.58±0.08	5.07±0.13
	(3.77–3.98)	(5.34 –5.47)	(3.85–3.95)	(3.49–3.63)	(4.02–4.15)
pH	6.43±0.15	7.10±0.00	6.47±0.12	6.67±0.06	6.83±0.12
	(6.30 – 6.60)	(7.10 –7.10)	(6.40–6.60)	(6.60–6.70)	(6.90 –7.00)
Total dissolved solid (mg/L)	2.33±0.09	3.97±0.08	2.28±0.08	5.30±0.04	4.07±0.07
	(2.27–2.43)	(3.90 –4.03)	(2.23–2.37)	(5.27–5.34)	(4.96 –5.21)
Salinity (parts per trillion)	11.49±0.01	11.35±0.19	10.61±0.22	10.97±0.01	11.22±0.01
	(11.48–11.49)	(11.21–11.57)	(10.36–10.74)	(10.97–10.98)	(11.22 –11.23)

Table 5 Pearson's correlation coefficients between abundance of gastropod species and physio-chemical parameters

Gastropod species	Physio-chemical parameter					
	Temp	Cond	DO	TDS	pH	Sal
Filopaludina sumatrensis polygramma	-0.267	-0.747	-0.429	-0.747	-0.661	-0.698
Filopaludina martensi martensi	0.357	-0.887*	-0.340	-0.887*	-0.717	-0.195
Bithynia funiculata	0.670	-0.549	-0.340	-0.546	-0.558	0.577
Bithynia siamensis siamensis	0.459	-0.030	-0.283	-0.026	-0.244	0.689
Lymnaea sp.	0.074	0.747	-0.538	0.749	-0.096	-0.245
Melanoides tuberculata	-0.634	0.193	0.803	0.190	0.809	0.384
Pomacea canaliculata	0.916*	-0.217	-0.316	-0.213	-0.425	0.650
Indoplanorbis sp.	0.074	0.747	-0.538	0.749	-0.096	-0.245

Temp = water temperature; Cond = conductivity; DO = dissolved oxygen; TDS = total dissolved solids; Sal = salinity.

Electrical conductivity varied widely at the different sampling stations of rice paddy and ranged from 57.27 µS/cm to 134.33 µS/cm. Salawu and Odaibo (2012) suggested reasons for such variation were the deposition of solute materials by run-off from surrounding environments followed by a reduction in ion uptake due to instability of the macrobenthos population in the microhabitat. In the current study, conductivity was negatively correlated with most of the gastropod species. More importantly, there was negative correlation between conductivity and the abundance of *F. martensi martensi* (r = -0.887, $p < 0.05$). There were similarities in the TDS variation in the rice paddies. The TDS ranged from 2.28 mg/L to 5.30 mg/L. The TDS was significantly and negatively correlated with *F. martensi martensi* (r = -0.887). *Filopaludina martensi martensi* was collected for a TDS range from 2.33 mg/L to 4.07 mg/L. These results indicated that most of the gastropod species could survive under low concentrations of TDS. However, Hairson et al. (1958) reported that gastropods were not found in water with low concentrations of TDS. Mohamed et al. (2011) reported that TDS is the main factor influencing freshwater snail distribution in a water body. Clearly, this needs further investigation for each gastropod regarding this parameter.

Conclusively, this study identified eight gastropod species and five out of these gastropods are of medical and veterinary importance. The most dominant and widely distributed species was *B. siamensis siamensis*. Furthermore, the findings showed that the survival of gastropods in the rice paddy environments was, to a large extent, dependent on the physio-chemical properties of the water, of which water temperature, electrical conductivity, and total dissolved solids were the most important. The findings may interest researchers, agro-ecologists and conservation biologists as supplementary information on biodiversity and public health, as well as on water quality assessment. Further studies incorporating wider landscape aspects will be carried out to investigate the extent of which parasitic infections are found in gastropods in this area.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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