Effects of Surface Salt on Distribution and Density of Snails in Family Viviparidae in Khon Kaen Province, Thailand, Analyses by Using Geographic Information System

ผลของเกลือผิวดินต่อการกระจายและความหนาแน่นของหอยวงศ์ Viviparidae ในจังหวัดขอนแก่น ประเทศไทย โดยการวิเคราะห์ข้อมูลด้วยระบบสารสนเทศภูมิศาสตร์

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ABSTRACT

Effects of surface salt on distribution of snails in family Viviparidae in Khon Kaen province, northeast Thailand were analyzed the association model by using geographic information system. Mollusks were collected in twenty localities base on various levels of surface salt, 16 - 20 stations/reservoir. Three species of viviparid snails were found in 9 out of 20 reservoirs, i.e. *Filopaludina (Siamopaludina) martensi martensi*, *F. (Filopaludina) sumatrensis speciosa* and *Idiopoma umbilicata.* Nine families (11 species) of sympatric mollusks shared the same habitat with viviparid snails. Water quality in the viviparid habitat revealed that, pH: 6.79 - 8.01, temperature: 23.06- 27.33 °C, turbidity: 3.26 - 163.00 NTU, conductivity: 0.42 - 10.25 mS/cm, salinity: 0.20 - 5.69 ppk and dissolved oxygen (DO): 0.43 - 6.01 mg/L. Dominant planktons in food content from digestive tracts of *F. (S.) martensi martensi* consisted of diatoms and they were the same type to *Bithynia siamensis goniomphalos*, first intermediate host of human liver fluke, *Opisthorchis viverrini.* That is viviparid snails may play important role in food competition with B. siamensis goniomphalos. The number of *B. siamensis goniomphalos* was negative correlation to the number of *F. (S.) martensi martensi*

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($r = -0.182$, $p < 0.05$). Only one type of Virgulate xiphidiocercariae was found in *F. (S.) martensi martensi* by using electric light, daytime cercarial shedding. Density of *F. (S.) martensi martensi* population was negative correlation to salinity ($r = -0.289$, $p < 0.01$). Geographic information system analysis showed considerably high distribution of *F. (S.) martensi martensi* in the area with surface salt >0 – <1% of surface area (index = 0.893) compared to other salinity levels and very low distribution in the area with; no surface salt (0%), 1 – 10%, 10 – 50% and >50% of surface areas revealed that the index of 0.079, 0.027, 0.001 and 0, respectively. The geographic information system analysis model was assessed and approved by mollusk survey.

บทคัดย่อ

ผลของเกลือผิวดินต่อการกระจายและความหนาแน่นของหอยในวงศ์ Viviparidae ในจังหวัดขอนแก่น ประเทศไทย โดยวิเคราะห์ข้อมูลด้วยระบบสารสนเทศภูมิศาสตร์ ศึกษาโดยเก็บตัวอย่างหอยในแหล่งน้ำที่มีสภาพเกลือผิวดินที่ระดับแตกต่างกัน ทั้งหมด 20 แหล่งน้ำ ทำการสุ่มเก็บตัวอย่างในแต่ละแหล่งน้ำ 16- 20 สถานี พบหอยในวงศ์ Viviparidae 3 ชนิดคือ *Filopaludina (Siamopaludina) martensi martensi*, *F. (Filopaludina) sumatrensis speciosa* และ *Idiopoma umbilicata* ในแหล่งน้ำ 9 แหล่ง จากจำนวนที่ทำการเก็บตัวอย่าง 20 แหล่ง พบหอยร่วมนิเวศ 9 วงศ์ (จำนวน 11 ชนิด) ลักษณะกายภาพน้ำที่พบหอยวงศ์ Viviparidae มี pH 6.79 – 8.01, อุณหภูมิ 23.06- 27.33 °C, ค่าความขุ่น 3.26 – 163.00 NTU, ค่าการนำไฟฟ้า 0.42 – 10.25 mS/cm, ค่าความเค็ม 0.20 – 5.69 ppk และ ค่าการละลายของออกซิเจน (DO) 0.43 – 6.01 mg/L. ในระบบทางเดินอาหารของหอย *F. (S.) martensi martensi* ที่เป็นประชากรส่วนใหญ่ในการศึกษาครั้งนี้ พบชนิดของแพลงก์ตอนเหมือนกันกับ Bithynia siamensis goniomphalos ซึ่งเป็นโฮสต์กลางของพยาธิใบไม้ตับของคนชนิด Opisthorchis viverrini จึงน่าจะเป็นสัตว์ที่แก่งแย่งอาหารกัน ซึ่งพบว่าจำนวนหอย *B. siamensis goniomphalos* มีความสัมพันธ์เชิงลบกับหอย *F. (S.) martensi martensi* ($r = -0.182$, $p < 0.05$) จากการสำรวจพบการติดเชื้อ Virgulate xiphidiocercariae ในหอย *F. (S.) martensi martensi* เพียงชนิดเดียว จากวิธีการ cercarial shedding โดยใช้แสงกระตุ้นตอนกลางวัน ความหนาแน่นของหอย *F. (S.) martensi martensi* มีความสัมพันธ์เชิงลบต่อระดับความเค็มของแหล่งน้ำ ($r = -0.289$, $p < 0.01$) การวิเคราะห์ความหนาแน่นด้วยข้อมูลสารสนเทศภูมิศาสตร์ พบความหนาแน่นของ *F. (S.) martensi martensi* สูง ในพื้นที่เกลือผิวดิน >0 – <1% ของพื้นที่ผิว (ค่าดัชนี = 0.893) เปรียบเทียบกับพื้นที่เกลือผิวดินอื่นๆ และพบความหนาแน่นต่ำในพื้นที่เกลือผิวดินที่ระดับ 0, 1 – 10, 10 – 50 และ >50% ของพื้นที่ผิวดินโดยมี ค่าดัชนีเท่ากับ 0.079, 0.027, 0.001 และ 0 ตามลำดับ ค่าดัชนีได้ทำการประเมินความถูกต้องโดยการสำรวจในพื้นที่ ที่ได้ทำการวิเคราะห์แล้วได้ค่าที่ถูกต้อง

Key Words : Viviparid snail, Surface salt, Geographic information system (GIS)
คำสำคัญ : หอยวงศ์หอยขม เกลือผิวดิน ระบบสารสนเทศภูมิศาสตร์

Introduction

Freshwater snails of family Viviparidae are worldwide distribution and play medical importance as second intermediate host of echinostomes (Bhaibulaya *et al.*, 1964, 1966; Brandt, 1974; Burch and Upatham, 1989; Radomyos *et al.*, 1982) and intermediate host of *Angiostrongylus cantonensis* (Crook *et al.*, 1968). They are operculate snails, medium size. Shell is solid, subglobose-conic shape with spiral lines, ridges or tuberculate, brown to green color and with or without color bands. Its corneous operculum is occupied by concentric manner containing subcentral nucleus. The right tentacle of male is transformed to be copulatory organ. Females produce offspring as ovoviviparous. In addition, they were prepared as food dish for Thai people (Brandt, 1974).

Topography of northeast Thailand is high land, big plateau with high variety of soil types, land used and ecology of the areas. Many areas are overlaid with surface salt and underneath contained underground rock-salt. Surface salt was dissolved by rain or irrigation water resulting of various salinity levels of surface and underground water. The estimated areas of 28,400 square km (17% of area) were affected by salt. The expansion of the salty areas due to man-made environmental changes for example of deforestation, construction of dams, weirs for irrigation and including roads (Wada *et al.*, 1994). Dissolving salt into water reservoirs caused salty water in different concentrations, lead to spread of some parasites by the results of the elevation of population and distribution of the snail intermediate hosts and also the survival and infectivity of those parasites (Mohamed *et al.*, 1978; Vercruysse *et al.*, 1994). The effects of surface salt may contribute to density and distribution of snails in the family Viviparidae and was analyzed by using geographic information system.

Materials and methods

Twenty localities were selected in seven districts of Khon Kaen province (Muang Khon Kaen, PhraYuen, Ban Haet, Ban Phai, Non Sila, Mancha Chiri and Sam Sung) based on various percentages of surface salt data providing by Department of Land Development, Ministry of Agriculture and Cooperatives (Fig 1). Mollusk sampling was done during November 2006 - January 2007 and November 2007 - January 2008. Global Positioning System or GPS (Garmin model nuvi-310, Taiwan) was used to locate the sampling localities.

Viviparid snails and sympatric species were collected by methods which were described by Tesana (2002). Eight to ten sampling sites were designed for mollusk collection for each reservoir; two stations/site that is station at the edge by manual collection (5 minutes/person) or scoop collection for 5 times at the station presented with water plants and station at deep water (1-4 meters dept) by using Ekman dredge (total 16-20 stations/reservoir, depending on size of reservoirs). At each deep water station, water quality was investigated such as pH, temperature, dissolved oxygen, salinity and conductivity by using Portable Electrochemical Analyser (TPS model 90FL, Australia) and turbidity by using Turbidimeter (HACH model 2100p, USA). Mollusk sample was identified according to shell morphology at the laboratory following Brandt (1974). Some of viviparid snails were fixed in 80% ethanol for examination of microorganisms in digestive tract. Each type of micro-organism was counted by dilution technique under light microscope, recorded, took photographs and identification by following Shirota (1966) and Parsons and Takahashi (1975).

Parasitic infection was examined by daytime (under electric light source) and nighttime (under dark condition) cercarial shedding and digestion with artificial gastric juice (0.3% Pepsin A solution).

The number of viviparid snails and water quality and the number of sympatric species of mollusks were analyzed for coefficients of the Pearson's correlations and regressions by using Statistical Package for Social Science (SPSS for Windows version 11.5). To create spatial model for predicted potential distribution of the snails in the family Viviparidae was used instant software ESRI ArcView version 3.3 for capturing, storing, analyzing, and displaying geographic information system data. Migratory abilities of viviparid snails were estimated for 500 meters radius of the site collection and nine buffer zones, where viviparid snails found, were created in surface salt layer and each surface area was calculated. For each surface salt class, the index was obtained by using the formula as description by Herbreteau *et al.* (2005) as following: Vi-index = Σ [(Si/St)*(Vi/Vt)]; Si = Surface area of the given surface salt class inside locality 'i'; St = total surface area per locality (= 78.14 ha); Vi = average number of viviparid snails collected inside locality 'i'; Vt = total of average number of viviparid snails collected.

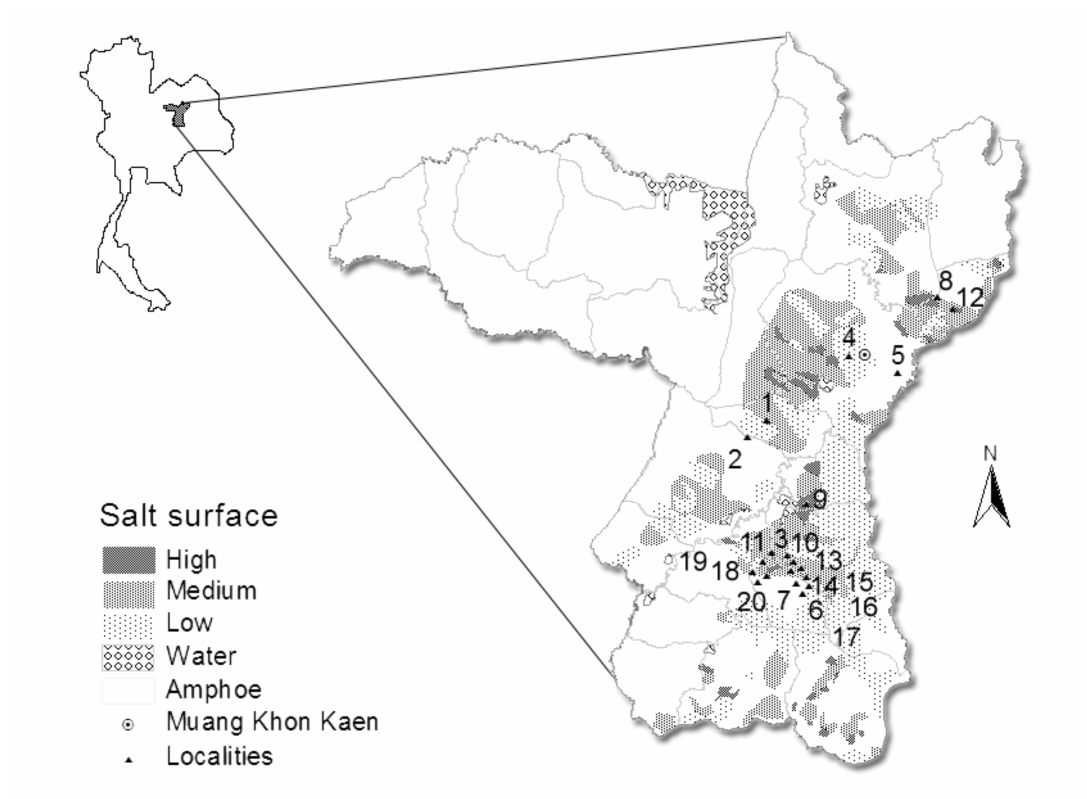

Figure 1 Schematic map of Khon Kaen province showed 20 sampling localities

Results

Three species of snails in the family Viviparidae were found in 9 out of 20 reservoirs i.e. Filopaludina (Siamopaludina) martensi martensi Frauefeld 1865, Filopaludina (Filopaludina) sumatrensis speciosa Dashayes 1876 and Idiopoma umbilicata Lea 1856 (Fig 2) with the total number of 1,640, 1,604 and 12, respectively. There were 9 families, 11 sympatric species of mollusks i.e. Melanoides tuberculata M?ller 1774, Tarebia granifera Lamarck, 1822, Clea (Anentome) helena Philippi 1874, Pomacea canaliculata Lamarck 1822,

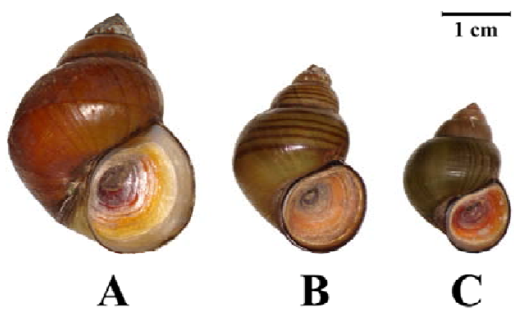

Figure 2 Three species of viviparid snails found in the study areas, A: *F. (S.) martensi martensi*, B: *F. (F.) sumatrensis speciosa* and C: *I. umbilicata*

Pila ampullacea Linnaeus 1758, *Indoplanorbis exustus* Dashayes 1834, *Lymnaea (Radix) auricularia rubiginosa* Michelin 1831, Corbicula sp. Mühlfeld 1811, *Scabies crispata* Gould 1843, *Scaphula pinna* Benson 1856 and *Bithynia (Digoniostoma) siamensis goniomphalos* Morelet 1866 (the first intermediate host of *Opisthorchis viverrini*) (Table 1). Quality of water of reservoirs where viviparid snails were inhabited; pH: 6.79 - 8.01, temperature: 23.06- 27.33 °C, turbidity: 3.26 - 163.00 NTU, conductivity: 0.42 - 10.25 mS/cm, salinity: 0.20 - 5.69 ppk and dissolved oxygen: 0.43 - 6.01 mg/L.

Planktons in digestive tracts of *F. (S.) martensi martensi* was mainly diatoms (dominant of *Narvicular*) 2.42-95.40% and minor organisms were *Trachelomonas*, *Aulacoseira*, *Merismopedia*, *Euglena*, *Scenedesmus*, etc.; *F. (F.) sumatrensis speciosa* was *Trachelomonas* 78.57% and following order of *Centritractus*, *Peridinium*, and the less were minor group of *Phacus*, diatoms, *Treubaria*, *Mougeotia*, *Scenedesmus* etc. and *I. umbilicata* was diatoms, *Trachelomonas* and *Scenedesmus* as 48.47, 18.85 and 15.17%, respectively and the less was minor group such as *Mougeotia*, *Phacus*, *Merismopedia*, *Ankistrodesmus* etc.

Trematode infection in *F. (S.) martensi martensi* by daytime cercarial shedding was found only one type of Virgulate xiphidiocercariae. The prevalence of infection in that reservoir (no. 4) was 0.24% (1 out of 460) and the infection rate was 0.0006% (1 out of 1,640). No metacercariae and larval stage of nematodes were found in viviparid samples by digestion method. The number of *F. (S.) martensi martensi* in each station in reservoirs were negative correlation with salinity ($r = -0.289$, $p < 0.01$) (Fig 3) and also to *B. siamensis goniomphalos* ($r = -0.182$, $p < 0.05$) (Fig 4).

Table 1 The number of sample mollusks in the selected localities in variety surface salt in Khon Kaen province, northeast Thailand

Order	Family	Sciencetific Name	Locality (Number of station)												Total
			1	2	3	4	5	6	7	8	9	10	11	12	
Mesogastropoda	Viviparidae	*F. martensi*	9	65	19	460	953	20	77	23	14	-	-	-	1,640
		F. speciosa	-	-	-	40	-	1,564	-	-	-	-	-	-	1,604
		I. umbilicata	-	-	-	-	-	-	-	12	-	-	-	-	12
	Bithyniidae	*B. goniomphalos*	401	192	248	23	185	435	253	52	660	459	564	674	4,146
	Thiaridae	*M. tuberculata*	5	105	1,518	40	24	13	91	-	-	88	-	-	1,884
		T. granifera	-	-	184	44	6	-	3	-	-	-	-	-	237
	Buccinidae	*C. helena*	20	-	-	-	-	3	-	-	-	-	-	-	23
	Ampullariidae	*P. canaliculata*	17	81	-	131	17	8	27	-	-	-	-	-	281
		P. ampullacea	-	-	-	-	-	-	1	-	-	-	-	-	1
Basomatophora	Planorbidae	*I. exustus*	1	72	-	149	47	-	-	-	-	-	-	-	269
	Lymnaeidae	*L. rubiginosa*	-	2	-	-	-	-	-	-	-	-	-	-	2
Uinonoida	Corbiculidae	*Corbicula sp.*	2	64	-	-	-	-	-	-	-	-	-	-	66
	Amblemidae	*S. crispata*	3	15	-	4	-	-	-	-	-	-	-	-	22
Arcoida	Arcidae	*S. pinna*	-	44	-	-	-	-	-	-	-	-	-	-	44
Total			458	640	1,969	891	1,232	2,043	452	87	674	547	564	674	10,231

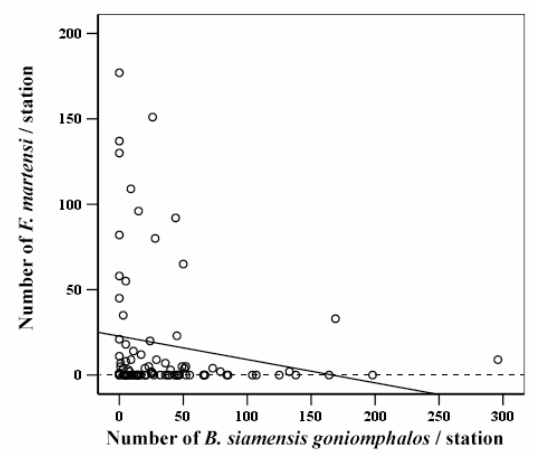

Figure 3 Negative correlation (r = - 0.182, p<0.05) on density of *B. siamensis goniomphalos* to *F. (S.) martensi martensi*

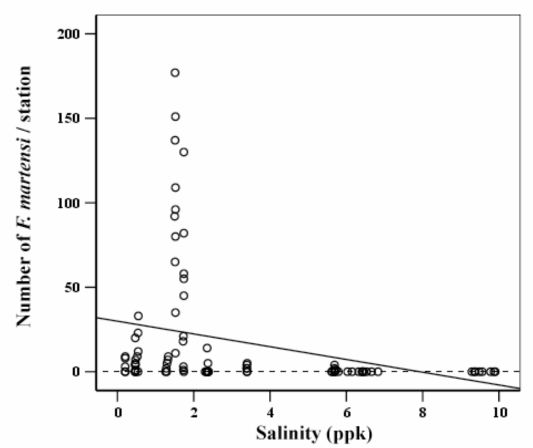

Figure 4 Negative correlation (r = - 0.289, p<0.01) on density of *F. (S.) martensi martensi* to salinity

Geographic information system data analysis showed high potential distribution of *F. (S.) martensi martensi* in the area with surface salt <1% of surface area (index = 0.893). Low density and distribution of vivparid snails was found in the areas; no surface salt, surface salt 1 - 10% and surface salt 10 - 50% of surface area which was calculated for index as 0.079, 0.027 and 0.001, respectively. *F. (S.) martensi martensi* could not find in the area with surface salt >50% of surface area as index 0.000 (Fig 5).

Discussion

Viviparidae are fresh water snails, distribute worldwide except South America continent (Brandt, 1974). These snails are prepared for food dish in many countries (Tropmed Technical Group, 1986). Eight subspecies/species were presented in Khon Kaen, Thailand *i.e. Filopaludina (Filopaludina) sumatrensis speciosa*, *F. (F.) sumatrensis polygramma*, *F. (Siamopaludina) martensi martensi*, *F. (Siamopaludina) martensi munensis*, *F. (Siamopaludina) martensi cambodjensis*, *Trochotaia trochoides*, *Idiopoma umbilicata* and *Mekongia pongensis* (Brandt, 1974). In this study, 3 subspecies/species were found in sampling areas. *F. (S) martensi martensi* widely distributed and presented in nine out of twenty reservoirs. In spite of *F. (S.) martensi martensi*, the distribution of *F. (F.) sumatrensis speciosa* and *I. umbilicata* were found only one to two out of twenty reservoirs, similar results as the study of Sri-aroon *et al.* (2005, 2007) and other species of viviparid snails were found in limited areas *i.e. F. (S.) martensi cambodjensis*, *F. (F.) filosa*, *F. (F.) sumatrensis polygramma*, *F. (F.) sumatrensis speciosa*, *T. trochoides*, *I. umbilicata* etc. The parasitic infection showed low trematode infection rate by cercarial shedding (0.24%) and no infection with metacercariae and larval stage of nematodes, similar to the study of Sri-aroon *et al.* (2005, 2007).

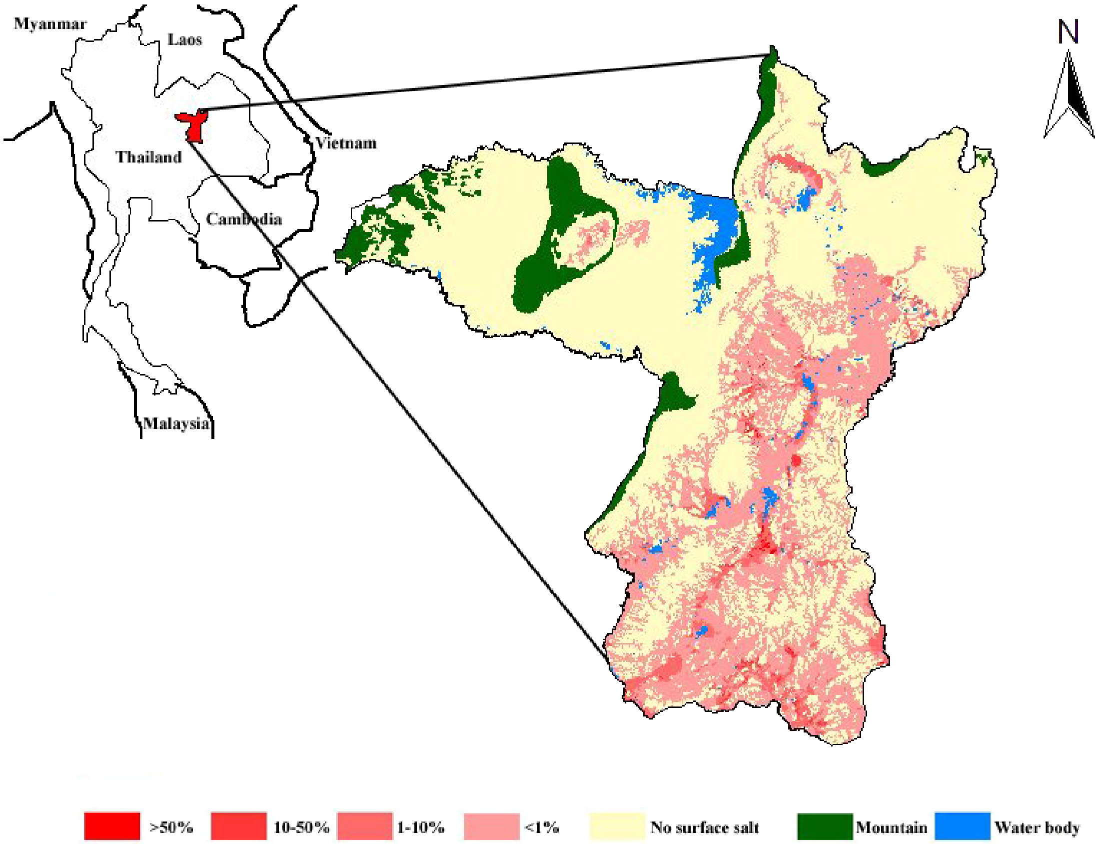

Figure 5 Model of *F. (S.) martensi martensi* distribution in Khon Kaen province using geographic information system analysis

The correlation of salinity to density of snails was studied only in *F. (S.) martensi martensi* which was found in all nine sampling localities but not for *F. (F.) sumatrensis speciosa* and *I. umbilicata*. The correlation was negatively related to the density of *F. (S.) martensi martensi* to salinity. The snails in this study could be found in the reservoirs where salinity was up to 5.69 ppk. The reasons may relate to its physiological properties of snail itself or their food available in different salinity levels. The salinity may effects directly to physicochemical for increasing metabolism rate lead to malfunction and approaching death (Cheung and Lam, 1995). Moreover, high salinity caused tissue dehydration which alters water content of snails resulting of aberration of snail metabolism. The consequence of the salinity causing of death in clams (*Lampsilis teres*) and apple snails (*Pomacaea bridgesi*) when they were exposed to 400 mOsm (Jordan and Deaton, 1999). Viviparid snails may unable to tolerant to higher salinity more than 5.69 ppk. That may involve in osmotic regulation as in the study in bivalves mollusks (Grainey and Greenberg, 1977). In addition, reservoirs with different level of salinity were effect to population of micro-organisms as food source (Shentu *et al.*, 2000; Barron *et al.*, 2002; Moisander *et al.*, 2002). The micro-organisms in digestive tract of viviparid snails from different salinity reservoirs showed majority micro-organisms were the same type. Those kinds of viviparid snails might be selected feeding the organisms. Salinity may effect on reduction of food source or snail population or both. The results showed different proportion of micro-organisms in digestive tracts of viviparid snails possibly due to the available of micro-organisms in those reservoirs.

Comparison of digestive contents of viviparid snails with another group of sympatric snails; *B. siamensis goniomphalos* presented the majority planktons in the same type of diatoms. They may be food competitor from statistically negative correlation ($r = -0.182$, $p < 0.05$). The control of opisthorchiasis could be done by increasing of viviparid snail population. The advantage on control of *B. siamensis goniomphalos* by viviparid snails with the reasons of very low infection rate and the intermediate host role i.e. echinostomes was less harmful effect compare to *O. viverrini*. Moreover, these snails have very important role in economic as food sources and usually prepare as well cooked. However further investigations should be done on using viviparid snails as biological control on *B. siamensis goniomphalos*. Consequently they may also compete to the ingestion of *O. viverrini* eggs contaminated their foods. It was the same as the study on competition of *Schistosoma mansoni* infection in their intermediate hosts (Decoy effect) with other species snails (Lardans and Dissous, 1998; Munoz-Antoli *et al*., 2003; Okere and Odaibo, 2005).

However, distribution and density of viviparid snails were not only affected by salinity, many factors may involve such as soil type, humidity, temperature, rainfall etc. these all factors may play important roles in distribution and density of viviparid snails since food source of snails affect from these factors. In many areas of northeastern Thailand appeared high surface salt causing difference in salinity. Therefore, most importance factor in this area is possibly salinity. Further investigation should work in other factors and parasitic infection rate in difference concentration of salt.

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