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Morphometry of mountain crabs (Crustacea: Decapoda: Brachyura: Potamidae) from Phetchabun Mountains Thailand

Wanniwat Suthamrit and Bungorn Thaewnon-ngiw*

Department of Biology, Faculty of science, Mahasarakham University, Mahasarakham 44150, Thailand.

Abstract

Mountain crabs are freshwater crabs which live in high mountain streams. They are an important food source for local villagers, but some species are threatened with extinction. The aims of this study was to collect and identify mountain crabs of family Potamidae using external morphology, and morphometric analysis. A total of 138 crabs (103 males and 35 females) were collected from 15 locations of the Phetchabun Mountains (310 to 845 meters above sea level). The morphological crab was classified based on gonopod and other characters. This study identified six species: *Indochinamon bhumibol, Indochinamon ahkense, Indochinamon mieni, Iomon nan, Vietopotamon phuluangense* and *Larnaudia chaiyaphumi*. All species showed relationship between the carapace width and weight, indicating that they maintain the same shape throughout life, making identification more difficult. The variety of morphological characteristics presents a challenge in the identification. *I. bhumibol*'s the first gonopod is extreme like other species and has high variation coloration. Therefore, taxonomists need to search for other characters and techniques for classification. It is suggested that species of crabs facing extinction be selectively propagated incapacity for release back into the wild.

Keywords: Morphometry, Potamidae, Phetchabun Mountains, mountain crabs.
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1. Introduction

The study of freshwater crabs in Thailand started about 1920. Most of the previous mountain crabs studies of mountain crabs placed them in the genus Potamon but they were separated into many genera later [1]. Now, there are 93 species in 25 genera of the family Potamidae in Thailand distributed in mountainous regions [2]. The decapod crustacean family Potamidae consist primarily of crabs of fast streams and waterfalls in, waterfall crab and mountain areas. These crabs are important in mountain ecosystems, and are indicators of non-polluted water [3, 4]. Some mountain crabs species are considered by the International Union for Conservation of Nature (IUCN) to be "Endangered (EN)". The mountain crabs have provided an important source of food and income for local villagers. Increasing exploitation has reduced the number of mountain crabs. Furthermore, village still lack basic information about their life cycle, abundance, kind of crabs and their distribution. On the other hand, mountain crabs are facing threats such as overconsumption, reduced forest area, tourism activities and water pollution. Freshwater crabs distributed in aquatic and terrestrials of tropical and subtropical region [5]. The Phetchabun Mountains are located in the Northeast of Thailand, it connected to the south of Luang- Prabang Range Laos, and is headwater streams with a high diversity of endemic organisms [6, 7].

Currently, mountain crabs are facing several threats, and they are not protected under the Wildlife Preservation and Protection Law of Thailand, it is urgent to study and identify mountain crabs of family Potamidae using external morphology, morphometric and distribution areas. It can apply knowledge for the selection of crab species for the conservation of mountain crabs.

2. Materials and Method

Field surveyed and the collection was carried out with the help of local peoples. The specimens were collected by traps from mountain streams in the Phetchabun Mountains for 3 months (May 2019 to September 2019). The sampling locations from located in five Provinces (Loei, Phetchabun, Nongkhai, Udonthani, and Chaiyaphum). Collective locations have 15 areas: Phuruea (PRI, PRII), Dansai (DS), Thali (TL), Phuluang (PLI), Lomkao (LK), Pakchom (PCH), Sangkhom (SK), Nayoong (NY), Nahaew

*Corresponding author; email: ttbungorn@hotmail.com

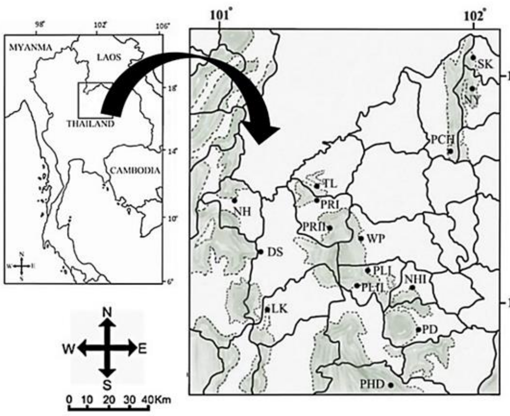

Figure 1: Sampling location of mountain crabs in Phetchabun mountains Thailand.

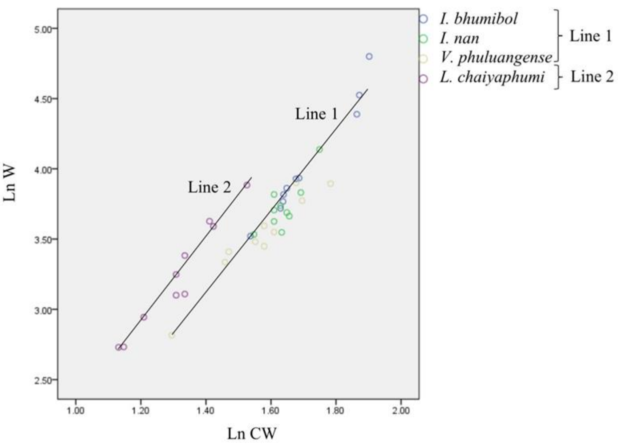

Figure 2: The relationship between weight and carapace width of six mountain crabs.

(NH), Nonghin (NHI), Phuluang (PLII), Wangsaphung (WP), Phukradueng (PD) and Phakdichumphon (PHD) (Figure 1). Specimens were cleaned and kept at -20 °C at the faculty of Science Mahasarakham University until being processed. The external morphological characters including carapaces, chelipeds, walking legs, abdomen, chelae, third maxilla, mandibular pals, first gonopods (G1) and second gonopod (G2) were studied using existing published methods of Chuensri (1973) [8], Yeo & Ng (2008) [9], Ng & Naiyanetr (1993, 1995, 2003) [11, 12], T. Pramual (1990) [13], Brandis (2000) [14], Supajantra (2002) [10] , Ng & Guinot (2008) [15] and Naruse et al (2018)[16]. We measured carapace width and carapace length of all crabs using a Vernier caliper. The specimens were weighed (wet weight: W) using an analytical pocket balance to the nearest 0.01 g. We use these data to study the relationship between carapace width (CW) and weight (W), using the equation $W = a(CW)^b$, where: (a) is the intercept on the y-axis and, (b) is a shape variable relating C and W. The above equation can be transformed to a linear regression by taking natural logarithms: $\ln W = \ln(a) + b \ln(CW)$. Linear regression analysis can be used to estimate the fitted values of a and b [17 – 19].

3. Results

3.1 Collecting sample and study locations

Sampling locations were scattered in five princes in Phetchabun Mountains of Thailand. It is located between latitudes 101 to 102 and longitude from 16.5 to 18.30. The crabs have collected 138 crabs (103 males and 35 females) from high mountain streams. It was found that *I. bhumibol* has the highest distribution as 369 to 845 meters above sea level. The most mountain crabs live under rocky stream but there are some species (*V. phuluangene*) prefer to dig a hole beside the soil stream. Their habitats have various kinds of rock including siltstone, sandstone, limestone and round pebbles (Table 1).

3.2 Morphometrics variation

The biggest size of crab is *I. bhumibol*, its mean W, CW and CL were 54.81 (98.15-31.55) g, 52.75 (42.54-65.43) mm, 41.00 (32.35-50.05) mm respectively. *V. phuluangense* is the least size. *L. chaiyaphumi* is the least of difference and ratio between CW and CL as 0.78 and 1.26 respectively (Table 2). The figure 2 shows growth pattern of specific body part. From the study, it was found that, almost mountain specimens shows relationship of the carapace width (CW) and wet weight (W). It could be explained by the linear graph regression that has normal distribution and linear equation as $\mathrm{W} = -2.776\mathrm{C}^{-0.661}$ and $\mathrm{Y} = -0.661 + 2.776\mathrm{X}$ ($\mathrm{R}^2 = 0.944$). *I. bhumibol, V. phuluangense* and *I. nan* have a high relationship (Line 1). *L. chaiyaphumi* has the least relationship with other species (Line 2) (Figure 2).

3.3 Morphological and color body variation

The 138 crabs were classified into four species. Some characteristics showed variation and unclear morphology, and various species had very similar characteristics. *I. nan*: dorsal view carapace and the color body were dark-brown-olive, carapace surface was crease and clear groove. The ventral body was white. The most of crabs had bigger right chelae than left, the chelae and walking legs tip had oranges. G1, the subterminal joint was wide base and narrow upper, the terminal joint was broken-curve and hook tip. G2, upright terminal segment was the nib (Figure 3); *V. phuluangense*: dorsal view carapace, and the color body were dark-brown or brown-yellow. The carapace surface was a smooth and unclear cervical groove. The ventral body was yellow-white. The most of crabs had bigger right chelae than left, the chelae and walking legs tip were brown-orange. G1, the subterminal joint

Table 1. List of specimens of six Potamidae species and each sample collecting locality, GPS coordinates and altitude.

Species/Locality	Geographic position	Elevation (m)	Total number (N) M = male, F = female	Habitat/ Rock*
Indochinamon bhumibol (Naiyanetr, 2001)			N = 84, M = 59, F = 25	
Phuruea District, Loei Province (PRI)	17 23’09.4”N 101 29’20.1”E	733	N = 8, M = 4, F = 4	rocky stream/siltstone
Phuruea District, Loei Province (PRII)	17 28’55.88”N 101 23’04.45”E	789	N = 10, M = 3, F = 7	rocky stream/siltstone
Dansai District, Loei Province (DS)	17 15’01.70”N 101 08’24.99”E	414	N = 10, M = 8, F = 2	rocky stream/siltstone
Thali District, Loei Province (TL)	17’32’09”N 101’19’41”E	829	N = 9, M = 6, F = 3	rocky stream/siltstone
Phuluang District, Loei Province (PLI)	17 06’04”N 101 33’28”E	845	N = 9, M = 7, F = 2	rocky stream/siltstone
Lomkao District, Phetchabun Province (LK)	17 06’25.94”N 101 19’06.62”E	602	N = 10, M = 7, F = 3	rocky stream/siltstone
Pakchom District, Loei Province(PCH)	17 02’50”N 101 50’56”E	720	N = 10, M = 9, F = 1	rocky stream/siltstone
Sang-Khom District, Nongkhai Province (SK)	18 12’05.01”N 102 06’39.51”E	369	N = 8, M = 7, F = 1	rocky stream/siltstone
Nayoong District, Udonthani Province (NY)	18 28’5 N 102 87’7 E	473	N = 10, M = 8, F = 2	rocky stream/round pebbles, sandstone
Iomon nan (Ng & Naiyanetr, 1993)			N = 10, M = 10, F = 0	
Nahaew District, Loei Province (NH)	17 18’16.90’N 101 05’49.93’E	795	N = 10, M = 10, F = 0	rocky stream/ sandstone
Vietopotamon phuluangense (Bott, 1970)			N = 41, M = 24, F = 17	
Nonghin District, Loei Province (NHI)	17 02’50”N 101 45’40”E	594	N = 10, M = 4, F = 6	rocky stream/red brown sandstone
Phuluang District, Loei Province (PLII)	17 05’29.37”N 101 34’11.31”E	461	N = 7, M = 5,F = 2	rocky stream/ sandstone
Wangsaphung District, Loei Province (WP)	17 16’16”N 101 34’42”E	411	N = 6, M = 2,F = 4	rocky stream/limestone
Phukradueng District, Loei Province (PD)	16 50’15.59”N 101 49’42.49	310	N = 11, M = 8,F = 3	rocky stream/brown sandstone
Larnaudia chaiyaphumi (Naiyanetr, 1982)			N = 10, M = 10,F = 0	
Phakdichumphon District, Chaiyaphum Province (PHD)	16 08’42.42”N 101 27’49.23”E	462	N = 10, M = 10,F = 0	rocky stream/sandstones, siltstones
			N = 138, M = 103, F = 35	
				sandstone

*Type of rock was identified from the data of Department of Mineral Resources (http://www.dmr.go.th/download/digest/Leai2.pdf)

was wide base and the smooth narrow upper, terminal joint was alike semilunar curve. G2, upright terminal segment had a curve sclerotized tube (Figure 4); *L. chaiyaphumi*: dorsal view carapace and the color body was bark-brown-orange. The carapace surface was a quite smooth, clear semi-circular and unclear crevicular groove. The ventral body was white-brown. Most of the chelae crabs had right bigger than left. The walking legs surface was Black spot pattern. G1, the subterminal joint was wide base and narrow upper, the terminal joint was an upright conical shape. G2, upright terminal segment was the nib (Figure 5); *I. bhumibol*: dorsal view carapace and the color body were dark-purple (morpho I), onyx-dark-blue (morpho II), brown-yellow (morpho II) or dark-brown (morpho IV). The carapace surface had a small granum, clear cervical groove and semicircular groove. The ventral body was brown-white or purple-white. Most of the crabs had bigger right chelae than left (Figure 6). *In. ahkense*: dorsal view carapace and the color body were brown-orange. The carapace have granule on lateral and frontal surface, clear cervical groove, and clear semi-circular groove. The ventral body was brown-white. G1’s the subterminal was wide base and

Figure 3: *Iomon nan* male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G, second gonopod.

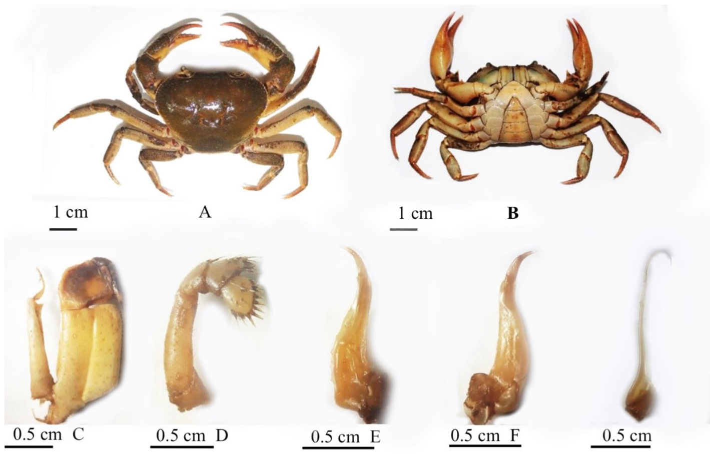

Figure 4: *Vietnopotamon phuluangense*, male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G, second gonopod.

narrow upper (a little hair), G1's flexible zone was unclear. The terminal joint was 45-degree angle and straight tip. G2, upright terminal segment had a curve sclerotized tube (Figure 7); *In. mieni*: dorsal view carapace and the color body were onyx-dark-blue. The carapace has granule on the lateral and frontal surface, clear cervical groove, and clear semi-circular groove. The ventral body was purple-white. The chelae and walking legs tip were white-oranges. G1's subterminal joint was narrow base and concave in the narrow upper (a little hair), G1's flexible zone was concave V-shape. The terminal joint was the 45-degree angle and slightly angled bent tip. G2's upright terminal segment had a curve sclerotized tube. The walking leg surface of *In. mieni* had a black spot pattern (Figure 8). All three species of genus Indochinamon, have small granum on the lateral and frontal surface, clear cervical groove, and semicircular groove. Their G1 character was very similar, but there were a little different each species. Most of the crabs had bigger right chelae than left.

4. Discussion

4.1 The distribution and collection samples

Tropical Southeast Asia is the species richness location, comprises many important of the world's biodiversity, Phetchabun mountains have abundant natural resources and various kind of animals and plants [7, 21]. This study found four species in four genera: *I. bhumibol, I. nan, V. phuluangense* and *L. chaiyaphumi*. All of them live in abundant location, clean water, and moderate flowing streams. They were important food for the locals especially *I. bhumibol*, because of its big body size (The biggest freshwater crab in Thailand). It is also the endemic species of Loei Province [22]. There were important endemic species every continent such as *Candidiopotamon rathbunae* in Taiwan [23] and *Sesarma* species Western Jamaica [24]. Almost of them are risking of extinction. From study of Shih & Ng (20011) found freshwater crabs in Eastern Asian distributed to china and upper ASEAN countries [25]. *I. nan* used to classify into genus *Potamon* (Its old name is *Potamon man*, it was first discovered in Nan Province

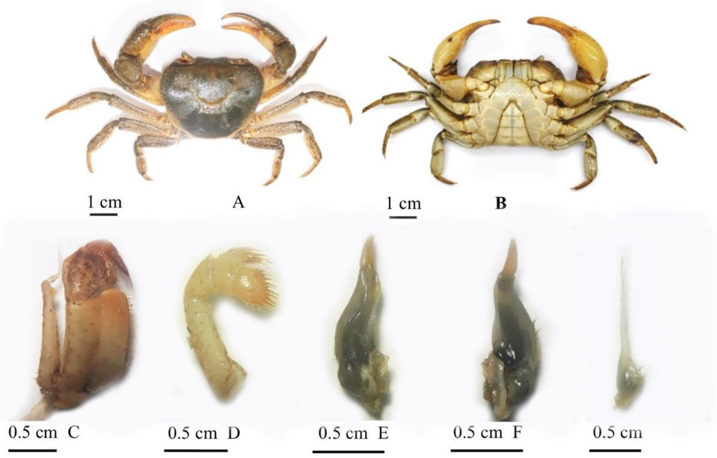

Figure 5: *Larnaudia chaiyaphumi*, male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G = second gonopod.

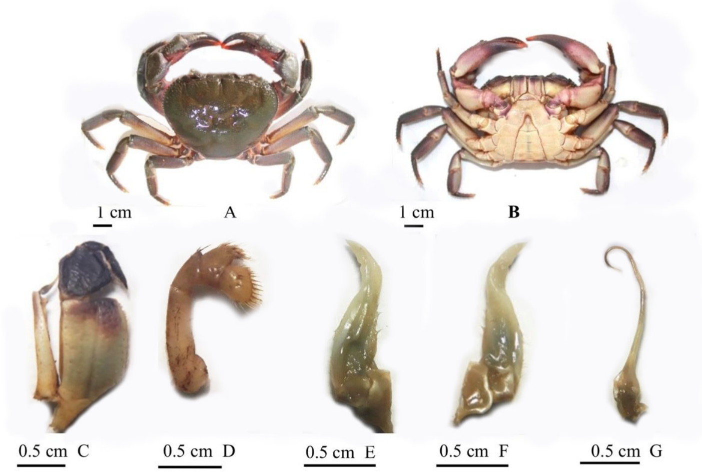

Figure 6: *Indochinamon bhumibol*, male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G, second gonopod.

[1, 11]. This study collected from Nahaew District, Loei Province (NH). This species was considered as EN, because its distributive area is really restricted (less than 500 km?) [26]; *V. phuluangense* was found distributional area between border of Vietnam, Laos and Thailand. Its characteristics is very similar to *Ranguna luangprabangensis* (Rathbun, 1904)[11]; *L. chaiyaphumi* was considerd as Least concern [25], It was found Phakdichumphon District, Chaiyaphum Province (Figure 1). From 1973 to 2019, Thailand's forest has been decreased from 43% to 31% [26]. The increasing of the anthropogenic activities results to discharging of chemical materials and pollutions to the environment such as: urbanizations, industries, agricultural development, tourism activities, mining and overexploitation. From these causes affected to decreasing of crabs habitat [27 – 32]. The dramatic effect was threat for crab's biodiversity. From this study two species were discovered and considered as EN such as *I. nan* and *I. bhumibol*. According with IUCN assessment, 27% of crustaceans were threatened with extinction [29].

4.2 Morphological and Morphometric analysis

Over decades ago, taxonomy depend on differentiation of external morphology. Some species was mistakenly classified, was had confused. For example *Iomon luangprabanges* used to incorrectly identified as *Iomon nan* and *Indochinamon cua* [13, 9]. *I. nan* had old name that *Potamon nan* [13]. It had previously been referred to *Ranguna luangprabangensis* (Rathbun, 1904). Its terminal joint of G1 was broken curve and hook tip like to *Doimon maehongsonensis* (Naiyanetr, 1992), but *D. maehongsonensis* was curvature and thickening on the mid-terminal joint of the G1. *I. bhumibol*: Its old name was *Potamon bhumibol* (Naiyanetr, 2001). It was moved to genus *Indochinamon*. Its G1, G2 and carapace characteristics were similar to those of the *Potamon tannanti* species

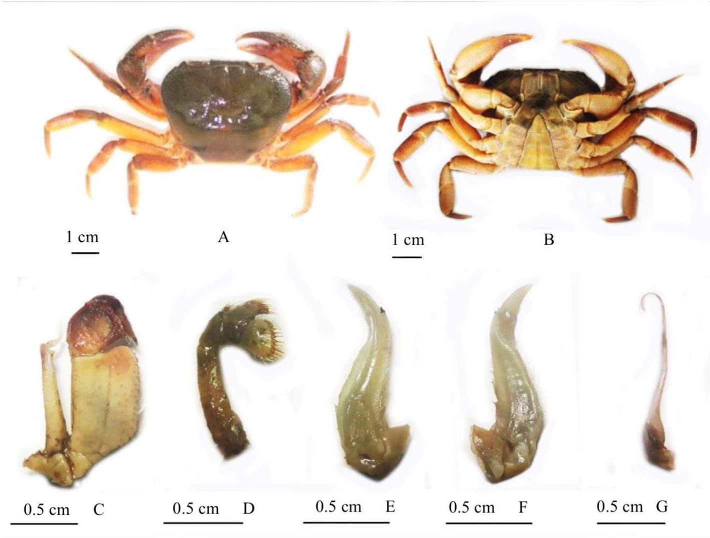

Figure 7: *Indochinamon ahkense*, male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G, second gonopod

Table 2. Morphometric characters for four species Potamidae.

species	weight			carapace						WC-L	CW/CL
				wide: WC (cm)			long: CL (cm)			average	average
	max	min	average	max	min	average	max	min	average		
I. bhumibol	98.15	31.55	**54.81**	6.54	4.24	**5.27**	5.00	3.23	**4.10**	1.18	1.29
In. ahkense	68.16	33.31	51.47	59.20	49.5	54.10	46.20	38.00	41.70	12.40	13.00
In. mieni	72.23	12.10	39.51	63.00	31.0	47.00	48.30	24.00	36.80	10.20	12.80
I. nan	62.65	34.23	42.25	5.75	4.70	5.15	4.45	3.60	3.98	1.17	1.29
V. phuluangense	37.5	9.445	22.49	4.82	2.91	3.89	3.68	2.27	2.99	0.9	1.29
L. chaiyaphumi	48.63	15.33	27.20	4.60	3.10	3.75	3.60	2.45	2.97	0.78	1.26

group. The *P. tannanti* group consisted of *Indochinamon jinpingense* (Dai, 1995) [Northern Vietnam, Southern China], *Indochinamon orleansi* (Rathbun, 1904), *Indochinamon mieni* (Dang, 1967), *Indochinamon guttus* (Yeo & Ng, 1998), *Indochinamon lipkei* (Ng & Naiyanetr, 1993) [Northern Thailand] [20, 15] and *Indochinamon ahkense* (Naruse, 2018) [Yunnan Province China] [16]. *V. phuluangense*: It had previously been identified as a subspecies as *P. luangprabangensis* (Ng & Naiyanetr, 1993). However, the G1 had characteristics like those of *Iomon luangprabangensis* (Rathbun, 1904), but the tip of terminal joint of *I. luangprabangensis* was more bent. In this the study found that various of G1 character within each species especially *I. bhumibol* and *V. phuluangense* [34] found that the frog crab (*Ranina ranina*) showed variations in the carapace color, white spots patterns, antenna shape, feeding apparatus and maxilliped each individual crabs. In some Potamonautidae used mandibular palps and third maxilliped for identifying [35], but it cannot use in Potamidae. However, G1 characteristics have a clear difference in inter-genus, but overlap within the genus. G2 characteristics were divided into two groups: the first group was upright sclerotized tubes (*I. nan* and *L. chaiyaphumi*); the second group was curved sclerotized tubes (*In. bhumibol, In. ahkense, In. mieni* and *V. phuluangense*). Mountain crabs showed high color variation, it may be a result of carapace formation that has to gotten minerals (Calcium carbonate) from food and environment after molting [32]. The animal color variation was the topic that linked to the history of the evolution. There was discovery on various animals which had color pattern changed, based on the environment. For example, land animal group were studied in primates, birds, butterflies [33], insects [34], centipede [35] and grass frog [36]. In this study, coloration variation of all four group species was discovered. The truth that the animal color is determined by genes in the body, but environment may influence to color variation. Morphometry of four species of Potamidae showed relationship between CW and W, in accordance with the study of Fadlaoui et al (2019) which found the allometric growth patterns of *P. algeriense* [19], Buatip et al. (2017) studied the relationship of CW and W in five freshwater crabs in southern Thailand [3]. *I. bhumibol* was the biggest crabs in this group, was similar to the biggest crab in the same genus in Chinese (CW = 59.4 mm) [16]. The relationship of the wide carapace and wet weight showed the growth pattern of moun-

Figure 8: *Indochinamon mieni*, male. A, dorsal view; B, ventral view; C, left third maxilliped; D, right mandibular palp; E, right first gonopod anterior view; F, right first gonopod posterior view; G, second

tain crabs. However, environments, foods, age and organism's chemical reaction may cause variation in morphological characteristics. Habitats influence the growth and shape of animals, according to the phenotypic plasticity theory [37].

5. Conclusions

The morphology of the mountain crabs showed external morphological variation that was influenced by the environment. The characteristics were varied in each habitat. These phenomena were explained by the phenotypic plastic theory. These mountain crabs were classified using gonopod characteristics as four species which were *I. bhumibol, I. nan, V. phuluangense, L. chaiyaphumi*. For the extremely close species was quite hard to classify. There were many possible factors that promoted morphological differentiation include: foods, water, mineral, and genetic structure. Therefore, taxonomists need to combine the study both of morphological characters and genetic molecular techniques in order to select breeders for commercial rearing.

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References

[1] D. C. J. Yeo, P. K. L. Ng, On the genus "Potamon" and allies in Indochina (Crustacea: Decapoda: Brachyura: Potamidae), The Raffles Bulletin of Zoology 16(2) (2008) 273 – 308.

[2] S. Potamidae, http://www.siamensis.org/species_index?nid=794#794–Family: Potamidae, 2010 (accessed 12 August 2019).

[3] S. Buatip, P. Yeesin, S. Samaae, Some aspects of the biology of 5 freshwater crabs in lower Southern Part of Thailand, Burapha Science Journal 23(1) (2017) 431–47.

[4] M. Dobson, A. M. Magana, J. Lancaster, J. M. Mathooko, Aseasonality in the abundance and life history of an ecologically dominant freshwater crab in the Rift Valley, Kenya Freshwater Biology 52(2) (2007) 215–25.

[5] N. Cumberlidge, P. K. L. Ng, D. C. J. Yeo, Freshwater crabs of the Indo-Burma hotspot: diversity, distribution, and conservation, status Distrib Freshw crabs (2011) 102–13.

[6] Department of Mineral Resources, Thai Geological SiteThe Invaluable Natural HeritageThai, http://www.dmr.go.th/main.php?filename=index_EN, 2017 [accessed 16 December 2019)

[7] K. Thawarorit, N. Sangpradub, J. C. Morse, Five new species of the genus cheumatopsyche (Trichoptera: Hydropsychidae) from the Phetchabun Mountains, Thailand, Zootaxa 3613(5) (2013) 445–54.

[8] C. Chuensri, Freshwater Crabs of Thailand, Freshwater Crabs of Thailand, 1973, pp. 18–20.

[9] D. C. J. Yeo, P. K. L. Ng, N. Cumberlidge, C. Magalhães, S. R. Daniels, M. R. Campos, Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater, Hydrobiologia 595(1) (2008) 275–86.

[10] P. K. L. Ng, P. Naiyanetr, Pudaengon, a new genus of terrestrial crabs (Crustacea: Decapoda: Brachyura: Potamidae) from Thailand and Laos, with descriptions of seven new species, The Raffles Bulletin of Zoology 43(2) (1995) 355–376.

[11] P. Ng, P. Naiyanetr. Zoologische Verhandelingen: new and recently described freshwater crabs (Crustacea:Decapoda:Brachyura:Potamidea,Gecarcinucidae and Parathelphusidae) from Thailand, 2003, pp. 1–117.

[12] T. Pramual, Taxonomy of rice-field crabs and charaters of Gonopod ommatidia by scanning electron microscopy, Chulalongkorn university, 1990.

[13] D. Brandis, The taxonomical status of the freshwater crab genus, Senckenbergiana Biologica (2000) 57–100.

[14] S. Supajantra, Taxonomy of freshwater crabs in The North-Eastern Thailand, Chulalongkorn university, 2002.

[15] P. Ng, D. Guinot, P. Davie, Systema Brachyurorum: Part 1. An Annotated checklist of extant brachyuran crabs of the world, The Raffles Bulletin of Zoology 17 (2008):1–286.
[16] T. Naruse, J. E. Chia, X. Zhou, Biodiversity surveys reveal eight new species of freshwater crabs (Decapoda: Brachyura: Potamidae) from Yunnan Province, China. PeerJ. 6(d) (2018) e5497.
[17] D. A. Somerton, A computer technique for estimating the size of sexual maturity in crabs, Canadian Journal of Fisheries and Aquatic Sciences 37(10) (1980) 1488–94.
[18] A. Kalate, A. Keikhosravi, R. Naderloo, T. Hajjar, C. D. Schubart, Morphometric characterization of the freshwater crab Potamon elbursi Pretzmann, 1962 in the Caspian Sea and Namak Lake hydrographic systems, Journal of Crustacean Biology 38(1) (2018) 91–100.
[19] S. Fadlaoui, M. Mahjoub, O. El Asri, M. Melhaoui, Allometric growth of the freshwater crab Potamon algeriense (Bott, 1967) (Decapoda, Brachyura, Potamidae) in Oued Zegzel, a Mountain Stream, in the Northeast of Morocco, International Journal of Zoology 2019(1) (2019) 1–8.
[20] K. Malila, Provenance of the Nam Duk formation and implications for the Geodynamic, Technology, Suranaree University of Technology, 2005.
[21] P. Naiyanetr, Potamon bhumiboln. sp., A newgaint freshwater crab from Thailand (Decapoda, Brachyura, Potamidae), Crustaceana 65(1) (1993) 1–7.
[22] H. T. Shih, H. C. Hung, C. D. Schubart, C. A. Chen, H. W. Chang, Intraspecific genetic diversity of the endemic freshwater crab Candidiopotamon rathbunae (Decapoda, Brachyura, Potamidae) reflects five million years of the geological history of Taiwan, Journal of Biogeography 33(6) (2006) 980–989.
[23] C. D. Schubart, J. Reimer, R. Diesel, M. Türkay, Taxonomy and ecology of two endemic freshwater crabs from western jamaica with the description of a new sesarma species (Brachyura: Grapsidae: Sesarminae), Journal of Natural History 31(3) (1997) 403–419.
[24] M. Rueda, M. A. Rodríguez, B. A. Hawkins, Identifying global zoogeographical regions: Lessons from Wallace, Journal of Biogeography 40(12) (2013) 2215–2225.
[25] IUCN. The IUCN red list of threatened species, https://www.iucnredlist.org/, 2019.
[26] Royal Forest Department. Forest Area in 1973 – 2018,http://forestinfo.forest.go.th/Content.aspx?id=9, 2018
[27] V. T. Do, Freshwater crabs of Vietnam: diversity and conservation, Journal of Vietnamese Environment 6(2) (2014) 109–114.
[28] R. C. Akpaniteaku, Evaluation of the strategy of utilization and conservation of freshwater crab, International Journal of Innovative Studies in Aquatic Biology and Fisheries 3(2) (2017) 18–22.
[29] T. Dalu, M. T. B. Sachikonye, M. E. Alexander, T. Dube, W. P. Froneman, K. I. Manungo, et al., Ecological assessment of two species of potamonautid freshwater crabs from the Eastern Highlands of Zimbabwe, with implications for their conservation, PLoS One. 11(1) (2016) 1–17.
[30] D. P. Matondo, C. G. Demayo, Morphological description of the red frog crab Ranina ranina Linnaeus, 1758 (Brachyura: Raninidae) from South Western Mindanao, Philippines 3(2) (2015) 251–256.
[31] S. R. Daniels, B. A. Stewart, L. Burmeister, Geographic patterns of genetic and morphological divergence amongst populations of a river crab (Decapoda, Potamonautidae) with the description of a new species from mountain streams in the Western Cape, South Africa, Zoologica Scripta 30(3) (2001) 181–197.
[32] H. Nagasawa, The crustacean cuticle: Structure, composition and mineralization, 2015.
[33] D. Osorio, M. Vorobyev, A review of the evolution of animal colour vision and visual communication signals, Vision Research 48(20) (2008) 2042–2051.
[34] A. D. Briscoe, L. Chittka, The evolution of color vision in insects, Annual Review of Entomology 446(1) (2001) 471–510.
[35] W. Siriwut, G. D. Edgecombe, C. Sutcharit, S. Panha, The centipede genus Scolopendra in mainland Southeast Asia: Molecular phylogenetics, geometric morphometrics and external morphology as tools for species delimitation, PLoS One 10(8) (2015) 1–37.
[36] P. Klahan, B. Thaewnon-ngiw, Genetic diversity of the grass frog (Fejervarya limnocharis , Gravenhorst, 1829) in northeastern Thailand using PCR-RFLP, Journal of Thai Interdisciplinary Research 13(1) (2018) 1–7.
[37] B. G. Miner, S. E. Sultan, S. G. Morgan, D. K. Padilla, R. A. Relyea, Ecological consequences of phenotypic plasticity, Trends in Ecology & Evolution 20(12) (2005) 685–692.