BUFFALO (*Bubalus bubalis*) PHENOTYPIC DIVERSITY CHARACTERIZATION REVEALS THE NEED FOR IMPROVED PERFORMANCE BASED ON QUANTITATIVE AND QUALITATIVE CHARACTERISTICS: A COMPARISON OF KALANG BUFFALO IN KALIMANTAN, INDONESIA AND THALE NOI BUFFALO IN PHATTHALUNG, THAILAND

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ABSTRACT

Kalang buffaloes (KBuf) are bred in swamplands, maintained in large cages, and originate from Kalimantan Island, Indonesia, hence, the local word "kalang". KBuf and Thale Noi buffaloes (TBuf) are important biodiversity resources in Indonesia and Thailand which permeate areas of culture, religion, meat supply, and livelihood. This study aimed to observe phenotypic characteristics within breeds of KBuf and TBuf based on quantitative and qualitative performance to define diversity. A total of two hundred and forty buffaloes were observed from North (NK), East (EK), South Kalimantan (SK) provinces of Indonesia, and Phatthalung (PT) province of Thailand. The phenotypic characterization consisted of quantitative, qualitative, and morphometric index analyses. The phenotypic characterization showed that female TBuf demonstrated the highest value on the quantitative parameters which was significantly different (P<0.05) compared to KBuf. Among Kalimantan buffaloes, SK males had the highest value on the qualitative parameters which was significantly different (P<0.05) from EK and NK. According to the morphometric index, male buffaloes from SK and PT have shown close index values (P>0.05). Also, females from EK, SK, and PT had a close relationship (P>0.05) in the morphometric indices. Based on qualitative characters, buffaloes in this study exhibited high variation in body appearance, skin, coat, and foot colors, horn pattern, backline, chevron, and whorls in the head, back, and rump. It was concluded that KBuf and TBuf have high variability in phenotypic diversity, the distribution area affects the parameter values as potentially influenced by lineage factors and ability to adapt to the environmental and management conditions.

Keywords: *Bubalus bubalis*, buffaloes, phenotype, biodiversity, Indonesia, Thailand

INTRODUCTION

Biodiversity is important to supports food security and sustained livelihoods through overall genetic diversity. It becomes the context of the analysis of ecology, sustainable development, and

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the protection of the local/endemic species of the natural environment. Biodiversity also represents all forms of life on earth as fundamental for the provision of ecosystem services, which we depend on for food, air, and water security, and multiple other natural benefits (FAO, 2019). Indonesia is an archipelagic country located between the two great continents of Asia and Australia, which is a source of the world's biodiversity (Putu, 2003). This strategic position of biological resources has diversity and endemism. More importantly, although the total area of Indonesia only covers 1.3% of the land area in the world, it has a high diversity of fauna species (Tappa, 2013).

Buffalo is an important part of Indonesia's fauna which has a significant role which underpins the economic growth in rural and remote areas (Ministry of Agriculture of the Republic of Indonesia, 2019). According to the Indonesia Directorate General of Livestock and Animal Health Services (2019), the number of buffaloes in 2019 increased by 27.62% compared to that in 2018. Currently, Indonesia has 1.141 million buffaloes, approximately 40% of which are males (522,400 heads). In addition, in Kalimantan island, buffaloes are the most important domesticated animal with highly-significant roles in religious, socio-cultural, tourism, economic, and applied animal science and technology.

Kalimantan is the biggest island in Indonesia which has great potential for buffalo development where it has sustainable likelihood, abundant natural resources, and spacious environmental habitat. KBuf is a local buffalo of Indonesia which has an original geographical distribution in East to South Kalimantan province and is authentic biodiversity in the region, which has been established by the Minister of Agriculture (Ministry of Agriculture of the Republic of Indonesia, 2012a; 2012b). KBuf is a wealth of genetic resources of Indonesian local livestock that need to be protected, preserved, and developed to increase performance in terms of production and reproduction, which, are still low (Lita, 2009). Thale Noi buffaloes (TBuf) is a breed originating from the Thale Noi wetlands located in Phatthalung province, southern Thailand, Thale Noi is one of the largest natural freshwater lakes in South East Asia and is home to almost 3,000 swamp buffaloes. The lake ecosystem supported by the availability of forage makes for an excellent habitat for improving buffalo performance (Phatthalung Province Statistics Report, 2017). Therefore, it is necessary to develop local commodities such as KBuf and TBuf, where it has a very bright prospect of supporting the achievement of self-sufficiency in red meat in Indonesia and Thailand.

The significance of conducting buffalo development research is to fill the gap in the fundamental science behind the diversity of KBuf and TBuf breeds. Previous research only reported the productivity and epidemiology of diseases on buffalo and provided limited information on genotypic and phenotypic traits (Komariah *et al*., 2014; Natalia *et al*., 2006). Research and development, therefore, on the exploration of phenotypic diversity and variation in KBuf and TBuf becomes essential. Measurement of the diversity could be done by phenotypic characterization to identify and document diversity within and between distinct breeds, based on their observable attributes (FAO, 2012). Phenotypic characterization, including information of quantitative and qualitative parameters are essential to observe the KBuf and TBuf diversity in Kalimantan and Phatthalung for the improved genetic management and development in the local and international industry.

The present study aimed to observe phenotypic characteristics within breeds of KBuf in East, South, and North Kalimantan provinces of Indonesia and TBuf from Phatthalung province of Thailand. The different study sites enriched the variety of data distribution by having a two-country comparison, as well as revealing local variations among KBuf and TBuf.

MATERIALS AND METHODS

The present study observed KBuf (n=180) and TBuf (n=60) guided by the sampling criteria such as state of sexual maturity, mature body, and age limit between three to five years. KBuf and TBuf were chosen based on the concentration of population density in each province, from North Kalimantan (NK) province (30 males and 30 females), East Kalimantan (EK) province (30 males and 30 females), South Kalimantan (SK) province, Indonesia (30 males and 30 females), and Phatthalung (PT) province, Thailand (30 males and 30 females). The diversity traits were observed based on phenotypic characteristics.

The phenotypic characterization of buffaloes was composed of quantitative and qualitative data. Quantitative data consisted of morphometric and body weight; 1) wither height, 2) body length, 3) heart girth, 4) shoulder width, 5) chest depth, 6) rump height, 7) rump width, 8) rump length, and 9) body weight estimation. Qualitative data; 1) body appearance, three classes; small (<300 kg), medium (300-400 kg), and large (>400 kg) was based on body weight classification (Diyono, 2009), 2) skin color, 3) coat color, 4) horns pattern, was based on buffalo horns patterns classification (Stepanus, 2008), 5) back-line, 6) chevron, 7) hair whorls on the head, 8) hair whorls on the back, 9) hair whorls on the rump, and, 10) foot color, were recorded based on Amano *et al.* (1981).

Bodyweight measurements were carried out while animals were in normal standing conditions with the bodyweight resting on both feet in a balanced condition (Amano *et al.*, 1981). The body weight (BW) was calculated by the following formula, based on heart girth (HG) and rump height (RH) (Galib *et al.*, 2017): a) BW (male) = 3.6435 (HG) + 0.1208(RH) - 265.43, b) BW (female) = 4.1783 (HG) - 0.3086 (RH) - 305.19.

Data analysis

The mean of the studied traits was calculated and used for statistical analysis (Gomez and Wiley, 1984). The average, standard deviation (SD) and coefficient of variation (CV) were calculated for the measured traits (Walpole, 1982).

The morphometric index can be used as an alternative in the assessment of livestock as a type indicator (meat type, dairy type or dual purpose) and the following indices were calculated from the mean values of body measurements, according to the method based on Alderson (1999) with the formula:

$$\text{Height slope} = \text{Wither height} - \text{Rump height}$$

$$\text{Length index} = \frac{\text{Body length}}{\text{Wither height}}$$

$$\text{Width slope} = \text{Rump width} - \text{Chest width}$$

$$\text{Depth index} = \frac{\text{Chest depth}}{\text{Wither height}}$$

$$\text{Foreleg length} = \text{Wither height} - \text{Chest depth}$$

$$\text{Balance} = \frac{\text{(Rump leghth x Rump width)}}{\text{(Chest depth x Chest width)}}$$

$$\text{Cumulative index: } \frac{\text{(Body weight)}}{\text{Average weight}} + \text{length index} + \text{balance}$$

Data recorded in this study were statistically analyzed by observing differences between treatments using Duncan Multiple Range Test (DMRT) at the level of 5% with the SPSS 24 program (Statistical Product and Service Solution) (Norusis, 1998). The coefficient of variation (CV%) was determined as a variability index.

RESULTS AND DISCUSSIONS

Quantitative characteristics

The results of the quantitative parameters of the present study are highly variable in terms of combinations of results that are similar, higher, or lower when compared to other reported results from studies in Asia and other parts of the world. For example, although the average wither height results of the current study agreed with results published from Thailand by Brunakarl *et al.* (2013) and in Brazil by de Melo *et al.* (2018), the average body length results of the present study were lower compared to the same study by de Melo *et al.* (2018), and higher compared to the same study by Brunakarl *et al.* (2013). These variations in results comparison in the different combinations of the nine quantitative parameters were similarly observed in published reports from Vietnam (Berthouly *et al*., 2009), Istanbul Turkey (Kocaman *et al*., 2017), Indonesia (Djaja, 2013; Galib *et al*., 2017; Gerli *et al*., 2012), Pakistan (Khan *et al*., 2013; Tariq *et al*., 2013), India (Dhillod *et al*., 2017), Bangladesh (Rahman *et al*., 2015), Argentina (Crudeli *et al*., 2007), Italy (Allegrini *et al*., 2007), and Egypt (Genedy *et al*., 2019). Similarly, variations in results among the nine quantitative parameters can also be observed within the same country from studies conducted at different periods as demonstrated in Indonesia, where the average body results of the present study agreed with reports from Djaja (2013) and Galib *et al.* (2017) but were lower compared to earlier reports from Gerli *et al.* (2012). The factor of the distribution of buffaloes can influence variations in results due to the adaptation to local environmental conditions and management strategies employed. The buffalo bodyweight is an important indicator of the quality of management and cultivation practices by farmers. Based on our results, it was observed that KBuf were well-maintained, and TBuf received the best management among the samples. The lower bodyweight of the KBuf in NK may be due to genetic factors and differences in the maintenance/management system, and selection direction of buffalo farmers (Sumantri *et al*., 2007; Gunawan and Sumantri, 2008). These results demonstrated the influence of area distribution on the phenotypic diversity among buffalo breeds.

According to the value of the nine quantitative parameters of morphometric characteristics, male buffalo originating from SK and PT have a close relationship, compared to NK and EK provinces. Also, a close relationship was observed from female KBuf from SK and EK (Table 1). This condition indicated a potential for common ancestry. Relative to interviews with farmers, it was stated that the history of KBuf development in the EK province was strongly influenced by people of the Banjar tribe who originated from SK territory. In 1918, the Banjar tribe migrated and brought their KBuf to EK (Ghofar, 2014). These pieces of evidence potentially define the closeness of phenotypes between SK and EK KBuf.

The results of our study showed the highest value of heart girth performance were observed from buffaloes from PT and SK provinces. The variability in the heart girth could be attributed to the nutritional factors as the circumference traits are more affected by nutrition. Further, the difference might be due to the variation of breeds, climatic influences, and feeding systems. Buffaloes that are maintained with extensive management have access to more nutritional feeds, additives, concentrates, and better forage quality. This may be the case for buffaloes from PT and SK as evidenced by the higher average values in the nine quantitative parameters as compared to the lower averages in KBuf from NK and EK. The heart girth is a very important parameter as it reflects other body size estimations, especially bodyweight, which is used to determine the quality of livestock and the selection of calves (Tariq *et al*., 2013). These observations may seem to imply sustainable strategies in buffalo breeding and management which addresses areas of environmental influences such as feed, climate, and treatment of buffalo in SK and PT which can be useful in other regions to improve buffalo quality.

Buffalo requires high humidity and an abundance of water to release heat from its body. Stress due to humidity can influence variations in heart girth (Suretno *et al*., 2017; Syawal *et al*., 2013). This, it may seem, influenced the lowest average values of morphometric parameters in KBuf from NK in the present study as North Kalimantan is recorded to have lower humidity as compared to the East and South Kalimantan Provinces, in Indonesia, and Patthalung province in Thailand (BPS-Statistics of Kalimantan Utara Province, 2018). The variations in morphometric measurements are shaped by demographic conditions and the interaction of past and current environmental conditions (Brooks *et al*., 2016). In addition, buffaloes from the PT and SK provinces thrived in vast swampy environments, which provided abundant water as well as enough exercise as the buffalo have a larger area to forage. This may be a positive influence on the superior results of buffalo in PT and SK over the lower average values of KBuf from EK and NK. These observations demonstrate the potential negative and positive influences (direct or indirect) that climate and habitat/distribution exert on buffalo quality.

The results of the present study indicated that differences in subpopulation areas affect body size and body weight. The body size of buffalo from Kalimantan Island was diverse as demonstrated by the high coefficient of variation (CV) values (Table 1). Geographically the subpopulation region or center of buffalo cultivation and breeding was in large and open access areas, although they are on the same island, Kalimantan Island is a vast landmass. Mwacharo *et al*. (2006); Zhang *et al*. (2007) explained that geographical distances in closed populations, extensive, and unselected buffalo maintenance systems increased the level of diversity of a population. If the geographical distance between areas has open access, the diversity of the population will be higher. In addition, diversity was enhanced by the introduction of buffalo breeds from outside of the region.

Morphometric characteristics index

Generally, the differences in quantitative parameter values from buffalo in the region have influenced the index values (Table 2). The results of the seven morphometric indexes of male and female buffalo based on the region subpopulations of the present study are highly variable when compared to reports in other countries, similar to the observations on the quantitative characteristic results as previously presented. For example, although the average height slope index of the current study was higher than the results published from Indonesia (Sulasmi *et al*., 2017; Takaendengan, 2011) and Nigeria (Yunusa *et al*., 2013), the average length index, depth index and foreleg length results of the present study were similar to published reports from the United Kingdom (Alderson, 1999). In our study, the length index values in EK buffaloes were higher compared to buffaloes from NK, SK, and PT. The average value of the width slope in KBuf in the present study was higher when compared to results published from another province in Indonesia (Sulasmi *et al*., 2017). The value of the balance index in this study was lower than reports from the United Kingdom (Alderson, 1999) and Indonesia (Sulasmi *et al*., 2017), while the cumulative index values were similar to values from Handiwirawan *et al*. (2011) who reported buffalo characteristics in West Java, Indonesia.

According to the graph of DMRT 5% on the seven index parameters, male buffaloes from SK and PT exhibited close index values with no significant difference in the seven parameters (Figure 1). Male buffaloes from SK, PT, and EK had no significant difference in the five parameters. However, KBuf from NK had a significant difference with other provinces in all parameters. Female buffalo from EK, SK, and PT provinces have a close relationship with no significant difference in the five index parameters. On three index parameters (height slope, length index, and width slope) TBuf showed a significant difference when compared to other provinces (Table 2). The cumulative index values can represent the type and function of livestock where higher values indicate optimal potential as a type of meat livestock. Index values of the present study were in line with Alderson (1999); Salako and Ngere (2002); Handiwirawan *et al*. (2011); Takaendengan (2011). The results of this study indicated that the highest cumulative index was found in KBuf from SK, followed by buffaloes from EK, PT, and NK provinces. This result indicates that although KBuf from SK was not leading in quantitative characteristics, it still presents an opportunity as suitable meat livestock.

Qualitative characteristics

The results of the nine qualitative parameters of the current study are highly variable in terms of combinations of results as was observed from the quantitative parameters and morphometric characteristics index. The body appearance and skin color of buffaloes in our study conform to publications from Thailand (Chantalakhana and Skunmum, 2002), South and East Kalimantan, Indonesia (Hamdan *et al*., 2010; Lita, 2009), North Sumatera, Indonesia (Sitorus and Anggraeni, 2008) and the United Arab Emirates (Presicce, 2016). The coat colors in the four regions (NK, EK, SK, and PT) agreed with studies from Europe (Cockrill, 1981) and Thailand (Nozawa and Na Phuket, 1974) that stated swamp buffalo coat was generally dominated by black to grayish black colors. The buffalo horn patterns observed from our four study sites were the Tarangga, Sikki, Sokko, and Langi patterns which were also observed from the parents and male descendants (Figure 2). It's were agreed with Erdiansyah and Anggraini (2008) who obtained data that Tarangga horn patterns were observed (98%) in West Nusa Tenggara, Indonesia. Meanwhile, the Pampang horn pattern was only observed from TBuf from PT.

Based on our results (Table 3), the high frequency of the flat backline indicated that buffaloes from NK, EK, SK, and PT were all under the good body performance category. According to Dudi *et al*. (2011), the back-line of buffalo determined the condition of the carcass and body condition score, the best carcass will be found on a buffalo with a flat backline. Our study observations demonstrated single stripe and double stripes chevron patterns (Figure 2). KBuf from EK and SK provinces mostly had double stripe chevron. In contrast, TBuf mostly demonstrated a single stripe chevron. However, KBuf from NK demonstrated both chevron patterns in almost the same percentage. In line with results from Erdiansyah and Anggraini (2008) in West Nusa Tenggara, Indonesia, buffalo demonstrated double stripe (80%) and a single stripe chevron (18.5%). Reports from Chantalakhana and Skunmum (2002) in Thailand indicated that chevron in buffaloes was a character considered for selection. Buffaloes in all regions of the present study demonstrated whorls in the head, back, and rump (Table 3). The results of the present study reported that TBuf had the highest percentage of one whorl in the back and rump, in contrast to KBuf from NK, EK, and SK that, on the average, manifested two whorls in the back and rump/hip. These observations were unique from the study in Banten, Indonesia (Dudi *et al*., 2011) where whorls were mostly found on the head (60%), back (26%), and rump (13%). Generally, buffaloes have more than one whorls and usually a pair, on the left and right of his body as described by Imsyar (2010) in West Sumatera, Indonesia. The foot color of buffaloes from NK and PT has a large percentage of dark gray legs/foot. In contrast, buffaloes from EK and SK had a large percentage of light gray colored legs/foot. These observations were in line with reports from Dudi *et al*. (2011) in Banten, Indonesia. Overall, the most common buffalo foot color in Indonesia was dark gray (44.67%) and the least common was light gray (23.33%).

The results of our study demonstrated that phenotypic variations are influenced by ancestry, distribution, environmental, and human management factors such as availability of resources, feeding or nutrition, climate, migration, diseases, breeding and reproductive management, and husbandry strategies. The prospect of buffalo development in Indonesia, Thailand, and other regions in Southeast Asia, in general, are feasible and should be developed using a sustainable framework for optimal benefits in terms of economy, maintenance of buffalo population as local biodiversity, improvement of breeds performance, and most importantly, to preserve genetic diversity. The selection of high-quality buffalo breeds is an important consideration in producing the best buffalo under the specifications required by the local and international markets. High-quality buffaloes will provide many benefits in the husbandry system and provide positive economic prospects for farmers.

In as far as phenotypic variations among buffaloes may be readily observed, it is recommended by the researchers that molecular analysis is explored in further studies to elucidate genetic ancestry, effects of cross-breeding, susceptibility to diseases, and the potential long-term effects of human management strategies and environmental changes at a cellular level.

CONCLUSION

The data of the present study demonstrated phenotypic diversity and the potential for improved breeding practices and management strategies

Table 1. Quantitative description of male and female buffalo based on subpopulation regions.

Parameters		NK		EK		SK		PT	
		Female	Male	Female	Male	Female	Male	Female	Male
1. Wither height (cm)	Average	124.38^{a}	122.57^{a}	132.02^{b}	130.00^{b}	136.07^{c}	131.08^{b}	135.05^{c}	139.80^{d}
	SD	5.28	3.35	4.07	3.51	3.18	3.03	3.24	2.70
	CV	4.24	2.74	3.08	2.70	2.34	2.31	2.40	1.93
2. Body length (cm)	Average	119.13^{a}	117.43^{a}	131.55^{bc}	132.87^{bcd}	134.53^{de}	130.37^{b}	133.95^{cd}	137.15^{e}
	SD	4.09	4.28	4.25	6.12	3.31	3.37	3.02	2.19
	CV	3.43	3.65	3.23	4.61	2.46	2.58	2.26	1.59
3. Heart girth (cm)	Average	170.43^{a}	172.53^{a}	183.28^{bcd}	180.18^{b}	186.43^{de}	182.12^{bc}	185.20^{cd}	189.15^{e}
	SD	5.11	4.89	4.16	5.73	3.72	6.51	3.14	2.56
	CV	3.00	2.84	2.27	3.18	2.00	3.58	1.69	1.35
4. Shoulder width (cm)	Average	38.98^{a}	40.93^{ab}	43.25^{ab}c	42.00^{ab}	45.32^{bc}	42.33^{ab}	45.15^{bc}	47.10^{c}
	SD	6.02	12.33	4.33	4.71	3.93	5.47	3.18	3.18
	CV	15.44	30.13	8.67	11.21	8.67	12.93	7.04	6.75
5. Chest depth (cm)	Average	69.55^{ab}	68.23^{a}	71.72^{b}	72.13^{b}	76.53^{c}	72.18^{b}	76.90^{c}	78.95^{c}
	SD	6.62	8.71	4.32	3.97	3.89	3.40	3.24	2.54
	CV	9.52	12.77	6.03	5.51	5.09	4.71	4.21	3.22
6. Rump height (cm)	Average	121.28^{a}	119.32^{a}	129.58^{bc}	127.13^{b}	132.02^{cd}	129.08^{b}	132.25^{d}	135.55^{e}
	SD	5.09	4.42	4.26	3.88	3.78	3.03	3.16	2.96
	CV	4.20	3.71	3.29	3.06	2.86	2.35	2.39	2.18
7. Rump width (cm)	Average	40.32^{a}	42.48^{ab}	45.20^{bc}	43.75^{abc}	47.67^{cd}	44.27^{abc}	47.70^{cd}	49.95^{d}
	SD	6.30	12.60	4.45	4.76	3.80	5.19	2.87	2.67
	CV	15.62	29.65	9.84	10.89	7.97	11.71	6.02	5.35
8. Rump length (cm)	Average	28.93^{a}	28.68^{a}	33.30^{bc}	31.75^{ab}	35.87^{c}	34.43^{bc}	34.85^{bc}	36.50^{c}
	SD	6.12	4.81	6.45	5.76	3.66	3.89	3.15	3.75
	CV	21.15	16.79	19.37	18.15	10.19	11.30	9.05	10.27
9. Body weight (kg)	Average	370.19^{a}	378.88^{a}	418.02^{bcd}	408.44^{b}	429.79^{d}	415.91^{bc}	425.32^{cd}	443.30^{e}
	SD	19.22	20.32	15.66	23.30	13.62	27.31	11.79	10.38
	CV	5.19	5.36	3.75	5.70	3.17	6.57	2.77	2.34

The average number accompanied by different superscripts has a significant difference at the level of 5%

Table 2. Morphometrics index of male and female buffalo based on subpopulation regions.

No	Parameters	NK		EK		SK		PT	
		Male	Female	Male	Female	Male	Female	Male	Female
1. Height slope	Average	3.11^{cd}	3.25^{d}	2.43^{bcd}	2.87^{cd}	1.82^{ab}	2.32^{abc}	1.80^{ab}	1.45^{a}
	SD	1.45	1.94	1.28	1.29	1.05	0.93	0.86	0.60
	CV	46.55	59.76	52.80	45.10	57.59	40.27	47.57	41.28
2. Length index	Average	0.96^{a}	0.96^{a}	1.00^{b}	0.99^{b}	0.03	0.99^{b}	0.99^{b}	0.98^{ab}
	SD	0.06	0.04	0.01	1.02^{c}	2.67	0.03	0.01	0.01
	CV	6.25	4.11	1.47	0.04	2.35^{bcd}	3.01	0.91	0.89
3. Width slope	Average	1.33^{a}	1.55^{a}	1.95^{abc}	3.78	0.85	1.93^{abc}	2.55^{cd}	2.85^{d}
	SD	0.71	0.91	0.94	1.75^{ab}	36.28	0.91	0.93	1.16
	CV	53.34	58.91	48.25	1.23	0.56^{a}	46.92	36.33	40.56
4. Depth index	Average	0.56^{a}	0.56^{a}	0.54^{a}	0.56^{a}	0.56^{a}	0.55^{a}	0.57^{a}	0.56^{a}
	SD	0.06	0.08	0.02	0.03	0.03	0.03	0.01	0.02
	CV	10.82	13.73	3.29	5.68	5.50	5.04	2.01	2.86
5. Foreleg length	Average	53.83^{ab}	54.33^{a}	60.30^{c}	57.87^{abc}	59.53^{c}	58.90^{bc}	58.15^{abc}	60.85^{c}
	SD	8.66	10.16	1.39	4.97	4.97	4.33	0.82	2.75
	CV	15.80	18.69	2.30	8.35	8.35	7.35	1.41	4.52
6. Balance	Average	0.43^{a}	0.44^{ab}	0.49^{bc}	0.46^{abc}	0.49^{bc}	0.50^{c}	0.48^{abc}	0.49^{bc}
	SD	0.08	0.08	0.10	0.08	0.03	0.06	0.03	0.05
	CV	17.52	19.14	20.16	18.45	5.45	11.58	5.85	9.46
7. Cumulative Index	Average	2.39^{a}	2.40^{a}	2.48^{b}	2.48^{b}	2.48^{b}	2.50^{b}	2.47^{b}	2.47^{b}
	SD	0.09	0.10	0.10	0.11	0.06	0.10	0.05	0.04
	CV	3.90	4.18	3.90	4.18	2.45	4.01	1.86	1.65

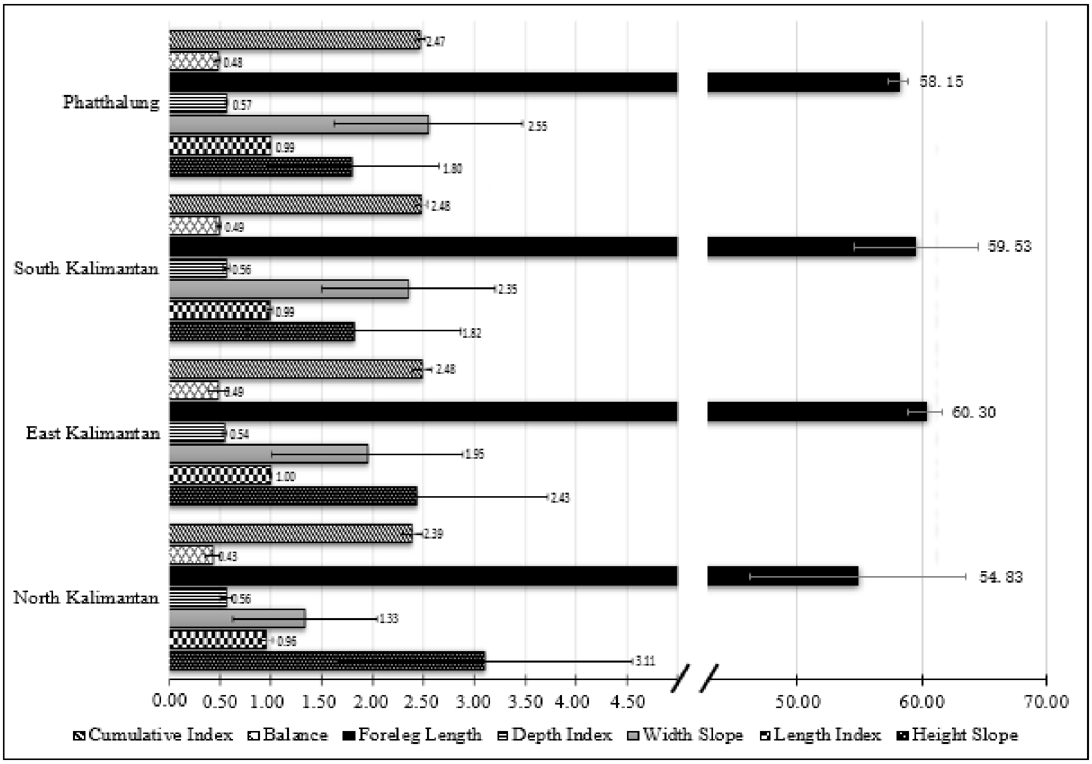
The average number accompanied by different superscripts has a significant difference at the level of 5%.

Table 3. Qualitative morphological characters of male and female buffalo based on subpopulation regions.

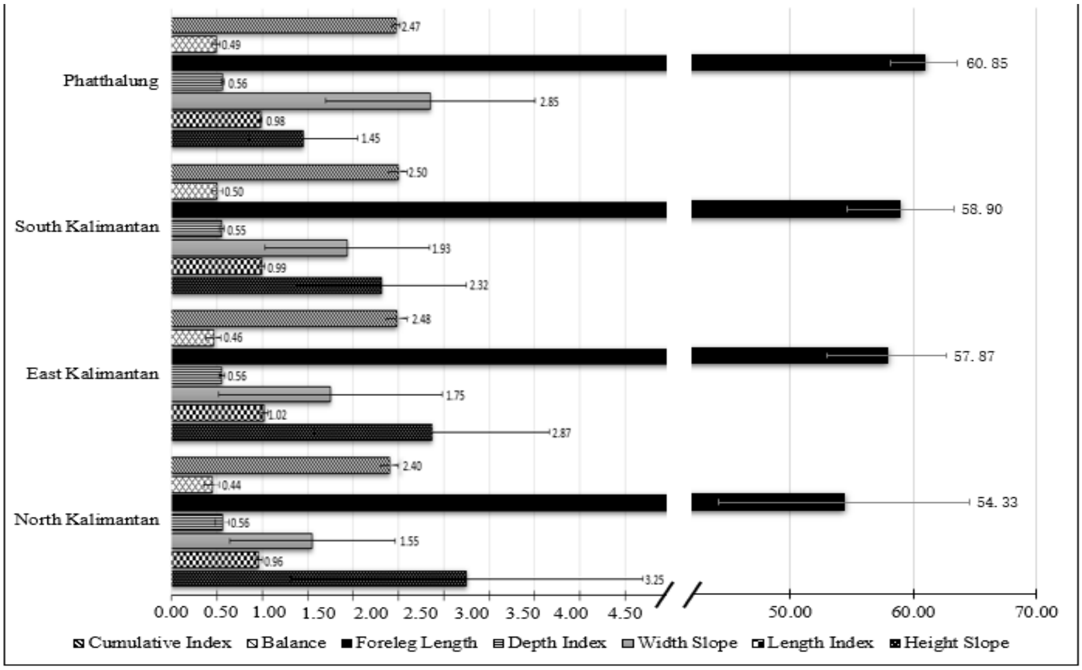
No.	Qualitative Characters	Region							
		NK		EK		SK		PT	
		Percentage (%)		Percentage (%)		Percentage (%)		Percentage (%)	
		Male	Female	Male	Female	Male	Female	Male	Female
1.	**Body appearance**								
a.	Big	20.00	33.33	40.00	50.00	50.00	53.33	60.00	80.00
b.	Medium	50.00	50.00	33.33	36.67	36.67	30.00	30.00	10.00
c.	Small	30.00	16.67	26.67	13.33	13.33	16.67	10.00	10.00
2.	**Skin color**								
a.	Black	53.33	46.67	16.67	23.33	20.00	26.67	50.00	60.00
b.	Grayish black	30.00	26.67	60.00	53.33	50.00	53.33	30.00	30.00
c.	Gray	16.67	26.67	23.33	20.00	26.67	20.00	10.00	10.00
d.	Albino	0	0	0	3.33	3.33	0	10.00	0
3.	**Coat color**								
a.	Black	46.67	43.33	66.67	70.00	56.67	63.33	50.00	60.00
b.	Grayish black	30.00	26.67	33.33	26.67	40.00	36.67	10.00	10.00
c.	Blonde	23.33	30.00	3.33	0	0	0	30.00	30.00
d.	White	0	0	0	3.33	3.33	0	10.00	0
4.	**Horns pattern**								
a.	Tarangga	66.67	63.33	60.00	63.33	60.00	70.00	70.00	80.00
b.	Pampang	0	0	0	0	0	0	10.00	0
c.	Sikki	30.00	36.67	40.00	33.33	33.33	26.67	20.00	20.00
d.	Sokko	0	0	0	0	3.33	0	0	0
e.	Langi	3.33	0	0	3.33	3.33	3.33	0	0
5.	**Back-line**								
a.	Flat	63.33	70.00	76.67	80.00	86.67	83.33	80.00	90.00
b.	Concave	36.67	30.00	23.33	20.00	13.33	16.67	20.00	10.00

Table 3. Qualitative morphological characters of male and female buffalo based on subpopulation regions. (Continue)

No.	Qualitative Characters	Region							
		NK		EK		SK		PT	
		Percentage (%)		Percentage (%)		Percentage (%)		Percentage (%)	
		Male	Female	Male	Female	Male	Female	Male	Female
6.	**Chevron**								
a.	Single strip	46.67	50.00	16.67	30.00	33.33	23.33	30.00	90.00
b.	Double strip	53.33	50.00	83.33	70.00	66.67	76.67	70.00	10.00
7.	**Hair whorls on the**								
a.	One	76.67	83.33	60.00	66.67	70.00	76.67	70.00	80.00
b.	Two	16.67	10.00	26.67	23.33	20.00	16.67	20.00	10.00
c.	Not observable	6.67	6.67	13.33	10.00	10.00	6.67	10.00	10.00
8.	**Hair whorls on the back**								
a.	One	10.00	6.67	23.33	20.00	16.67	13.33	30.00	40.00
b.	Two	83.33	76.67	60.00	66.67	73.33	76.67	60.00	50.00
c.	Not observable	6.67	16.67	16.67	13.33	10.00	10.00	10.00	10.00
9.	**Hair whorls on the rump**								
a.	One	16.67	12.50	16.67	10.00	23.33	16.67	40.00	20.00
b.	Two	63.33	87.50	70.00	83.33	70.00	76.67	50.00	70.00
c.	Not observable	20.00	0	13.33	6.67	6.67	6.67	10.00	10.00
10.	**Foot color**								
a.	Dark gray	63.33	50.00	33.33	16.67	13.33	6.67	60.00	60.00
b.	Light gray	26.67	33.33	53.33	60.00	66.67	76.67	30.00	20.00
c	White	10.00	16.67	13.33	23.33	20.00	16.67	10.00	20.00



a



b

Figure 1. Morphometric index of male (a) and female (b) buffaloes based on based on subpopulation regions.

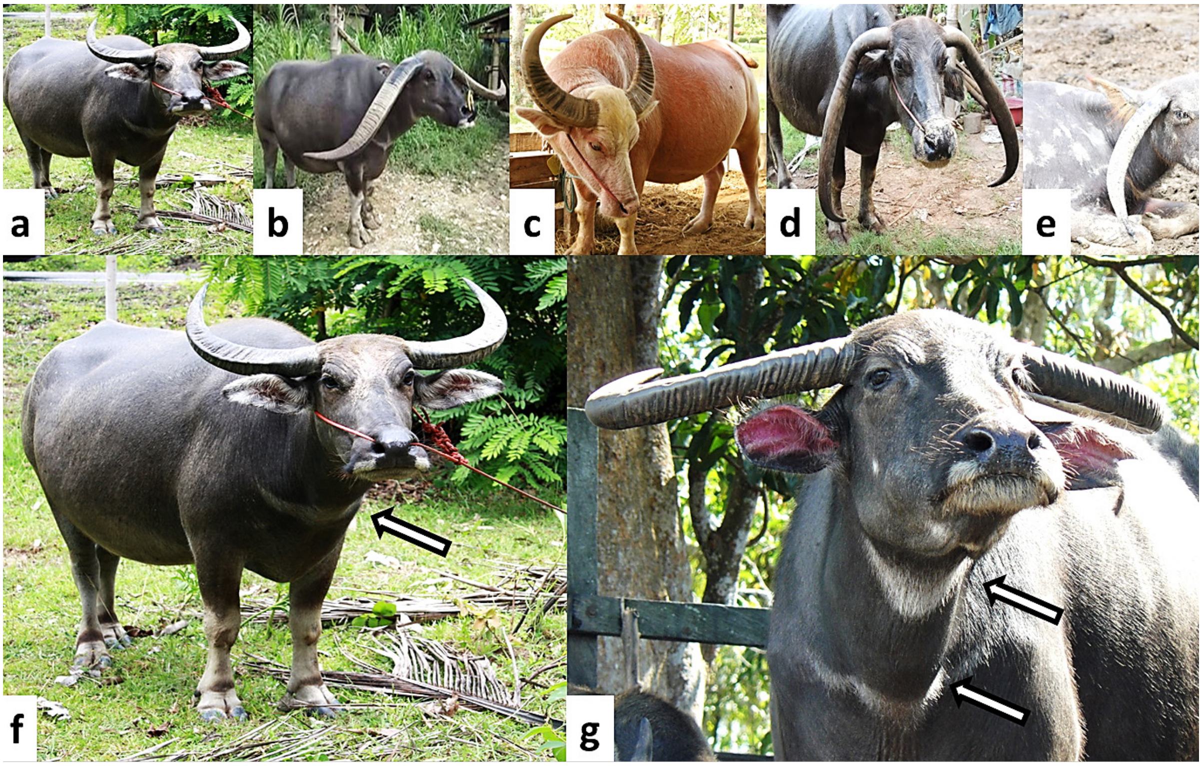


Figure 2. Horn patterns and the appearance of chevron in KBuf. Horn patterns (a to e).

a. Tarangga: horns grow upwards to form a half circle;

b. Pampang: horns that grow sideways and tend to be very long, this pattern is usually observed from a castrated male buffalo;c. Sikki: horn growth is similar to tarangga with points almost meeting;

d. Sokko: horns grow downward with points under the neck;

e. Langi: horns grow in opposite directions. Chevron presence (f and g in);

f. Single stripe (white arrow);

g. Double stripes (white arrows).

Source: (Modified from Stepanus, 2008).

among Kalang buffaloes in Kalimantan, Indonesia and Thale Noi buffaloes from Phatthalung, Thailand based on qualitative, quantitative, and morphometric characteristics index analysis. Area distribution is a significant factor that influences phenotypic characteristics and overall quality. Also, phenotypic variations are influenced by ancestry, direct and indirect influences of environmental conditions and climate, human resources, feeding or nutrition, migration, diseases, breeding, and reproductive management, and husbandry system.

The phenotypic diversity among Kalang and Thale Noi buffaloes was found to be rich as inferred from variations in qualitative and quantitative parameters as well as morphometric indices. The phenotypic variations observed aside from being attributed to genetic variations among breeds were also influenced by a variety of natural and controlled factors. Natural factors include but are not limited to environmental and climatic conditions and habitat profile, availability and type of nutrition, and the presence or absence of diseases. Controlled factors include but are not limited to farmer management systems like breeding and reproductive management, husbandry system, and supplemental nutrition.

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