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The Effect of Environmental Factors on the Morphological Variation of the Common Pheasant, *Phasianus colchicus* in China

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LW and FL conceived and designed the study. FL and LW performed the experiments. JA, CD and AD provided the help in experimental work. FL wrote the paper.

Key words
***Phasianus colchicus*, Ring-necked or Common pheasant, Altitude, Morphological variation, Environmental factor**

ABSTRACT

This study aims to assess morphological variation of the ring-necked or common pheasant *Phasianus colchicus* across mainland China in response to environmental factors. We collected 399 pheasant and divided them into two groups: high altitude (>1500m) and low altitude (<1500m). The results that all morphological size measures of males were significantly higher than those of females ($P<0.05$). Most measures of size at low altitude significantly greater than those at high altitudes, including body weight, body length, and wing length for males ($P<0.05$), and body weight and wing length for females. The results showed that males and females are different in response to environmental factors. The body weight, wing length, tarsus, skull length and interorbital distance in females were significantly correlated with atmospheric pressure ($P<0.05$), along with body weight, body length, rictus, wing length, tarsus and skull length in males ($P<0.05$). A significant positive correlation was observed between wing length of males and wind speed ($P=0.017$). Conversely, body weight, body length, wing length and tail length in males were significantly negatively correlated with air temperature ($P<0.05$). Many measures of body size (wing length and tail length for males; tail length for females) increased with latitude after controlling for altitude, indicating that the body size of this species, especially in males, is significantly larger at high latitudes. It is the common pheasant's adaptability to considerable environmental change that has facilitated the vast distribution of this species.

INTRODUCTION

Geographic variation in morphology is a common occurrence in species of birds, and widespread patterns are often explained within an adaptive framework (Healy and Price, 2008). Intraspecific geographic variation in body size is assumed to reflect adaptation to local environmental conditions, such as altitude, latitude and ambient temperature (Millien *et al*., 2006; Yom-Tov and Geffen, 2011; Sun *et al*., 2017). Altitudinal variation in body size has been well-documented (Blackburn *et al*., 2001; Bulgarella *et al*., 2007; Sun *et al*., 2017). For instance, animals inhabiting higher altitudes generally have higher energy demands for cold surroundings (Storz, 2007; Storz *et al*., 2010). The body size is significantly negative correlated with altitude (P<0.01) in tree sparrow (Lan *et al*., 2018). Although latitudinal and altitudinal gradients show similar trends in temperature decline (Ashton and Feldman, 2003), some climate factors, such as solar radiation and lower temperatures, are often accompanied by decreased atmospheric pressure and constant, strong wind. Thus, these climatic components are more strongly associated with variation in altitude than latitude (Liao *et al*., 2006, 2010; Körner, 2007). Similarly, limited oxygen availability may decrease digestive efficiency, thus eliciting a negative effect on body size; the mechanism of which has been demonstrated in geographic size variation in some lizards and mammals (Liao *et al*., 2006; Jin *et al*., 2007). Previous studies have demonstrated a positive relationship between body size and latitude in some species of birds and mammals (Ashton, 2002; Meiri and Dayan, 2003; Gardner *et al*., 2009; Olson *et al*., 2009). Associated morphological adaptations in birds and mammals are known to include variations related to body

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size (Blackburn *et al*., 1999; Blackburn and Ruggiero, 2001).

The common pheasant (*Phasianus colchicus*) belongs to the genus *Phasianus* of the family Phasianidae, under the order Galliformes. A significant degree of sexual dimorphism exists in this species, which ranges across most of China (Zheng, 2011). Therefore, it is an ideal species to understand morphological variation in different geographical locations. The study of this species has largely been focused on phylogeography (Qu *et al*., 2009; Liu *et al*., 2010; Zhang *et al*., 2014), distribution of subspecies (Braasch *et al*., 2011), physiology and biochemistry (dos Santos Schmidt *et al*., 2007; Kececi *et al*., 2011), heavy metal accumulation in tissues (Dzugan *et al*., 2012), as well as breeding ecology (Musil *et al*., 2009; Kayvanfar *et al*., 2014). However, the morphological variation of this species in response and adaptation to environmental factors is unknown. In this study, we collected 399 samples both from male and female common pheasants, across differing altitudinal and samples sites distributions in mainland China. Our objectives are to determine: 1) the difference in response to environmental effects between male and female conspecifics; 2) whether there is significant difference in morphology along the altitudinal gradient; and 3) the environmental factors which significantly affect the morphological size, by analyzing the relationship between size and environmental factors.

MATERIALS AND METHODS

A total of 399 individuals were obtained from: the Institute of Zoology, Chinese Academy of Sciences (CAS); the Kunming Institute of Zoology, CAS; the South China Institute for Endangered Animals; or collected from the wild. We used a Vernier caliper (0.1mm) to measure the morphological size of males and females, including: body length, tail length, culmen, rictus, wing length, tarsus, skull length, skull width, interorbital distance and so forth. Body mass was measured by an electric balance (0.1g). The sample sites were situated from 76.17°E - 129.17°E and 18.53°N - 52.97°N, while the region's altitude spanned from 2m - 4472m (Tables I, II). Two populations were devised from the sample sites according to altitude: a high altitude population (>1500m) and a low altitude population (<1500m). The high altitude population consisted of 130 males and 65 females, while 136 males and 68 females comprised the low altitude population. We analyzed the correlation between environmental factors and morphological size of both males and females using the principal component analysis method, respectively. Twenty one environmental factors included: longitude, latitude, altitude, extreme minimum atmospheric pressure, extreme maximum atmospheric pressure, average atmospheric pressure, extreme minimum wind speed, average wind speed, extreme maximum wind speed, extreme maximum air temperature, extreme minimum air temperature, average air temperature, average maximum temperature, average minimum temperature, precipitation, average vapour pressure, average relative humidity, daily precipitation, maximum daily precipitation, sunshine duration, and percentage of sunshine. All the meteorological data was obtained from national meteorological data center of China. We used the independent sample T-test method, and analysis of the morphological differences between males and females, and high altitude and low altitude populations for male and female, respectively. All data were analyzed in SPSS 20.0 software.

RESULTS

Sexual size dimorphism

The results of the independent sample T-test illustrated that all the morphological size measures of males were significantly greater than those of females ($P<0.05$) (Table III).

Relationship with environmental factors

From principal component analysis, four principal components were obtained: PC1 (-0.966) (atmospheric pressure factor), PC2 (0.927) (precipitation factor), PC3 (0.916) (air temperature factor), and PC4 (0.887) (wind speed factor). The four principal components can explain 92% of the total variance in 21 environmental factors analyzed. Based on analysis of environmental factors and morphological characteristics, the results indicated that body weight, wing length, tarsus, skull length and interorbital distance had significant positive correlations with the atmospheric pressure factor in females ($P<0.05$). There was no significant correlation observed between any measure of morphological size and the wind speed factor neither in females, nor for female morphological size and the precipitation factor ($P>0.05$) (Table IV). Following the analysis of environmental components and morphological traits in males, the results illustrated that body weight, body length, rictus, wing length, tarsus and skull length had a significant positive correlation with the atmospheric pressure factor ($P<0.05$). Conversely, body weight, body length, wing length and tail length had significant negative correlations with the air temperature factor ($P<0.05$). Additionally, a significant positive correlation between wing length and the wind speed factor was revealed, while no significant correlation was observed between any morphological size measure and the precipitation factor for males ($P>0.05$) (Table IV).

Table I. Sampling sites of males of *Phasianus colchicus*.

Sites	Gender	Date	Sampling size	Longitude	Latitude	Altitude (m)
Wuhu, Anhui	♂	1908	1	118.43	31.35	11
Yuexi, Anhui	♂	2013	8	116.36	30.85	694
Beijing	♂	1932/1966/1980/1954/1965	8	116.41	39.90	48
Dangchang, Gansu	♂	2013	2	104.39	34.05	2350
Minqin, Gansu	♂	2013	6	102.99	38.58	1384
Minxian, Gansu	♂	2013	9	104.04	34.44	2428
Pingliang, Gansu	♂	2013	9	106.65	35.22	1580
Wuwei, Gansu	♂	2013	6	102.64	37.93	1537
Zhangxian, Gansu	♂	2013	5	104.47	34.85	2034
Lianyang, Guangdong	♂	1959	3	111.18	23.72	372
Shaoguan,Guangdong	♂	2013	2	113.04	24.69	722
Anshun, Guizhong	♂	-	1	105.89	25.99	1398
Tongren, Guizhong	♂	-	2	109.05	25.83	425
Chengde, Hebei	♂	1927/1932/1960	9	117.91	40.95	338
Dongling, Hebei	♂	1929/1930/1935	14	117.66	40.18	108
Harbin, Heilongjiang	♂	1922/1952/1960	4	129.21	48.24	370
Jishou, Hunan	♂	-	2	109.70	28.26	378
Yizhang, Hunan	♂	1955/1956	5	113.02	28.21	38
Xianghai, Jilin	♂	2013	2	122.35	45.03	162
Nanjing, Jiangsu	♂	1960/1929	3	120.44	32.07	4
Nanchang, Jiangxi	♂	1960	1	115.86	28.68	21
Aohan Banner, Inner Mongolia	♂	2013	8	120.39	42.13	601
Haggin Banner, Inner Mongolia	♂	2013	5	108.74	39.83	1394
Wuhai, Inner Mongolia	♂	1960	9	106.80	39.66	1093
Jingyuan, Ningxia	♂	2013	3	106.33	35.50	1935
Longde, Ningxia	♂	2013	15	106.11	35.63	2106
Guide, Qinghai	♂	2013	6	101.43	36.04	2301
Huzhu, Qinghai	♂	2013	7	101.96	36.84	2762
Menyuan, Qinghai	♂	1960	6	101.62	37.36	3435
Minhe, Qinghai	♂	1959	1	102.78	36.12	2277
Woodhong, Qinghai	♂	1959/2013	4	96.44	36.38	2857
Tongren, Qinghai	♂	1960/2013	9	102.02	35.52	2549
Golmud, Qinghai	♂	2013	6	93.16	36.91	2875
Xining, Qinghai	♂	1959	8	101.78	36.62	2270
Zeku, Qinghai	♂	1960	2	101.79	35.20	3473
Zequ, Qinghai	♂	2013	1	101.47	35.04	3662
Qixia, Shandong	♂	1964	8	121.07	37.19	216
Lishi, Shanxi	♂	1964/2013	2	111.15	37.52	942
Qinshui, Shanxi	♂	1960/1962	4	112.19	35.69	856
Taiyuan, Shanxi	♂	2013	1	112.33	37.47	778
Yicheng, Shanxi	♂	1962/2013	5	111.72	35.74	623
Foping, Shaanxi	♂	1957/2013	2	107.99	33.52	1008
Ningshan, Shaanxi	♂	2013	1	108.30	33.65	1611
Xi'an, Shaanxi	♂	1957	5	108.94	34.34	383
Yangxian, Shaanxi	♂	1957	2	107.55	33.22	482
Shanghai	♂	1957	2	121.55	31.22	7
Hongyuan, Sichuan	♂	1961	1	102.46	32.51	3612
Huidong, Sichuan	♂	1960	2	102.58	26.63	2135
Meigu, Sichuan	♂	1960	1	103.13	28.60	2255
Muli, Sichuan	♂	-	1	101.28	27.93	3461
Pingwu, Sichuan	♂	1969	2	104.53	32.41	1209
Ruoergai, Sichuan	♂	-	1	102.96	33.58	3490
Mangkang, Tibet	♂	1976	2	98.59	29.68	4283
Aksu, Xinjiang	♂	1958	1	80.26	41.17	1108
Yuli, Xinjiang	♂	-	1	86.25	41.36	931
Baoshan, Yunnan	♂	-	2	98.49	25.02	1810
Dali, Yunnan	♂	-	1	100.58	25.83	1651
Honghe, Yunnan	♂	-	3	103.36	23.40	1310
Kunming, Yunnan	♂	1962	5	102.61	25.06	2166
Lijiang, Yunnan	♂	1960	5	100.23	26.86	2405
Luxi, Yunnan	♂	1965	2	98.59	24.45	907
Simao, Yunnan	♂	-	1	100.83	24.45	1337
Yuxi, Yunnan	♂	-	1	102.41	24.17	1642
Zhaotong, Yunnan	♂	-	5	103.72	27.34	1921
Zhongdian, Yunnan	♂	1981/1959	3	103.23	25.23	1799
Haiyan, Zhejiang	♂	1925	2	120.95	30.53	5

Table II. Sampling sites of females of *Phasianus colchicus*.

Sites	Gender	Date	Sampling size	Longitude	Latitude	Altitude (m)
Yuexi, Anhui	♀	2013	8	116.36	30.85	694
Beijing	♀	1965/ 1966	4	116.41	39.90	48
Dangchang, Gansu	♀	2013	4	104.39	34.05	2350
Minqin, Gansu	♀	2013	5	102.99	38.58	1384
Minxian, Gansu	♀	2013	4	104.04	34.44	2428
Pingliang, Gansu	♀	2013	3	106.65	35.22	1580
Wuwei, Gansu	♀	2013	4	102.64	37.93	1537
Zhangxian, Gansu	♀	2013	5	104.47	34.85	2034
Lianyang, Guangdong	♀	1959	2	111.18	23.72	372
Shaoguan,Guangdong	♀	2013	4	113.04	24.69	722
Anshun, Guizhong	♀	-	1	105.89	25.99	1398
Qianxi, Guizhou	♀	-	1	104.90	25.09	1353
Chengde, Hebei	♀	1960/ 1974	2	117.91	40.95	338
Dongling, Hebei	♀	1935	4	117.66	40.18	108
Harbin, Heilongjiang	♀	1960	2	129.21	48.24	370
Yichang, Hunan	♀	1959	1	113.02	28.21	38
Xianghai, Jilin	♀	2013	3	122.35	45.03	162
Nanchang, Jiangxi	♀	1960	1	115.86	28.68	21
Aohan Banner, Inner Mongolia	♀	2013	8	120.39	42.13	601
Haggin Banner, Inner Mongolia	♀	2013	5	108.74	39.83	1394
Wuhai, Inner Mongolia	♀	1963/ 1964	3	106.80	39.66	1093
Longde, Ningxia	♀	2013	14	106.11	35.63	2106
Guide, Qinghai	♀	2013	6	101.43	36.04	2301
Guinan, Qinghai	♀	1959	2	100.75	35.58	3412
Menyuan, Qinghai	♀	1959	1	101.62	37.36	3435
Tongren, Qinghai	♀	1960	3	102.02	35.52	2549
Xining,Qinghai	♀	1959	4	101.78	36.62	2270
Qixia, Shandong	♀	1964	1	121.07	37.19	216
Qinshui, Shanxi	♀	1962	1	112.19	35.69	856
Yicheng, Shanxi	♀	1962	2	111.72	35.74	623
Foping, Shaanxi	♀	1957	1	107.99	33.52	1008
Xi'an, Shaanxi	♀	1957	2	108.94	34.34	383
Yangxian, Shanxi	♀	1957	1	107.55	33.22	482
Batang, Sichuan	♀	1960	1	99.11	30.00	4687
Hongyuan, Sichuan	♀	1961	2	102.46	32.51	3612
Muli, Sichuan	♀	1959	2	101.28	27.93	3461
Pingwu, Sichuan	♀	1969	1	104.53	32.41	1209
Wanyuan, Sichuan	♀	1958	1	108.03	32.08	1033
Mangkang, Tibet	♀	1976	1	98.59	29.68	4283
Aksu, Xinjiang	♀	1958	1	80.26	41.17	1108
Kunming, Yunnan	♀	1962	3	102.61	25.06	2166
Lijiang, Yunnan	♀	1960	2	100.23	26.86	2405
Yuxi, Yunnan	♀	-	2	102.41	24.17	1642
Zhaotong, Yunnan	♀	-	1	103.72	27.34	1921
Zhongdian, Yunnan	♀	-	1	103.23	25.23	1799
Haiyan, Zhejiang	♀	1925	3	120.95	30.53	5

Table III. Sexual size dimorphism in common pheasant, *Phasianus colchicus.*

	Male	Female	t	df	P
Bodyweight	1050.42± 33.12	804.47± 33.54	5.146	87	<0.001
Body length	76.75±1.14	53.72±0.99	15.250	107	<0.001
Culmen	3.29±0.04	2.84±0.05	7.145	108	<0.001
Rictus	3.29±0.02	2.91±0.02	10.969	102	<0.001
Wing length	23.84±0.50	20.67±0.19	5.069	108	<0.001
Tail length	44.02±1.04	25.76±0.64	14.939	93.856	<0.001
Tarsus	6.34±0.12	5.72±0.08	3.904	109	<0.001
Claw	1.24±0.02	1.07±0.02	5.749	81	<0.001
Skull length	4.06±0.04	3.64±0.05	6.364	81	<0.001
Skull width	2.78±0.04	2.59±0.04	3.578	81	<0.001
Interorbital distance	2.37±0.04	2.00±0.04	5.912	81	<0.001
Wing-spans	71.71±1.13	64.45±1.02	4.763	20	<0.001
Toe length	4.92±0.15	4.35±0.13	2.802	20	0.011

Note: Bold font represents a statistically significant size difference between male and female pheasants at the significance level of 0.001

Furthermore, we analyzed the relationship between morphological size and latitude after controlling for altitude, as well as the relationship between morphological size and altitude after controlling for latitude. The results showed that female tail length had a significant positive correlation with latitude when controlling for altitude (P<0.05), while female body weight and skull length had significant negative correlation with altitude when controlling

Table IV. The correlation of principal environmental factors with morphology of *Phasianus colchicus* of male and female.

	Statistical parameters		Body weight	Body length	Culmen	Rictus	Wing length	Tail length	Tarsus	Skull length	Skull width	Interorbital distance
Female	PC1	r	0.515	0.222	-0.156	0.067	0.324	0.135	0.367	0.451	-0.047	0.341
		df	37	46	46	46	46	45	46	34	34	34
		P	0.001	0.138	0.301	0.656	0.028	0.377	0.012	0.007	0.792	0.048
	PC2	r	-0.026	-0.160	0.231	-0.127	-0.034	-0.228	0.174	0.014	-0.274	0.128
		df	37	46	46	46	46	45	46	34	34	34
		P	0.878	0.289	0.122	0.400	0.824	0.132	0.247	0.939	0.116	0.472
	PC3	r	0.299	-0.167	0.024	-0.107	-0.184	-0.479	0.042	-0.161	0.089	-0.314
		df	37	46	46	46	46	45	46	34	34	34
		P	0.072	0.269	0.877	0.479	0.221	<0.001	0.781	0.362	0.616	0.070
	PC4	r	0.202	0.109	0.079	-0.027	0.081	-0.066	0.152	-0.216	0.082	-0.023
		df	37	46	46	46	46	45	46	34	34	34
		P	0.231	0.471	0.6002	0.859	0.591	0.669	0.312	0.219	0.643	0.895
Male	PC1	r	0.395	0.260	0.033	0.259	0.293	0.215	0.598	0.407	0.129	0.136
		df	49	64	65	59	64	60	65	49	49	49
		P	0.005	0.038	0.797	0.048	0.019	0.098	<0.001	0.004	0.376	0.350
	PC2	r	0.123	-0.001	0.141	-0.197	-0.129	-0.046	0.008	0.253	0.164	-0.038
		df	49	64	65	59	64	60	65	49	49	49
		P	0.399	0.991	0.262	0.134	0.309	0.729	0.949	0.080	0.260	0.798
	PC3	r	-0.437	-0.407	0.196	-0.252	-0.256	-0.500	-0.177	-0.039	-0.110	-0.163
		df	49	64	65	59	64	60	65	49	49	49
		P	0.002	<0.001	0.117	0.055	0.041	<0.001	0.159	0.791	0.454	0.263
	PC4	r	0.098	-0.047	0.042	-0.073	0.297	-0.100	0.027	-0.059	-0.134	0.029
		df	49	64	65	59	64	60	65	49	49	49
		P	0.503	0.71	0.7409	0.582	0.017	0.449	0.833	0.686	0.359	0.845

Note: PC1: atmospheric pressure factor; PC2: precipitation factor; PC3: air temperature factor; PC4: wind speed factor. Bold font represents a statistically significant correlation between the environmental factor and the size of the trait measured, at the significance level of 0.05.

for latitude (P<0.05) (Table V). Our analysis also showed that male body weight, rictus, wing length and tail length had significant positive correlations with latitude when controlling for altitude (P<0.05). Conversely, male tarsus and skull length had significant negative correlations with altitude when controlling for latitude (P<0.05) (Table V).

Variation of morphology with altitude

The results indicated that most measures of morphological size at low altitude sites were significantly greater than those at high altitude sites, including body weight, body length, culmen, rictus, wing length, tarsus, and skull length for males (P<0.05), as well as body weight, wing length, tarsus, and skull length for females (Fig. 1, Table VI).

DISCUSSION

Sexual selection is one of the evolutionary motive forces, and the selection pressures affecting mating opportunities and mating competitiveness have led to sexual dimorphism in animals (Williams, 1992; Andersson, 1994). Our study indicates that body size is greater in males than females. It is common that pheasant family exhibits significant sexual dimorphism. It also performs a feature that male body size is greater than female. The morphology size is the weapons or reliable signals of male quality directed both to females and rivals in pheasants (Mateos, 1998). The superior body condition of males ensures better offspring viability in birds, such as barn swallow *Hirundo rustica* (Møller, 1994; Petrie, 1994; Sheldon *et al*., 1997). Therefore, we believe that this characteristic is

Table V. The partial correlation analysis of altitude and latitude with morphology of *Phasianus colchicus* of male and female.

Control variable	Variable		Body weight	Body length	Culmen	Rictus	Wing length	Tail length	Tarsus	Skull length	Skull width	Interorbi-taldistance
Altitude (F)		r	-0.04	0.3	-0.291	-0.157	0.212	0.638	-0.05	0.219	0.082	0.193
	Latitude	df	23	23	23	23	23	23	23	23	23	23
		P	0.85	0.145	0.159	0.455	0.308	0.001	0.811	0.293	0.696	0.356
Latitude (F)		r	-0.546	0.111	-0.028	-0.256	-0.142	0.248	-0.295	-0.435	-0.076	-0.241
	Altitude	df	23	23	23	23	23	23	23	23	23	23
		P	0.005	0.599	0.893	0.216	0.497	0.232	0.153	0.03	0.718	0.246
Altitude (M)		r	0.339	0.212	-0.089	0.528	0.44	0.336	0.286	-0.109	-0.123	0.189
	Latitude	df	37	37	37	37	37	37	37	37	37	37
		P	0.035	0.196	0.59	0.001	0.005	0.037	0.078	0.51	0.457	0.248
Latitude (M)		r	-0.216	-0.177	-0.274	-0.274	-0.27	0.012	-0.649	-0.481	-0.195	-0.136
	Altitude	df	37	37	37	37	37	37	37	37	37	37
		P	0.187	0.282	0.091	0.092	0.096	0.943	<0.001	0.002	0.234	0.41

Note: Bold font indicates a significant correlation between altitude or latitude and the morphological measure in question, at the significance level of 0.05. F: female, M: male.

Table VI. Morphological variations between high and low altitude regions for male and female pheasants of *Phasianus colchicus*.

		Body weight/g	Body length/cm	Culmen/ cm	Rictus/ cm	Wing length/cm	Tail length/cm	Tarsus/ cm	Skull length/cm	Skull width/cm	Interorbitald-istance/cm
Female	Low Altitude	824.90± 26.29	54.82± 0.74	2.91± 0.06	2.89± 0.05	21.18± 0.20	26.17± 0.45	5.94± 0.13	3.73± 0.07	2.60± 0.04	2.05± 0.05
	High Altitude	692.79± 30.21	52.38± .00	2.77± 0.09	2.88± 0.04	20.05± 0.30	26.02± 1.09	5.55± 0.12	3.50± 0.06	2.57± 0.06	1.92± 0.07
	t	3.30	1.14	1.36	0.05	3.26	0.13	2.18	2.26	0.38	1.46
	df	35.00	24.19	44.00	44.00	44.00	24.12	44.00	32.00	32.00	32.00
	P	0.002	0.266	0.181	0.964	0.002	0.898	0.034	0.031	0.704	0.154
Male	Low Altitude	1094.63± 32.24	79.00± 1.54	3.39± 0.05	3.33± 0.04	23.71± 0.16	45.25± 1.28	6.66± 0.07	4.16± 0.05	2.81± 0.06	2.38± 0.05
	High Altitude	949.36± 36.62	74.36± 1.59	3.19± 0.05	3.23± 0.03	22.96± 0.17	42.42± 1.71	6.19± 0.11	3.93± 0.06	2.75± 0.05	2.35± 0.08
	t	2.99	2.09	2.88	2.09	3.18	1.36	3.65	2.71	0.72	0.27
	df	47.00	61.76	63.00	57.00	61.32	58.00	63.00	47.00	47.00	47.00
	P	0.004	0.041	0.005	0.041	0.002	0.180	0.001	0.009	0.477	0.788

Note: Bold font indicates a statistically significant difference in size at the significance level of 0.05.

an important result of its wide distribution in evolutionary adaptation.

The most measures of morphological size are significantly greater at low altitudes than at high altitudes both for male and female common pheasants. Some researchers have shown that in the *Galerida*, body size does not increase with altitude in *G. cristata* (Alban *et al*., 2008). Also, Lu *et al*. (2009) reported two sympatric *Montifringilla* snow finch species (*M. taczanowskii* and *M. ruficollis*) in a higher altitude region, and compared the data with those of their lower altitude conspecifics. Their results indicated that relative to their lower altitude conspecifics, the higher altitude snow finches had smaller body sizes. Similarly, in some mammal species, such as the Daurian pika (*Ochotona daurica*), skull size is negatively correlated with altitude (Liao *et al*., 2006). The body size of avian fauna is affected by the availability of food and interspecific competition (Scholander, 1955; McNab, 1971).

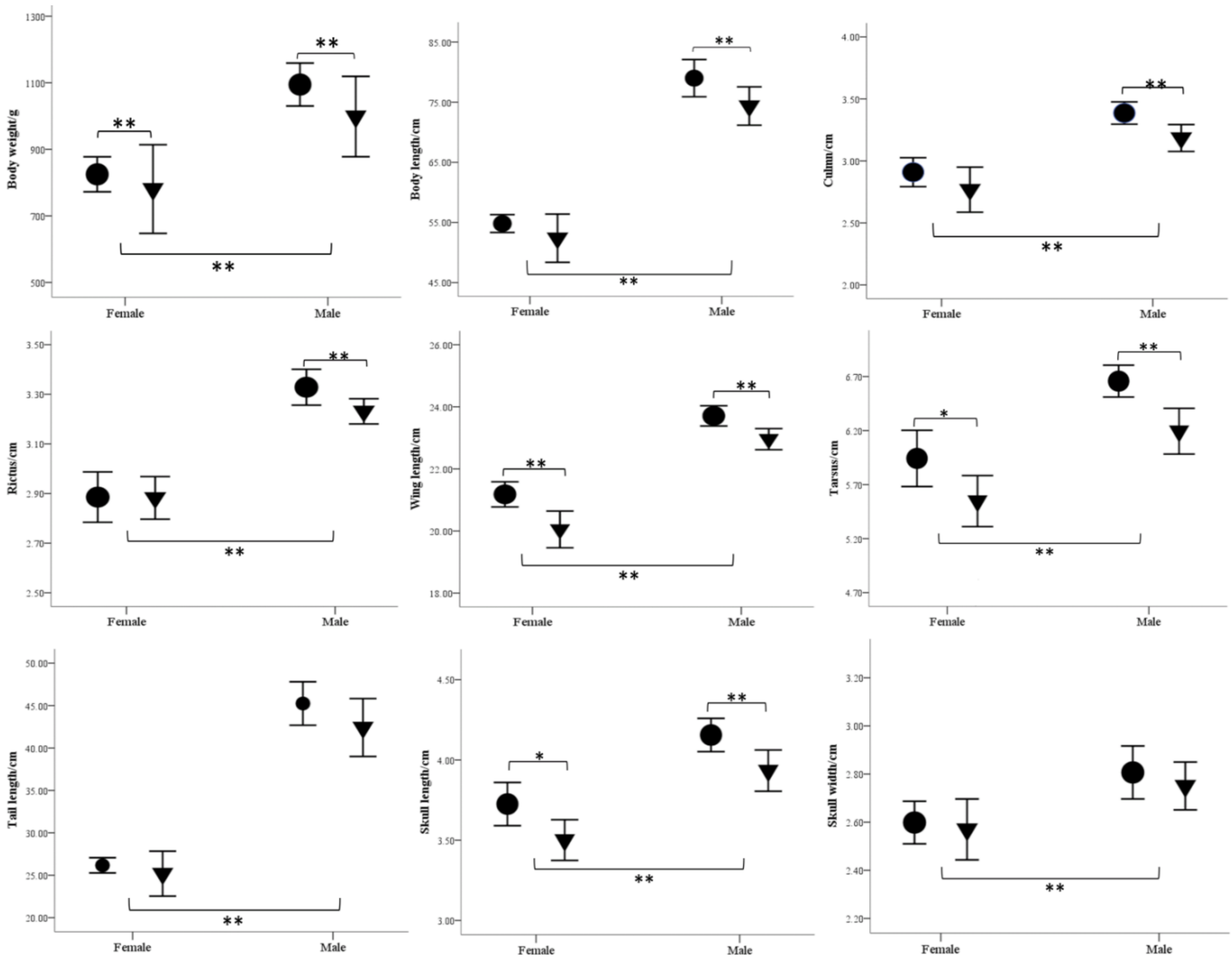

Fig. 1. Sexual size dimorphism and variation of morphology of *Phasianus colchicus* compared at differing altitudes.
Note: Black circles represent the lower altitude population (<1500m); while black triangles represent the higher altitude population (>1500m); Additionally, * represents statistical significance at a 0.05 significance level; while statistical significane at the level of 0.01 is represnted by **.

Individual size is significantly positive correlated with the degree of primary productivity in any environment (Rosenzweig, 1968). Although latitudinal and altitudinal gradients show similar temperature decline trends (Ashton and Feldman, 2003), some climate factors such as solar radiation and lower temperatures, which are often accompanied by decreased atmospheric pressure and constant strong wind are more strongly associated with variation in altitude than latitude (Liao *et al.*, 2006, 2010; Körner, 2007; Scholander, 1955; McNab, 1971). The body size patterns observed may be attributed to constraints on individual growth by climate severity, food scarcity and hypoxia at higher altitudes (Lu *et al.*, 2009). The body size of avian could be affected on food available and interspecies competition (Scholander, 1955). The primary productivity is positively correlated with body size in any environments (McNab, 1971; Rosenzweig, 1968). The body size, such as body weight, wing length and tarsus, could be significantly smaller at higher altitude areas due to lower level of primary productivity and few air ($P<0.01$) (Lan *et al.*, 2018). We argue that body size tends to decrease with altitude in common pheasant due to the harsh conditions brought forth by environmental factors at high altitudes.

The results indicated that the atmospheric pressure factor and the air temperature factor had significant effects on both male and female body size. Atmospheric pressure and temperature are often associated with a significant decrease with rising elevation; for every additional 100m above sea level, temperature drops by 0.6℃, while atmospheric pressure is reduced by 0.67 KPa. However, male body weight, body length, wing length and tail length had significant negative correlations with the air temperature factor (P<0.05). Usually, air temperature decreases with rising altitude and latitude. The overall pheasant body size (such as weight, wings length, etc.) is larger with increasing latitude. Essentially, the body size of the common pheasant is significantly larger at high latitudes in colder regions than at low latitudes of warmer regions (Table VI). Conversely, some measures of body size, such as skull length, decrease as the altitude rises. That is to say that the body size of the common pheasant is significantly smaller at high altitudes than at low altitudes (Table VI). Therefore, altitude is the primary factor of morphological variation in different areas, as compared to latitude. Furthermore, the wind speed factor had a significant effect on male wing length (P=0.017) (Table IV), thus indicating that the greater the wind speed in a given area, the longer the wing length of male common pheasants situated in said region. Longer wings have increased flight ability (Sun *et al*., 2016) and allow for easier acclimation to the environment, in order to survive. Therefore, geographic variation in body size is assumed to reflect adaptation to local environmental conditions for conspecifics (Mayr, 1956; Millien *et al*., 2006; Yom-Tov and Geffen, 2011). It is the common pheasant's adaptability in response to environmental changes that has facilitated the vast distribution of this species.

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Statement of conflict of interest

The authors declare that "there is no conflict of interests regarding the publication of this article".

REFERENCES

Alban, G., Jean, B.F., Eric, D., Bernard, G. and Pierre, A.C., 2008. Testing Bergmann's rule in the presence of potentially confounding factors: A case study with three species of Galerida larks in Morocco. *J. Biogeogr*., **35**: 579-591.

Andersson, M., 1994. *Sexual selection.* Princeton University Press. United States of America.

Ashton, K.G., 2002. Do amphibians follow Bergmann's rule? *Canadian J. Zool*., **80**: 708-716. https://doi.org/10.1139/z02-049

Ashton, K.G. and Feldman, C.R., 2003. Bergmann's rule in nonavian reptiles: turtles follow it, lizards and snakes reverse it. *Evolution*., **57**: 1151-1163. https://doi.org/10.1111/j.0014-3820.2003.tb00324.x

Blackburn, T.M., Gaston, K.J. and Loder, N., 1999. Geographic gradients in body size: a clarification of Bergmann's rule. *Div. Distrib*., **5**: 165-174. https://doi.org/10.1046/j.1472-4642.1999.00046.x

Blackburn, T.M. and Ruggiero, A., 2001. Latitude, elevation and body mass variation in Andean passerine birds. *Global Ecol. Biogeogr*., **10**: 245-259. https://doi.org/10.1046/j.1466-822X.2001.00237.x

Braasch, T., Pes, T., Michel, S. and Jacken, H., 2011. The subspecies of the common pheasant *Phasianus colchicus* in the wild and captivity. *World Pheasant Assoc*., **2**: 6-13.

Bulgarella, M., Wilson, R.E., Kopuchian, C., Valqui, T.H. and McCracken, K.G., 2007. Elevatio- nal variation in body size of crested ducks (*Lophonetta specularioides*) from the central high Andes, Mendoza, and Patagonia. *Ornitol. Neotrop*., **18**: 587-602.

dos Santos Schmidt, E.M., Paulillo, A.C., Santin, E., Dittrich, R.L. and de Oliveira, E.G., 2007. Hematological and serum chemistry values for the ring-necked pheasant (*Phasianus colchicus*): variation with sex and age. *Int. J. Poult. Sci*., **6**: 137-139. https://doi.org/10.3923/ijps.2007.459.461

Dzugan, M., Zielinska, S., Heclik, J., Pieniazek, M. and Szostek, M., 2012. Evaluation of heavy metals environmental contamination based on their concentrations in tissues of wild pheasant (*Phasianus colchicus* L.). *J. Microbiol. Biotechnol. Fd. Sci*., **2**: 238.

Gardner, J.L., Heinsohn, R. and Joseph, L., 2009. Shifting latitudinal clines in avian body size correlate with global warming in Australian passerines. *Proc. R. Soc. Lond. B: Biol. Sci*., rspb20091011. https://doi.org/10.1098/rspb.2009.1011

Healy, S. and Price, T., 2008. Speciation in Birds. *Genet. Res*., **90**: 293. https://doi.org/10.1017/S0016672308009403

Jin, Y., Liu, N. and Li, J., 2007. Elevational variation in body size of *Phrynocephalus vlangalii* in the North Qinghai-Xizang (Tibetan) Plateau. *Belgian J. Zool*., **137**: 197-202..

Kayvanfar, N. and Aliabadian, M., 2014. Distribution, density and biological breeding of white wing pheasant (*Phasianus colchicus principalis*, Sclater, 1885) in Northeast of Iran. *Res. Linguist*., **5**: 33-45.

Kececi, T. and ÇÖL, R., 2011. Haematological and biochemical values of the blood of pheasants (*Phasianus colchicus*) of different ages. *Turkish J. Vet. Anim. Sci*., **35**: 149-156.

Körner, C., 2007. The use of 'altitude' in ecological research. *Trends Ecol. Evolut*., **22**: 569-574. https://doi.org/10.1016/j.tree.2007.09.006

Lan, M., Fan, L., Liu, F., Wen, L., Jing, X., Zhu, C., Wang, L., Hu, M. and Zu, X. 2018. The adaptive evolution of the Tree Sparrow (*Passer montanus*) phenotype to environment factors. *Acta Ecol. Sin*., **38**: 1392-1400. https://doi.org/10.5846/stxb201612152585

Liao, J.C., Zhang, Z.B. and Liu, N.F., 2006. Altitudinal variation of skull size in Daurian pika (*Ochotona daurica Pallas*, 1868). *Acta Zool. Acad. Scient. Hung*., **52**: 319-329.

Liao, J., Wang, Y., Zhao, L. and Liu, N., 2010. Effects of environmental factors on organ mass of midday gerbil (*Meriones meridianus Pallas*, 1773). *Mammal. Biol. Z. Säuge-tierk*., **75**: 381-388. https://doi.org/10.1016/j.mambio.2009.11.003

Liu, Y., Zhan, X., Wang, N., Chang, J. and Zhang, Z., 2010. Effect of geological vicariance on mitochondrial DNA differentiation in Common Pheasant populations of the Loess Plateau and Eastern China. *Mol. Phylogen. Evolut*., **55**: 409-417. https://doi.org/10.1016/j.ympev.2009.12.026

Lu, X., Ke, D.H., Zeng, X.H. and Yu, T.L., 2009. Reproductive ecology of two sympatric Tibetan snow finch species at the edge of their altitudinal range: response to more stressful environments. *J. Arid Environ*., **73**: 1103-1108. https://doi.org/10.1016/j.jaridenv.2009.06.011

Mateos, C., 1998. Sexual selection in the ring-necked pheasant: a review. *Ethol. Ecol. Evolut*., **10**: 313-332. https://doi.org/10.1080/08927014.1998.9522846

Mayr, E., 1956. Geographical character gradients and climatic adaptation. *Evolution*, **10**: 105-108. https://doi.org/10.1111/j.1558-5646.1956.tb02836.x

McNab, B.K., 1971. On the ecological significance of Bergmann's rule. *Ecology*, **52**: 845-854. https://doi.org/10.2307/1936032

Meiri, S. and Dayan, T., 2003. On the validity of Bergmann's rule. *J. Biogeogr*., **30**: 331-351. https://doi.org/10.1046/j.1365-2699.2003.00837.x

Millien, V., Kathleen Lyons, S., Olson, L., Smith, F.A., Wilson, A.B. and Yom-Tov, Y., 2006. Ecotypic variation in the context of global climate change: revisiting the rules. *Ecol. Lett*., **9**: 853-869. https://doi.org/10.1111/j.1461-0248.2006.00928.x

Møller, A.P., 1994. Male ornament size as a reliable cue to enhanced offspring viability in the barn swallow. *Proceed. natl. Acad. Sci.,* **91**: 6929-6932.

Musil, D.D. and Connelly, J.W., 2009. Survival and reproduction of pen-reared vs. translocated wild pheasants *Phasianus colchicus*. *Wildl. Biol*., **15**: 80-88. https://doi.org/10.2981/07-049

Olson, V.A., Davies, R.G., Orme, C.D.L., Thomas, G.H., Meiri, S., Blackburn, T.M., Gaston, K.J., Owens, I. P.F. and Bennett, P.M., 2009. Global biogeography and ecology of body size in birds. *Ecol. Lett*., **12**: 249-259. https://doi.org/10.1111/j.1461-0248.2009.01281.x

Petrie, M., 1994. Improved growth and survival of offspring of peacocks with more elaborate trains. *Nature*, **371**: 598-599.

Qu, J., Liu, N., Bao, X. and Wang, X., 2009. Phylogeography of the ring-necked pheasant (*Phasianus colchicus*) in China. *Mol. Phylogen. Evolut*., **52**: 125-132. https://doi.org/10.1016/j.ympev.2009.03.015

Rosenzweig, M.L., 1968. Net primary productivity of terrestrial communities: prediction from climatological data. *Am. Natural*., **102**: 67-74. https://doi.org/10.1086/282523

Scholander, P.F., 1955. Evolution of climatic adaptation in homeotherms. *Evolution*, **9**: 15- 26. https://doi.org/10.1111/j.1558-5646.1955.tb01510.x

Sheldon, B.C., Merilö, J., Qvarnström, A., Gustafsson, L. and Ellegren, H., 1997. Paternal genetic contribution to offspring condition predicted by size of male secondary sexual character. *Proceed. R. Soc. London B: Biol. Sci.*, **264**: 297-302.

Storz, J.F., 2007. Hemoglobin function and physiological adaptation to hypoxia in high- altitude mammals. *J. Mammal*., **88**: 24-31. https://doi.org/10.1644/06-MAMM-S-199R1.1

Storz, J.F., Runck, A.M., Moriyama, H., Weber, R.E. and Fago, A., 2010. Genetic differences in hemoglobin function between highland and lowland deer mice. *J. exp. Biol*., **213**: 2565-2574. https://doi.org/10.1242/jeb.042598

Sun, Y.F., Ren, Z.P., Wu, Y.F., Lei, F.M., Dudley, R. and Li, D.M., 2016. Flying high: limits to flight performance by sparrows on the Qinghai-Tibet Plateau. *J. exp. Biol*., **219**: 3642-3648. https://doi.org/10.1242/jeb.142216

Sun, Y., Li, M., Song, G., Lei, F., Li, D. and Wu, Y., 2017.

The role of climate factors in geographic variation in body mass and wing length in a passerine bird. *Avian Res.*, **8**: 1. https://doi.org/10.1186/s40657-016-0059-9

Williams, G.C., 1992. *Natural selection: domains, levels, and challenges.* Oxford University Press. Britain.

Yom-Tov, Y. and Geffen, E., 2011. Recent spatial and temporal changes in body size of terrestrial vertebrates: probable causes and pitfalls. *Biol. Rev.*, **86**: 531-541. https://doi.org/10.1111/j.1469-185X.2010.00168.x

Zhang, L., An, B., Backström, N. and Liu, N. 2014. Phylogeography-based delimitation of subspecies boundaries in the common pheasant (*Phasianus colchicus*). *Biochem. Genet.*, **52**: 38-51. https://doi.org/10.1007/s10528-013-9626-5

Zheng, G., 2011. *A checklist on the classification and distribution of the birds of China*, second edition. Science Press. China.