An Inference of The Wading Depths of The Cranes in Wintering Wetlands Through Photographic Sampling: a Case Study of Black-Necked Cranes (*Grus Nigricollis*) in Caohai Wetland, China

Xue Gou (2362125320@qq.com)
Guizhou University https://orcid.org/0000-0001-9085-308X
Xijiao Sun
Guizhou University
Romaan Hayat Khattak
Northeast Forestry University
Ruisha Zhao
Guizhou University
Yao Hu
Guizhou University
Canshi Hu
Guizhou University
Mingming Zhang
Guizhou University
Haijun Su
Guizhou University

Research Article

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Abstract

Several overwintering crane species like Black-necked cranes (*Grus nigricollis)* mainly depends on wetlands for foraging or roosting, preferring stable water depths. Understating the wading depths of cranes is a pressing concern for the better management of wetlands and robust conservation of the overwintering cranes populations. Yet, practically it is very difficult to precisely measure the wading depths due to several limitations like, inaccessibility and sampling difficulties. In the current study a sample of 1288 wading photographs of cranes, based on the constancy of proportion of tibiotarsus to tarsometatarsus were taken in Caohai wetland situated in the Northwest Guizhou Province of south west China. Caohai Wetland is the biggest overwintering wetland around the world, and a very promising area to infer the exact ranges of wading depths of these cranes. The ratio of tibiotarsus to tarsometatarsus of the cranes standing on the lands and the ratio of tibiotarsus to the rest of tarsometatarsus of the cranes standing in water were measured; to infer the projection depths of the part of tarsometatarsus submerged in water, which was used to calculate the accurate depth range of the cranes by comparing with the referenced values. According to the results, 89.92% of individuals preferred the water depths from (0-20]cm, 76.11% preferred (0-10]cm% while water depths for 49,04% individuals was (0-5]cm. Thus we conclude that the Black-necked Cranes prefer a depth range of (0-10]cm. This water depth may be relative to the swamps around the lake, which are very important foraging and roosting sites for cranes, For better habitat management, we strongly recommend to pay special attention to swamps with specific water depth ranges, particularly when the water level changes.

1. Introduction

The Black-necked Cranes (*Grus nigricollis*) is the only crane species in the world that lives on the plateau for their whole lives, and their life history is inseparable from the wetlands (Li *et al*., 2014). Being large wading birds, the Black-necked Cranes oftenly feed and perch in shallow waters, especially in wintering wetlands Shallow wetlands are the most important habitats necessary for their fixed night roosting activities. Coupled with many factors like food conditions, leg lengths and walking resistance, water depths have a direct effect on their behavior and habitat utilization (Sun et al., 2018). The Black-necked Cranes have certain selectivity to the depths of inhabited waters. In some studies the depths of the roosting sites of the cranes have been t estimated. Hu et al. (2002) found that the water depths of the roosting sites of the overwintering Black-necked Cranes in Dashanbao Wetland in Yunnan Province were about 30 cm. Liu et al. (2008) reported that the Black-necked Cranes in Napahai Wetland in Yunnan Province preferred lakeshores or stream confluences with the water depths higher than 10 cm for night roosting. He Peng *et al*. (2011) and Li Jie *et al*. (2017) believed that the of the water depth of the selected site by the Black-necked Cranes in Napahai wetland was less than 30 cm. However, non among all aforementioned studies are based on detailed sampling data. Subject to the sampling difficulties in assessing cranes or the standing points, authentic reports based on accurate and convincing research are scarce.

It is generally believed that the ratio of femur or tibiotarsus to tarsometatarsus is constant and interspecific (Zhang et al., 2008). This article hypothesis, if the adult black-necked crane overwintering in the Caohai Wetland of Guizhou has a constant ratio of tibiotarsus (A) to tarsometatarsus (B). Based on it, we calculated the ratio of the tibiotarsus to the part of tarsometatarsus higher than the water level accurately as possible as we could, then we could infer the length of the part of tarsometatarsus submerged in the water through the real measurements (Wu et al., 2016). The photographic sampling was used to calculate this accurate ratio according to the principle of geometric morphometry, and it is known that the shape of the proportion of all parts of an organism will not change due to the changes of sizes (Klingenberg P C, 2016). In this way, the photographs of the Black-necked Cranes can be fully used, although many photographs were taken by different distances and angles, the ratio of tibiotarsus to tarsometatarsus shall be nearly invariable. In this paper, This hypothesis was tried to be tested and the exact depth range of wadding of wintering the Black-necked cranes was calculated ultimately.

2. Study Area

The current study 2018 was conducted at Caohai (N 26°47' ~ 26°52', E 104°10' ~ 104°20') Wetland Weining, Guizhou china (Fig. 1). This wetland is located in the hinterland of Wumeng mountains in the central part of Yunnan-Guzhou plateau and is a typical representative of low altitude plateau wetlands in China, with an elevation range of 2200-2250m Above Sea Level (ASL). Te total area of Caohai is 120 km^2 with 25 km^2 of water. The elevation of the normal water level is 2171.7 m, and the maximum water depth is 5.0 m. Caohai belongs to the subtropical plateau monsoon climate, with the yearly average temperature of 10.9°C and the coldest monthly average (January) temperature of 2.1°C. Every winter, more than 80 species of waterbirds and 80,000 individual birds live in Caohai Wetland (Zhang et al., 2014). This wetland is surrounded by gentle undulating topography, relatively with slight variation in elvation. Seven sites at Caohai lake and the surrounding agricultural lands have been declared by the local government as roosting sites for Black-necked cranes. Every year by the end of October and start of November the Black-necked cranes start migrating from their breeding grounds area at Ruoergai Marsh in northern Sichuan to Caohai for wintering, and leave again in March.

3. Research Methods

3.1. Data Acquisition

3.1.1. Photographic sampling and measurements

Black-necked cranes were randomly photographed using (EOS 7D Mark II) for consecutive four years (winter 2016–2019) at Caohai. Photographs were taken throughout the whole winter (including early-winter [11th of November to 31st of December, EW], mid-winter [1st of January to 20th of February, MW], and late-winter [21st of February to 31st of March, LW]. After ensuring the bird foraging on land or wading in water, photographs were taken by normal standing posture and lateral views. All the photographs were taken in day light. We also collected One hundred photographs taken by other bird-watchers in the same area, and a total of 1,288 photographs were collected. 405 photographs were taken for birds standing on land and 883 photographs for wading in water. .

3.1.2. Photographs processing

AutoCAD Software (Version 2007; Autodesk Corporation, USA) was used by the same manipulators to accurately measure the lengths of parts of these adult Black-necked Cranes on the pictures, including the lengths of tarsometatarsus (Length of B: from the joints of tarsometatarsus and claw to the joints of tibiotarsus and tarsometatarsus when the cranes were standing on land; Length of B_1: from the joints of tibiotarsus and tarsometatarsus to the water surface when the cranes were wading in water) and the projection length of tibiotarsus (Length of A or A_1: from the joints of tibiotarsus and tarsometatarsus to the margin of thigh covered with feather) (see Fig. 1).

3.1.3. Acquirement of actual data for verification

The actual physical measurement data were mainly derived from literature records and real measurements. A total of 10 accurate measurements of tarsometatarsus of cranes (a_1) were collected (Table 1). About the sexual dimorphism, the statistical analysis of 15 Black-necked Cranes was collected from Caohai from 1987 ~ 1989 by Guizhou Provincial Institute for Animal Husbandry and Veterinary Medicine, which showed that the most average values of the measurements between males and females of the Black-necked Cranes were not significantly different. Except for the peak lengths ($P < 0.05$), there was no significant difference in body weights, body lengths, wing lengths, tail lengths and tarsometatarsus ($P > 0.05$) (Li and Li, 2005). Therefore, while using the actual measurements the influences of gender differences were not considered. The real measurement data were used to calculate and verify the proportions of the tibiotarsus and tarsometatarsus on the photographs.

Table 1
The actual measurement data of the Black-necked Cranes

Individual	Gender	Weight/g	Body length/cm	Mouth peak/cm	Wing length/cm	Tail length/cm	Tarsometatarsus ()/cm
01	▯	4880	116.6	11.9	58.9	22.8	24.2
02	▯	3850	114.0	11.4	58.5	22.5	23.1
03	▯	5360	120.0	12.4	63.5	23.1	25.3
04	▯	5230	118.1	11.6	56.1	22.0	23.6
05	▯	5000	116.1	11.5	54.0	21.8	23.8
06	▯	5550	120.0	11.7	58.2	22.1	23.3
07	▯	3500	113.0	12.0	57.0	22.0	23.0
08	▯	5270	112.0	12.5	57.0	34.0	23.0
09	▯	4500	116.0	11.5	57.0	25.0	25.0
10	▯	Defect	Defect	Defect	Defect	Defect	25.0

Source: Samples No. 1–4 were from (Li and Li, 2005)]; Samples No. 5–6 were from (Wu *et al*., 1986); Samples No. 7–9 were from (Xiao et al., 1999); sample No. 10 was from the specimens of the Black-necked Cranes kept by Bureau of Xishui National Nature Reserve in Guizhou Province.

3.2. Statistical methods

3.2.1. Inferencing Formula

Initially, the pictures of the cranes standing on land were used to analyze the density function distribution and its constancy ratio of tibiotarsus (A) and tarsometatarsus (B), which is the premise for inferring the projected length of tarsometatarsus submerged in water. According to the formula, can be called as land ratio and as wading ratio, and when the density functions of the both are similar, our general assumption is established, and the projection value of water depth can be furtherly calculated. As shown in Fig. 2, The rationale also was illustrated (Wu et al., 2016). The formula is:

$\frac{A}{B} = \frac{A_1}{B_1 + r}$, and: = $\frac{A_1 B}{A}$ - B_1 , $WD = a_1 \times r$

(Note: A, B, A_1, B_1, and r are all projection length values.no unit dimension for this projection.)

[Where, A and B is the projection length of tibiotarsus and tarsometatarsus of black necked Crane standing on land, respectively; A_1 and B_1 is the projection lengths of the tibiotarsus and tarsometatarsus of black necked Crane standing in water, respectively. r is the length projection of the tarsometatarsus submerged of black necked Crane in water; a_1 is the actual length of tarsometatarsus (Table 1); *WD* is the Water Depth]

3.2.2. Data Analysis

Kolmogorov-Smirnov was used to test whether the ratios of *land ratio* and *wading ratio* are normally distributed, respectively (H_0: the total distribution of samples comes from the normal distribution, a significant level was set a = 0.001), then the respective ratio histograms were drawn, and the kernel density estimation curve (Kernel Density Estimation (KDE) was used to compare with the normal distribution probability curve (Gauss fitting curve) (GFC) to determine the sampling method. we used bootstrap resampling to calculate the *land ratio* of 405 samples and *wading radio* of 883 samples to verify the reasonableness of the general hypothesis formula according to the comparison between the two curves. Then, the *land ratio*,A_1 And B_1 obtained by bootstrap resampling were separately used to calculate the wading depth projection values r in the formula. The 10 actual measured values a_1 (cm) of tarsometatarsus that we collected were used to calculate the r according to the formula WD = a_1**r*. Similarly, 10 actual samples were used for bootstrap sampling with 883 pictured samples had been repeated for 883 times to figure out 883 wading depths $WD(cm)$. Finally, the frequencies and ranges of these results of wading depths were analyzed to determine the exact range of water depths of wading of the Black-necked Cranes.

All analytical calculations and drawings were done using R Software (Xue *et al.*, 2007; R Core Development Team, 2019).

4. Results And Analysis

4.1.Land Ratio $(\frac{A}{B})$ and Wading ratio $(\frac{A_1}{B_1+r})$

The Kolmogorov-Smirnov test showed that the *land ratio* was in accordance with normal distribution (n = 405, P = 0.0062 > a), it is found that there is a certain difference between the kernel density estimation curve and the probability density curve of normal distribution (Fig. 3). Therefore, it is necessary to continue to resample the *land ratio*. The right deviation of *land ratio* in the curve was significantly improved and closer to the fitting estimation curve of normal distribution after bootstrap resampling. Therefore, bootstrap resampling was used for subsequent sampling, namely, it was more reasonable to use the bootstrap-resampled *land ratio* to infer the projection for exploring the real wading depth.

As shown in, the comparison between *land ratio* and *wading ratio* revealed that they both were matched on the forms of curves (Fig. 4)These results verified that the formulas used in our study could be reasonable and in line with actual situations.

4.2. Wading Depth Projection Values *r*

According to the frequency (Table 2), 627 wading depth projection values can be obtained within (0–10], reaching 71.01 % of the total samples.

Table 2
Frequency table of total frequency of wading depth projection *r*

Interval	Frequency	Relative frequency (%)
(0–10]	627	71.01
(10–20]	16	1.81
(20–30]	14	1.59
(30–40]	29	3.28
(40–50]	21	2.38
(50–60]	21	2.38
(60–70]	31	3.51
(70–80]	21	2.38
(80–90]	19	2.15
(90–100]	17	1.93
(100–200]	53	6.00
(200–300]	10	1.13
(300–400]	3	0.34
(400–413]	1	0.11

Amongst all ranges, (0–1] accounts for 59.68%, which means that most of the water depth projection values are in the range of (0–10] .

Table 3
Frequency table of wading depth projection values amongst $(0, 10]$

Interval	Frequency	Relative frequency (%)
(0–1]	527	59.68
(1–2]	58	6.57
(2–3]	20	2.27
(3–4]	9	1.02
(4–5]	3	0.34
(5–6]	1	0.11
(6–7]	2	0.23
(7–8]	5	0.57
(8–9]	2	0.23
(9–10]	0	0

4.3. The actual wading depths (WD) of the Black-necked Cranes

Bootstrap sampling had been carried out and repeated for 883 times after introducing the 10 actual values of tarsometatarsus to obtain the actual wading depths. However, the results of $WD > 50$ cm were excluded; because in reality there is extremely low possibility of the cranes standing in water more than 50 cm depth. As shown as most of results of WD were concentrated at the intervals less than 30 cm (Fig. 5).

Statistics further revealed that 95.24% of the total samples (n = 883) involved were within (0,30)cm. And, 88.67% (n = 783) were less than 20 cm. If more specifically, 75.31% (n = 665) were amongst (0,10)cm, while nearly the half (47.23%) preferred to wade in water with the depths less than 5 cm (Table 4).

Table 4
Frequency distribution of Wading Depth (WD) of the Black-necked Cranes in Caohai Wetland

Interval (cm)	Frequency	Relative frequency (%)
(0–10]	665	75.31
(10–20]	118	13.36
(20–30]	58	6.57
(30–40]	30	3.40
(40–50]	12	1.36
(0–5]	417	47.23
(5–10]	248	28.09
(10–15]	74	8.38
(15–20]	44	4.96

5. Discussion

Nondestructive or non-disturbance sampling is always recommended for investigating animal ecology (Richards et al., 2014). In our study, the ratio of tibiotarsus and tarsometatarsus when the cranes were standing on land and the ratio of tibiotarsus and tarsometatarsus submerged in water were verified using the photographic sampling, and both ratios obeyed the normal distributions and had the similar density functions, which represented that the overall inference hypothesis in our study was reasonable and feasible. When the *land ratio* has been calculated, it was very critical for sequent calculations about how to get the wading depth projection value *r*.

Our results showed that the Black-necked Cranes preferred to choose the shallow water areas with the water depth less than 20 cm, especially less than 10 cm and they nearly do not prefer to the water depths higher than 30 cm. In field investigation in Caohai, the Black-necked Cranes almost never drowned their whole tarsometatarsus when choosing wading habitats. This is similar to the field observation results from Dashanbao and Napahai in Yunnan (Li and Li, 2005), as well as similar to the overwintering Black-necked Cranes found on the sides of lakes, reservoirs or river shoals in Tibet (Lei et al., 2012). Similarly with the other crane species, for example, the Siberian Cranes (*Grus leucogeranus*), a closely related species to the Black-necked Cranes, overwinter in Shahu and Poyang Lake. Wu et al. (2013) estimated that 58% of the white cranes moved in the water depths of 5–27 cm and the Siberian Cranes were also mainly in shallow water with depths below the tarsometatarsus (Wu et al., 2013). He et al. (2002) observed that small groups or family of Siberian Cranes were mainly scattered in some scattered shallow water pools with the depth of the water mostly 2 ~ 10 cm in Momoge Nature Reserve, Jilin Province, China, but for large flocks of cranes, the water depth was relatively deeper, ranging from 10–30 cm (He et al., 2002). Lv et al. (2007) reported that the wading water depth of the Red-crowned Crane (*Grus japonensis*) was generally below 30 cm and few cranes were wading at the higher depth of 30 cm (Lv *et al.*, 2007), and the research results of the common cranes (*Grus grus*) and the

Sandhill Cranes (*Grus canadensis*) (JM *et al*., 2004; Folk *et al*., 1990)were in agreement with our results. All the aforementioned results were derived from subjective estimation; yet, out results are based on relatively big sample size and fine derivations.

Field observations in our study showed that, the Black-necked Cranes overwintering in Caohai Lake mainly preferred to stay in the lacustrine regions, sedge meadows, shallow meadows, barren grasslands, corn fields, and vegetable fields. Shallow swamps and sedge meadows, provides a vast range of plant communities that cranes can consume, In addition with abundant supply of snail and small fishes that can serve as rich protein sources for these birds (Wu and Li, 1985; Li, 1999). Therefore, the Black-necked Cranes were observed to frequently preferred wading in these shallow areas with the water depth of (0–10)cm.

Currently the authorities are planning to raise the water level of Caohai from 2171.7m-2173m, to expand the water surface area upto 33 km^2 (Ran et al., 2017). The overall water level will be raised by more than 1m, which will drastically affect the current distribution of foraging and roosting sites of the Black-necked Cranes. During the increased and high water levels, it becomes difficult for cranes to locate the food. Our study in this regards provide reliable guidance to better maintain the water levels and habitat management for the Black-necked cranes at Caohai and the other overwintering sites. Based on the results of the current study we strongly recommend to maintain the stable water levels, and to predict the formation of new suitable overwintering habitats. Furthermore, we believe slow adjustments of water level can gradually enhance the cranes adaptability; and ultimately the Blacked-necked cranes habitats can be better protected and managed, both quantitatively and qualitatively.

Declarations

Declarations: Ethics approval and consent to participate. The investigations comply with the current laws of China, where they were performed.

Consent for publication: Not applicable.

Availability of data and material: The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: XG and HS conceived the study, XG and XS implemented the field surveys and collected the data, XG, RZ, CH and YH anlysed the data, XG wrote the manuscript. HS supervised the research and provided multiple revisions of the writing. Romaan HK, CH and MZ conducted research method guidance for the article. All authors read and approved the final manuscript.

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Figures

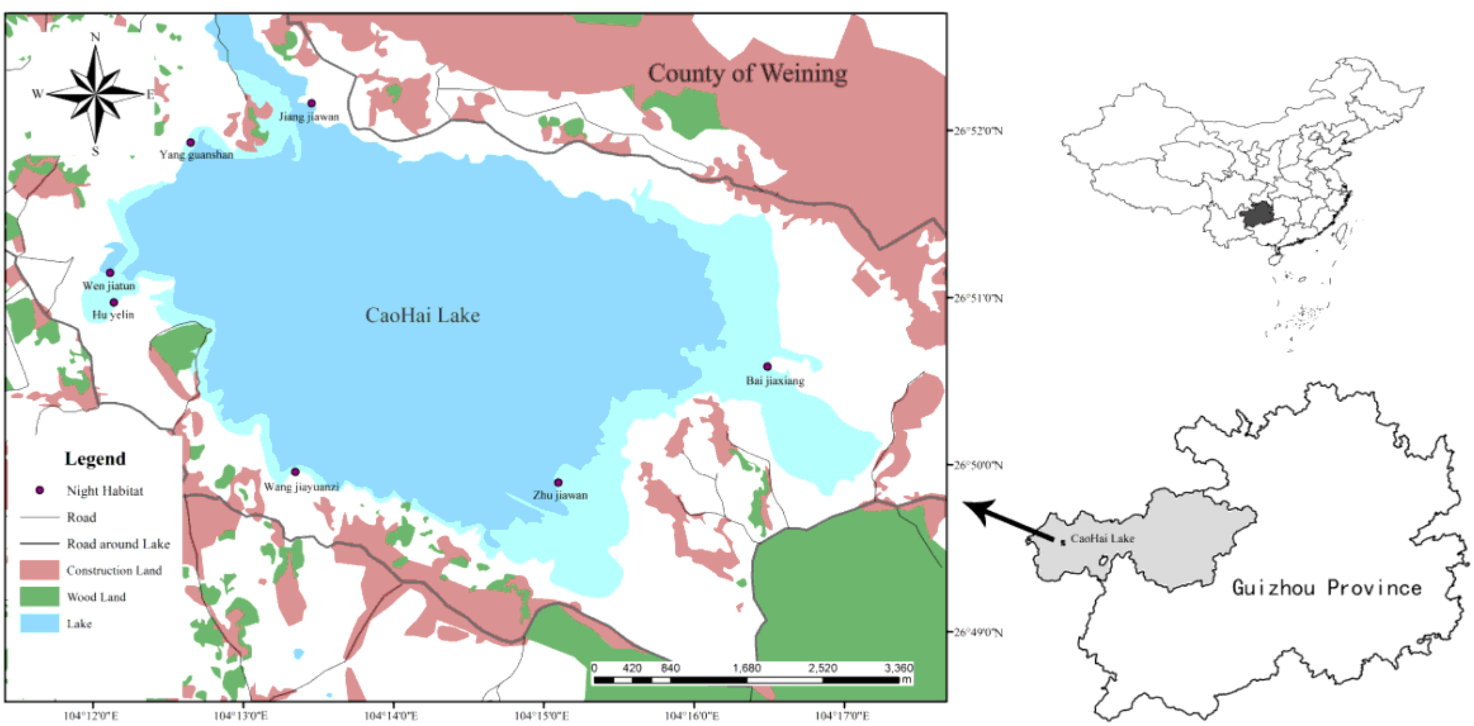

Figure 1

Land use map of Black-necked crane roosting sites and cultivated land area in Caohai Wetland

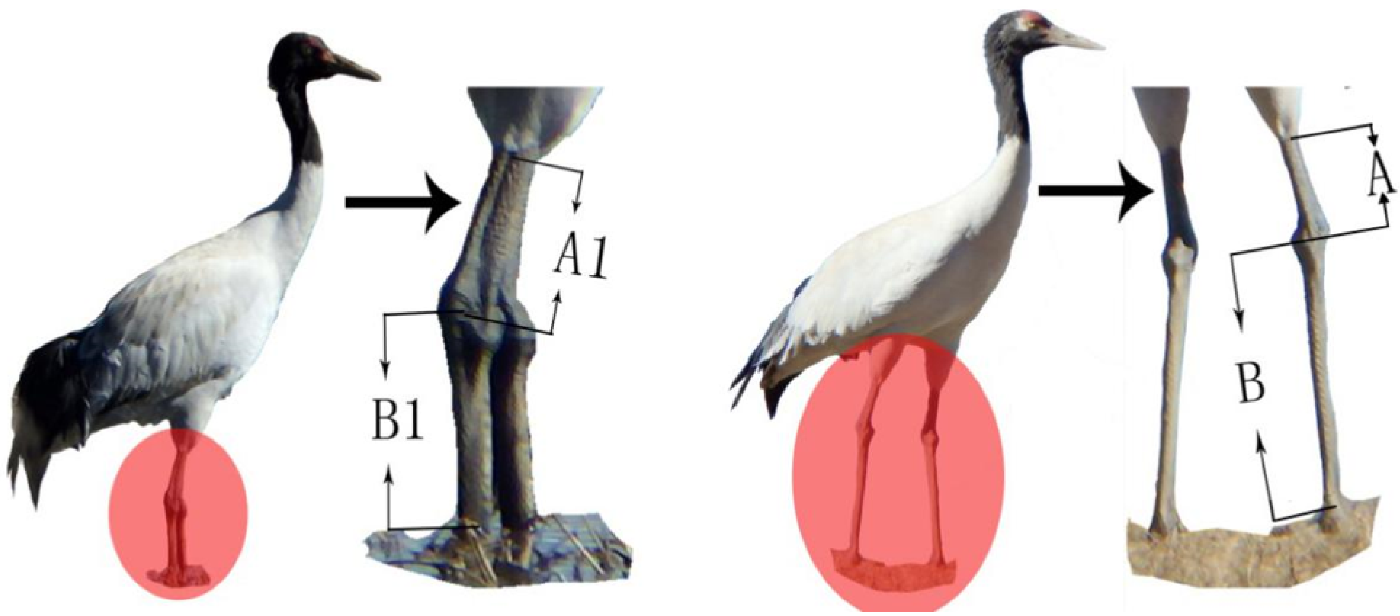

Figure 2

Measurements on the tibiotarsus (A1 or A) and tarsometatarsus (B1 plus the part submerged in water, or B) of black-necked cranes when wading in water and standing on land from pictures

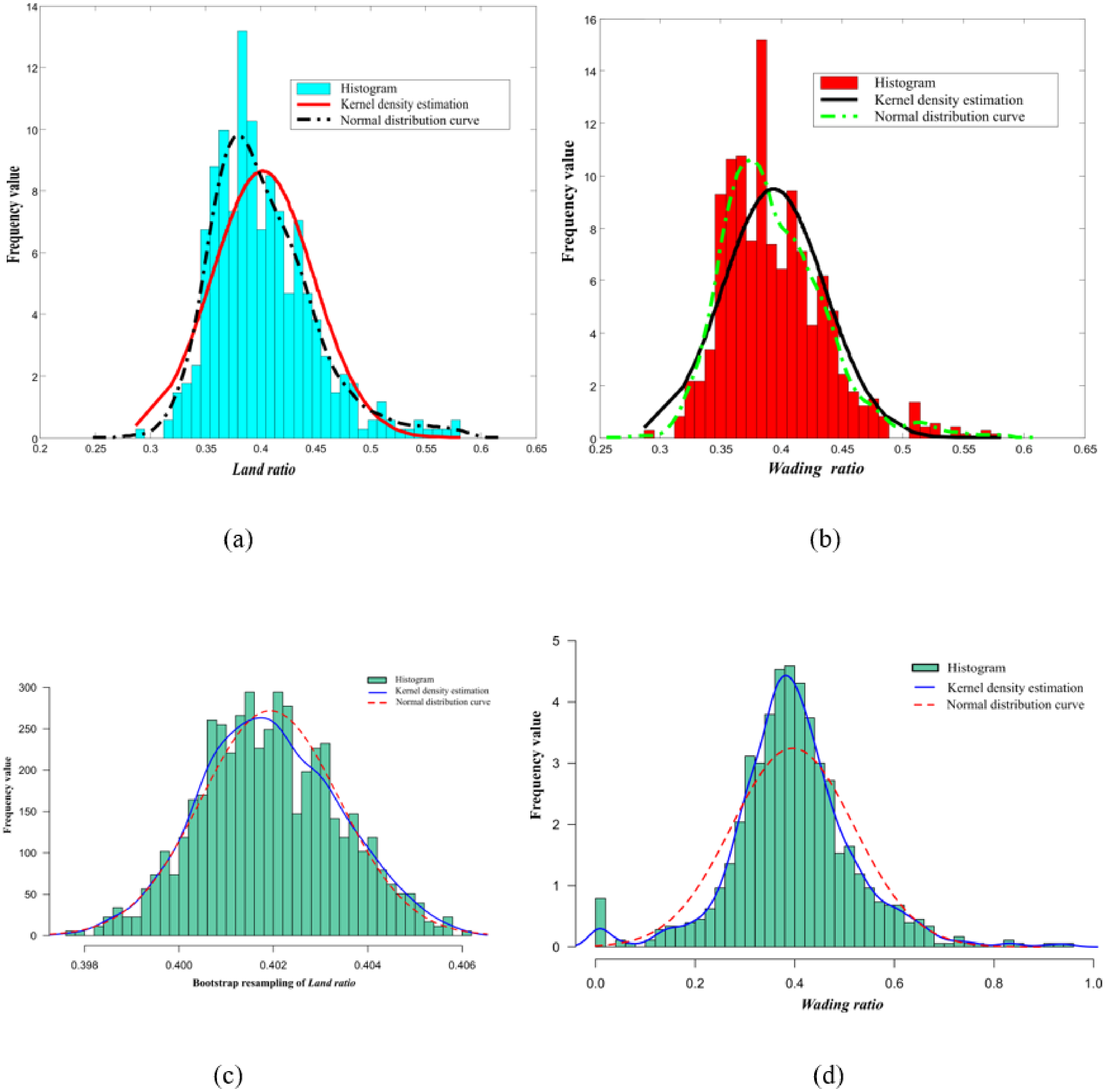

Figure 3

(a) Normality test of Land Ratio (A/B) of 405 samples; (b) Normality test of (A1/B1) of 883 samples; (c) Bootstrap resampling of Land Ratio (A/B) of 405 samples; (d) Curves of wading ratio (A1/(B1+r)) calculated using bootstrap resampled Land Ratio for r.

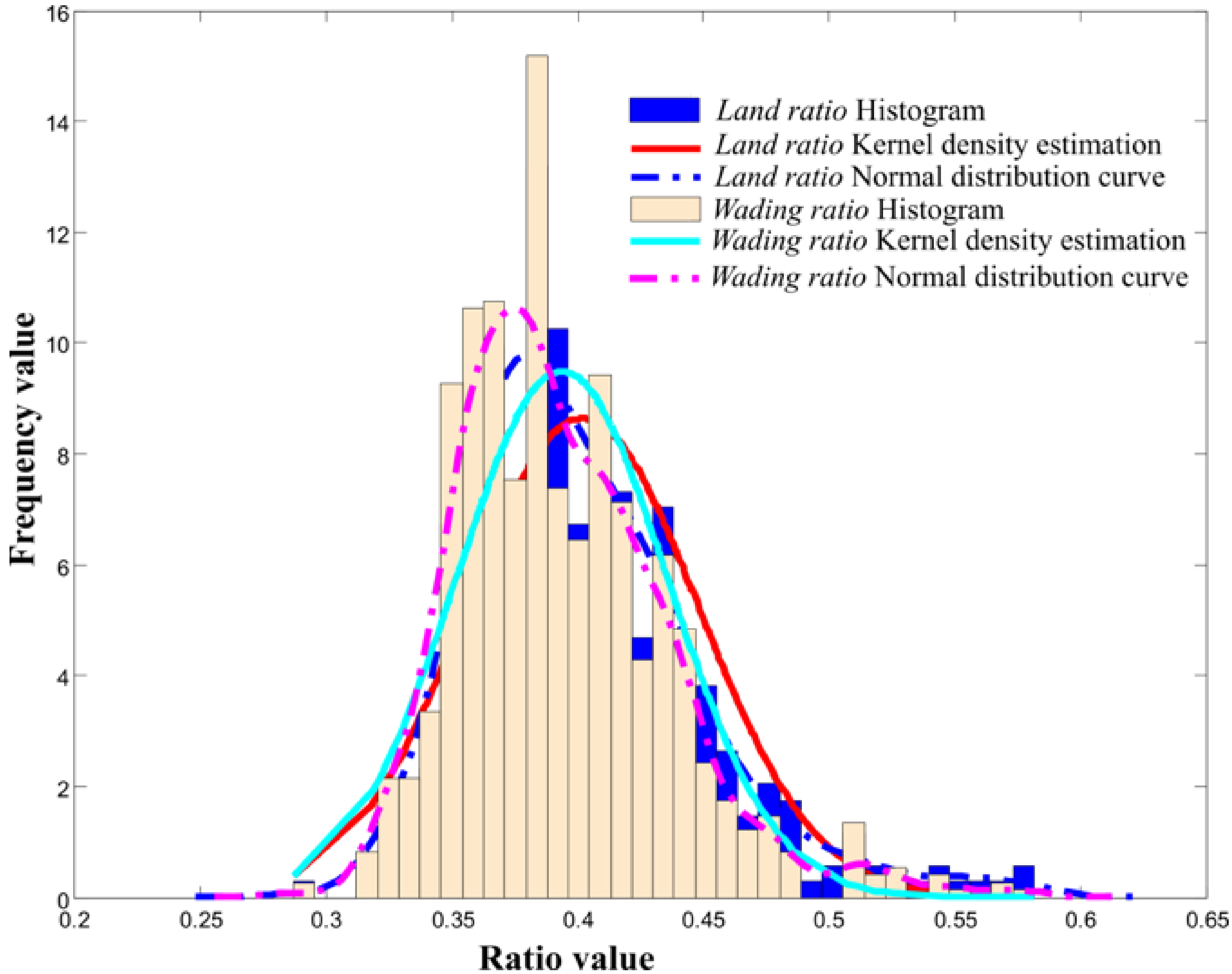

Figure 4

Comparison of straight and fitting curves between dry land and sampling water intake ratio

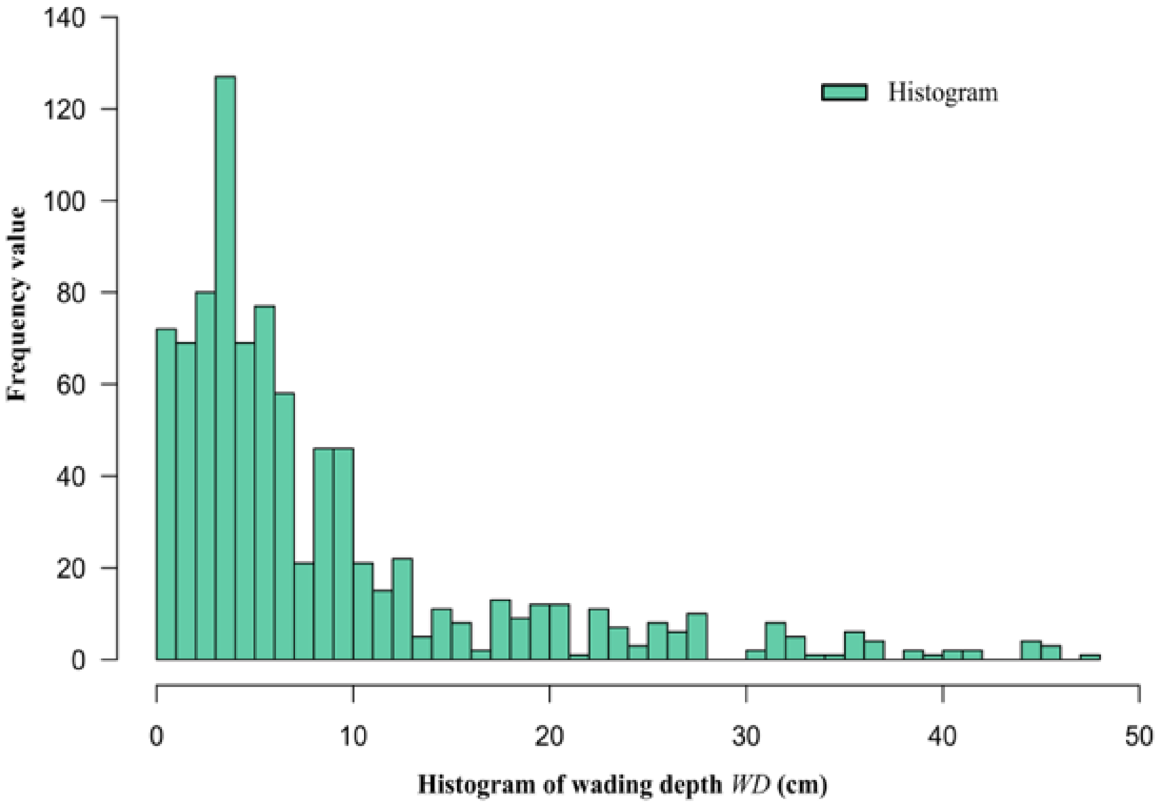

Figure 5

Histogram of wading depth (cm)