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The Effect of Climate Change on the Population Fluctuation of Overwintering Red-Crowned Crane in Yancheng Nature Reserve, China

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ABSTRACT

Exploring the effect of climate changes on population fluctuation of red-crowned crane is of great significance for the species protection and management. Here, based on the annual maximum population size of red-crowned crane wintering in Yancheng Nature Reserve (YNR) from 1981 to 2016, we tested the correlation between population size and the climate variables. The results showed that mean air temperature in wintering period showed a linear upward trend. Annual maximum wintering crane population was 623±33. Fitting the population size and the climate variables in the same year with GAMs indicated significant correlations between population size and mean maximum air temperature in November, mean minimum air temperature in December, mean air temperature in December, respectively. Time-lag effects were found between population fluctuation of red-crowned crane and the climate variables within 2, 4, 6 and 7 years earlier in December and February of the following year. Combination of the highest interpretations of the climate variables on population size included mean air temperature in January of the following year 6 years earlier, precipitation in January of the following year 7 years earlier and mean air temperature in December. Our results highlighted the importance of considering the effects of long-term climate variables on the population size of endangered birds, red-crowned crane. Then, an interpretation model with high deviance explained was explored. More and continuous attention should be paid to improve considerable measures of crane conservation based on climate change.

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Authors' Contribution
CL and SL conceived and designed the study. All authors conducted field survey. PX, BL and CL drafted this manuscript.

Key words
Red-crowned crane, Yancheng Nature Reserve, Population fluctuation, Climate change, Wintering area.

INTRODUCTION

As an important ecological environment factor, the survival of the organism is more or less affected by the climate conditions. Birds are highly sensitive to climate and weather changes, coupled with strong locomotion ability; they are often regarded as pioneer indicator species of climate change on animals (Stephens *et al*., 2016). Therefore, avian scientists had been focused on the effects of rapid changing climatic conditions on the population of wild birds over the past few decades. Global climate change has affected the survival of many bird species (Crick, 2004; Wu *et al*., 2012). Geographical distribution, breeding ecology and population dynamics of birds have altered to adapt the global climate change (Chen *et al*., 2011; Bård *et al*., 2005; Gasner *et al*., 2010).

Global warming has caused high frequency of extreme climates. Short-term severe climate changes usually have strong effects on birds. For example, extreme climate events may result in an increase of bird mortality directly (Li *et al*., 2017). Long-term bird population fluctuation mechanism is very complex. Bird populations tend to regulate themselves to a certain level after transient or longer-term changes in a particular component of a species' demography (Newton and Brockie, 1998; Marchant *et al*., 2004). However, before distinct population fluctuation, the detection of population change in response to climate change is likely to be affected by the masking effects of density-dependent regulation (Crick, 2004). Effects of conventional and mild climate change on the life history of birds are secular processes. And this time-lag effect will also take a long time to emerge. Hence, as an important research content of bird population ecology, it is worthy of continued concern to reveal the influence mechanism of long-term climate change on bird population dynamics (Bergmann, 1999). Due to the inherent difficulty of getting the long-term data of climate variables and population information of birds (Berthold *et al*., 1998), study on the effects of long-term climate change on bird population fluctuations are still limited.

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Red-crowned crane (*Grus japonensis*) is the endemic birds in East Asia. The number of wild population in the world is only about 3000, which is listed as an endangered class by the World Conservation Union (IUCN) and is listed as the national first class protected animal in China (BirdLife International, 2016). The wild migratory population mainly breeds in southeastern Russia and Northeast China. Yancheng Nature Reserve is the main overwintering land of the western migratory population in China. Its population in the wild has continued to decrease in recent years (Su and Zou, 2012).

The number of this endangered crane was monitored for a long time because of their protective status. To explore the impact of climate change on population dynamics of red-crowned crane and to analyze the trend of population fluctuation is of great significance for the protection and management. Meanwhile, such studies can also provide evidences for the impact of climate change on birds. In the present study, the maximum number of overwintering red-crowned cranes population from 1981 to 2016 were used to analyze the relationship between inter annual climate changes and the population dynamics. We mainly tested that if there was significant correlation between population trend and winter climate variables and whether the time lag effect of winter climate variables on the red-crowned crane population fluctuation presence or not. Finally, we elucidated the best combination of climatic factors which effect on population fluctuation trend significantly and suggest a reasonable regression model.

MATERIALS AND METHODS

Study site

The Yancheng Nature Reserve (YNR) (32°48′47″-34°29′28″N, 119°53′45″-121°18′12″E) is located on the east of Jiangsu Province with a total area of 247,260 ha. Its jurisdiction includes partial Dongtai, Dafeng, Sheyang, Binhai and Xiangshui along the coast. As the transition region of warm temperate zone to subtropical zone, mild and humid climate, ample sunshine, abundant rainfall, four distinct seasons occur in the year with an annual mean air temperature of 14-15°C, a frost free period of 216-225 days and a mean annual precipitation of 1000 mm. The YNR is the largest wetland nature reserve mainly designed to protect the coastal wetland ecosystem. It is a principal refuge for red-crowned crane and many other rare species, an important station for migrant waterfowls (Zhu *et al*., 2004).

Methods

The data of the overwintering population of red-crowned crane in the YNR from 1981 to 2016 came from the monitoring of full line survey on the distribution of red-crowned crane in Yancheng coastal beach organized by the environment protection department of the city from 1981 to 1983 (Lv, 2008, 2009) and the maximum monitoring number of two times (December and January in the next year) simultaneous survey conducted by the researcher and management staff of YNR every year from 1984 to 2016.

Climate data of the wintering period in YNR from 1981 to 2016 was collected from the monthly data set of China's ground climate data, which was downloaded from China Meteorological Data Sharing Service System (http://data.cma.cn/site/index.html).

First, the regional climate change is analyzed. To estimate the wintering population size of the red-crowned crane in YNR, we analyzed its inter-annual variation from 1981 to 2016. Then, we used generalized additive models (GAMs) to plot the partial effect of climate variables on wintering population size (Hastie and Tibshirani, 1990). GAMs accommodates a flexible and nonparametric method for calibrating species response to environmental predictors (Fewster *et al*., 2000; Wood, 2008). The model also provides other information of population trend. Each variable was analyzed separated, so spatial auto correlation would not be a problem in this process. Climate variables including mean air minimum temperature, mean air temperature, mean air maximum temperature and monthly precipitation in the same year were involved in the models. Pearson correlation analysis was used to test the correlation between the overwintering climate variables and the population size of red-crowned crane within 10 years (Li *et al*., 2014). So the time-lag effect could be estimated. The results of the correlation analysis were tested to eliminate the impact of extreme values, and retained if significant correlation were found. To quantify the combination of the highest interpretations of climatic factors that have significant impact on the crane population fluctuation, we adopted an all subsets regression analysis (Ralph, 2000). The models were ordered by the specified model selection statistic and was particularly useful when factors were more than ten. Adjusting R square was used to determine the best model. Finally, because of the Multicollinearity among variables in a model artificially inflate the standard error of parameter estimates, the deviance explained by the best subset of regression factors were analyzed in GAM with low correlated variables. An equation of linear regression also was explored between climate variables and population size. Numerical statistics used mean value±standard error (SE). All statistical analyses were conducted in SPSS 24 and R3.1.4. (R Development Core Team, 2014) with package MGCV, LEAPS and LM.

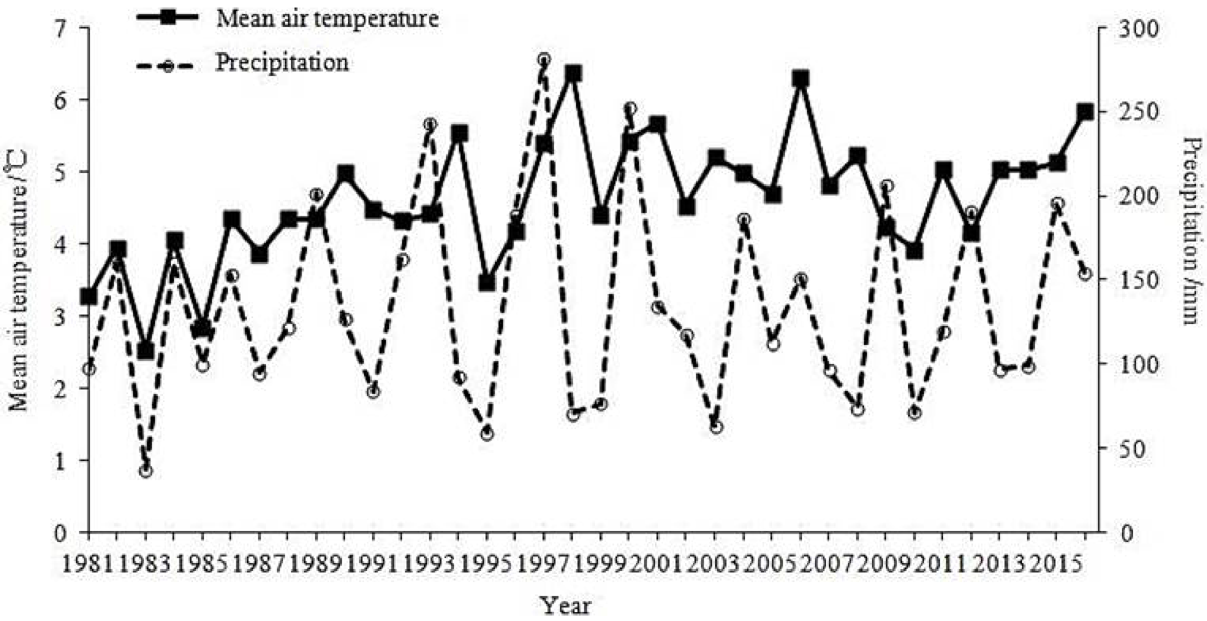

Fig. 1. Annual fluctuation of the mean air temperature and precipitation in the YNR during the wintering period of red-crowned crane from 1981 to 2016.

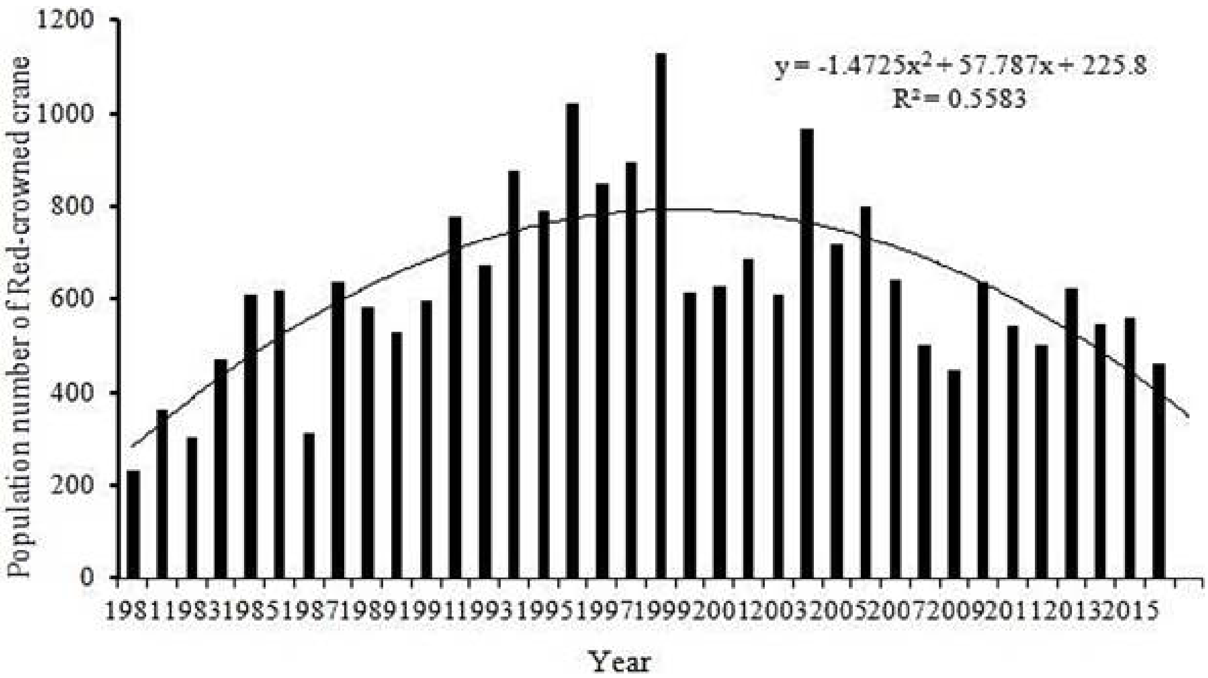

Fig. 2. The change trends of the maximum wintering number of red-crowned crane inside YNR from 1981 to 2016.

RESULTS

Climate fluctuation of the wintering area

Mean air temperature of YNR 1981-2016 in wintering period was (4.6 ± 0.1°C). The highest temperature (6.4°C) was appeared in 1998, and the lowest (2.5 °C) in 1983. There was significant annual fluctuation with a linear upward trend (R^2=0.300, F=14.595, df=34, P=0.001) overall (Fig. 1). Mean maximum temperature (R^2=0.357, F=18.840, df=34, P=0.000) and mean minimum temperature

(R^2=0.128, F=4.982, df=34, P=0.032) of wintering period showed the same trend. Mean precipitation among years was 134.3±9.8 mm, which showed a drastic annual fluctuation with no significant increasing trend (R^2=0.004, F=0.126, df=34, P=0.724) (Fig. 1).

Inter-annual variation of the red-crowned crane population

The average population number of red-crowned crane in the YNR during 1981-2016 was (623±33), the largest number was 1128 in 1999, and the least was 230 in 1981. From 1981 to 1999, the number of overwintering population showed an upward trend, and a slow decline trend from 2000 to 2016, but the trend was not significant (R^2=0.031, F=1.082, df=34, P=0.306) (Fig. 2).

Relationship between population number and climate variables in the same year

The GAMs were used to fit the trend of the maximum overwintering population size of the red-crowned crane with the climatic variables. The top 3 of the deviance explained were V2, V5 and V7. Besides, larger R-sq. (adj), F value and smaller GCV value were also found (Table I). There was a linear correlation between 11 variables and population size, but only V2 was significant. There was a curvilinear relationship between population size and other 5 variables (edf >1), but only V5 and V7 was significant (Fig. 3).

Time-lag effect between population number and climate variables

There was no time-lag effect between the population fluctuation of red crowned cranes in YNR and the climate variables in November within 10 years from 1981 to 2016.

Time-lag effects were found between population fluctuation of red-crowned crane and the climate variables within 10 years in December and February of the following year. There were significant positive correlation between population size and mean air minimum temperature

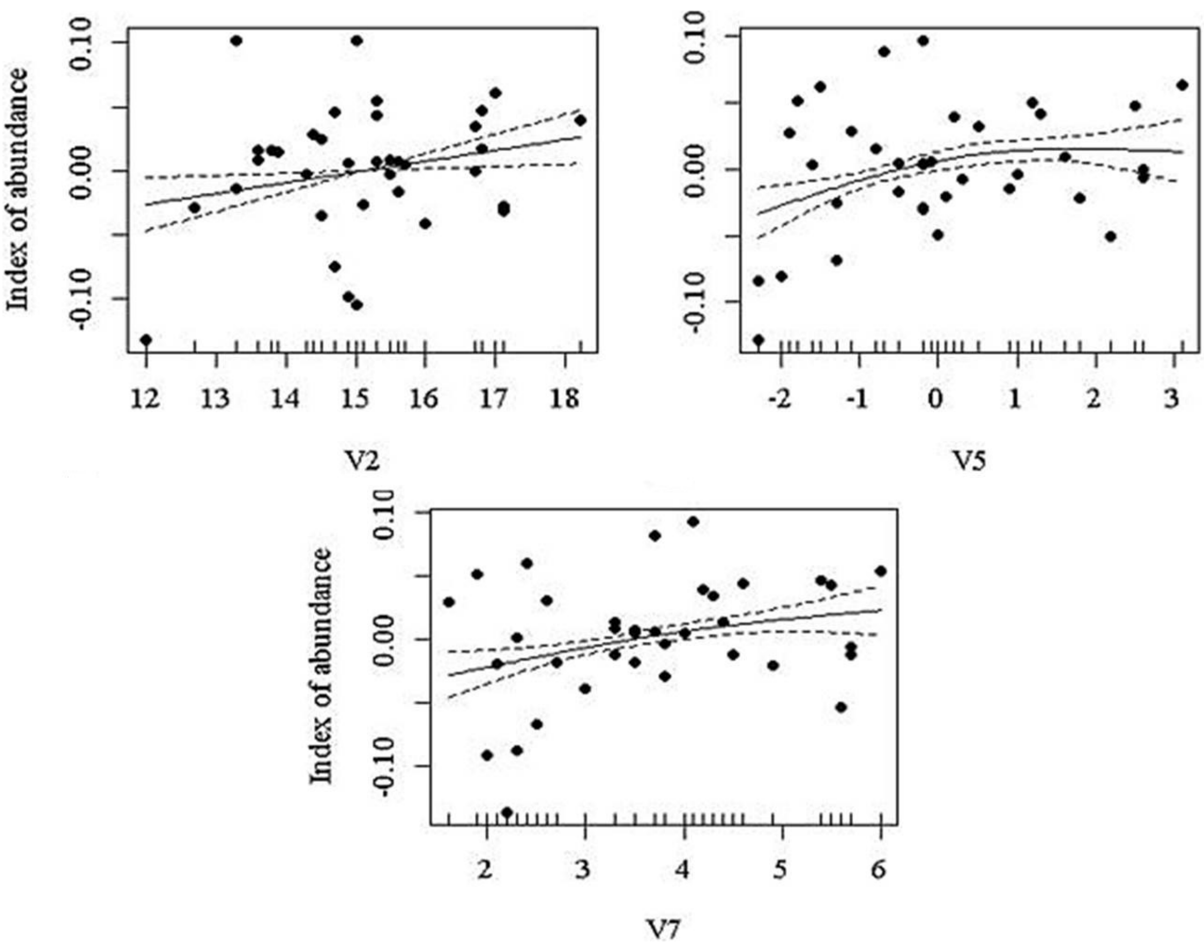

Fig. 3. Estimated changes in population sizes of the red-crowned crane under the effect of 3 climate variables, which was significant, from 1981 to 2016 in YNR using GAMs.

(r=0.426, P=0.010, n=36), mean air temperature (r=0.385, P=0.020, n=36) in December 2 years earlier, mean minimum air temperature in January of the following year 4 years earlier (r=0.341, P=0.042, n=36), mean minimum air temperature (r=0.504, P=0.002, n=36), mean air temperature (r=0.454, P=0.005, n=36), precipitation (r=0.364, P=0.029, n=36) in January of the following year 6 years earlier, precipitation in January of the following year 7 years earlier (r=0.364, P=0.029, n=36). After eliminate extreme values, no significant correlation were found between population size and mean air temperature in December 2 years earlier (r=0.314, P=0.070, n=34), precipitation in January of the following year 6 years earlier (r=0.286, P=0.101, n=34). The effect the other 5 variables were still significant. GAMs were applied to estimate the effects of climate variables on population size. 5 positive linear relationships were found among 5 climate variables (Fig. 4).

Significant correlation was found between population size and mean maximum air temperature in February of the following year 1 year earlier (r=0.350, P=0.037, n=36). But no significant correlation was found when removing the extreme values (r=0.234, P=0.182, n=34).

Combination of the highest interpretations of the climate variables on population size

All subsets regression analysis of climate variables, which have significant impact on the crane population fluctuation, indicated that combination constituted by F1, F3, F4, F5, F7 and F8 was best. We removed F1 F4 and F7 because of correlation with other variables, and assessed the rest factors to GAM (Fig. 5). The result showed high R-sq. (adj) (0.684), low GCV (0.05). The deviance explained was as high as 75.8%. Equation of linear regression:

$$\text{Number}=52.182*(F3)+3.54*(F5)+61.545*(F8)+429.601.$$

Where, Number represents maximum population of the overwintering red-crowned crane each year.

Table I.- Results of the Generalized Additive Models (GAMs) analyzing the effect of 16 climate variables on the overall changes in population size of the red-crowned crane in YNR.

Variable	Smooth terms					
	GCV	R-sq. (adj)	DE (%)	edf	F	P
V1	0.121	0.003	3.19	1	1.120	0.297
V2	0.106	0.130	15.40	1	6.166	0.018*
V3	0.115	0.058	8.5	1	3.143	0.085
V4	0.121	0.027	7.28	1.659	0.925	0.399
V5	0.094	0.247	28.5	1.731	7.123	<0.01**
V6	0.111	0.100	13.7	1.448	2.070	0.096
V7	0.095	0.233	26.3	1.375	5.918	<0.01**
V8	0.121	0.022	6.24	1.457	1.219	0.417
V9	0.116	0.051	7.78	1	2.816	0.102
V10	0.125	-0.028	0.14	1	0.047	0.829
V11	0.120	0.020	4.78	1	1.687	0.203
V12	0.119	0.027	5.47	1	2.001	0.166
V13	0.124	-0.014	1.47	1	0.507	0.481
V14	0.117	0.042	6.91	1	2.521	0.122
V15	0.120	0.013	4.16	1	1.473	0.233
V16	0.125	-0.028	0.174	1	0.058	0.810

DE, Deviance explained; V1, mean minimum air temperature in November; V2, mean maximum air temperature in November; V3, mean air temperature in November; V4, precipitation in November; V5, mean minimum air temperature in December; V6, mean maximum air temperature in December; V7, mean air temperature in December; V8, precipitation in December; V9, mean minimum air temperature in January of the following year; V10, mean maximum air temperature in January of the following year; V11, mean air temperature in January of the following year; V12, precipitation in January of the following year; V13, mean minimum air temperature in February of the following year; V14, mean maximum air temperature in February of the following year; V15, mean air temperature in February of the following year; V16, precipitation in February of the following year; *, p<0.05; **, p<0.01.

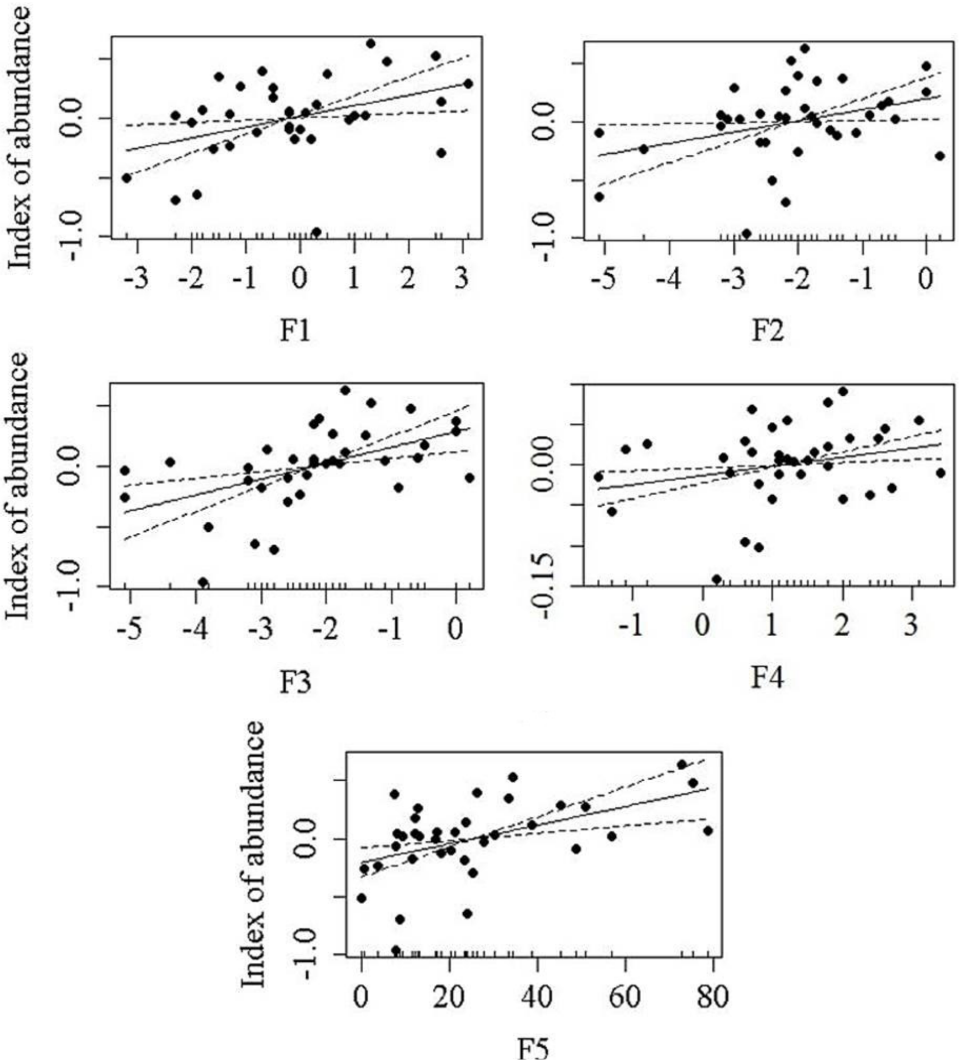

Fig. 4. The significant correlation between the maximum number of red-crowned crane in the YNR and 5 climate variables within 10 years. F1, mean minimum air temperature in December 2 years earlier; F2, mean minimum air temperature in January of the following year 4 years earlier; F3, mean minimum air temperature in January of the following year 6 years earlier; F4, mean air temperature in January of the following year 6 years earlier; F5, precipitation in January of the following year 7 years earlier.

DISCUSSION

Population fluctuation

Exploring how population size of endangered birds respond to climate change is an important part to clarify the status of the endangered bird (Charmantier *et al.*, 2008). Mean air temperature rose in overwintering region of red crowned crane, which was consistent with global climate change trend. For a long period of time, the global climate will be changing in the future, at the same time, its influence on the population fluctuation of birds continues.

For migratory birds, especially long distance migratory birds, the factors that influence their population dynamics are more complex (Jiang *et al*., 2018; Both *et al*., 2006; Berthold, 2001). There are different climate conditions in wintering area, migration stopover area and breeding area. Monitoring of the migratory red-crowned crane at stopover region showed that the population in 2000 also decreased significantly (Li *et al*., 2012), suggesting that the red-crowned crane experienced sharp decline at breeding area. Climate and habitat conditions change may explain this phenomenon. After a sharp decline in 2000, the population of red crowned cranes recovered gradually, and the density restriction of population affected the population. Meanwhile, the change of climatic conditions at wintering areas from 1981to 2016 also had an impact.

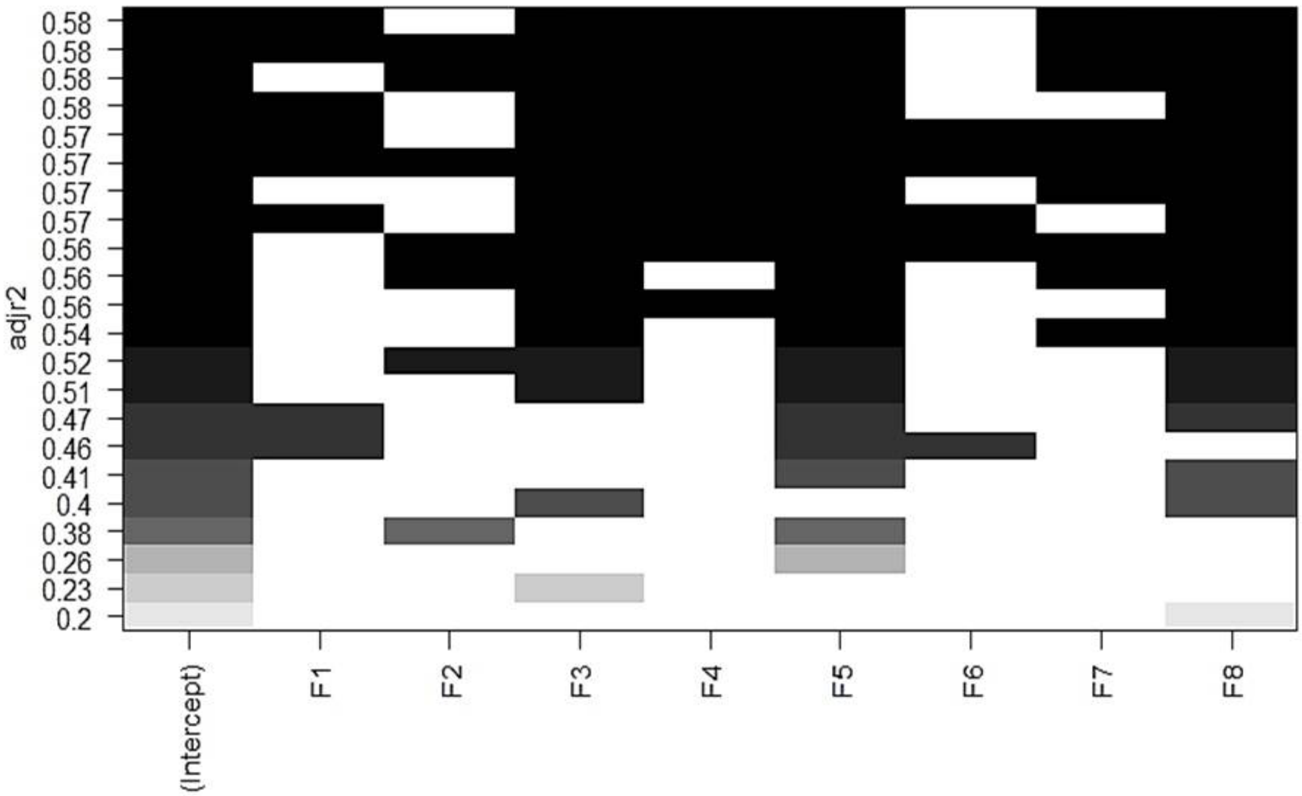

Fig. 5. All subsets regression analysis to determine the best combination of climate factors. F1-F5 had been illustrated in Figure 4. F6, mean maximum air temperature in November; F7, mean minimum air temperature in December; F8, mean air temperature in December.

Effect of climate change on population size

Significant linear relationship between wintering population of red-crowned crane and mean minimum air temperature in November was found at this study. Warm weather at the beginning of winter was conducive to the improvement of food resource (such as fish, shrimp, snails and worms) (Ma *et al*., 2010) abundance and availability; On the other hand, warm weather could reduce energy consumption on body temperature regulation. As the temperature increased in mid-winter, curvilinear relationship meant that cranes might choose to spend the winter at high latitude region and not go south. This also explained that the number of cranes increased at the Yellow River Delta Nature Reserve (Sun *et al*., 2015).

Time-lag effect of climate change on population size

The change of environment will lead to the time-lag effect of population growth rate (Kyle *et al*., 2011). The number of red-crowned cranes was significantly related to the climatic variables in 2, 4 and 6 years earlier. This time-lag effect indicated the influences of climate changes on unfledged cranes. Temperature dropped in January, in which food resource was lack, but the cranes began to migrate in February. January was an important period of energy supplement, especially for the young crane. On the other hand, sexual maturity age the crane was 2 to 4. So number of unfledged cranes in 2, 4 and 6 years earlier had a significant effect on the reproductive success rate and the size of the individual in the overwintering population in the same year.

Combination of climates with the highest interpretation

All possible combination models would be plotted and one or more subsets of factors which have optimum prediction performance would be found by rank in all subsets regression analysis (Xu *et al*., 2013). Adjusting R square evaluate the models. When using GAM to explore the explanatory degree of 3 variables (F4, F5, F8) with low correlation. Deviance explained was high. At last, a climate-based model by multiple linear regressions could also be useful for future population prediction (Murtaugh, 2009).

Our results highlighted the importance of considering the effects of long-term climate variables on the population size of endangered birds, red-crowned crane. Then, an interpretation model with high deviance explained was explored. More and continuous attention should be paid to improve considerable measures of conservation to deal with the effect of climate change, especially for this endangered species.

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Statement of conflict of interest

Authors have declared no conflict of interest.

REFERENCES

Bård, G.S., Anders, P.M., Bernt-Erik, S., Goetz, R. and Hans, G., 2005. Weather in the breeding area and during migration affects the demography of a small long-distance passerine migrant. *Auk*, **122**: 637-647. https://doi.org/10.1642/0004-8038(2005)122[0637:WITBAA]2.0.CO;2

Bergmann, F., 1999. Long-term increase in numbers of early-fledged Reed Warblers (*Acrocephalus scirpaceus*) at Lake Constance (Southern Germany). *J. Ornithol.*, **140**:81-86. https://doi.org/10.1007/BF02462091

Berthold, P., Fiedler, W., Schlenker, R. and Querner, U., 1998. 25-year study of the population development of Central European songbirds: A general decline, Most evident in long-distance migrants. *Naturwissenschaften*, **85**: 350-353. https://doi.org/10.1007/s001140050514

Berthold, P., 2001. *Bird migration: A general survey*. Oxford University Press, Oxford, United Kingdom.

BirdLife International, 2016. *Grus japonensis*. *The IUCN red list of threatened species, Version 2016-3*. www.iucnredlist.org

Both, C., Bouwhuis, S., Lessells, C.M. and Visser, M.E., 2006. Climate change and population declines in a long-distance migratory bird. *Nature*, **441**: 81-83. https://doi.org/10.1038/nature04539

Charmantier, A., Mccleery, R.H., Cole, L.R., Perrins, C., Kruuk, L.E.B. and Sheldon, B.C., 2008. Adaptive phenotypic plasticity in response to climate change in a wild bird population. *Science*, **320**: 800-803. https://doi.org/10.1126/science.1157174

Chen, I., Hill, J.K., Ohlemüller, R., Roy, D.B. and Thomas, C.D., 2011. Rapid range shifts of species of climate warming. *Science*. **333**: 1024-1026. https://doi.org/10.1126/science.1206432

Crick, H.Q.P., 2004. The impact of climate change on birds. *Ibis*, **146**: 48-56. https://doi.org/10.1111/j.1474-919X.2004.00327.x

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R. and Wilson, J.D., 2000. Analysis of population trends for farmland birds using generalized additive models. *Ecology*, **81**: 1970-1984. https://doi.org/10.1890/0012-9658(2000)081[1970:AOPTFF]2.0.CO;2

Gasner, M.R., Jankowski, J.E, Ciecka, A.L., Kyle, K.O. and Rabenold, K.N., 2010. Projecting the local impacts of climate change on a Central American montane avian community. *Biol. Conserv.*, **143**: 1250-1258. https://doi.org/10.1016/j.biocon.2010.02.034

Jiang, Z.Q., Li, F.S., Ran, J.H., Zhao, C.H., Zhang, M. and Li, H., 2018. Nest size and its contributing factors for black-necked cranes *Grus nigricollis*. *Pakistan J. of Zool.,* **50**:877-884.

Hastie, T.J. and Tibshirani, R.J., 1990. *Generalized additive models*. Chapman and Hall, London, UK.

Kyle, W.M., Hipfner, J.M., Gwylim S.B. and David J.G., 2011. Effects of extreme climate events on adult survival of three Pacific auks. *Auk*, **128**: 707-715. https://doi.org/10.1525/auk.2011.10198

Li, Y., Song, C., Yang, Y., Li, X., Li, F., Huang, J. and Huang, X., 2012. Monitoring population dynamics of the migratory red-crowned crane (*Grus japonensis*) at Shuangtaihekou National Nature Reserve, northeastern China, from 1991 to 2012. *Chinese Birds*, **3**: 225-229. https://doi.org/10.5122/cbirds.2012.0029

Li, Y., Qian, F., Shan, J., Li, J., Yuan, F., Miao, L. and Xie, G., 2014. The effect of climate change on the population fluctuation of the Siberian crane in Poyang Lake. *Acta Ecol. Sin.*, **34**: 2645-2653.

Li, T., Ma, Z., Wang, Q., Liu, H., Tang, D., Wang, Y. and Zhou, X., 2017. Impacts of Climate Change on Waterbirds and Their Responses. *Chinese J. Wildl.*, **38**: 529-534.

Lv, S., 2008. Current distribution of red crown crane and its development trends in Yancheng Coastal Marshes. *Ecol. Sci.*, **27**: 154-158.

Lv, S., 2009. Relationship between the population dynamics of the wintering red-crowned crane in natural reserve for rare birds in beach region and wetland environment variance of Yancheng. *J. Nanjing Norm. Univ. (Nat. Sci. Ed.)*, **32**: 89-93.

Ma, Z., Wang, Z. and Tang, H., 2010. Habitat use and selection by red-crowned crane *Grus japonensis* in winter in Yancheng Biosphere Reserve, China. *Ibis*, **141**: 135-139. https://doi.org/10.1111/j.1474-919X.1999.tb04272.x

Marchant, J.H., Freeman, S.N., Crick, H.Q.P. and Beaven, L.P., 2004. The BTO Heronries Census of England and Wales 1928–2000: New indices and a comparison of analytical methods. *Ibis*, **146**: 323-334. https://doi.org/10.1111/j.1474-919X.2004.00272.x

Murtaugh, P.A., 2009. Performance of several variable-selection methods applied to real ecological data. *Ecol. Lett.*, **12**: 1061-1068. https://doi.org/10.1111/j.1461-0248.2009.01361.x

Newton, I. and Brockie, K., 1998. Population limitation in birds. *Quart. Rev. Biol.*, **21**: 481-555.

R Development Core Team R, 2014. *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna.

Ralph, M.N., 2000. Regression and model-building in conservation biology, biogeography and ecology: The distinction between- and reconciliation of- 'predictive' and 'explanatory' models. *Biodiv. Conserv.*, **9**: 655-671. https://doi.org/10.1023/A:1008985925162

Stephens, P.A., Mason, L.R, Green, R.E., Gregory, R.D., Sauer, J.R., Alison, J., Aunins, Brotons, L.A., Butchart, S.M.H., Campedelli, T., Chodkiewicz, T., Chylarecki, P., Crowe, O., Elts, J., Escandell, V., Foppen, R.P.B., Heldbjerg, H., Herrando, S., Husby, M., Jiguet, F., Lehikoinen, A., Lindström, A., Noble, D.G., Paquet, J., Reif, J., Sattler, T., Szép, T., Teufelbauer, N., Trautmann, S., Strien, A.J., Turnhout, C.A.M., Vorisek, P. and Willis, S.G., 2016. Consistent response of bird populations to climate change on two continents. *Science*, **352**:84-87.

Su, L. and Zou, H., 2012. Status, threats and conservation needs for the continental population of the Red-crowned Crane. *Chinese Birds,* **3**:147–163.

Sun, X., Zhang, Y., Cao, M., Zhu, S. and Shan, K., 2015. Structure of waterfowl community in relation to habitat in the Yellow River Delta Nature Reserve in autumn migratory and wintering periods. *J. Ecol. Rural Environ*., **31**:514-521.

Wood, S.N., 2008. Fast stable direct fitting and smoothness selection for generalized additive models. *J. R. Stat. Soc.,* **70**:495-518.

Wu, W., Xu, H., Wu, J. and Cao, M., 2012. The impact of climate change on birds: A review. *Biodivers. Sci*., **20**:108-115.

Xu, X., Madden, L., Edwards S., Doohan, F., Moretti, A., Hornok, L., Nicholson, P. and Ritieni, A., 2013. Developing logistic models to relate the accumulation of DON associated with Fusarium head blight to climatic conditions in Europe. *Euro. J. Plt Pathol.*, **137**:689-706.

Zhu, H., Qin, P. and Wang, H., 2004. Functional group classification and target species selection for Yancheng Nature Reserve, China. *Biodivers. Conserv*., **13**:1335-1353