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The response of the distributions of Asian buffalo breeds in China to climate change over the past 50 years

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ABSTRACT

The effects of prior climate change on the distribution of buffalo breeds remain uncertain. We measured the changes in distribution of 29 buffalo breeds over the past 50 years, and examined whether these changes can be attributed to climate change in China. Long-term records of buffalo breed distributions, grey relational analysis, the fuzzy sets classification techniques and attribution methods were used. Over the past 50 years, the distributions of some buffalo breeds have mainly shifted northward or eastward or southward, and most of the changes were related to the thermal index. Drive by climatic factors over the past years, the distribution boundaries and distribution centers of certain buffalo breeds mainly shifted northward, eastward or southward with fluctuation. The observed and predicted changes in distribution were highly consistent for some buffalo breeds. The changes in the northern boundary of 2 buffalo breeds, the change in the eastern boundary of distribution of 1 breed, and the change in the distribution center latitude coordinate of 1 breed can be attributed to climate change.

1. Introduction

Climate change presents a challenge for biodiversity conservation (Bellard et al., 2012). Recent several decades, climate change and other factors have altered the distributions of species (Parmesan and Yohe, 2003; Root et al., 2003). Detecting and explaining these changes are crucial for predicting the effects of climate change on the species distributions and biodiversity conservation (Stone et al., 2013). Livestock genetic diversity is critical for food security and rural development (Ajmone-Marsan, 2010; Groeneveld et al., 2010). It allows farmers to select stock or develop new breeds in response to climate change (Seo et al., 2010; Hoffmann, 2010, 2013; Mu et al., 2013;Boettcher et al., 2015). Climate change have brought threat to the livestock breeds (Burns et al., 1997; Sirohi and Michaelowa, 2007; Thornton et al., 2009). Buffalo breeds usually distribute in the tropical and subtropical regions in Asian (Zheng, 1992). Because highly specialized habitat requirements, slow life histories, the breeds may be highly vulnerable to climate change. Therefore, identifying the changes in the distribution of buffalo breeds and their causal factors is important for anticipating future distributions and extinction events as the climate warms.

Previous studies have analyzed the response of livestock breeds to heat stress, such as the effect of heat stress on the production (Finocchiaro et al., 2005; Bohmanova et al., 2005), thermoregulatory or heat tolerance or acclimation to heat tress (Renaudeau et al., 2007; Dikmen et al., 2008; McManus et al., 2008), genotype related to heat stress (Bohmanova et al., 2008; Collier et al., 2008) and temperature–humidity indices related to heat stress (Bohmanova et al., 2007; Mader et al., 2010; Dikmen and Hansen, 2009; Kohli et al., 2014). However, relatively few studies have identified crucial climatic factors influencing the distributions of buffalo breeds in various spatial and temporal scales.

Compared to the wild animal groups (e.g. bird groups, etc), the effects of climate warming on livestock breeds remain relatively unexplored(Christensen et al., 2004). And in a survey on threats to livestock diversity (FAO, 2009), climate change was mentioned as a minor factor in the context of extensive land-based production systems.However, local livestock production will be affected by climate change (Baker et al., 1993). And several papers provide a general overview of the expected impact of climate change on livestock production (Adams et al., 1998; Smit and Skinner, 2002; Finocchiaro et al., 2005; Henry et al., 2012), and other papers present models of changes in production systems and species composition under climate change (Seo and Mendelsohn, 2008; Mader et al., 2009; Gauly et al., 2013). In addition, some study has

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analyzed the effects of climate variability on the cattle holdings (Lunde and Lindtjørn, 2013), or the effects of climate change on the cattle nutrition (Craine et al., 2010) or on the livestock carrying capacity (McKeon et al., 2009), or the influence of climate factors on spatial distribution of cattle breeds (Zhang et al., 2013), or the adaptation of cattle breed to climate change (Hayes et al., 2009). Regardless of previous studies, the big mismatch between the low resolution of available data and the complexity of agricultural production systems makes it difficult to model the effects of climate change even for organisms with well-known environmental envelopes, because detailed data on most breed adaptation traits, including their spatial distribution, are not available (Jarvis et al., 2008; Jones and Thornton, 2009).Consequently, the insufficient date are available on the detection and attribution the effect of climate change on the changes in distribution of buffalo breeds.

If the distributional changes of species are indeed mainly determined by climatic factors, the rapid climatic warming of recently several decades predicts that organisms should move their distribution polewards and towards higher altitudes (Parmesan and Yohe, 2003; Root et al., 2003). However, numerous species have not shown a change in distribution in response to climate change (Parmesan and Yohe, 2003). Additionally, global climate changes have changed greatly in the last 100 years, yet the changes in distribution limits of species have occurred in recent decades. These suggest that factors other than climate also account for distribution limits of buffalo breeds. Despite a substantial body of work on the relationship between livestock breeds and environmental factors, relatively few studies have been done on the attribution of the effects of current climate change on the changes in distribution of buffalo breeds.

Based on the date of animal genetic resources in China, there are about 26 buffalo breeds (not including Taiwan buffalo breed, Shanghai buffalo breed and Shandong buffalo breed), and these breeds mainly distribute in 19 provinces or regions of south China (China National Commission of Animal Genetic Resources, 2011). And according to the date of "Science and Technology in Chinese Buffalos", the buffalo breeds (including Taiwan buffalo breed, Shanghai buffalo breed and Shandong buffalo breed) mainly distribute 18 provinces or regions of south China (Zhang, 2000). Therefore, based on a comprehensive dates of these literatures, we can certain that there are about 29 buffalo breeds in China, and they mainly distribute in south China (Zhang, 2000; China National Commission of Animal Genetic Resources, 2011).Over time, the distributions of some buffalo breeds have changed, but whether these changes are attributable to climate change remain unclear.

The aim of this study was to detect the changes in distribution pattern of buffalo breeds over the past 50 years and confirm whether the changes can be attributed to climate change in China.

2. Materials and methods

2.1. The distribution of Asian buffalo breeds

Twenty nine breeds of Asian buffalo in China were selected for study: Binhu buffalo breed (Binhu *Bubalus bubalus*), Binglanjiang buffalo breed (Binglanjiang *Bubalus bubalus*), Dechuang buffalo breed (Dechuang *Bubalus bubalus*), Dehong buffalo breed (Dehong *Bubalus bubalus*), Diangdongnan buffalo breed (Diangdongnan *Bubalus bubalus*), Fuling buffalo breed (Fuling *Bubalus bubalus*), Fuan buffalo breed (Fuan *Bubalus bubalus*), Fuzhong buffalo breed (Fuzhong *Bubalus bubalus*), Guizhou white buffalo breed (Guizhou *Bubalus bubalus*), Guizhou buffalo breed (Guizhou Bubalus bubalus), Jianghan buffalo breed (Jianghan *Bubalus bubalus*), Poyanghu buffalo breed (Poyanghu *Bubalus bubalus*), Shannan buffalo breed (Shannan *Bubalus bubalus*), Shanghai buffalo breed (Shanghai *Bubalus bubalus*), Taiwan buffalo breed (Taiwan *Bubalus bubalus*), Wenzhou buffalo breed (Wenzhou *Bubalus bubalus*), Xiling buffalo breed (Xiling *Bubalus bubalus*), Xiajiang buffalo breed (Xiajiang *Bubalus bubalus*), Xingfeng mountain buffalo breed (Xingfeng *Bubalus bubalus*), Xinglong buffalo breed(Xinglong *Bubalus bubalus*), Xuyu mountain buffalo breed (Xuyu *Bubalus bubalus*), Yangjing buffalo breed (Yangjing *Bubalus bubalus*), Yibing buffalo breed (Yibing *Bubalus bubalus*), Haizi buffalo breed (Haizi *Bubalus bubalus*), Dongliu buffalo breed (Dongliu *Bubalus bubalus*), Xingyang buffalo breed (Xingyang *Bubalus bubalus*), Shandong buffalo breed (Shandong *Bubalus bubalus*), Jianghuai buffalo breed (Jianghuai *Bubalus bubalus*), Enshi mountain buffalo breed (Enshi *Bubalus bubalus*). Complete point-distribution data are available for these buffalo breeds, and these data are crucial to detect the distributional changes (See Appendix A in Supplementary Materials). In addition, many new distribution records have been found outside of the historical distribution boundaries of these breeds (See Appendix A in Supplementary Materials), and such records are also critical for identifying the distributional changes of buffalo breeds.

The data sources included national-level distribution data and records from field investigations, sampling reports; China domestic animal genetic resources database (http://www.cdad-is.org.cn); local or regional distribution records from censuses, and investigation or collections at the regional, provincial, district, county, and township level(See Appendix A in Supplementary Materials).

The distributions were determined from two groups of records: records prior to 1951 and records from 1951 to 2010. To analyze distributional changes of buffalo breeds over specific time periods, the time series distribution records for each buffalo breeds were divided into decade time intervals: 1951 to 1960, 1961 to 1970, 1971 to 1980, 1981 to 1990, 1991 to 2000, and 2001 to 2010. The distribution records data from 1951 to 1960 were used to calculate the parameters of the predicted model, and the records from 1961 to 2010 were used to detect the changes in buffalo breed distribution over the past years. The records dated prior to 1951 served as an auxiliary to improve the accuracy of the records that were dated from 1951 to 1960.

A large proportion of the buffalo breeds survey data included different scales, and many records of prior distributions are provided as an approximate location or through a gazetteer (i.e., lacking the exact longitude and latitude of the location).Therefore, all of the buffalo breed distribution records were first geo-referenced to precise longitudes and latitudes. To improve the precision of the geo-referencing processes, we used an index of the Atlas of the People's Republic of China (The Research Institute of Toponomy, Chinese State Bureau of Surveying and Mapping, 1997) to interpolate the longitude and latitude records of every buffalo breed distributions in China for each decade based on sightings or entries in the gazetteer index without coordinates. This index includes 33,211 gazetteer locations.

To reduce the bias resulting from temporal and spatial fluctuations in the samples, we removed the sites with extremely uncertain locations or with multiple entries that referenced the same specimen, and questionable distribution information was then cross-checked and corrected in the records by comparing similarities between climate, vegetation and human activities. We also investigated temporal factors to verify and minimize data errors. We corrected bias in the presence or absence of buffalo breed distributions by using a geographical sketch of China as well as livestock breeds checklists and provincial livestock checklists of China (See Appendix A in Supplementary Materials) that indicate buffalo breed distributions throughout broad geopolitical, geographic or bioclimatic regions. We also inferred absences over large areas by using expert-drawn outlines of buffalo breed