# Local Gazetteers Reveal Contrasting Patterns of Historical Changes between Apex Predators and Mesopredators in Eastern China

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**Abstract**

This research uses both presence and absence records from local gazetteers innovatively to reconstruct the distribution of 6 kinds of mammalian predators in eastern China from 1723 A.D. to 1949 A.D.. With the human population booming, the distribution of tiger, leopard and bear retreated in varying degrees, but the distribution of wolf, fox and dhole expanded in varying degrees, indicating that eastern China experienced a mesopredator release phenomenon.

**Keywords:** Local gazetteer; Historical distribution; Mesopredator release

## 1.Introduction

It has been widely accepted that Earth is facing a biodiversity crisis (Rahbek & Colwell 2011). In the past 500 years, a wave of extinction and declines in local animal population have been recorded, with both the rate and magnitude of this recent period of extinction being comparable to the five previous periods of mass extinction (Pimm *et al.* 1995; He & Hubbell 2011; Dirzo *et al.* 2014). Unlike these five previous periods of mass extinction which were primarily driven by global changes in climate and atmospheric-ocean chemistry, volcanism, and bolide impacts (Barnosky *et al.* 2011), the modern loss of biodiversity is considered as the consequence of human socioeconomic activities (Dirzo & Raven 2003; Ceballos *et al.* 2015). Humans have been causing the sixth wave of extinction through changing global climate, overkilling species, co-opting resources, introducing exotic species, spreading infectious diseases, and destructing and modifying habitat (Leakey & Roger Lewin 1996; MacPhee *et al.* 1999; Dirzo & Raven 2003; Thomas *et al.* 2004; Martin 2005; Jackson 2008; Wake & Vredenburg 2008; Ceballos *et al.* 2015; Yap *et al.* 2015).

Although there is no doubt that the impact of the recent "sixth period of mass extinction" has extended across distinctive taxonomic groups, each species responds differently to climatic shifts, habitat fragmentation, and decline in species abundance caused by anthropogenic disturbance (Cardillo *et al.* 2008; Lorenzen *et al.* 2011).

Moreover, the life history characteristics of different species are also to some extent correlated with their risk of being threatened by human activities (Davidson *et al.* 2009; Öckinger *et al.* 2010; Cardillo & Meijaard 2012). Despite this, such studies usually had poor predictive power to reliably link species' vulnerability with their life history traits (Jablonski 2001, 2008; Pocock 2011). Even relatively well-established patterns of correlation, such as large body size being known to be related strongly to extinction risk in mammals, still failed to accurately predict the extinction risk of a specific species affected by human activities. This is due to (*i*) multiple ecological factors and human activities interact to affect species that differ by orders of magnitude in life history traits (Davidson *et al.* 2009), and (*ii*) human disturbance to specific species is usually regulated by the local community structures and population dynamics in which the species is embedded (Kitahara & Fujii 1994; Gill 2007; Tylianakis *et al.* 2007). A phenomenon termed "mesopredator release" represents one of the best-referred examples. Large-bodied predators were persecuted by humans, but the abundance of mesopredators might undergo dramatic increases as a result of trophic cascading effects in communities (Prugh *et al.* 2009; Wallach *et al.* 2015). Consequently, in view of the complex synergy of both intrinsic species traits and human's role at different spatial-temporal and ecological scales, more specific quantitative assessments of the relationships between local extinction of endangered species and anthropogenic factors are urgently required (Fritz *et al.* 2009; Dirzo *et al.* 2014; Sandom *et al.* 2014; Wan *et al.* 2019; Teng *et al.* 2020).

In China, the distribution of wild animals has changed greatly over time, with many formerly widely distributed wild animals are now endangered or even extinct (Qian *et al.* 2020). Meanwhile, the population in China has increased significantly since the introduction of American crops in the 16$^{th}$ century, which triggered prosperous socioeconomic activities which may be responsible for the extinction of wild animals in China (Li 1998; Cao 2001). China has a long history of using local gazetteers to record momentous events, including those related to local wildlife (He 1993; 1997; Wen 2009; 2013; 2018). By exploring these historical records in various ways, researchers have attempted to reconstruct the spatio-temporal distribution and extinction of engendered animals in China, and then disentangle the relative roles of anthropogenic and climate changes in shaping their distribution and extinction (Jiang *et al*. 1995; Li *et al.* 2002, 2020; Zhou & Zhang 2013; Li *et al.* 2015; Turvey *et al.* 2015, 2017; Wan & Zhang 2017; Nüchel *et al.* 2018; Zhao *et al.* 2018; Wan *et al.* 2019; Qian *et al.* 2020; Teng *et al.* 2020). However, such studies have relied on biased species occurrence data which only focused on the "presence" records of local animals but neglected the "absence" records. For each species, they often defined the time of extirpation as the last occurrence time which is interpreted from the most recent record. But the collection of data from gazetteer-rich and gazetteer-poor regions/eras may cause obvious biases in the estimation of the distribution of wild animals, for the distribution of gazetteers is neither regular in space nor in time. For example, there are few gazetteers in war-torn or sparsely populated areas, and there were only one or two gazetteer from many regions throughout history. Therefore, to accurately evaluate the spatio-temporal distribution and extinction of wild animals in

China, we need to take into account these biases in the data collected, and then do the re-collection job to track changes in biodiversity and analyze how human activities would have affected such changes (Boakes *et al.* 2010).

Here, we first recollected the presence and absence data of 6 kinds of wild mammals in eastern China from 1723 A.D. to 1949 A.D. We chose this time period and region to avoid potential biases, because (*i*) eastern China was the main activity area of ancient Chinese people; (*ii*) during this period, China experienced a rapidly growing human population; (*iii*) a greater quantity of records of wild animals in regional gazetteers The data were re-organized from scanned local gazetteers (county-level or prefectural-level) in the Chinese Digital Gazetteer Database (http://x.wenjinguan.com/). All 6 of the mammals we studied are predators of distinctive body sizes, are widely distributed across gazetteer records and are also easily distinguishable in traditional folk taxonomy. Furthermore, by performing new analytical techniques (*Methods*), we reconstruct the spatial and temporal distribution patterns of 6 predators with both presence and absence records. The ultimate objective of this study was to quantitatively estimate how specifically human socioeconomic activities would have affected the distribution and extirpation of these 6 predators in eastern China.

## 2.Methods:

### 2.1 Data resources

We collected the data from the Chinese Digital Gazetteer Database.

There are two kinds of invalid records, the first kind recorded only livestock, and the second kind did not record comprehensively, but recorded only several large mammals roughly. To avoid above invalid records, we filtered the gazetteer record by the following rule: a valid record should record any wild mammal of which the body length is below 1 meter (including those are not analyzed in this research, like macaca monkey, badger or wild rabbit) (*Table 1*).

Table 1: Qualifying the valid data.

| Standards | Qualification |
|---|---|
| Only livestock | Invalid data |
| Only wild mammals with body length ⩾1m | Invalid data |
| Wild mammals with body length ⩾1m, and wild mammals with body length <1m | Valid data |
| Only wild mammals with body length <1m | Valid data |

### 2.2 Spatial processing:

Although the names and areas of many counties have changed since the Qing Dynasty, we were able to locate the data on modern maps by using the current local government locations to identify the corresponding locations of the local gazetteers.

We selected 22 province-level regions in eastern continent China as the research area (excluding Tibetan Plateau part in Sichuan and Yunnan) which roughly corresponds withthe eastern region of the Heihe-Tengchong Line (*Fig.1*), , containing approximately 90% of the human population of China from ancient to modern eras(Hu 1935).

We used the Thiessen polygons (or called Voronoi) tool to reconstruct the distribution based on the valid records using ArcGIS Desktop 10.3. In these reconstructions, the potential high-possibility ( ⩾ 50%) polygons generated by the presence records, and the potential low-possibility (<50%) polygons generated by the absence records. This tool is used to divide the areas covered by the input data point features into polygons, and each polygon represent the full areas where any location within it is closer to its associated input point than to any other input points(Chi 2011). Finally, we use the fishnet tool to build 10819 20km*20km grids, to extract the data from the layers.

2.3 Temporal processing:

To keep the balance between the diachronicalspatial dimensions, we selected 1723-1949 as the research span, and sorted the valid points into 3 periods according to the reigning emperor, since many of local gazetteers are labeled under the reigning emperor's title without specifying the year, and adopted the later one when there is more than one record in the same location in one period.

Period A covers the period of 1723-1820, with 688 valid data points, Period B covers 1821-1911 , with 780 valid data points, and Period C covers 1912-1949, with 447 valid data points.

This research has excluded the modern distribution of mammalian predators because their distribution was greatly reduced as a consequence of a campaign by the Chinese government to hunt the "harmful beasts" since the 1950s.

2.4 Relations of predator distribution：

We used the Gamma coefficient to measure the relations between each predator in SPSS 22. This statistic is a measure of the strength and direction of associations between two Ordinal variables. Gamma treats the variables symmetrically and ranges in [-1,1], with the ±symbol reflecting the direction of correlation and the absolute value indicating the strength of association (Goodman & Kruskal 1953; Agresti 2002).

$$\text{Gamma}=(N_c - N_d)/(N_c + N_d)$$

Nc is the number of concordant pairs, and Nd is the number of discordant pairs.

2.5 Anthropogenic influence on predator distribution:

The human population data in the periods were extracted from the reconstruction of censuses from 1820 (Period A), 1910 (Period B) and 1953 (Period C) by Cao (2001). We then mapped the data using the Kernel Density tool with a 200km search-radius in ArcGIS Desktop 10.3.

We measured the influence of human population density(HPD) on predator distribution between each predator by Somers' $d_{yx}$ statistic in software SPSS 22. This statistic is a measure of the influence strength of an ordinal variable on the other ordinal variable. The $d_{yx}$ ranges in [-1,1], the sign reflects the direction of influence and the absolute value reflects the strength (Somers 1962).

$$d_{yx}=(N_c - N_d)/(N_c + N_d + T_y)$$

$N_c$ is the number of concordant pairs, $N_d$ is the number of discordant pairs. $T_y$ is the number of tied pairs only on dependent variable.

**3.Result:**

3.1 The change of distribution area

We reconstructed the distribution of target predators and human population density (HPD) (*SI*).

The distribution of the three largestpredators, (tigers, leopards and bears), retreated by varying degrees; by contrast, the distribution of the smaller bodied predators (wolves, foxes and dholes), expanded (*Fig.2, Fig.3*).

Based on the body size and the trend of distribution change, we sorted tigers, leopards and bears into the large/apex predator group, and wolves, foxes and dholes into the mesopredator group.

3.2 Relations between each predator and others

According to the relations of distributions between predators (*Fig.4*), the predators in the large/apex predator group displayed strongly positive correlations with each other in all periods. In the mesopredator group, wolves and foxes were highly correlated, the correlation between wolves/foxes and large/apex predators were weak but still generally positive; while for dhole, it was strongly positive correlated with the large/apex predators but much weaker with other mesopredators.

3.3 Anthropogenic influence on predator distribution

The results (*Fig.5*) show that HPD exerted negative influence upon the distributions of each predator during each period. While the influences on tigers, leopards and bears keptare clearly negative throughout, the influences upon wolves, foxes and dholees were slightly negative in period A, but became more strongly negative in later periods.

3.4 The high-possibility proportion in different HPD area in each period

We sorted the area into groups by HPD value to calculate the proportion of

high-possibility predator distribution area in these groups (*Fig.6*). In all periods, the high-possibility area proportion of large/apex predators decreased with higher HPD in general. By contrast, the decreasing trend of mesopredators was much milder in Period A, but became steeper in the later periods, with the proportion in lower HPD area increasing.

## 4.Discussion：

The reconstruction of distributions using both presence and absence data is more accurate than previous studies with have only used presence data (*Fig.7*). It overcomes several disadvantages of the latter: (1) how large area does a data point represent is determined by subjectivity of different researchers (Zhou & Zhang 2013; Li *et al.* 2015; Turvey *et al.* 2015; Wan *et al.* 2019; Teng *et al.* 2020), but now it is replaced by objective interpolation; (2) there are few gazetteers in the area with social turbulence or few human population, causing the presence records were also few there (*Fig.7.a*), we fixed this bias by the Thiessen polygons; (3) if there are new data, the reconstruction might change obviously (e.g. there are much more new found records in Wen(2018)'s new research than his previous research (Wen 2009) then the reconstruction changed obviously), instead of it, new data will just improve the resolution ratio of reconstruction in our methods.

The distribution of wild animals is significantly shaped by anthropogenic disturbances thoughout the long history of China (Chatterjee *et al*. 2012). We found that the distribution of large/apex predators retreated over successive periods of time, supporting similar views of previous studies (He 1993; 1997; Wen 2009; 2013; 2018; Wan *et al.* 2019; Teng *et al.* 2020) , and reflecting the recession of the eco-system over the same time frame.

Not to be noted by previous studies, we find the distributions of mesopredator expanded in eastern China, supporting the mesopredator release hypothesis (Prugh *et al*. 2009), which said that the population of mesopredator would grow rapidly after the constrains from large/apex predators were withdrawn.

The correlations among the three large/apex predators (tigers, leopards and bears) were strongly positive during all periods, indicating that these species have similar environmental requirements. The distribution of dholes was also strongly and positively correlated with the large/apex predators, even though its distribution expanded slightly. The major relations between wolf/fox and large/apex predators were just slightly positive. On one hand, there were many co-low-possibility grid where the extremely high HPD constrained all of the predators. On the other hand, the mesopredators could be co-existent with the large/apex predators, especially at the edges of both ranges (Newsome *et al*. 2017).

The expansion of wolves was mainly in low-mid HPD (<100 person/km$^2$ ) areas. The body mass of wolves is transitive between apex predator and mesopredator. Although wolves are attributed the role of a retreating apex predator in many studies (Prugh *et al*. 2009; Newsome *et al*. 2017), our results are more consistent with

research conducted in Sikhote, Russia (Miquelle *et al*. 2005) where wolves are viewed as mesopredators being constrained by tigers. This difference shows that the classification between apex and mesopredator depends not only on species (Wallach *et al.* 2015), but also on the local eco-system.

Although dholes are a kind of mesopredator with a middling body size and its high-possibility area expanded slightly, it distribution was strongly positively correlated with the large/apex predators, and only slightly positive with the other mesopredators. As a mesopredator dholes would be supposed to suffer from the constraints of apex predators, but recent studies in South and South-east Asia revealed that dholes can in general peacefully co-exist with tigers and leopards (Johnsingh 1992; Karanth & Sunquist 2000; Wang & Macdonald 2009; Jerks *et al*. 2012; Hayward 2014; Rayan & Linkie 2016), and thus form a relationship as a "predator guild". This study supports the view of such a predator guild, and supports it over a longer temporal span than previous studies. The relationship between dholes and bears is also strongly positively correlated, but we did not find any relevant predator guild study. So we infer that the reason is that the environmental demands of bears are similar to those of tigers and leopards, as the cause of such similar co-existing relations.

The influence of HPD on large/apex predators is evidently negative, proving that the retreat of large/apex predator is likely caused by human disturbance. For the mesopredators, the increasingly negative influence of HPD, and the higher distribution proportion in lower HPD area in the later period, also suggests that the competition from large/apex predators constrained the distribution of mesopredators. We propose that there was a trade-off phenomenon in which under a moderate HPD the expulsion of larger predators may compensate the directly negative influence of HPD on mesopredators.

## 5.Conclusion and Prospect:

Our study aimed to correct the existing method for reconstruction of historical distribution based on local gazetteers by adopting the use of both presence and absence data. Based on our reconstructions, we provide direct proof of human disturbance on mammal distribution in China, and extend support for the mesopredator release hypothesis.

We have also collected records for other wild mammals from local gazetteers in China, and have built a database of Wild Mammal Records in Chinese Local Gazetteers. We aim to continue relevant studies using this data in the future.

**Author Contributions:**

Kaijin Hu designed research, collected data and wrote the paper; and Chunhui Hao modified the introduction.

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**Reference:**

Agresti, A. (2002). Categorical Data Analysis. In *Contemporary Sociology* (Vol. 22, Issue 1). John Wiley & Sons, Inc. https://doi.org/10.1002/0471249688

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., Mersey, B., & Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*(7336), 51–57. https://doi.org/10.1038/nature09678

Boakes, E. H., McGowan, P. J. K., Fuller, R. A., Chang-qing, D., Clark, N. E., O'Connor, K., & Mace, G. M. (2010). Distorted Views of Biodiversity: Spatial and Temporal Bias in Species Occurrence Data. *PLoS Biology*, *8*(6), e1000385. https://doi.org/10.1371/journal.pbio.1000385

Cao, S. (2001). *History of Population in China, vol. V.* Fudan University Press.(In Chinese)

Cardillo, M., Mace, G. M., Gittleman, J. L., Jones, K. E., Bielby, J., & Purvis, A. (2008). The predictability of extinction: biological and external correlates of decline in mammals. *Proceedings of the Royal Society B: Biological Sciences*, *275*(1641), 1441–1448. https://doi.org/10.1098/rspb.2008.0179

Cardillo, M., & Meijaard, E. (2012). Are comparative studies of extinction risk useful for conservation? *Trends in Ecology & Evolution*, *27*(3), 167–171. https://doi.org/10.1016/j.tree.2011.09.013

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Science Advances*, *1*(5), 9–13. https://doi.org/10.1126/sciadv.1400253

Chatterjee, H., Tse, J. S. Y., & Turvey, S. (2012). Using Ecological Niche Modelling to Predict Spatial and Temporal Distribution Patterns in Chinese Gibbons: Lessons from the Present and the Past. *Folia Primatologica*, *83*, 85–99. https://doi.org/10.1159/000342696

Chi, J. (2011). *Be Proficient in ArcGIS Geographical Information Zystem*. Tsinghua University Press.(In Chinese)

Davidson, A. D., Hamilton, M. J., Boyer, A. G., Brown, J. H., & Ceballos, G. (2009). Multiple ecological pathways to extinction in mammals. *Proceedings of the National Academy of Sciences*, *106*(26), 10702–10705. https://doi.org/10.1073/pnas.0901956106

Dirzo, R., & Raven, P. H. (2003). Global State of Biodiversity and Loss. *Annual Review of Environment and Resources*, *28*(1), 137–167. https://doi.org/10.1146/annurev.energy.28.050302.105532

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., & Collen, B. (2014). Defaunation in the Anthropocene. *Science*, *345*(6195), 401–406. https://doi.org/10.1126/science.1251817

Fritz, S. A., Bininda-Emonds, O. R. P., & Purvis, A. (2009). Geographical variation in predictors of mammalian extinction risk: big is bad, but only in the tropics. *Ecology Letters*, *12*(6), 538–549. https://doi.org/10.1111/j.1461-0248.2009.01307.x

Gill, J. A. (2007). Approaches to measuring the effects of human disturbance on birds. *Ibis*, *149*(SUPPL. 1), 9–14. https://doi.org/10.1111/j.1474-919X.2007.00642.x

Goodman, L. A., & Kruskal, W. H. (1954). Measures of Association for Cross Classifications. *Journal of the American Statistical Association*, *49*(268), 732–764. https://doi.org/10.1080/01621459.1954.10501231

Hayward, M. W., Lyngdoh, S., & Habib, B. (2014). Diet and prey preferences of dholes (Cuon alpinus): dietary competition within Asia's apex predator guild. *Journal of Zoology*, *294*(4), 255–266.

He, F., & Hubbell, S. P. (2011). Species-area relationships always overestimate extinction rates from habitat loss. *Nature*, *473*(7347), 368–371. https://doi.org/10.1038/nature09985

He, Y. (1997). *The distributions of rare mammal (II) in China*. Hunan Normal University Press.(In Chinese)

He, Y. (1993). *The distributions of rare mammal in China*. Hunan Science & Technology Press.(In Chinese)

Hu, H. (1935). Distribution of Population in China. *Acta Geographica Sinica*, *02*, 33–74.(In Chinese)

Jablonski, D. (2008). Extinction and the spatial dynamics of biodiversity. *Proceedings of the National Academy of Sciences*, *105*(Supplement 1), 11528–11535. https://doi.org/10.1073/pnas.0801919105

Jablonski, D. (2001). Lessons from the past: Evolutionary impacts of mass extinctions. *Proceedings of the National Academy of Sciences*, *98*(10), 5393–5398. https://doi.org/10.1073/pnas.101092598

Jackson, J. B. C. (2008). Ecological extinction and evolution in the brave new ocean. *Proceedings of the National Academy of Sciences*, *105*(Supplement 1), 11458–11465. https://doi.org/10.1073/pnas.0802812105

Jenks, K. E., Kitamura, S., Lynam, A. J., Ngoprasert, D., Chutipong, W., Steinmetz, R., Sukmasuang, R., Grassman, L. I., Cutter, P., Tantipisanuh, N., & others. (2012). Mapping the distribution of dholes, Cuon alpinus (Canidae, Carnivora), in Thailand. *Mammalia*, *76*(2), 175–184.

Jiang, H., Lian, J., Wang, J., Liu, Z., & Feng, M. (1995). Influence of population growth stress on distribution of macaque monkey in south China. *Chinese Journal of Applied Ecology*, *6*(2), 176–181.(In Chinese)

Johnsingh, A. J. T. (1992). Prey selection in three large sympatric carnivores in Bandipur. *Mammalia*, *56*(4). https://doi.org/10.1515/mamm.1992.56.4.517

Karanth, K. U., & Sunquist, M. E. (2000). Behavioural correlates of predation by tiger (*Panthera tigris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. *Journal of Zoology*, *250*(2), 255–265.

Kitahara, M., & Fujii, K. (1994). Biodiversity and community structure of temperate butterfly species within a gradient of human disturbance: An analysis based on the concept of generalist vs. Specialist strategies. *Researches on Population Ecology*, *36*(2), 187–199. https://doi.org/10.1007/BF02514935

Leakey, R. E., & Roger Lewin. (1996). *The sixth extinction: Patterns of life and the future of humankind*. Anchor.

Li, B., He, G., Guo, S., Hou, R., Huang, K., Zhang, P., Zhang, H., Pan, R., & Chapman, C. A. (2020). Macaques in China: Evolutionary dispersion and subsequent development. *American Journal of Primatology*, *82*(7), e23142. https://doi.org/10.1002/ajp.23142

Li, B., Pan, R., & Oxnard, C. E. (2002). Extinction of snub-nosed monkeys in China during the past 400 years. *International Journal of Primatology*, *23*(6), 1227–1244. https://doi.org/10.1023/A:1021122819845

Li, G. P. (1998). *Agriculture in Ancient China*. The Commercial Press.(In Chinese)

Li, X., Jiang, G., Tian, H., Xu, L., Yan, C., Wang, Z., Wei, F., & Zhang, Z. (2015). Human impact and climate cooling caused range contraction of large mammals in China over the past two millennia. *Ecography*, *38*(1), 74–82.

Lorenzen, E. D., Nogués-Bravo, D., Orlando, L., Weinstock, J., Binladen, J., Marske, K. A., Ugan, A., Borregaard, M. K., Gilbert, M. T. P., Nielsen, R., Ho, S. Y. W., Goebel, T., Graf, K. E., Byers, D., Stenderup, J. T., Rasmussen, M., Campos, P. F., Leonard, J. A., Koepfli, K. P., … Willerslev, E. (2011). Species-specific responses of Late Quaternary megafauna to climate and humans. *Nature*, *479*(7373), 359–364. https://doi.org/10.1038/nature10574

MacPhee, DE, R., & eds Hans-Dieter Sues. (1999). Extinctions in Near Time. In *Extinctions in Near Time*. Springer Science & Business Media. https://doi.org/10.1007/978-1-4757-5202-1

Martin, P. S. (2005). *Twilight of the mammoths: Ice Age extinctions and the rewilding of America*. Univ of California Press. https://doi.org/10.5860/choice.43-4679

Miquelle, D., Stephens, P., Smirnov, E. N., Goodrich, J., Zaumyslova, O. Y., & Myslenkov, A. I. (2005). *Tigers and Wolves in the Russian Far East: Competitive Exclusion, Functional Redundancy and Conservation Implications* (pp. 179–207).

Newsome, T. M., Greenville, A. C., Ćirović, D., Dickman, C. R., Johnson, C. N., Krofel, M., Letnic, M., Ripple, W. J., Ritchie, E. G., Stoyanov, S., & Wirsing, A. J. (2017). Top predators constrain mesopredator distributions. *Nature Communications*, *8*(May), 1–7. https://doi.org/10.1038/ncomms15469

Nüchel, J., Bøcher, P. K., Xiao, W., Zhu, A.-X., & Svenning, J.-C. (2018). Snub-nosed monkeys (Rhinopithecus): potential distribution and its implication for conservation. *Biodiversity and Conservation*, *27*(6), 1517–1538. https://doi.org/10.1007/s10531-018-1507-0

Öckinger, E., Schweiger, O., Crist, T. O., Debinski, D. M., Krauss, J., Kuussaari, M., Petersen, J. D., Pöyry, J., Settele, J., Summerville, K. S., & Bommarco, R. (2010). Life-history traits predict species responses to habitat area and isolation: a cross-continental synthesis. *Ecology Letters*, *13*(8), no--no. https://doi.org/10.1111/j.1461-0248.2010.01487.x

Pereira, H. M., Leadley, P. W., Proença, V., Alkemade, R., Scharlemann, J. P. W., Fernandez-Manjarrés, J. F., Araújo, M. B., Balvanera, P., Biggs, R., Cheung, W. W. L., Chini, L., Cooper, H. D., Gilman, E. L., Guénette, S., Hurtt, G. C., Huntington, H. P., Mace, G. M., Oberdorff, T., Revenga, C., … Walpole, M. (2010). Scenarios for global biodiversity in the 21st century. *Science*, *330*(6010), 1496–1501. https://doi.org/10.1126/science.1196624

Pimm, S. L., Russell, G. J., Gittleman, J. L., & Brooks, T. M. (1995). The Future of Biodiversity. *Science*, *269*(5222), 347–350. https://doi.org/10.1126/science.269.5222.347

Pocock, M. J. O. (2011). Can traits predict species' vulnerability? A test with farmland passerines in two continents. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1711), 1532–1538. https://doi.org/10.1098/rspb.2010.1971

Prugh, L. R., Stoner, C. J., Epps, C. W., Bean, W. T., Ripple, W. J., Laliberte, A. S., & Brashares, J. S. (2009). The Rise of the Mesopredator. *Bioscience*, *9*, 9.

Qian, T., Chi, Y., Xi, C., Li, Z., & Wang, J. (2020). Changes in the historical and current habitat ranges of rare wild mammals in China: A case study of six taxa of small-to large-sized mammals. *Sustainability (Switzerland)*, *12*(7), 1–19. https://doi.org/10.3390/su12072744

Rahbek, C., & Colwell, R. K. (2011). Species loss revisited. *Nature*, *473*(7347), 288–289. https://doi.org/10.1038/473288a

Rayan, D. M., & Linkie, M. (2016). Managing conservation flagship species in competition: Tiger, leopard and dhole in Malaysia. *Biological Conservation*, *204*, 360–366.

Sala, O. E. (2000). Global Biodiversity Scenarios for the Year 2100. *Science*, *287*(5459), 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Sandom, C., Faurby, S., Sandel, B., & Svenning, J.-C. (2014). Global late Quaternary megafauna extinctions linked to humans, not climate change. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1787), 20133254. https://doi.org/10.1098/rspb.2013.3254

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A. S. L., Stuart, S. N., Temple, H. J., Baillie, J., Boitani, L., Lacher, T. E., Mittermeier, R. A., Smith, A. T., Absolon, D., Aguiar, J. M., Amori, G., Bakkour, N., … Young, B. E. (2008). The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. *Science*, *322*(5899), 225–230. https://doi.org/10.1126/science.1165115

Somers, R. H. (1962). A New Asymmetric Measure of Association for Ordinal Variables. *American Sociological Review*, *27*(6), 799. https://doi.org/10.2307/2090408

Teng, S. N., Xu, C., Teng, L., & Svenning, J. C. (2020). Long-term effects of cultural filtering on megafauna species distributions across China. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(1), 486–493. https://doi.org/10.1073/pnas.1909896116

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., De Siqueira, M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Peterson, A. T., Phillips, O. L., & Williams, S. E. (2004). Letter to nature: Extinction risk from climate change. *Nature*, *427*(145–148), 145–148.

Turvey, S. T., Crees, J. J., & Di Fonzo, M. M. I. (2015). Historical data as a baseline for conservation: reconstructing long-term faunal extinction dynamics in Late Imperial–modern China. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1813), 20151299. https://doi.org/10.1098/rspb.2015.1299

Turvey, S. T., Crees, J. J., Li, Z., Bielby, J., & Yuan, J. (2017). Long-term archives reveal shifting extinction selectivity in China's postglacial mammal fauna. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1867), 20171979. https://doi.org/10.1098/rspb.2017.1979

Tylianakis, J. M., Tscharntke, T., & Lewis, O. T. (2007). Habitat modification alters the structure of tropical host–parasitoid food webs. *Nature*, *445*(7124), 202–205. https://doi.org/10.1038/nature05429

Wake, D. B., & Vredenburg, V. T. (2008). Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Academy of Sciences*, *105*(Supplement 1), 11466–11473. https://doi.org/10.1073/pnas.0801921105

Wallach, A. D., Izhaki, I., Toms, J. D., Ripple, W. J., & Shanas, U. (2015). What is an apex predator. *Oikos*, *124*(11), 1453–1461.

Wan, X., Jiang, G., Yan, C., He, F., Wen, R., Gu, J., Li, X., Ma, J., Stenseth, N. C., & Zhang, Z. (2019). Historical records reveal the distinctive associations of human disturbance and extreme climate change with local extinction of mammals. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(38), 19001–19008. https://doi.org/10.1073/pnas.1818019116

Wan, X., & Zhang, Z. (2017). Climate warming and humans played different roles in triggering Late Quaternary extinctions in east and west Eurasia. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1851), 20162438. https://doi.org/10.1098/rspb.2016.2438

Wang, S. W., & Macdonald, D. W. (2009). Feeding habits and niche partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. *Journal of Zoology*, *277*(4), 275–283.

Wen, R. S. (2013). *Geographical distribution of wild animals in ancient China*. Scientific and Technological Press of Shandong.(In Chinese)

Wen, R. S. (2009). *The distribution and changes of rare wild animals in China*. Scientific and Technological Press of Shandong.(In Chinese)

Wen, R. S. (2018). *The distribution and changes of rare wild animals in China(sequel)*. Scientific and Technological Press of Shandong.(In Chinese)

Yap, T. A., Koo, M. S., Ambrose, R. F., Wake, D. B., & Vredenburg, V. T. (2015). Averting a North American biodiversity crisis. *Science*, *349*(6247), 481–482. https://doi.org/10.1126/science.aab1052

Zhao, X., Ren, B., Garber, P. A., Li, X., & Li, M. (2018). Impacts of human activity and climate change on the distribution of snub-nosed monkeys in China during the past 2000 years. *Diversity and Distributions*, *24*(1), 92–102. https://doi.org/10.1111/ddi.12657

Zhou, Y. H., & Zhang, P. (2013). Distribution and vicissitude of gibbons（*Hylobatidae*）in China during the last 500 years. *Acta Theriologica Sinica*, *33*(3), 258–266.(In Chinese)

**Fig.1** Research area (blue) in eastern China and the Heihe-Tengchong Line (red).

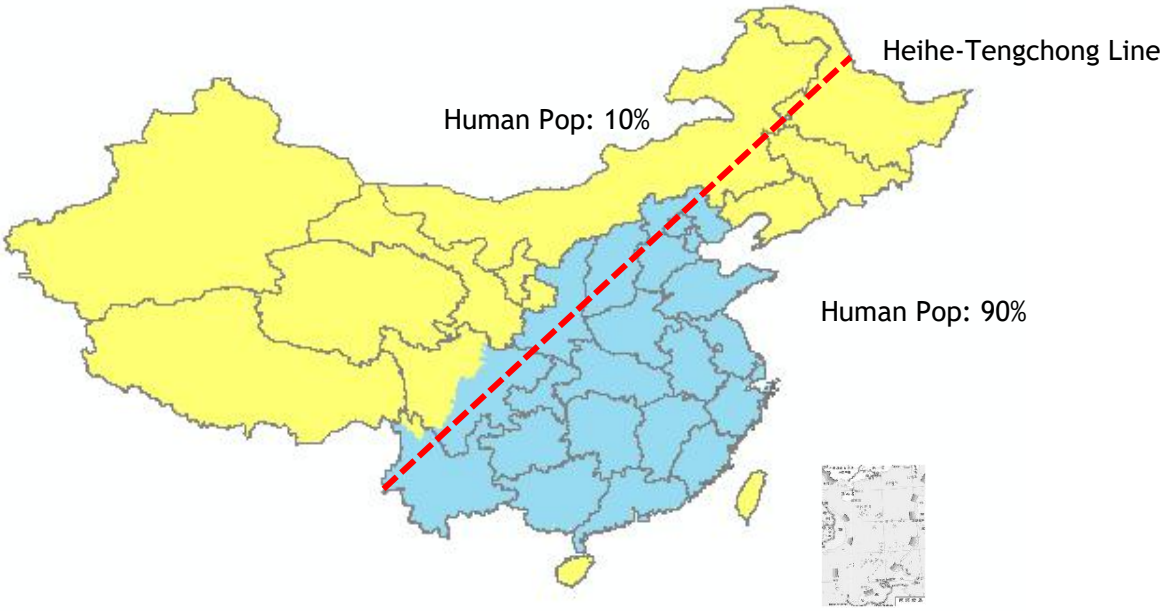


**Fig.2** The change of high-possibility area of predators from Period A to Period C.

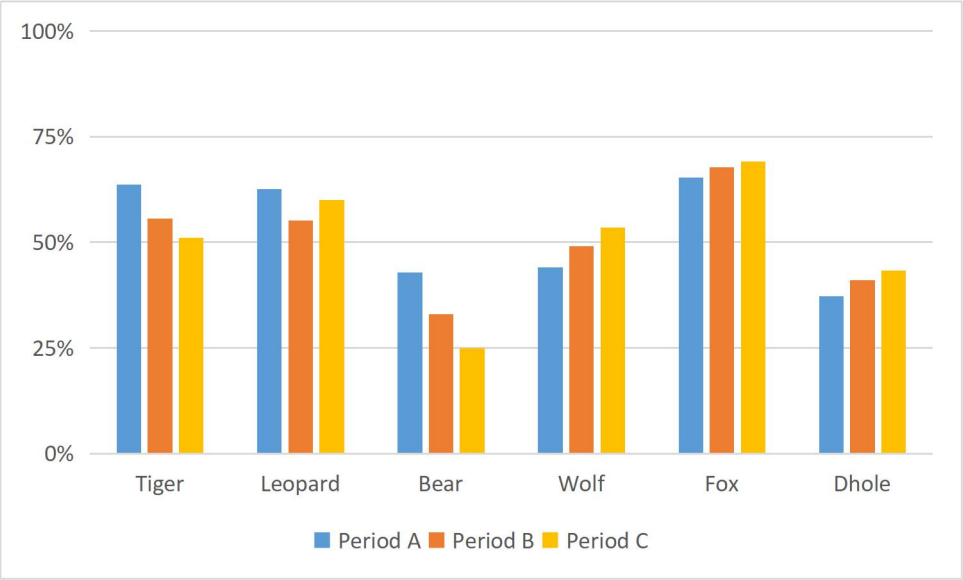



**Fig.3** The change from Period A to Period C(Change from Period A to Period C: Value=$(S_C-S_A)/S_A$)

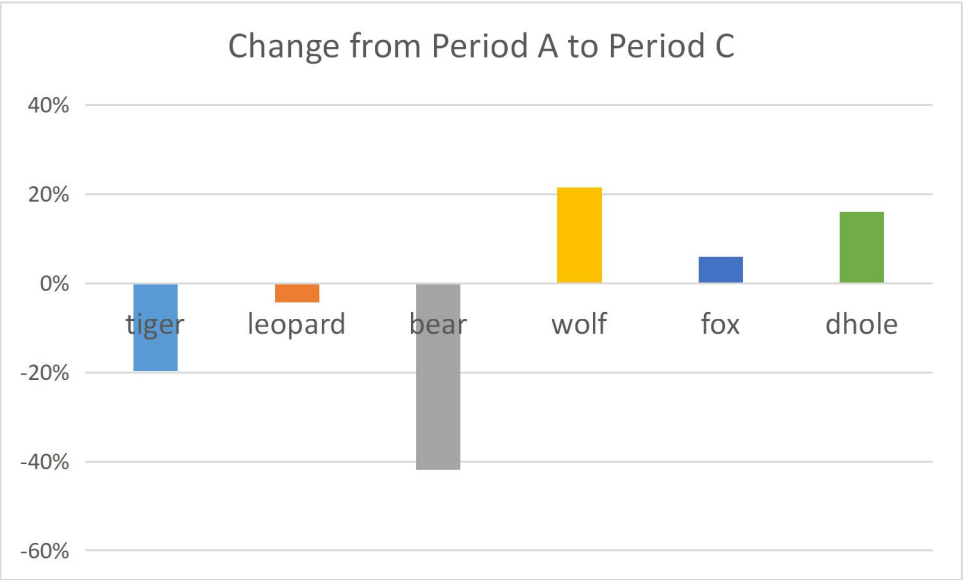


**Fig.4** Relations between each predator and others (Goodman and Kruskal's Gamma coefficient) (N.S : not significant)

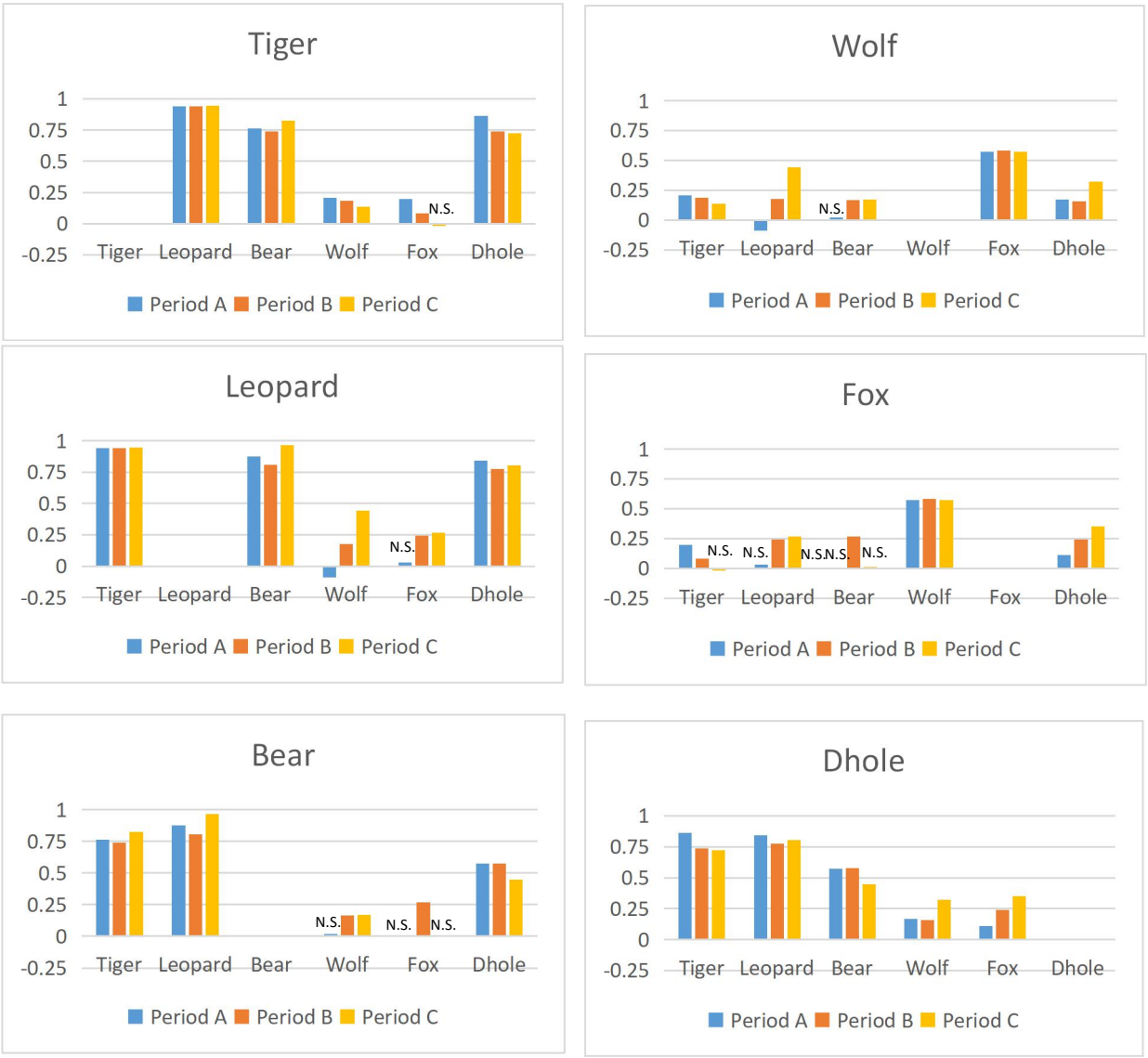


**Fig.5** HPD Influence on predator distribution (Somers' dyx) (N.S : not significant)

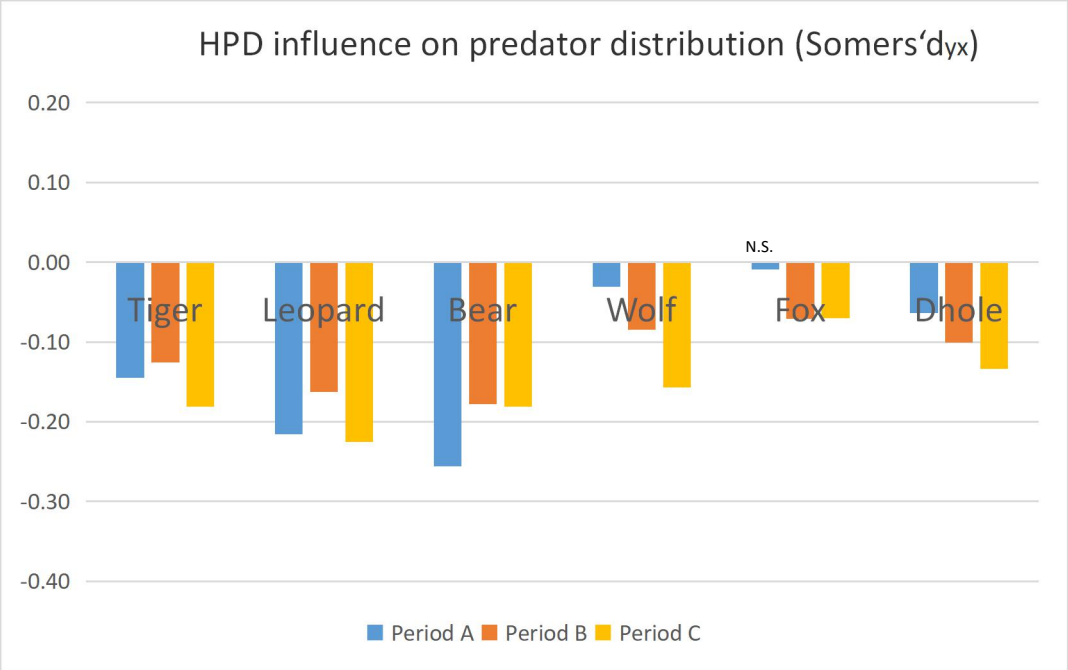
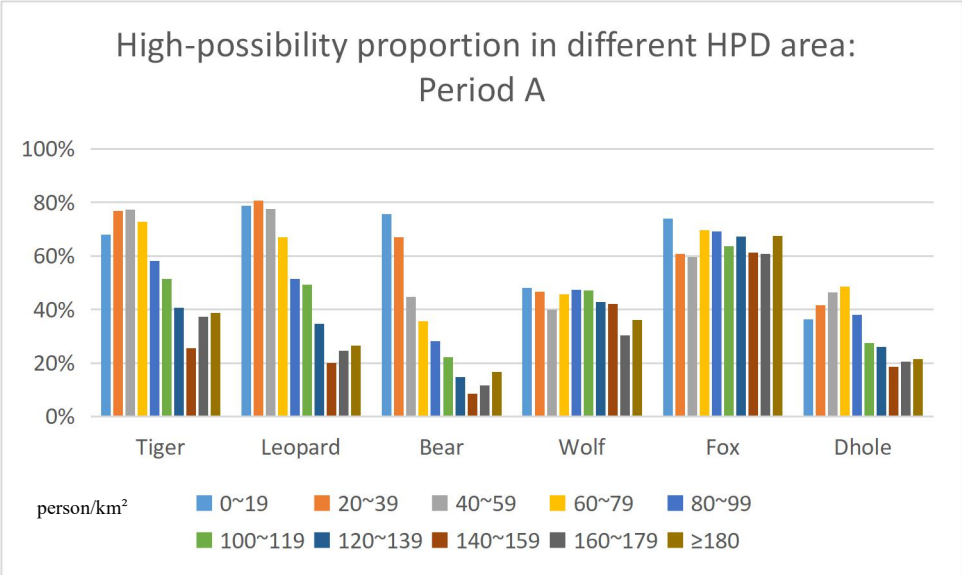
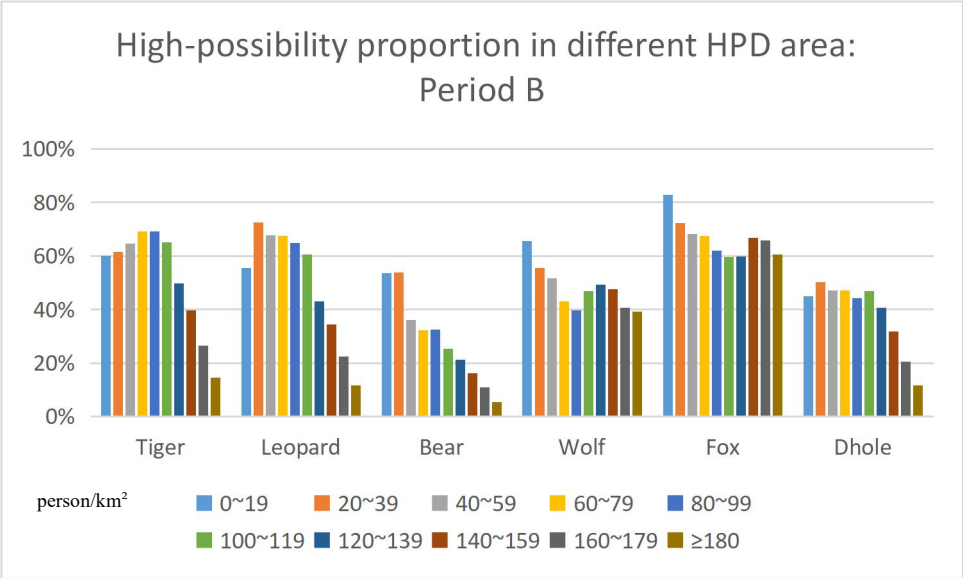



**Fig.6** High-possibility proportion in different HPD area in each period





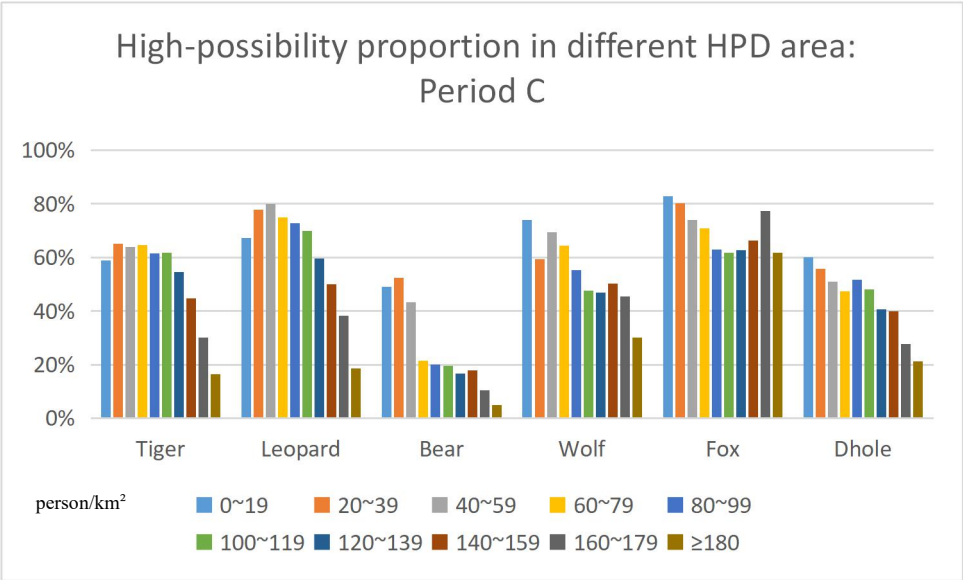
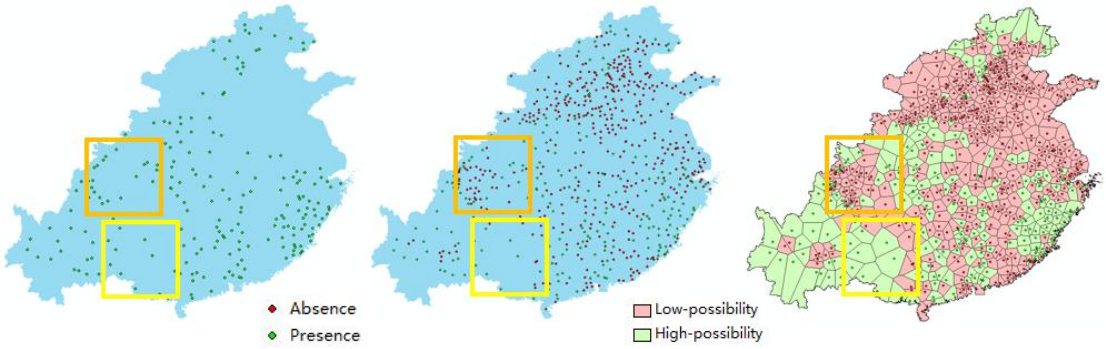



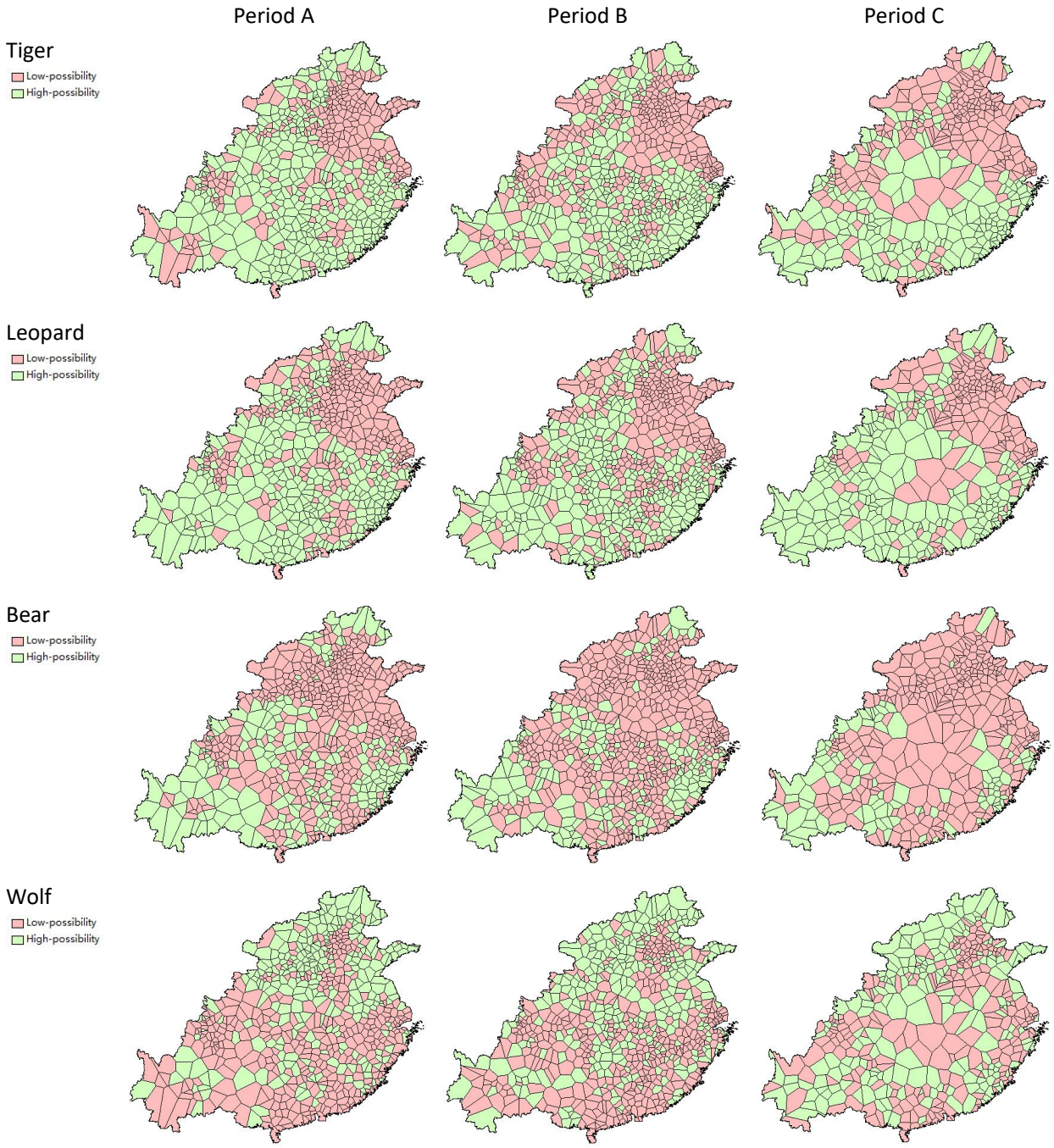

**Fig.7** a.The bear presence records(green) in Period A; b. The bear presence records(green) and absence records(red) in Period A; c. The Thiessen polygon reconstruction of bear distribution based on b., high-possibility area(green) and low-possibility area(red).

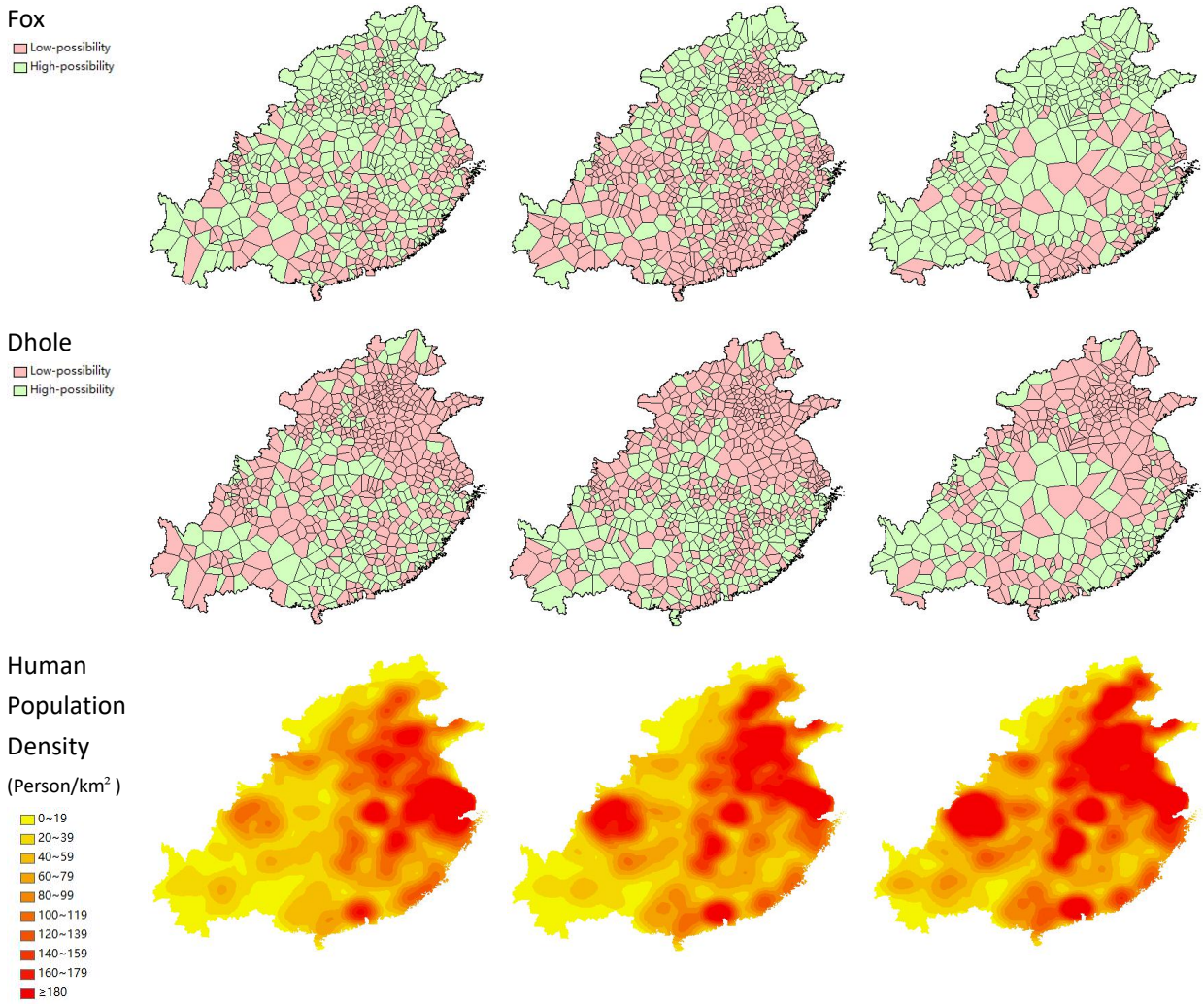



a b c

**Supplementary Information:**

The distribution of predators and human population density(HPD)




Fox
Low-possibility
High-possibility
Dhole
Low-possibility
High-possibility
Human
Population
Density
(Person/km$^2$ )
0~19
20~39
40~59
60~79
80~99
100~119
120~139
140~159
160~179
≥180