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

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Abstract:

Background: Humans have been causing the sixth wave of mass extinction of biodiversity. The situation of predators, especially of carnivores, is a key indicator of biodiversity, and the mesopredator release is a typical phenomenon in ecosystem recess. Local gazetteers(地方志) are a rich resource for historical biodiversity research. But there are obvious biases in previous studies focusing in only presence records and neglecting the absence records. We recollected and analyze the records by fixed methods to research historical change of biodiversity.

Methods: Innovatively, this research uses both presence and absence records from local gazetteers to reconstruct the distribution of 8 kinds of mammalian predators (i.e. tiger, leopard, bear, wolf, fox, civet, dhole and mustelid) in eastern China from 1573 A.D. to 1949 A.D. (sorted into 4 periods). Then we analyze the distribution changes, the relation between animals and the influence from human.

Results: With the human population booming, the distribution of large/apex predators retreated overall, but the distribution of mesopredators expanded overall. Besides, the predator distribution relations formed different groups, not match the body size groups totally.

Conclusions: Based on our reconstructions, we provide direct proof of human disturbance on mammal distribution in China, and extend support for the mesopredator release hypothesis. And we tested the predator guild hypothesis by proving that dhole were successful to coexist with tiger and leopard in history.

Prospects: We have also collected records for other wild animals from local gazetteers in China. Based on the collection, we have built the Database of Wild Mammal Records in Chinese Local Gazetteers and are building the Database of Wild Bird Records in Chinese Local Gazetteers. We aim to continue relevant studies using these databases in the future.

Keywords: Local gazetteer; Historical distribution; Mesopredator release; Predator Guild

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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 (Chatterjee et al. 2012; Qian *et al.* 2020). Meanwhile, the population in China has

increased significantly since the introduction of American crops in the 16th century, which triggered prosperous socio-economic 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 and situations, including those related to local wildlife, and previous researchers had published numerous collection list of animal records (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 observation 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 observation (or called last occurrence) time which is interpreted from the most recent record there. But the collection of data from gazetteer-rich and gazetteer-poor regions/periods 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 8 kinds of wild mammals in eastern China from 1573 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/) and *The Series of Rare Local Gazetteers in National Library*（Fu *et al.* 2016）. All 8 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 8 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 8 predators in eastern China.

2.Methods:

Overview:

We chose the eastern part of China as research area, and the temporal span 1573-1949 as research period, for there are rich amount of local gazetteers preserved, and the human population experienced a huge increase. We collected both presence and absence data of each target mammal predator from local gazetteers, and sorted them into 4 periods. In each period, we used the tool Inverse Distance Weighed (IDW) to reconstruct the distribution probability layers by ArcGIS 10.3. Then we used 20km*20km grids to extract the continuous value in those layers and the human population density layers, to analyze the distribution changes, the relation between animals and the influence from human. (see *Fig. 1*)

(Insert Fig.1)

2.1 Data collection

We collected the data from the Chinese Digital Gazetteer Database (http://x.wenjinguan.com/) and *The Series of Rare Local Gazetteers in National Library*（Fu *et al.* 2016）. Previous studies used only presence points to reconstruct the presence and pseudo-absence(actually data missing) maps, then extracted the binary value in each grid to analyse with limited maths methods. Different to above way, we used both presence and absence points to reconstruct the probability maps. Then we extracted the continuous value in each grid to analyse.Previous studies collect the presence records of the target animal, but in this research, we collected the valid animal diversity records, and acquire the presence and absence records of the target animal. For example, there are two animal records in different local gazetteers(see row 1 in Fig.1), A recorded “Tiger, Leopard, Deer, Roe Deer .... Hedgehog, Vole, Ibex.” (Wolf not existed), and B recorded “Cattle, Horse ... Wolf, Dog, Badger, Rabbit, Mouse” (Wolf existed). The previous studies would output “There were wolves in B” merely, but our study would output “There were wolves in B, and there were no wolves in A” (see row 2 in *Fig.1*).

There are two kinds of invalid records we excluded. 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 records 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, gibbon or wild rabbit) (see *Table 1*).

(Insert Table.1)

We select 8 kinds of wide distributed predators, i.e. tiger, leopard, bear, wolf, fox, civet, dhole, mustelid, to research. And we match the folk animal kinds to the modern species in China(Smith & Xie 2009) (see *Table. S1*), the the folk toxonomy animal kind can be matched to one or several modern scientific taxonomy species. We sorted tiger, leopard, bear into the large/apex predator group, and the rest into the mesopredator group, according to the definition of megafauna, body mass>45kg or occupying the relevant ecological niche (Roberts *et al.* 2001; Barnosky 2008; Boulanger & Lyman 2014; Villavicencio *et al.* 2016; Moleon *et al*. 2020).

2.2 Spatial processing:

(Insert Fig.2)

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 with the eastern region of the Heihe-Tengchong Line (see *Fig.2*), , containing approximately 90% of the human population of China from ancient to modern eras (Hu 1935). 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 used the Inverse Distance Weighted (IDW) tool to reconstruct the distribution based on the valid records using ArcGIS Desktop 10.3. This tool has been widely applied to species distribution reconstruction (Roberts *et al.* 2004; Hijmans 2012; Takahashi *et al.* 2014; Barbosa 2015; Areias-Guerreiro *et al.* 2016; Palacio *et al.* 2020). The interpolation value in each grid was generated by the the nearest 12(default value) records, including presence records or absence records. The main assumption is that species are more likely to be found closer to presence points and farther from absences (i.e. spatial auto-correlation), and the local influence of points (weighted average) diminishes with distance (Palacio *et al.* 2020). The result value means the probability of animal occurrence, in [0,1]. Besides the accuracy of data, the smoothy probability value is continuous, so we can analyse the distributions much subtler.

Finally, we use the fishnet tool to build 10819 20km*20km grids (in WGS 1984 World Mercator projected coordinate system), to extract the data from the layers.

2.3 Temporal processing:

To keep the balance between the diachronical-spatial dimensions, we selected 1573-1949 as the research span, and sorted the valid points into 4 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 1 covers the span of 1573-1722, with 706 valid data points; Period 2 covers the span of 1723-1820, with 707 valid data points; Period 3 covers the span of 1821-1911 , with 787 valid data points; and Period 4 covers the span of 1912-1949, with 451 valid data points. This layers are cross sections and based on both presence/absence points, so it is appropriate that spans are different in periods. 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.

Since the America crops were introduced to China via Spanish Philippines in the late 16th century and widely expanded in later centuries, the Chinese human

population(which was severely damaged in wars in early 17th century) recovered rapidly and surpassed the historic apex (Li 1998; Cao 2001). According to the HYDE 3.2 database(Goldewijk *et al.* 2017), the average human population density(HPD) increased from 34.9 persons/km² in 1720 to 145.3 persons/km² in 1950.

2.4 Relations of predator distribution：

We used the Kendall's tau-b 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. Kendall's tau-b 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.

$$\text{tau-b}=(N_c - N_d)/[(N_c + N_d + T_x)(N_c + N_d + T_y)]\text{^}0.5$$

N_c is the number of concordant pairs, N_d is the number of discordant pairs. T_x & T_y are the number of tied pairs on each variable.

2.5 Anthropogenic factor influence on predator distribution:

The official censuses in 1820, 1911, 1953 were widely recognized by academy and were the base of Chinese population reconstruction. We selected the nearest layers (1820, 1910 & 1950) in HYDE 3.2 database(Goldewijk *et al.* 2017) to match Period 2, 3 & 4, and selected layer in 1720 to match the breakpoint between Period 1 and Period 2.

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], with the ± symbol reflecting 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 on dependent variable.

3.Result：

3.1 The change of distribution area

We reconstructed the distribution of target predators and human population density (HPD) (see *Table S2*). In the large/apex predator group, distribution of two largest predators, tigers and bears retreated, while the smaller one, leopard, remained almost unchanged; by contrast, the distribution of predators in mesopredator group expanded in varying degrees (see *Fig.3, Fig.4 & Table S3*).

(Insert Fig.3, Fig.4)

3.2 Relations between each predator and others

(Insert Fig.5)

According to the relations of distributions between predators (see *Fig.5 & Table. S4*), 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 negative overall; while for dholes and civets, they were positive correlated with the large/apex predators and each other, but weakly negative with wolves/foxes overall; for mustelids, the values with leopards and bears were negative in earlier periods but turn positive later, and the value with other predators(including tigers) were positive.

3.3 Anthropogenic influence on predator distribution

(Insert Fig.6)

The results (see *Fig.6 & Table. S5*) show that HPD exerted negative influence upon the distributions of each large predator during each period, the influences on tigers, leopards and bears kept are clearly negative throughout. But for mesopredators: (1)wolves, foxes and civets were slightly positive in early periods, but became negative in later periods; (2)dholes were negetive in all periods, like large predators; and (3) mustelids were strongly positive in period 1 to period 3, but turn almost not related and not significant in period 4.

3.4 The average probability in different HPD area in each period

We sorted the area into groups by HPD value to calculate the average probability of predator distribution in these area groups (see *Fig.7*). In all periods, the average probability of large/apex predators and dholes decreased with higher HPD in general. By contrast, the trends of other mesopredators were increasing or inverse-U in earlier periods, but also turn decreasing in the later periods.

(Insert Fig.7)

4.Discussion：

The reconstruction of distributions using both presence and absence data is more accurate than previous studies (Zhou & Zhang 2013; Li *et al.* 2015; Turvey *et al.* 2015; Wan *et al.* 2019; Teng *et al.* 2020) with have only used presence data (see *Fig.8*), especially with the last observation method (see *Fig.9 & Fig.10*). It overcomes several disadvantages of previous studies :

(1)Sampling bias: there are few gazetteers in the area/period with social turbulence or few human population, causing the presence records were also few there/then (*Fig.8.a,*). we fixed this bias by the IDW.

Besides, there are few local gazetteers which were written before 1573 A.D. and still preserved today. That means the presence records (also absence records) are rare in this periods. And the Chinese human population experienced several fluctuations in history. It is inappropriate to infer the decline trend with the sample with these biases. So we did not analyze this period in this research.

(2) New data: 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), for the last observation method, it would lead to inverse interpolation. While in our methods, new data will subtlize the reconstruction.

(3) Subjective: how large area (circle or square, 50km*50km or 100km*100km, etc.) does a data point represent is determined by subjectivity of different researchers (Zhou & Zhang 2013; Turvey *et al.* 2015; Wan *et al.* 2019; Teng *et al.* 2020), leading to different result of distribution area, but in this research, it is replaced by objective interpolation of IDW.

(4). Monotonic recession prejudged: Last observation method can not reflect the expansion or recovery of animal distribution, but only monotonic recession, it is a kind of prejudge. While in our method, the expansion or recovery can also be noted.

Above all, there are several biases in previous studies, and the methods in this study mended them.

(Insert Fig.8, Fig.9 & Fig.10)

We exemplify the contrast of two methods by the distribution of wolf(see *Fig.9 & Fig.10*). The results in last observation method show a retracting trend, but the result values are much different between 100km*100km square grids and 50km*50km square grids. In contrast, the result in IDW method shows a expanding trend.

The distribution of wild animals is significantly shaped by anthropogenic disturbances throughout 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. The decline trend of bears was severe than it of tigers. but the bears are still living in several protected area in research area, while tigers are already extirpated. We infer that the reason is the different home range sizes. Tigers, with large home range, would appear in wide sink-habitat out of source-habitat and be exposed to anthropogenic dangers; while Bears' habitat were majorly source-habitat, and they would survive when the small range habitats are preserved .

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, suggest that these species have similar environmental requirements. The distributions of dholes and civets were also strongly and positively correlated with the large/apex predators, even though its distribution

expanded slightly, suggest that they were adapted to coexisting with large/apex predators.

The major relations between wolves/foxes/mustelids and large/apex predators were negative firstly overall, but tend to turn slight positive overall. We infer that the reasons are 1.there were many co-low-probability grids where the extremely high HPD constrained all of the predators; 2.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-probability area expanded slightly, the 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. And civets are similar with dholes, but still not noticed by previous researches. Mustelids were well adapted (most well one in mesopredator group) to the environment with human disturbing, and they coexisted well with other mesopredator and tiger.

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 suggest 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 methods 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 proofs of human disturbance on mammal distribution in China, and extend support for the mesopredator release hypothesis and the predator guild hypothesis.

We have also collected records for other wild animals from local gazetteers in China. Based on the collection, we have built the Database of Wild Mammal Records in Chinese Local Gazetteers and are building the Database of Wild Bird Records in Chinese Local Gazetteers. We aim to continue relevant studies using these databases 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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Fig.1 Flow Chart

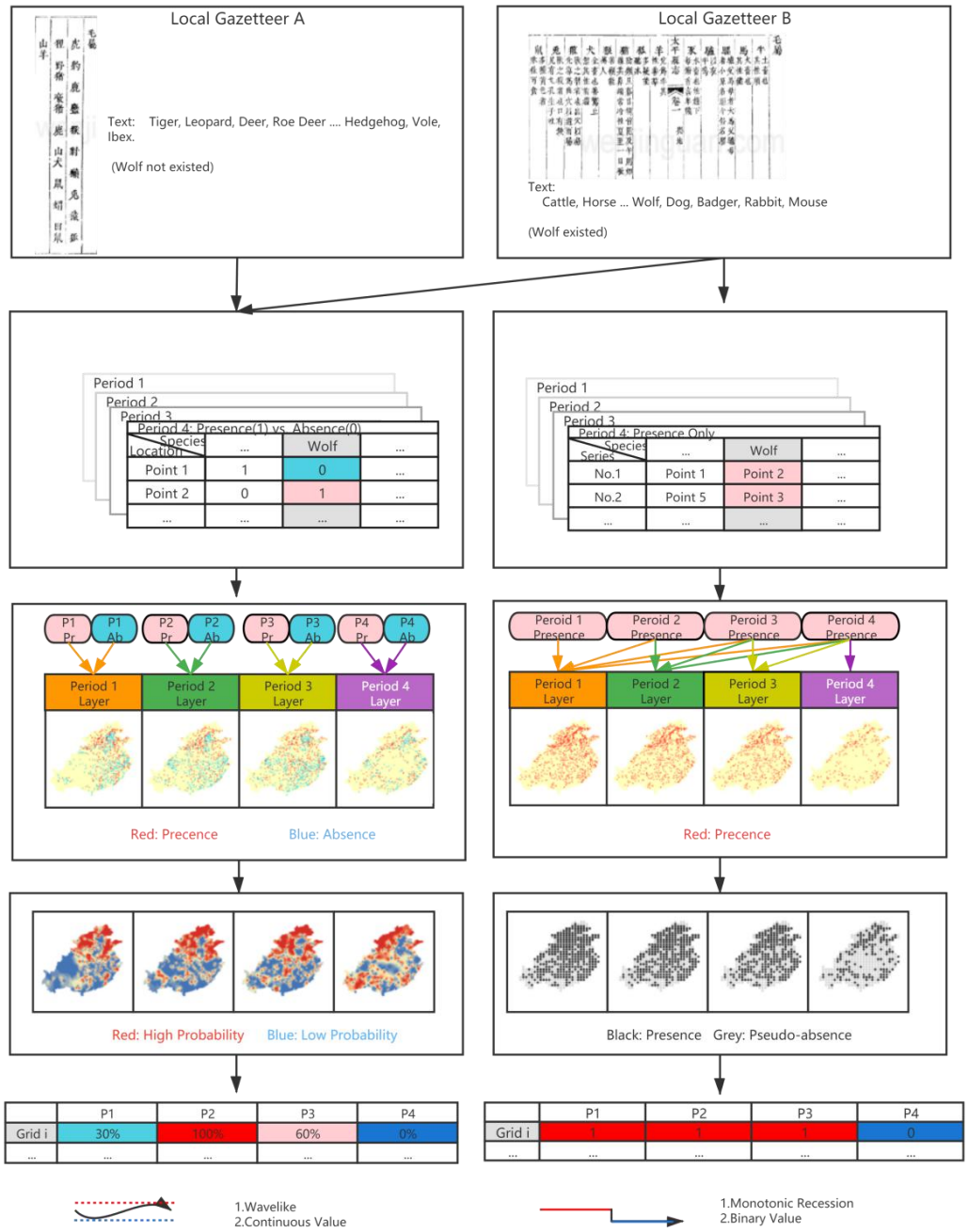


Table.1 Qualifying the valid data.

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

Fig.2 Research area (blue) in eastern China and the Heihe-Tengchong Line (red).

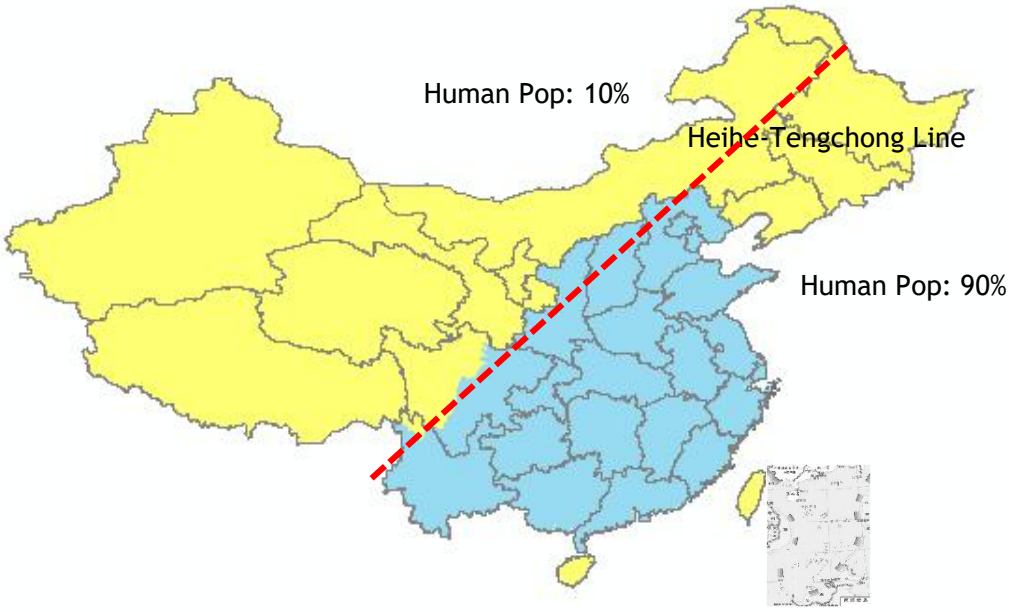


Fig.3 The change of average probability of predators from Period 1 to Period 4.

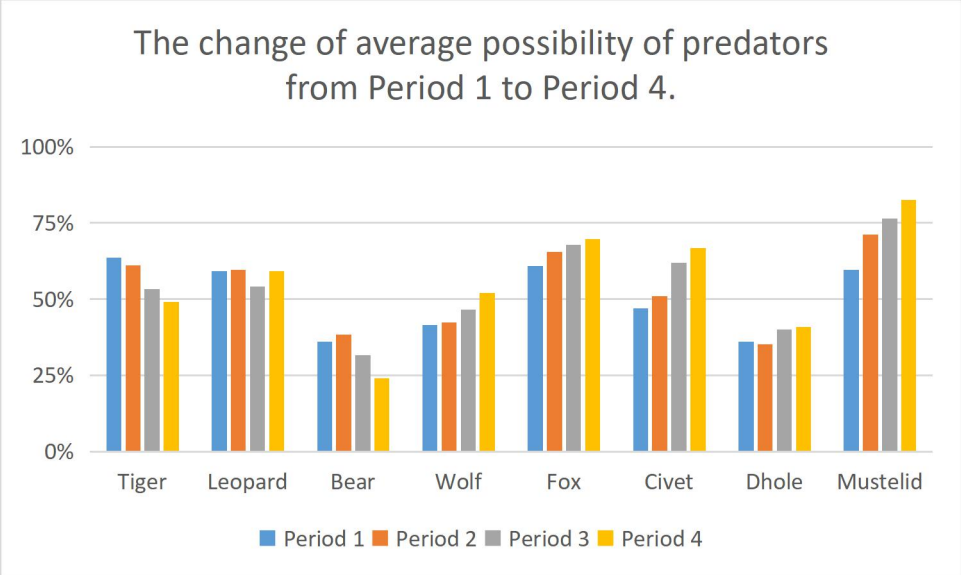


Fig.4 The change from Period 1 to Period 4(Value=$(S_4-S_1)/S_1$)

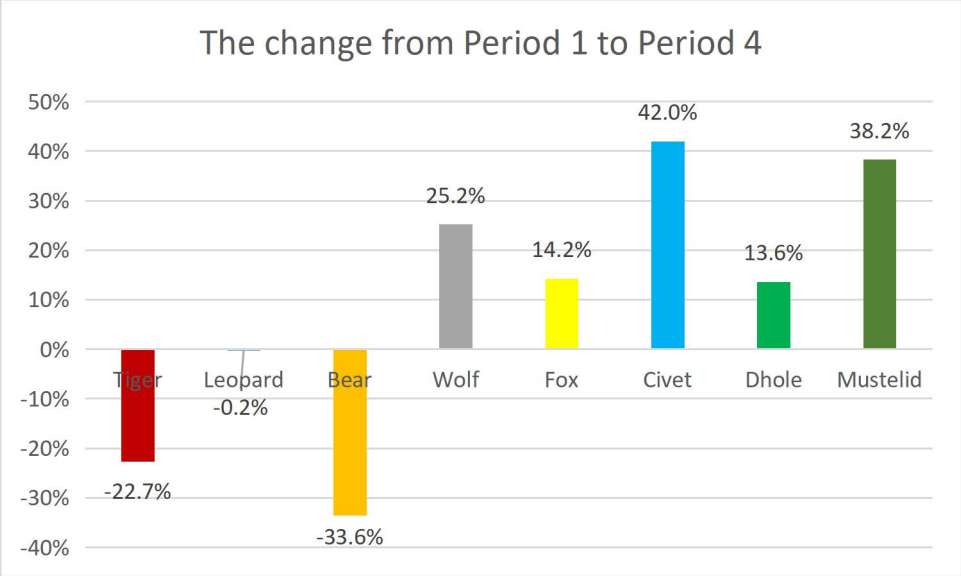
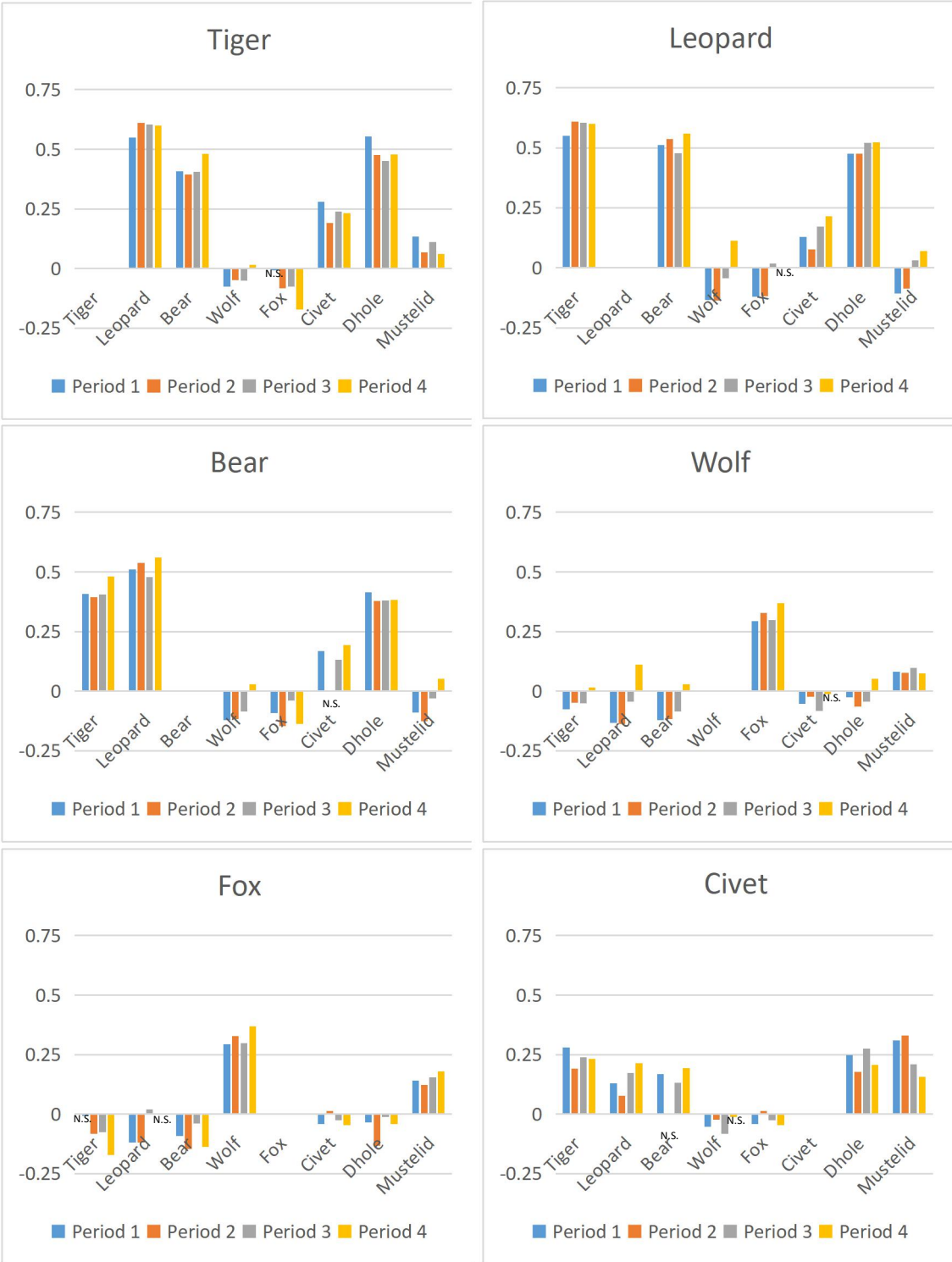


Fig.5 Relations between each predator and others (Kendall's tau-b) (N.S : not significant)



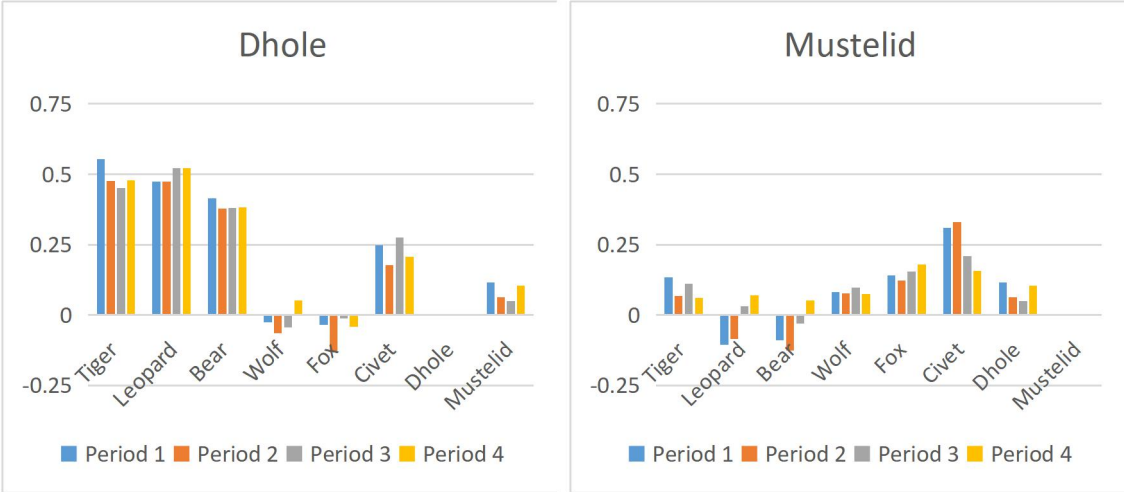


Fig.6 HPD Influence on predator distribution (Somers' dyx) (N.S. : not significant)

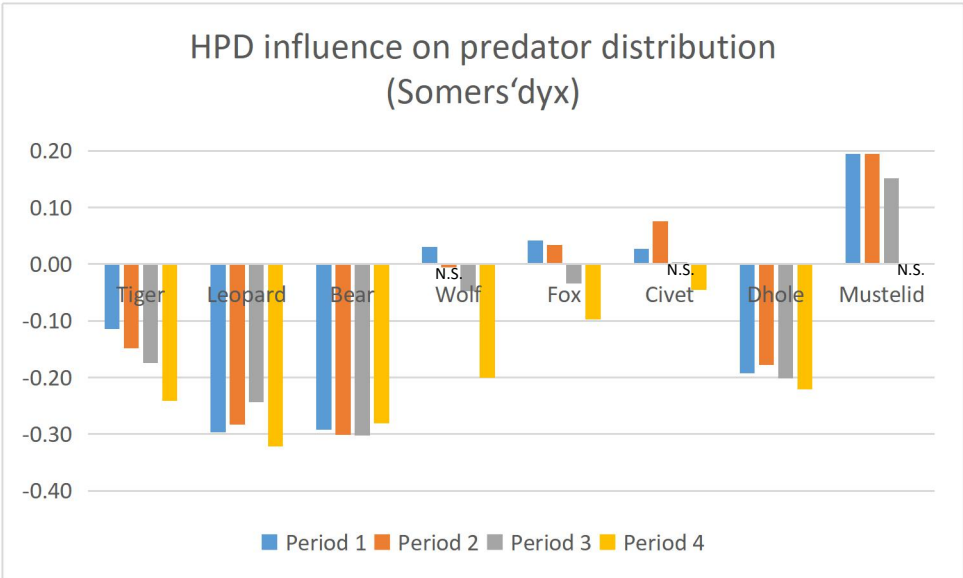
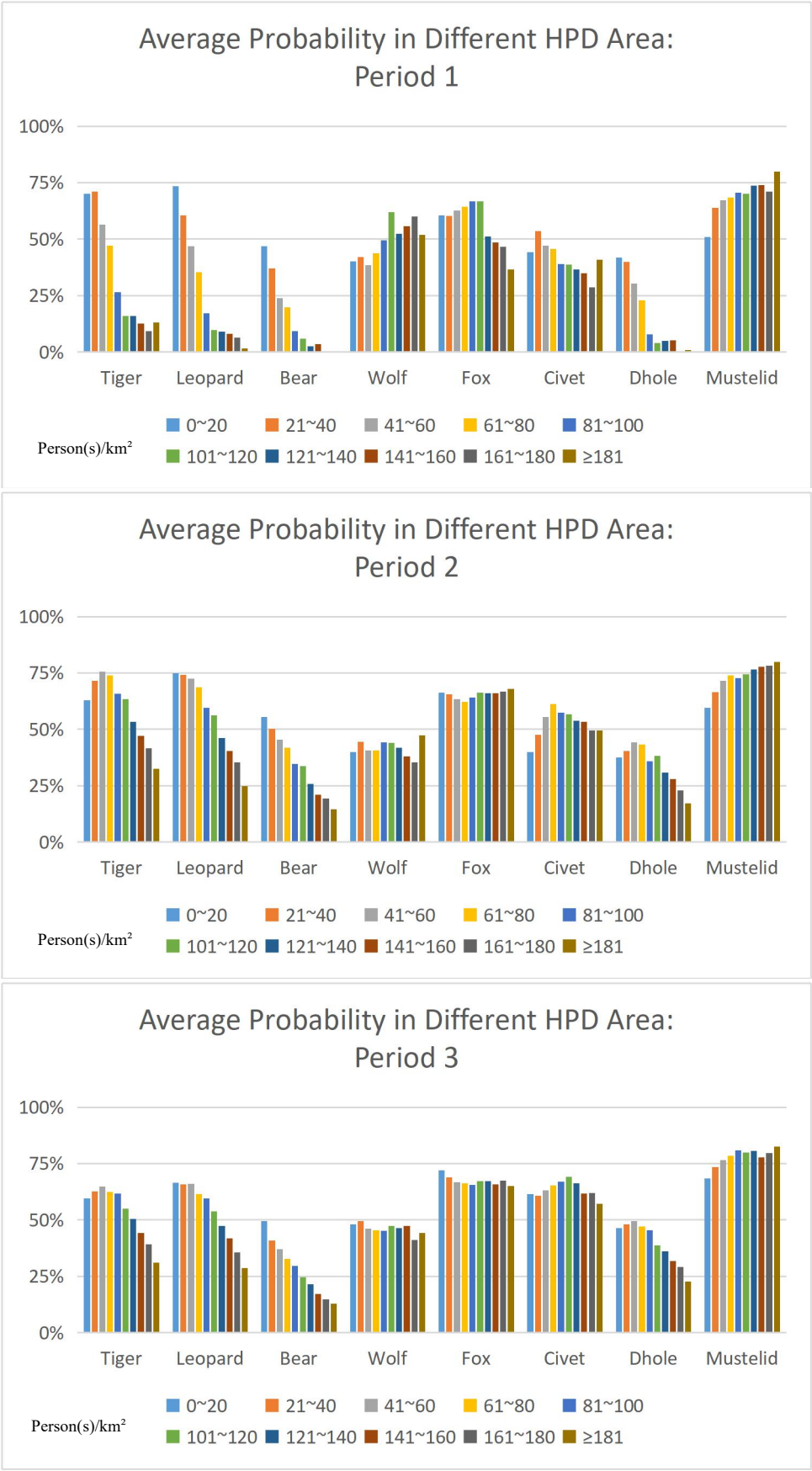


Fig.7 Average probability in different HPD area in each period



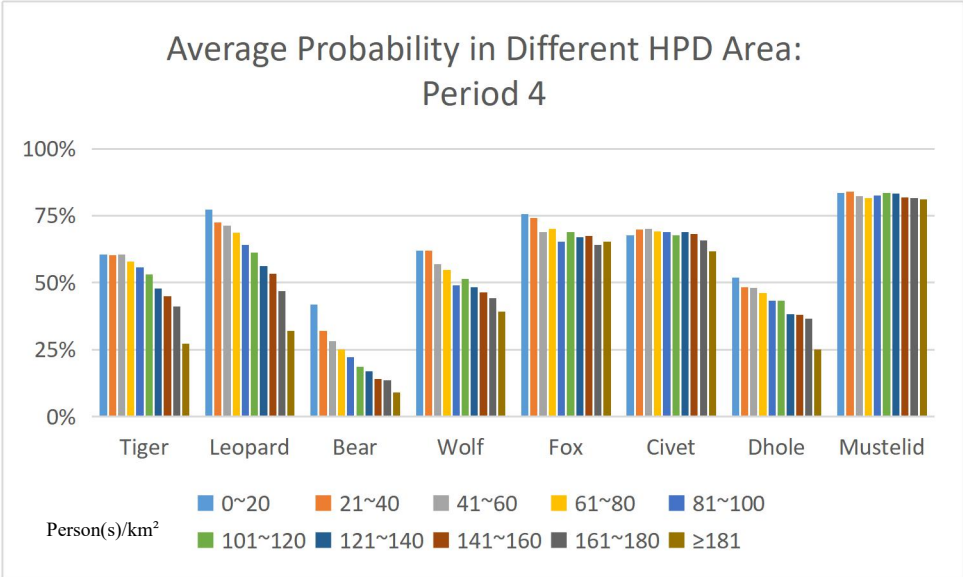
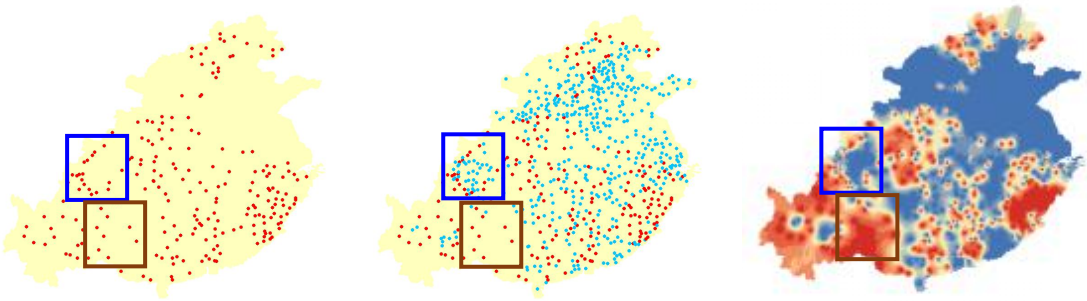


Fig.8 Criticizing the presence-only method

a.The bear presence records(red points) in Period 2, both frames are almost empty; b. The bear presence records(red points) and absence records(blue points) in Period 2, there are many absence records in the blue frame, but few in the brown frame; c. The IDW reconstruction of bear distribution based on b., high-probability area(red) and low-probability area(blue), the blue frame is fulfilled by low-probability area but the brown frame is fulfilled by high-probability area.



a b c

Fig.9 Criticizing the last observation method

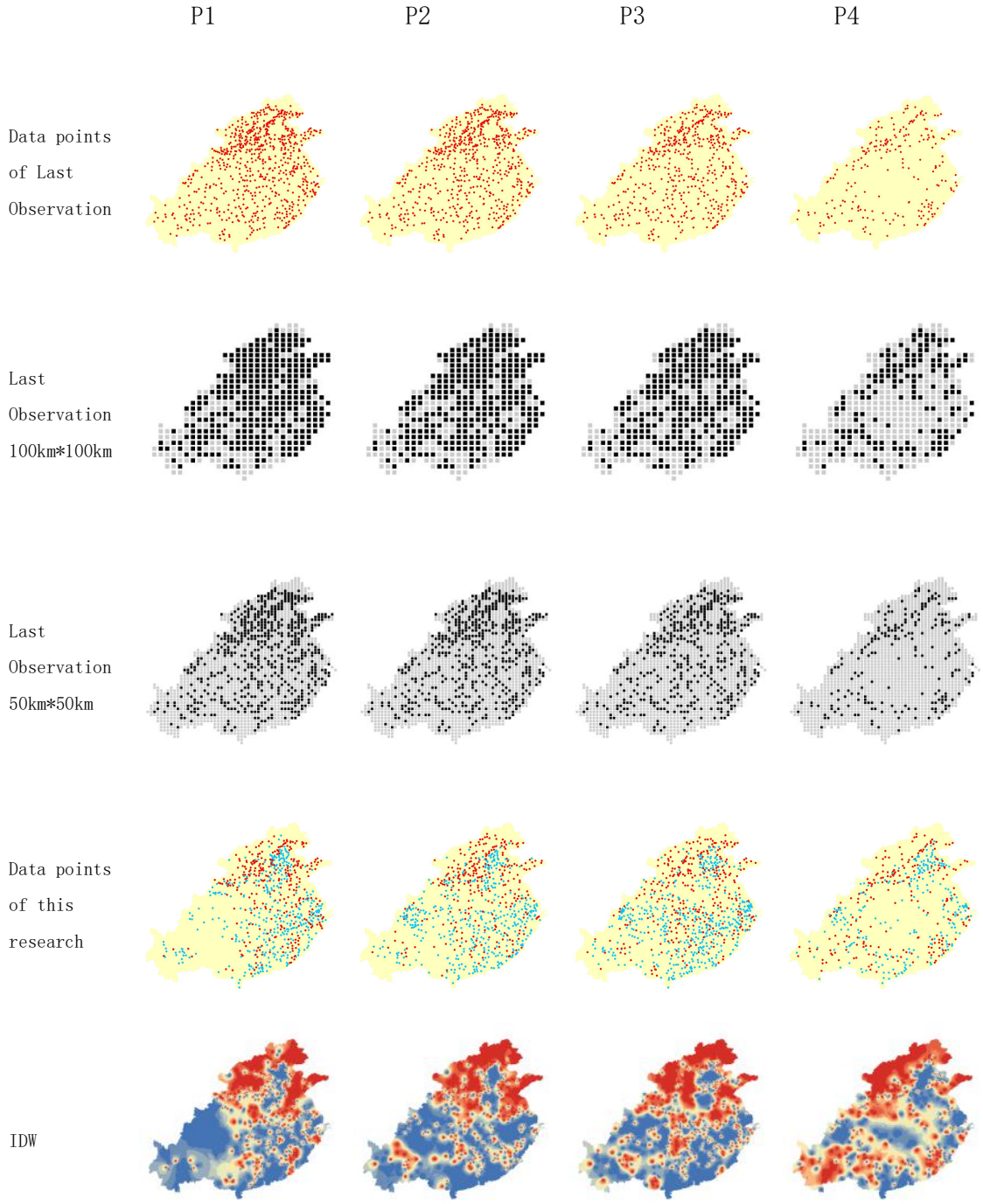
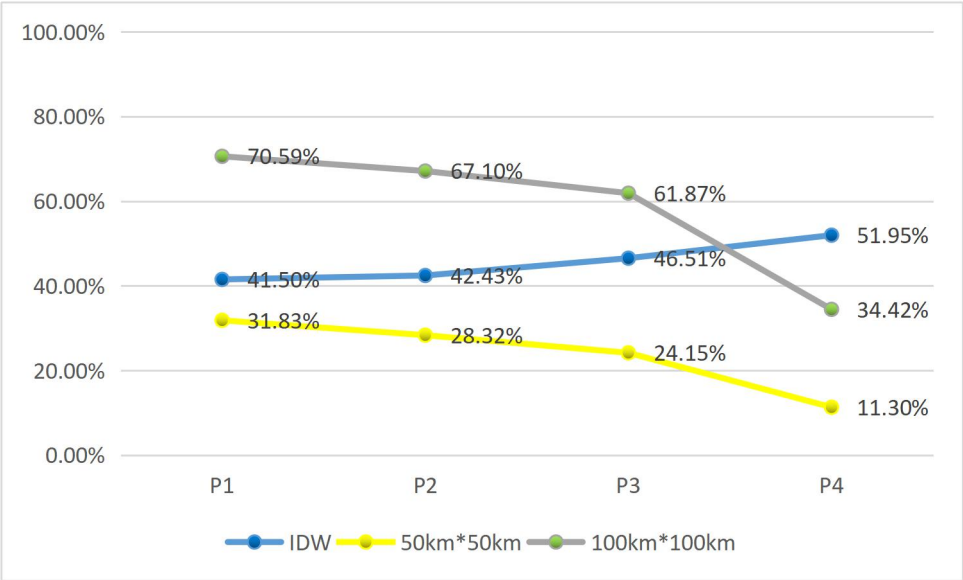


Fig.10 Different results of IDW, Last Observation(50km*50km) & Last Observation(50km*50km)



Supplementary Information:

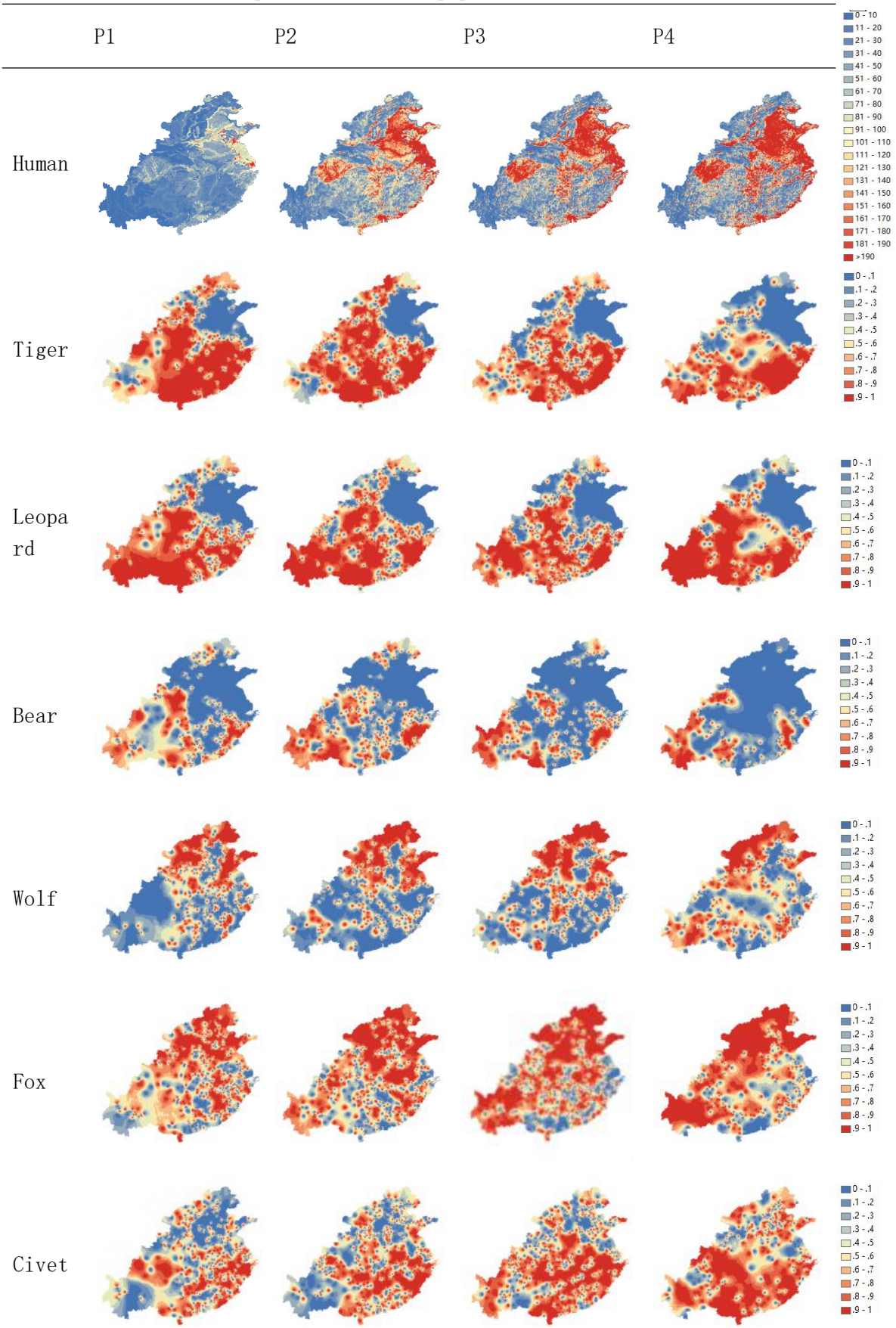
Table. S1 Folk name of predators in local gazetteers and relevant species in scientific taxonomy

Folk name in pre-modern China	Scientific name	English name
Tiger 虎	*Panthera tigris*	Tiger
Leopard 豹	*Panthera pardus*	Leopard
	Neofelis nebulosa	Clouded Leopard
	Uncia uncia	Snow Leopard
Bear[1] 熊	*Helarctos malayanus*	Sun Bear
	Ursus arctos	Brown Bear
	Ursus thibetanus	Asian Black Bear
Wolf 狼	*Canis lupus*	Wolf
Fox 狐	*Vulpes corsac*	Corsac Fox
	Vulpes ferrilata	Tibetan Fox
	Vulpes vulpes	Red Fox
Civet (viverrids & small wild felids) 狸/香猫/野猫	*Vormela peregusna*	Marbled Polecat
	Catopuma temminckii	Asian Golden Cat
	Felis bieti	Chinese Mountain Cat
	Felis chaus	Jungle Cat
	Felis manul	Pallas' Cat

	Felis silvestris	Wildcat
	Pardofelis marmorata	Marbled Cat
	Prionailurus bengalensis	Leopard Cat
	Chrotogale owstoni	Owston's Palm Civet
	Arctictis binturong	Binturong
	Arctogalidia Trivirgata	Small-Toothed Palm Civet
	Paguma larvata	Masked Palm Civet
	Paradoxurus hermaphroditus	Common Palm Civet
	Prionodon pardicolor	Spotted Linsang
	Viverra megaspila	Large-Spotted Civet
	Viverra zibetha	Large Indian Civet
	Viverricula indica	Small Indian Civet
Dhole 豺/赤狗	*Cuon alpinus*	Dhole
Mustelid (Badger, Otter, etc.) 獭/鼬/獾/貂/龙狗/龙猪/山狗/猯	*Aonyx cinerea*	Asian Small-Clawed Otter
	Lutra lutra	Eurasian Otter
	Lutrogale perspicillata	Smooth-Coated Otter
	Arctonyx collaris	Hog Badger
	Martes flavigula	Yellow-Throated Marten
	Martes foina	Beech Marten
	Meles leucurus	Asian Badger
	Melogale moschata	Chinese Ferret Badger
	Melogale personata	Burmese Ferret Badger
	Mustela altaica	Mountain Weasel
	Mustela erminea	Ermine
	Mustela eversmanii	Steppe Polecat
	Mustela kathiah	Yellow-Bellied Weasel
	Mustela nivalis	Least Weasel
	Mustela sibirica	Siberian Weasel
	Mustela strigidorsa	Back-Striped Weasel

1. We didn't distinguish the brown bear, sun bear and Asian black bear in this research, because the majority of local gazetteers only refer "熊(bear)", only a few of them distinguish "狗熊(Asian black bear)", "马熊/罴(brown bear)" or "猪熊(suspected to be sun bear)". There are specific name "貘"of panda, not included in this research.

Table. S2 The distribution of predators and human population density(HPD)



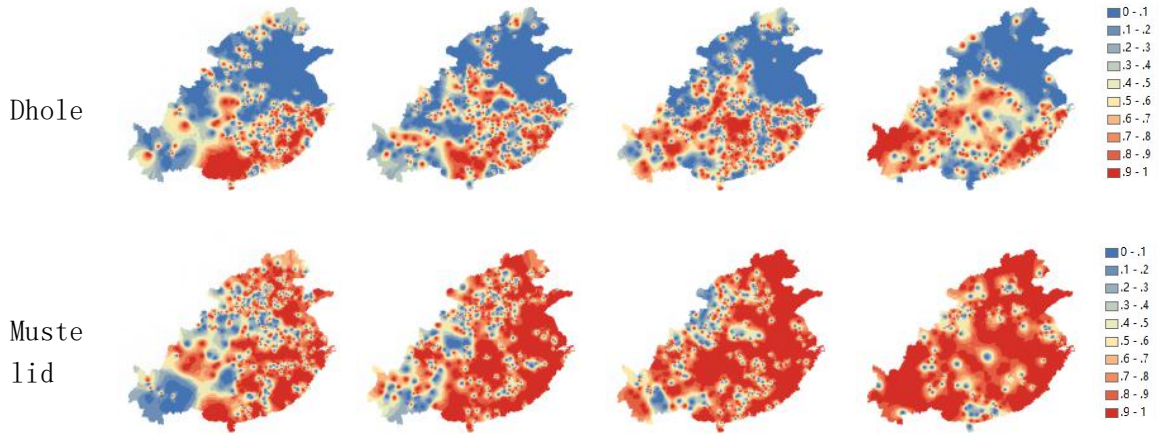


Table. S3 The change of average probability of predators from Period 1 to Period 4.

	Tiger	Leopard	Bear	Wolf	Fox	Civet	Dhole	Mustelid
Period 1	63.59%	59.25%	36.12%	41.50%	60.96%	47.06%	36.03%	59.69%
Period 2	61.15%	59.58%	38.30%	42.42%	65.42%	51.00%	35.16%	71.23%
Period 3	53.21%	54.18%	31.59%	46.51%	67.80%	61.92%	40.10%	76.47%
Period 4	49.13%	59.11%	24.00%	51.95%	69.64%	66.81%	40.93%	82.52%

Table.S4 Relations between each predator and others (Kendall's tau-b coefficient)

Period 1	Tiger	Leopard	Bear	Wolf	Fox	Civet	Dhole	Mustelid
Tiger	1	.550**	.408**	-.076**	-.008 N.S.	.281**	.553**	.133**
Leopard	.550**	1	.511**	-.134**	-.120**	.130**	.475**	-.106**
Bear	.408**	.511**	1	-.121**	-.091**	.169**	.415**	-.089**
Wolf	-.076**	-.134**	-.121**	1	.293**	-.052**	-.026**	.081**
Fox	-.008 N.S.	-.120**	-.091**	.293**	1	-.042**	-.034**	.141**
Civet	.281**	.130**	.169**	-.052**	-.042**	1	.249**	.309**
Dhole	.553**	.475**	.415**	-.026**	-.034**	.249**	1	.116**
Mustelid	.133**	-.106**	-.089**	.081**	.141**	.309**	.116**	1

Period 2	Tiger	Leopard	Bear	Wolf	Fox	Civet	Dhole	Mustelid
Tiger	1	.610**	.395**	-.048**	-.082**	.190**	.476**	.067**
Leopard	.610**	1	.537**	-.137**	-.119**	.078**	.475**	-.086**
Bear	.395**	.537**	1	-.116**	-.146**	.002 N.S.	.379**	-.126**
Wolf	-.048**	-.137**	-.116**	1	.328**	-.024**	-.065**	.076**
Fox	-.082**	-.119**	-.146**	.328**	1	.014*	-.132**	.123**
Civet	.190**	.078**	.002 N.S.	-.024**	.014*	1	.177**	.330**
Dhole	.476**	.475**	.379**	-.065**	-.132**	.177**	1	.064**
Mustelid	.067**	-.086**	-.126**	.076**	.123**	.330**	.064**	1

Period 3	Tiger	Leopard	Bear	Wolf	Fox	Civet	Dhole	Mustelid
Tiger	1	.605**	.405**	-.050**	-.075**	.238**	.451**	.111**
Leopard	.605**	1	.478**	-.043**	.019**	.172**	.521**	.031**
Bear	.405**	.478**	1	-.085**	-.039**	.132**	.381**	-.031**
Wolf	-.050**	-.043**	-.085**	1	.298**	-.083**	-.045**	.097**
Fox	-.075**	.019**	-.039**	.298**	1	-.025**	-.013*	.155**
Civet	.238**	.172**	.132**	-.083**	-.025**	1	.276**	.210**
Dhole	.451**	.521**	.381**	-.045**	-.013*	.276**	1	.050**
Mustelid	.111**	.031**	-.031**	.097**	.155**	.210**	.050**	1

Period 4	Tiger	Leopard	Bear	Wolf	Fox	Civet	Dhole	Mustelid
Tiger	1	.599**	.480**	.015*	-.172**	.231**	.479**	.061**
Leopard	.599**	1	.560**	.112**	.001 N.S.	.214**	.522**	.071**
Bear	.480**	.560**	1	.028**	-.138**	.193**	.382**	.052**
Wolf	.015*	.112**	.028**	1	.368**	-.012 N.S.	.052**	.074**
Fox	-.172**	.001 N.S.	-.138**	.368**	1	-.047**	-.041**	.179**
Civet	.231**	.214**	.193**	-.012 N.S.	-.047**	1	.208**	.157**
Dhole	.479**	.522**	.382**	.052**	-.041**	.208**	1	.105**
Mustelid	.061**	.071**	.052**	.074**	.179**	.157**	.105**	1

**sig< .01;*sig< .05; N.S.: not significant.

Table.S5 HPD Influence on predator distribution (Somers' dyx)

	Period 1	sig.	Period 2	sig.	Period 3	sig.	Period 4	sig.
Tiger	-.114	.000	-.149	.000	-.174	.000	-.241	.000
Leopard	-.297	.000	-.283	.000	-.243	.000	-.322	.000
Bear	-.292	.000	-.301	.000	-.302	.000	-.281	.000
Wolf	.030	.000	-.006	.368 N.S.	-.048	.000	-.200	.000
Fox	.042	.000	.034	.000	-.034	.000	-.098	.000
Civet	.027	.000	.076	.000	.003	.635 N.S.	-.045	.000
Dhole	-.193	.000	-.178	.000	-.202	.000	-.221	.000
Mustelid	.195	.000	.195	.000	.151	.000	.001	.918 N.S.

N.S. : not significant