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Current Conservation Status and Research Progress on Asian Elephants in China

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The general situation of the Asian elephant

As a large territorial herbivorous mammal, the Asian Elephant (*Elephas maximus*) or Indian elephant, mainly inhabits forests and jungles, and often occurs in the gullies, river side and bamboo-broadleaf mixed forest with altitudes under 1000 m. It is a class I protected animal in China, and listed as an endangered species by the International Union for the Conservation of Nature and Natural Resources (IUCN).

Historically, the Asian elephant was widely distributed. It is estimated that there were about 100,000 elephants scattered from the drainage area of Tigris and Euphrates of Syria and Iran to the West, the Yellow River in China in the East, and Indonesia in the South at the beginning of 12th century. But their habitats have reduced rapidly because of climate change, sharply increased population and forest loss. Therefore, they only occur in some fragmented habitats in their historical distribution range. At present, the wild Asian elephant population is about 34,390~56,045, and the area of their habitat is about 436,230 km^2, in which an area of approximately 131,820 km^2 are National Parks or Nature Reserves (Sukumar 2003). Habitat loss and fragmentation are the main threats to elephant survival, and may increase the extinction risk of isolated populations.

The previous estimated number of wild elephants in China was about 200~250 (Zhang *et al.* 2003) based on limited field surveys and published data. Many surveys have been done on the population number of wild elephants in China; however, due to the different survey methods and the improvement and amending of survey techniques, the estimated values fluctuated from 1960s. This fluctuation was not due to the alteration of the number of elephants, but caused by the limitations of survey methods and survey times, movement of elephants among different habitats, or the transfer between neighboring countries such as Laos and Burma.

Since 1999, our group has made detailed investigation on the distribution (Fig. 1) and the number of Asian elephant populations, and estimated the current population to be 165-213 (Table 1) (Zhang *et al*. 2006). We also began to use morphological characteristics to identify individual elephants. We have also used molecular markers to identify individuals more accurately in the conservation genetic field. Consequently we can get to know the conservation genetic characteristics, population number and the social structure of wild Asian elephants in China.

The research status of elephant population ecology in China

Research on Asian elephant ecology mainly refers to individual physiological ecology, behavioral ecology, and population ecology. On the aspect of population number and distribution of Asian elephant, Sun *et al*. (1998) analyzed the space-time rules and the reasons for regional terrain withdrawal through historical data, and indicated that the increasing growth of human population pressure was the primary reason for the rapid southwards withdrawal of Asian elephants in China.

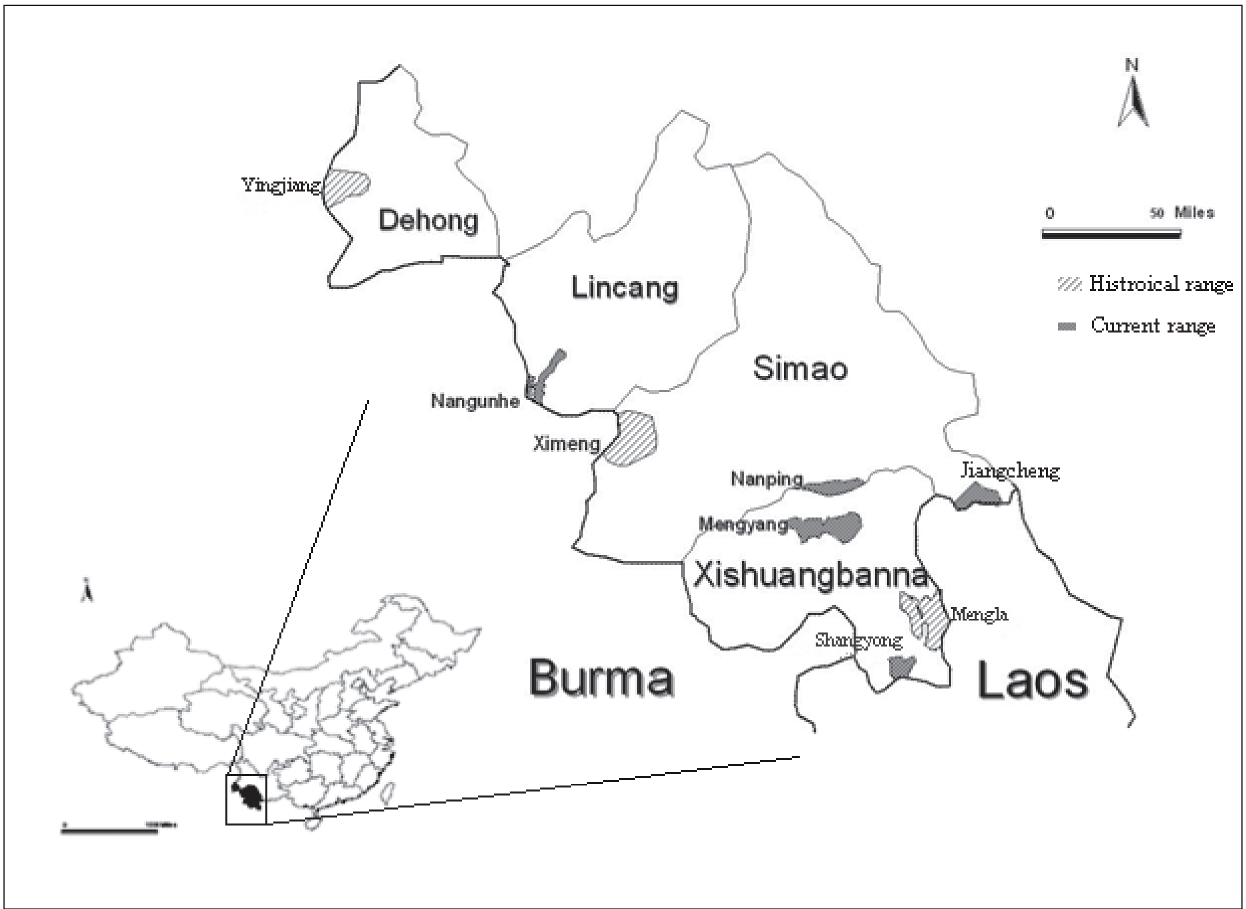

Figure 1. Distribution map of Asian elephants in China (Zhang *et al*. 2006).

On the aspect of Asian elephant habitat, Zhang *et al.* (2003) made a preliminary study on the habitat selection of 5 Asian elephants in Simao. Via trace-tracking and transect techniques, they found that the home range size of the herd during the dry seasons was 35.67 km^2, with 3 core foraging areas used circularly; while during the rainy season it was 18.42 km^2, with only one core foraging area. They also recorded the species of wild plants that elephants eat (Fig. 2). By applying remote sensing and geographic information system techniques, Li (1996) established the primary information database of Asian elephant habitat in Mengyang Nature Reserve, and assessed the habitat. Feng *et al.* (2005) found that Asian elephants preferred valley habitats where the altitude was less than 1000 m and the slope less than 10°, facing north or south. The selected habitats were bamboo-evergreen-broadleaf mixed forest, shrub and grassland. Furthermore, the main threats to the survival of Asian elephants were habitat loss and increasing illegal hunting in Shangyong Nature Reserve.

Research on the behavior, anatomy and physiology of elephants was mostly on captive elephants. Although there were significant differences between wild and captive elephants, they also had many common behaviours. It was confirmed that the estrus in Asian elephants was 16 weeks, including a luteal stage of 8-12 weeks and a follicular stage of 4-6 weeks. The sex pheromone excreted by oestrus female elephants in the urine was the chemical foundation in which bulls were interested (Schulte 2000). Through studying the variation in urinary oestrogen of 3 female Asian elephants at Beijing zoo it was hypothesized that inactive ovaries might be the cause of low oestrogen levels and lack of obvious periodic fluctuation in captive elephants. The lack of oestrus influences the birth rate of the captive population. In addition, the nutrition components of food for Asian elephants in wild and in captivity were analyzed, and it was observed that they had a relatively high need for calcium.

Table 1. Estimated population number and distribution of elephants in China (Zhang *et al.* 2006).

Year / County	1976	1983	1997	2003	2005	2006
Mengla	37	23	0	14-17	12-24	30
Mengyang	26	130	115-137	80-100	80-100	46-69
Shangyong	38	60	50-60	90-100	40-80	60-80
Simao	7	0	18	5-18	11-21	11
Linchang	22	12	18	18	18-23	18-23
Yingjiang	16	0	0	0	0	0
Total	146	225	201-233	207-253	161-266	165-213

Social structure crucially influences the development and evolution of diversified elephant's social behaviour. Cooperative and helping behaviour always occur when they search for food and water, dodge hunters and nurse offspring. Some studies were carried out on the foraging behaviour of Asian elephants in Sanchahe area, Wild Elephant Valley, Mengyang Nature Reserve, Xishuangbanna. Female elephants and their offspring foraged in groups, whereas bulls foraged alone. There was no significant difference on the foraging behaviour of elephants between daytime and nighttime and they foraged crops mainly at night. Asian elephants foraged in a circuitous pattern in the forests, which not only greatly improved the quality of the food in their wild habitat, but also benefited the development of the tropical rain forest ecosystem.

Meanwhile, via the individual morphological characteristics technique, the social relationship and behaviour of elephant populations was studied in Mengyang Nature Reserve. In total, 46 different elephants were successfully identified from the 524 direct observations of wild elephants, of which 38 belonged to 7 family groups, and the other 8 males were bull tuskers. It was also found that elephant groups and bulls appeared seasonally in the Wild Elephant Valley, and there were significant differences among the appearance frequencies of the 7 groups, which were positively correlated to the group size.

Research on conservation genetics of Asian elephants

Owing to the depredated environment and increased sustainence of human activities for a long time, Asian elephant habitats have been badly destroyed, which induced fragmentation of habitats, isolated populations, and intermittent gene flow. Poaching by humans and fragmented habitats are the main threats to Asian elephant survival. So, it is imperative to protect Asian elephants under such situations. Although some measures have been taken to establish several nature resersves in Xishuangbanna, Simao, and Nangunhe in Yunnan province, and we gained primary progress, there is not a credible system to describe the status of Asian elephant populations in China. We could never achieve our conservation aims if we just protect the areas where wild elephants exist.

There are some differences between various molecular methods in the application domains and capacity of solving problems when we cope with questions in different conservation levels or research objects (Li *et al*. 2001). Our group selected a fragment of mitochondrial DNA (mtDNA) as a molecular marker, including the hypervariable left domain of the d-loop (Fernando *et al.* 2000; Vidya *et al*. 2005), to assess the genetic diversity of the Asian elephant in Yunnan province, southwest China. If we fully understand the population structure and the genetic diversity in this area, we can provide some more feasible conservation suggestions and strategies to protect this endangered species.

Our results demonstrated that the genetic diversity was very low ($h = 0.150$, $ð = 0.00044$) in Xishuangbanna, Yunnan province, and there were few differences among those four geographic populations in Xishuangbanna. Analysis of Molecular Variance (AMOVA) suggested that there is no significant genetic divergence ($Fct = -0.09013$) within Xishuangbanna local populations. Most individuals in the four local populations shared the same haplotype with no genetic divergence, and there was high gene flow between the two local populations: MY-SM and ML-SY. These data warrant the identification of Xishuangbanna elephants as an evolutionarily significant unit (ESU) on the mtDNA level.

Since 1960, much original forest has been reclaimed to plant rubber trees in Mengla County, and after 1980 the area kept growing bigger. As a result of the price of rubber rising in the international market in recent years, original forests were cut massively for planting rubber trees in Xishuangbanna, thus it formed ecological isolation of Mengxing-Xiangming-Yiwu, including the big and small Kongming hills and Yao areas, and formed a geographic obstruction between Shangyong-Mengla (SY-ML) and Simao-Mengyang (SM-MY), which drove elephants to withdraw to current ecology spots. There has been no intercommunion of elephant populations between the two areas in the past several decades, and the populations just move in small ranges. However, the nucleotide substitution rate of elephant mitochondrial DNA D-loop is 3.5% per million years; therefore mutantations observed in individuals in these two areas, are generated by a history of belonging to different family groups, rather than geographic isolation.

Figure 2. Feeding elephant.

The evolutionary course of wild Asian elephant populations is very slow because it is a large mammal with a big appetite, wide territory, long reproductive cycle (the reproductive age of females is normally 18-20 years old, while the youngest age is 14-15 years), and low birth rate (they give birth to a infant per 2.5-8 years on average). In recent decades, on account of the massive cutting of forests and reclaiming of farmland, the habitats of elephants were fragmented, converting the original forests to rubber woods and farmlands, and no genetic flow occured between the two isolated populations. But this just occurred in recent years, so there is no significant genetic difference and no obvious genetic divergence.

The best solution to this problem is to establish ecological corridors to enhance intercommunication among the geographically isolated populations. The feasibility and necessity of building ecological corridors among Mengyang nature reserve (MY), Shangyong nature reserve (SY), and Mengla nature reserve (ML) was discussed, and one corridor was marked out to connect the three nature reserves according to practical conditions, formeing a protection and management unit in Xishuangbanna (Fig. 3). Combined with our study result, we believe a corridor programme among the isolated populations is critical and important to the survival of Asian elephants in China. So we suggest that the Reserve Management Department should establish the corridor as soon as possible, to reduce the fragmentation of the habitats and the pressure of human activities, improve the intercommunication and then to promote the genetic stability and diversity of Asian elephant populations in China.

There were no shared haplotypes between the populations of Xishuangbanna and Nangunhe. The Nangunhe population could diffuse into Burma in the 1980s, but because of the severe destruction of vegetation, there is no diffusion since 1997, so the Nangunhe population has become an isolated population composed of 13-18 individuals. This matches the low nucleotide diversity of mitochondrial DNA (h = 0.350) and haplotype diversity (ð = 0.0034). There is significant difference between the Nangunhe population and the 4 geographic populations in Xishuangbanna based on the F_{ST} test on the haplotype frequencies (Table 2). The results of AMOVA analysis indicate that there is distinct genetic divergence between the Nangunhe population and the Xishuangbanna one, which respectively belong to two distinct assemblages, β and α, according to the phylogenetic tree. In summary, we suggest that when the Reserve Management Department make up the policy to protect the elephants in Xishuangbanna and Nangunhe districts, they should consider them two separate populations.

Corridor designing and habitat restoration

Lin *et al.* (2007) analyzed a series of GIS, RS and GPS information on elephant range areas, ecological factors including altitude, landform, relief, villages and roads which affected the distribution and movement of Asian elephants, and suggested the possibility of designing and establishing corridors in Xishuangbanna National Nature Reserve. One important aim of planning and designing ecological corridors was to build a passage for elephants in Mengyang to migrate outside to communicate with those in Mengla and Shangyong and even those in Laos. Mangao sub-reserve was located far away from the others and no elephants lived there, so planning corridors linking it to the others was beyond consideration. Menglun sub-reserve was located between Mengyang and Mengla sub-reserves. It would be ideal if corridors could be established to link it with Mengyang and Mengla. But the large number of villages, farmlands and plantations as well as busy roads made it almost impossible to build corridors along this route because moving of lots of villages, redistribution of collectivistic forests and large amounts of compensation would be impossible. So it was suggested that corridors be established to link Mengyang, Mengla and Shangyong (Fig. 3).

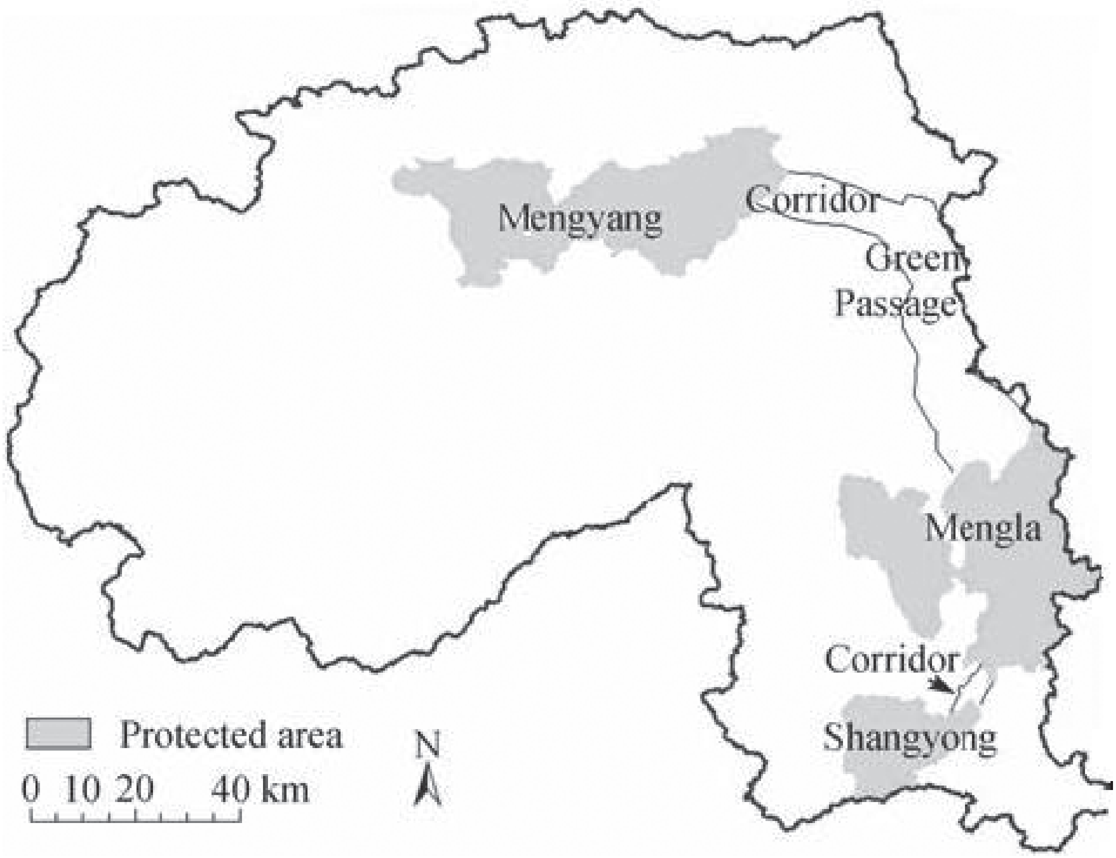

Figure 3. Panorama of designed corridors in Xishuangbanna (Lin *et al.* 2007).

Table 2. Analysis of molecular variance based on mitochondrial haplotypes (AMOVA).

Level of analysis	Variance components	Percentage variation	F-statistics	P-value
Among regions (MY-SM, SY-ML)	-0.01150 Va	-9.01	F_{CT}=-0.09013	0.780
Among populations within regions	0.01464 Vb	11.48	F_{SC}=0.10528	0
Within populations	0.12445 Vc	97.54	F_{ST}=0.02464	<0.001
Between regions (Xishuangbanna, NGH)	7.21347 Va	97.29	F_{CT}=0.97293	0
Among populations within regions	0.00322 Vb	0.04	F_{SC}=0.01605	<0.001
Within populations	0.19746 Vc	2.66	F_{ST}=0.97337	0

Details of the corridor routes should be determined based on comprehensive consideration. To link Mengyang and Mengla, a linear corridor would not be adopted because it would traverse a large number of villages and farmlands. A suitable corridor should traverse areas with less villages and more natural forests. Figure 3 showed that the long and narrow area which was located north to Mengla sub-reserve and west to the national boundary was occupied by continuous natural forests with few villages and many rivers in it. Earlier studies had indicated that a linear natural forest zone between isolated habitats had good potential and obvious advantages for corridor building (de Lima & Gascon 1999; Laurance & Laurance 1999). So this area was called a "Green Passage". And more inspiringly, there had been a few records of elephant activities in this area. So the "Green Passage" would be ideal for corridors linking Mengyang and Mengla.

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Elephants in Xishuangbanna, China
Photo by Li Zhang