What triggered the Asian elephant's northward migration across southwestern Yunnan?

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The Asian elephant (*Elephas maximus*), an endangered species on the International Union for Conservation of Nature Red List, is the largest terrestrial animal living in Asia. They require a relatively large space to live in. In China, the wild Asian elephants exist only in XiShuangBanNa, Pu'Er, and LinCang of southern Yunnan Province, with 95% of the wild population residing in the XiShuangBanNa National Nature Reserve. In recent years, territorial conflicts have arisen between humans and elephants around the national nature reserve. A herd of wild Asian elephants roamed north, venturing over 500 km from the largest area of the reserve, MengYang (998 km^2, 600–1,500 m above sea level [ASL] in altitude), in March of 2020 to KunMing (the capital of Yunnan Province, ca. 2000 m ASL in altitude) in early June 2021 (Figure 1A). These elephants, traipsing north through fields, highways, villages, and towns, have stepped into the international spotlight, not only because such long-distance migration never happened in the past half a century but also because the United Nations Biodiversity Conference will be held in KunMing in the coming October. However, no one knows exactly why this has happened, as elephant migration, a complex ecological process, can be of varied duration, distance, timing, and driver. There are several potential explanations for this event: habitat shrinkage, food shortages, population growth, opportunistic behavior, straying of the herd's leader, and geomagnetic change etc. Currently, there are no quantitative data to back up these assertions.

We collected and analyzed the temporal data of climate and land use changes in XiShuangBanNa in both the past six decades and the most recent 5 years (Figures 1B–1E). The annual mean temperature has steadily risen since the late 1990s and was 1.6°C higher in 2019–2020 than in 1981–2010. The annual mean precipitation did not exhibit a persistent long-term trend but showed a marked decrease in 2019 and 2020. A high temperature with precipitation deficit caused a moderate drought in 2019, followed by an extreme drought throughout 2020 (Figure 1C). In the most recent 2 years, the monthly drought index decreased steadily and reached an unusually low level in March of 2020, the very month when this herd of elephants started their northward migration (Figure 1D). Asian elephants inhabit forests and grassland, feeding on more than 100 different plant species, mainly Malvales, legume, palm, sedge, and true grass. Based on remote sensing data, vegetation productivity showed a deep drop-off in March 2020, coinciding with both the severe drought and the start of the migration (Figure 1E). It appears that an extremely hot-dry climate caused sharp degradation in herbaceous and

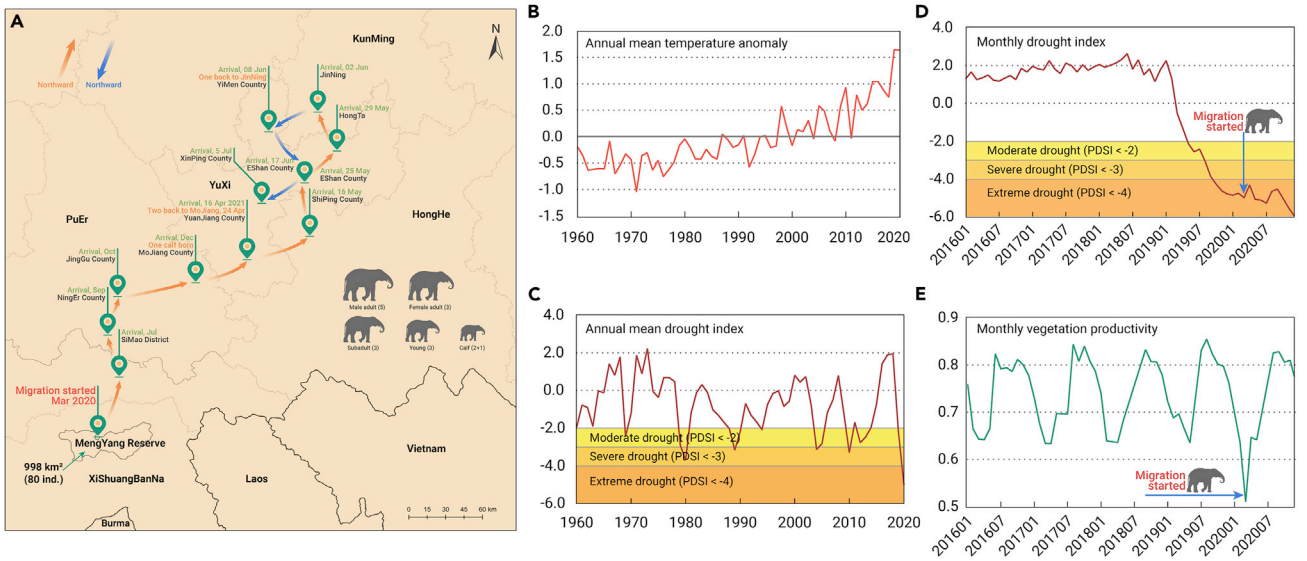

Figure 1. Migration routes of the Asian elephants and the related climate and vegetation changes (A) Migration routes of the Asian elephants. (B–D) Climatic changes over XiShuangBanNa. (B) Annual mean temperature anomaly (°C) from 1960 to 2020 relative to the 1981–2010 climate. (C) Annual mean drought index (self-calibrating Palmer Drought Severity Index] [scPDSI) from 1960 to 2020. (D) Monthly drought index from Jan 2016 to Dec 2020. (E) Changes of vegetation productivity in the MengYang Nature Reserve where the herd of Asian elephants started their northward migration. Monthly vegetation productivity measured by Moderate-resolution Imaging Spectroradiometer (MODIS)-derived normalized difference vegetation index (NDVI) from January 2016 to December 2020. Mean NDVI was calculated for the grasslands and open woodlands within the reserve at each time point (low-quality pixels are excluded).

shrub plants, consequently triggering the herd's northward and upward migration.

The herd's migration may also be related to the increase in both the elephant population and habitat degradation. Elephants are megaherbivores, with an adult consuming 100–300 kg of food and 80–200 L of water daily. Benefiting from conservation efforts by the Chinese government, the elephant's population has been steadily increasing from less than 150 in the 1960–1970s, to 216–243 in 2016, and to nearly 300 in 2020. On the contrary, elephant's distribution shrunk and fragmented over the past decades due to human settlement and agriculture. In southwestern Yunnan where wild elephants lived, the forest cover decreased from 69.3% in 1975 to 57.8% in 2014, the farmland area decreased from 21.13% to 6.45%, whereas plantations of rubber and tea tree increased from 9.3% to 34.7%.[1] Thus, the elephants' northward migration was most likely caused synergistically by multiple stressors; i.e., the increasing food shortage caused by population growth and habitat degradation during the past decades was suddenly magnified by the hot and dry weather during 2019 and 2020, triggering the astonishing northward migration.

The migratory behavior of Asian elephants might be driven by a complex integration of various intrinsic or external factors, varying with different temporal-spatial scales. Fossil records show that Asian elephants conducted large-scale migrations during the Holocene. They reached as far north as the Yellow River basin more than 7,000 years ago.[2] In the early Holocene, a warmer and more humid climate likely provided abundant vegetation and drinking water to support more elephants expanding northward. With gradual cooling and intense human activities, elephants gradually retreated to southwestern Yunnan Province. Large-scale elephant migrations between the south and north likely occurred repeatedly with cyclical climatic variations. Relatively short-distance migration also occurred between the 1960s and 1990s: dozens of Asian elephants ventured northward from the MengLun-MengLa area to the MengYang Nature Reserve, perhaps seeking better food and habitat. It remains unclear whether the increasing temperature could be a direct factor driving the elephants' current northward migration. We still need more detailed monitoring data on the movement behavior as well as the associated environmental factors to better understand the mechanisms underlying the partial elephant migration, such as the dynamic relationship between these pachyderms and the ecosystems they inhabit.

The influence of hot and arid climates on elephants is happening across the globe, although in different ways. A mass mortality event of more than 300 African elephants (*Loxodonta africana*) happened in Botswana in May and June of 2020. This nearly coincided with the northward migration of elephants in Yunnan. In Botswana, persistent hot and arid conditions stimulated cyanobacterial growth and cyanotoxin production, leading to a massive die off of African elephants who drank cyanotoxin-rich water.[3] A similar event happened again in Botswana from January to March of 2021, with 39 African elephants dying of unknown causes. In Botswana, fences in the reserves restricted the free movement of the elephants, causing them to be exposed to the polluted drinking water. Throughout the 21st century, impacts of climate change on Earth ecosystems are expected to increase, adding even greater stress to the survival of terrestrial mammals such as the Asian and African elephants.[3–5] Therefore, to effectively protect endangered wildlife, increased attention should be paid to synergistical effects of human activities and climate changes, especially extreme climatic events, so that we can establish adaptive management strategies, such as re-designing nature reserves to increase habitats, expanding and linking of migrating migration corridors connectivity, as well as increasing food resources.

Decades of efforts by Chinese government have yielded substantial achievements when it comes to Asian elephant protection (they are a first-level protected species in China) and elephant-human coexistence in southwestern Yunnan. However, we remain challenged by elephants, as we can neither communicate with these intelligent creatures nor make reliable long-term climate forecasts. Through government cooperation with scientists, farmers, locals, and a variety of social media platforms, great efforts are being made to ensure the safety of these elephants and avoid human-elephant conflict. How we achieve a long-lasting harmonious coexistence with elephants in the context of global climate changes will remain an important scientific issue for the foreseeable future. It is needed to evaluate the carrying capacity of the reserve so as to optimize territorial and population managements of Asian elephants. Continuing to gather more data will help guide our interactions with these intelligent creatures and hopefully ensure their survival for many centuries to come.

REFERENCES

1. Liu, P., Wen, H., Harich, F.K., et al. (2017). Conflict between conservation and development: cash forest encroachment in Asian elephant distributions. Sci. Rep. ***7***, 6404.
2. Wen, H.R., et al. (1995). The Shift of the Plant and Animal in China in the Historical Period. Chongqing Publishing House, Chongqing, China. Chongqing Publishing House, Chongqing, China.
3. Wang, H., Xu, C., Liu, Y., et al. (2021). From unusual suspect to serial killer: cyanotoxins boosted by climate change may jeopardize megafauna. Innovation ***2***, 100092.
4. Deb, J.C., Phinn, S., Butt, N., et al. (2019). Adaptive management and planning for the conservation of four threatened large Asian mammals in a changing climate. Mitigat. Adapta. Strateg. Glob. Change ***24***, 259–280.
5. Li, W., Yu, Y., Liu, P., et al. (2019). Identifying climate refugia and its potential impact on small population of Asian elephant (*Elephas maximus*) in China. Glob. Ecol. Conserv. ***19***, e00664.

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DECLARATION OF INTERESTS

The authors declare no competing interests.