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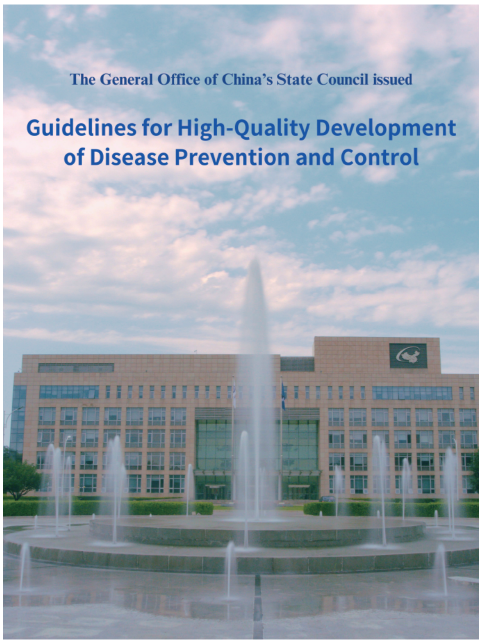

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Recommendations

Comprehensive Strategic Planning and Enhancement of China CDC Contributes to High-Quality Development of the National Disease Control and Prevention System

Hongbing Shen[1,#]

The Chinese government has always attached great importance to disease control and prevention efforts. Recently, the general office of China's State Council issued the "Guidelines for High-Quality Development of Disease Prevention and Control" (hereinafter referred to as the "Guidelines") (*1*). The Guidelines focus on promoting high-quality development of disease control and prevention and the strategic goal of "Healthy China," providing specific implementation pathways for the development of national disease control and prevention in the new era, including overall planning, restructuring of governance, enhancing core capabilities, strengthening talent development, and improving organizational support. As a national level disease control and prevention institution, China CDC will firmly seize the historic opportunity of national disease control and prevention system reform, and effectively promote the modernization of China CDC to better serve the goal of building a healthy China and fulfill its historical mission of safeguarding economic and social stability.

Reinforce China CDC's Pivotal Functions of Cultivating Strategic Scientific Strength, Building Talent Teams, and Fostering Global Health Collaboration

The Guidelines propose strengthening the core functions of disease control and prevention agencies at all levels, specifically strengthening those of China CDC in terms of health emergency response capacity, scientific research, education and training, and global public health cooperation in order to meet the health needs of the people. The Guidelines also propose that national and provincial CDCs should incorporate the Academy of Preventive Medicine to strengthen scientific research and technical support. China CDC will use this reform opportunity to optimize and adjust the "Three Fixed Plans" (fixed organization, fixed function, and fixed staffing) to achieve mutual support between China CDC and the Chinese Academy of Preventive Medicine through synchronous reform and coordinated development, strengthen and balance the development of key functions and tasks, and achieve the goal of shared strength with mutually beneficial outcomes. These include the following:

One: cultivate national strategic scientific and technological strength for disease control and prevention by strengthening exploration of scientific and technological frontiers of forward-looking major national strategies, fully leveraging the foundational role of key national laboratories, undertaking major national scientific and technological research tasks, generating significant original achievements, and creating a source of innovative technology.

Two: optimize the nurturing and training of the talent pool for disease control and prevention by stimulating and using the high-quality public health field practice and training resources of China CDC, vigorously promoting cooperation with high-level public health schools in colleges and universities, and cultivating high-level multidisciplinary public health as well as practical field epidemiological talent at all levels.

Three: strengthen global public health efforts by actively participating in global public health governance and using the national "Belt and Road," BRICS, and China-Africa cooperation mechanisms and platforms to fulfill the responsibilities and tasks of China CDC in serving the national strategy; contribute valuable Chinese wisdom, solutions, and power in the process of reforming and improving the global public health governance system and building a community with a shared future for all mankind.

Comprehensively Enhance the Eight Core Competencies of China CDC

The Guidelines put forward new requirements for building the capacity of the national disease control and prevention system. In line with the functional positioning of China CDC, problem-oriented, goal-oriented, and results-oriented measures are being taken that address weaknesses and shortcomings exposed in epidemic prevention and control practices. These measures aim to promote high-quality disease control and prevention initiatives and ensure effective implementation:

One: enhance the capacity of public health surveillance by optimizing vertical and horizontal networks for reporting infectious diseases and public health emergencies, establishing an intelligent multi-trigger early warning mechanism, promoting data exchange between the information systems and infectious disease monitoring systems of medical institutions, strengthening data linkages and real-time data sharing, removing barriers to data and information exchange across multiple departments, improving early warning and information release systems, and enhancing collaborative monitoring, rapid identification, and prompt information release.

Two: strengthen emergency response capacity for infectious diseases and public health emergencies by further improving the emergency response system, enhancing remote and international support capabilities of China CDC's emergency response team for acute infectious diseases, establishing specialized and versatile emergency training facilities, and conducting regular practice drills. Additionally, mechanisms for stockpiling emergency supplies are being improved.

Three: enhance national governance capacity for biosafety and laboratory testing by leading the establishment of a highly efficient national network of biosafety laboratories that will meet the demands for prevention and control of major infectious disease epidemics to enhance biosafety governance capacity; further strengthen the national public health laboratory testing and monitoring network, and significantly improve laboratory testing capabilities.

Four: improve disease control information systems and capabilities by accelerating digital transformation of disease control work, promoting the construction and applications of the public health big data platform at China CDC, leveraging information and data as fundamental support, and using technologies such as big data, cloud computing, and artificial intelligence to improve data integration, risk identification, intelligent analyses, and timely warning capabilities.

Five: enhance scientific and technological innovation and the ability to translate research findings into practical applications by establishing mechanisms for regular participation in national science and technology strategic decision-making; concentrating resources and effort on key scientific research projects related to prevention and control of major diseases and health hazards in terms of core technologies and key equipment; establishing scientific and technological innovation support platforms and key laboratories to enhance disease control and prevention innovation capacity; and supporting the establishment of collaborative platforms for industry, academia, research institutions and enterprises to strengthen translation and application of scientific and technological achievements.

Six: improve the ability to cultivate public health talent by strengthening cooperation and exchange between China CDC and schools of public health in colleges and universities in terms of personnel exchange, educational platform construction, data sharing, and establishing joint training bases for public health personnel; continuously implement the China Field Epidemiology Training Program (CFETP) with an emphasis on practical skills.

Seven: enhance strategic decision-making and advisory services from expert groups by establishing a National Committee of Experts on Disease Prevention and Control with a key consultative role in epidemic analysis and decision-making; guide scientific research to serve strategic public health decision-making and enhance public health consultation capacity.

Eight: improve global public health governance and foreign cooperation capabilities by cultivating global public health emergency response talent, actively engaging in global public health cooperation and assistance, strengthening international public health cooperation and exchanges, and shifting assistance from "fighting wildfires" to "scientifically managing forests." The national disease control system will be mobilized to promote the establishment of overseas cooperative project offices and collaborative laboratories by national-level disease control institutions, further strengthening the national biosafety barrier.

Improve the Management and Operations Systems of China CDC

China CDC will fully adhere to the requirements outlined in the Guidelines and actively promote reforms in personnel management, performance evaluation, and incentive mechanisms. China CDC will strengthen leadership in provincial-level CDCs and regional public health centers, further elevating its outlook with a focus on the development of a unified, nationwide disease control effort, to ultimately achieve the goal of using China CDC reforms as a driving force for modernization of the national disease control and prevention system.

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REFERENCES

1. China's State Council. Guidelines for High-Quality Development of Disease Prevention and Control. 2023. https://www.gov.cn/zhengce/content/202312/content_6922483.htm. [2024-1-16]. (In Chinese).

Preplanned Studies

Mushroom Poisoning Outbreaks — China, 2023

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Summary

What is already known about this topic?

Mushroom poisoning poses a significant food safety concern in China, with a total of 196 species identified in poisoning incidents by the end of 2022.

What is added by this report?

In 2023, the China CDC conducted an investigation into 505 cases of mushroom poisoning spanning 24 provincial-level administrative divisions. This investigation resulted in 1,303 patients and 16 deaths, yielding a case fatality rate of 1.23%. A total of 97 mushrooms were identified as the cause of 6 distinct clinical disease types, with 12 species newly documented as poisonous mushrooms in China.

What are the implications for public health practice?

Close collaboration among CDC staff, physicians, and mycologists remains crucial for the control and prevention of mushroom poisoning in the future.

Mushroom poisoning in China has emerged as a significant food safety concern. Over the past decade, the government, CDCs, hospitals, and mycological researchers have collaborated to establish a comprehensive network for collecting information on mushroom poisoning, facilitating diagnosis, and providing treatment support. This network utilizes various communication methods such as WeChat, telephone, and email (*1–4*). Following an incident of mushroom poisoning, CDC staff and hospital professionals promptly collect mushroom specimens and photos, which are then sent to mycologists for identification based on morphological and molecular evidence. In parallel, toxin detection is performed on both the mushrooms and biological samples such as blood and urine. By combining the results from species identification, toxin detection, and clinical manifestations, patients are accurately diagnosed and treated in a timely manner (*1–4*). In 2023, the China CDC conducted an investigation into 505 incidents of mushroom poisoning across 24 provincial-level administrative divisions (PLADs). This resulted in 1,303 patients and 16 deaths, corresponding to a case fatality rate of 1.23%. A total of 97 poisonous mushroom species, including 12 newly recorded ones, leading to 6 distinct clinical manifestations, were successfully identified. This brings the cumulative number of mushroom species involved in poisoning incidents in China to approximately 220 by the end of 2023.

In 2023, there were multiple incidents of mushroom poisoning, with the number of cases per incident ranging from 1 to 15 and an average of 2. Out of these incidents, only 6 involved more than 10 patients. Among the cases, 23 patients from 11 incidents consumed poisonous mushrooms purchased from markets, while 23 patients from 9 incidents were poisoned after consuming dried mushrooms. Additionally, 217 patients and 5 deaths resulted from 70 incidents where individuals consumed mixed wild mushrooms either self-collected or purchased from markets (Supplementary Table S1, available at https://weekly.chinacdc.cn/).

The temporal distribution analysis revealed that cases of mushroom poisonings were reported throughout the year, with the highest frequency observed between May and October (461 incidents, 1,207 patients, and 15 deaths), reaching a peak in June (127 incidents, 342 patients, and 3 deaths). The first death occurred in late April in Hunan Province. The months with the highest number of deaths were May (7 deaths), followed by June (3 deaths), and August (2 deaths) (Figure 1).

In terms of geographical distribution, mushroom poisoning incidents were reported in 24 PLADs. Among these, 12 PLADs had more than 10 incidents. The PLADs of Hunan, Yunnan, Guizhou, Sichuan, and Hubei were the top 5 affected regions. Hunan had 116 incidents with 223 patients and 1 death, followed by Yunnan with 81 incidents, 225 patients, and 1 death, Guizhou with 72 incidents, 231 patients, and 1

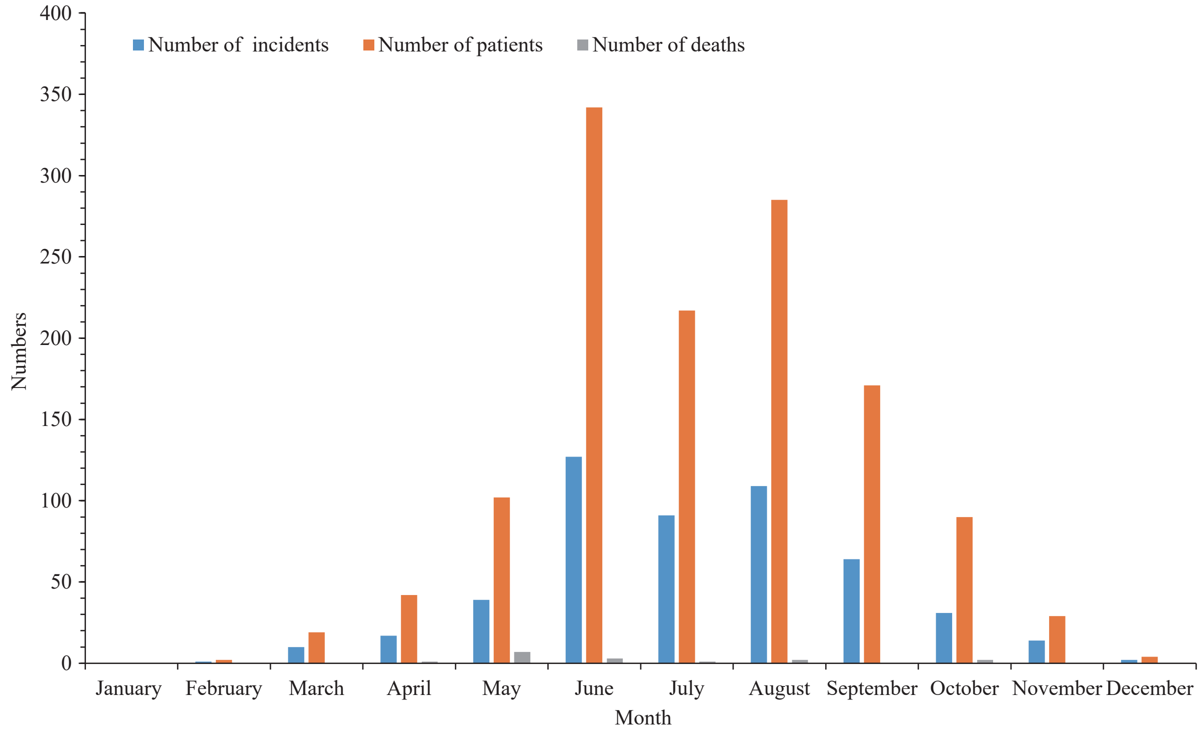

FIGURE 1. Monthly distribution of mushroom poisonings in China in 2023.

death, Sichuan with 48 incidents and 134 patients, and Hubei with 35 incidents and 69 patients (Table 1). Out of the 24 PLADs, 14 had more than 20 patients, with Guizhou, Yunnan, and Hunan having over 200 patients each (Table 1). Regarding fatalities, Guangdong, Guangxi, and Chongqing were the top 3 PLADs, with 5, 4, and 2 deaths, respectively (Table 1).

In 2023, a total of 97 species of poisonous mushrooms were identified in mushroom poisoning cases, leading to 6 distinct clinical syndromes. Among these species, 12 were newly discovered as poisonous in China (Supplementary Table S1). Specifically, *Collybia subtropica*, *Russula brevispora*, *R. flavescens*, and *R. pseudojaponica* were four newly described species in China in 2023 (*5*–*6*). *Collybia subtropica* contained muscarine and caused stimulation of the parasympathetic nervous system, while the last three species caused gastroenteritis. *Collybia subtropica* affected 3 individuals in Hunan from early October to mid-November. *Russula brevispora* was involved in 3 incidents affecting 5 patients, either on its own or in combination with other mushrooms, from June to July in Hunan. *Russula flavescens* was responsible for 2 incidents involving 4 patients from late August to early November in Yunnan. *Russula pseudojaponica* caused 17 incidents, affecting 65 patients, from early June to early November in various regions of China, including South, Southwest, Central, and East China. Additionally, three other newly recorded poisonous mushrooms in China that caused gastroenteritis were *Coprinopsis strossmayeri, Gymnopus dysodes*, and *G. similis*. *Coprinopsis strossmayeri* affected 2 patients in Jiangsu in June. *Gymnopus dysodes* affected 3 patients in June in Yunnan. *Gymnopus similis* was involved in 2 incidents affecting 3 patients in April and July in Hunan. Moreover, *Amanita collariata*, *Inocybe amelandica*, *Pseudosperma conviviale*, *P. triaciculare*, and *P. ushae* were newly described species causing psycho-neurological disorders in Eurasia after 2020 (*7*–*11*). *Amanita collariata*, discovered in Central China in 2022 (*7*), caused 1 incident involving 4 patients in April in Guangxi, 2023. *Inocybe amelandica*, originally discovered in the Netherlands in 2020 (*8*), was involved in 1 incident along with *Pseudosperma umbrinellum*, *P. arenarium*, and *I. serotina* (which contain muscarine) in early October in Ningxia, 2023, affecting 2 patients. *Pseudosperma conviviale*, discovered in Italy in 2020 (*9*), caused 1 incident involving 2 patients in early October in Anhui. *Pseudosperma triaciculare*, discovered in Pakistan in 2020 (*10*), caused 1 incident involving 2 patients in mid-September in Beijing. Lastly, *Pseudosperma ushae*, discovered in Germany in 2022 (*11*), caused 1 incident involving 2 patients in early October in Jilin, together

TABLE 1. Geographical Distribution of Mushroom Poisoning Incidents in China, 2023.

PLADs	Number of incidents	Number of patients	Deaths	Mortality (%)
Hunan	116	223	1	0.45
Yunnan	81	225	1	0.44
Guizhou	72	231	1	0.43
Sichuan	48	134	0	0
Hubei	35	69	0	0
Guangxi	22	83	4	0
Chongqing	21	50	2	4.00
Guangdong	19	51	5	9.80
Jiangsu	17	50	0	0
Fujian	13	39	0	0
Shandong	12	25	1	4.00
Zhejiang	11	21	0	0
Ningxia	9	22	0	0
Anhui	7	26	0	0
Jiangxi	6	11	1	9.09
Hebei	4	13	0	0
Hainan	3	9	0	0
Henan	2	5	0	0
Shanxi	2	3	0	0
Gansu	1	4	0	0
Xinjiang	1	4	0	0
Beijing	1	2	0	0
Jilin	1	2	0	0
Inner Mongolia	1	1	0	0
Total	505	1,303	16	1.23

Abbreviation: PLADs=provincial-level administrative divisions.

with *Cortinarius saturninus*.

The three most deadly mushrooms were identified as *Amanita fuligineoides*, *A. subpallidorosea,* and *Russula subnigricans*, causing 7, 2, and 2 deaths respectively (Supplementary Table S1). Among them, *Chlorophyllum molybdites* was found to have the widest distribution, being discovered in 12 PLADs. This mushroom was also associated with the highest number of poisoning incidents, appearing in 150 incidents and affecting 303 patients. Additionally, it had the longest active period, spanning from early April to early November.

In 2023, a total of 7 species of *Amanita*, 1 species of *Galerina*, and 1 species of *Lepiota* were identified as the cause of acute liver failure in China (Supplementary Table S1). Among these, *Amanita fuligineoides* was found to be the most dangerous, resulting in 7 deaths in 2 incidents involving 18 patients. Another incident involving *Amanita subpallidorosea* and *A. subfuliginea* caused 2 deaths. Additionally, *Amanita exitialis*, *A. subjunquillea*, and *Galerina sulciceps* each caused 1 death. The three most lethal mushroom species responsible for the highest number of incidents were *Amanita exitialis* (10 incidents, 21 affected patients, and 1 death), *Lepiota brunneoincarnata* (9 incidents and 29 affected patients), and *Amanita subjunquillea* (7 incidents, 23 affected patients, and 1 death).

Three species, namely *Amanita oberwinklerana*, *A. pseudoporphyria*, and *A. kotohiraensis*, were identified as the causes of acute renal failure in 2023 (Supplementary Table S1). *Amanita oberwinklerana* was the most prevalent species, present in 13 incidents involving 26 patients, either alone or in combination with other species. *Amanita pseudoporphyria* resulted in 2 fatalities out of 5 incidents and affected a total of 17 patients.

Russula subnigricans caused 14 cases of rhabdomyolysis, affecting a total of 38 patients and resulting in 2 fatalities, either on its own or in conjunction with other mushroom species. Additionally, *Cordierites frondosus* caused photosensitive dermatitis in 4 patients across 2 separate incidents in Yunnan during June (Supplementary Table S1).

A total of 50 mushroom species causing gastroenteritis were identified in China in 2023 (Supplementary Table S1). Among these species, 6 were newly identified as poisonous mushrooms and have been added to the Chinese poisonous mushroom list (*1*–*4*). The three most commonly encountered species in this category were *Chlorophyllum molybdites*, *Entoloma omiense*, and *Russula japonica*.

In 2023, a total of 33 mushroom species associated with psycho-neurological disorders were identified in China (Supplementary Table S1) (*1*). The three most frequently encountered species were *Amanita sychnopyramis* f. *subannulata*, which was involved in 10 incidents and affected 30 patients either alone or in combination with other species, followed by *Amanita subglobosa*, found in 9 incidents and affecting 40 patients, and *Psilocybe cubensis*, observed in 8 incidents and impacting 27 patients.

DISCUSSION

In 2023, mushroom poisoning incidents showed an increase compared to the years 2019 to 2022, with the exception of 2020. The number of patients in 2023 was higher than that of 2019 and 2021, but lower than that of 2020 and 2022. The number of deaths decreased in 2023 (*1–4*). Among the poisoning incidents in 2023, a total of 97 poisonous mushroom species were successfully identified, with 73 of them already recorded in the years 2019 to 2022 (*1–4*). This brings the total number of mushroom species involved in incidents to approximately 220 in China by the end of 2023. The most dangerous mushrooms causing fatalities in 2023 were *Amanita fuligineoides*, which differed from the years 2019 to 2022 (*1–4*).

The temporal distribution analysis revealed that mushroom poisonings in 2023 were primarily observed from May to October, which is consistent with the patterns observed in 2019 and 2020. However, the duration of the incidents in 2023 was shorter compared to those in 2021 and 2022 (*1–4*). Similar to 2022, the peak of mushroom poisonings in 2023 was observed in June (*1–4*). Notably, unlike the previous years, no incidents were recorded in January 2023 (*1–4*)(Figure 1).

In 2023, the province of Hunan had the highest number of incidents among all PLADs, consistent with the occurrences in 2019, 2020, and 2021, but differing from 2022 (*1–4*).

From late October to early November, three patients from two separate incidents in Northeastern China experienced poisoning from *Cortinarius saturninus*, either alone or in combination with *Pseudosperma ushae* (Supplementary Table S1). All three patients developed gastroenteritis and exhibited varying degrees of liver and kidney damage, which is not consistent with the typical symptoms of orellanine poisoning. Further investigation is necessary to identify the specific toxins involved and elucidate the mechanism of toxication.

A study conducted in 2023 focused on the species diversity of *Russula* subgenus *Brevipedum* in China. This study identified and named three new species: *Russula brevispora*, *R. flavescens*, and *R. pseudojaponica*. Interestingly, all three of these species were found to be responsible for cases of gastroenteritis poisoning in the same year. As a result, they have been included in the Chinese poisonous mushroom list (Supplementary Table S1).

This study represents only incidents that were investigated by a system comprising CDC staff, doctors, and mycologists. Our primary focus is on key areas and target populations affected by mushroom poisoning in China. We aim to identify the diversity of poisonous mushrooms, as well as the spatial and temporal distribution characteristics of mushroom poisoning. However, it should be noted that in numerous poisoning incidents, no mushroom specimens or even photos were obtained, making it challenging to confirm the exact species of poisonous mushrooms and provide targeted treatment for patients.

To achieve this goal, we propose the development and dissemination of diverse and accessible educational materials on toxic mushrooms. By reaching a wider audience, we can effectively reduce the incidence of mushroom poisoning.

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REFERENCES

1. Li HJ, Zhang HS, Zhang YZ, Zhang KP, Zhou J, Yin Y, et al. Mushroom poisoning outbreaks — China, 2019. China CDC Wkly 2020;2(2):19 – 24. https://doi.org/10.46234/ccdcw2020.005.
2. Li HJ, Zhang HS, Zhang YZ, Zhou J, Yin Y, He Q, et al. Mushroom poisoning outbreaks — China, 2020. China CDC Wkly 2021;3(3):41 –

5. https://doi.org/10.46234/ccdcw2021.014.
3. Li HJ, Zhang HS, Zhang YZ, Zhou J, Yin Y, He Q, et al. Mushroom poisoning outbreaks — China, 2021. China CDC Wkly 2022;4(3):35 – 40. https://doi.org/10.46234/ccdcw2022.010.
4. Li HJ, Zhang YZ, Zhang HS, Zhou J, Liang JQ, Yin Y, et al. Mushroom poisoning outbreaks — China, 2022. China CDC Wkly 2023;5(3):45 – 50. https://doi.org/10.46234/ccdcw2023.009.
5. He ZM, Chen ZH, Bau T, Wang GS, Yang ZL. Systematic arrangement within the family clitocybaceae (tricholomatineae, agaricales): phylogenetic and phylogenomic evidence, morphological data and muscarine-producing innovation. Fungal Diversity 2023;123 (1):1 – 47. https://doi.org/10.1007/s13225-023-00527-2.
6. Chen YL, An MY, Liang JY, Li WJ, Deng CY, Wang J, et al. Morphological characteristics and molecular evidence reveal four new species of *Russula* subg. Brevipedum from China. J Fungi 2023;9(61): 61. https://doi.org/10.3390/jof9010061.
7. Su YT, Cai Q, Qin WQ, Cui YY, Chen ZH, Yang ZL. Two new species of *Amanita* section *Amanita* from central China. Mycol Prog 2022;21(9):78. https://doi.org/10.1007/s11557-022-01828-7.
8. Bandini D, Oertel B, Schüssler C, Eberhardt U. Noch mehr risspilze: fünfzehn neue und zwei wenig bekannte arten der gattung *Inocybe*. Mycol Bavarica 2020;20:13-101. https://www.biotaxa.org/Phytotaxa/article/view/phytotaxa.480.2.6.
9. Cervini M, Bizio E, Alvarado P. Nomenclatural novelties. Index Fungorumno4412020:1-2https://www.indexfungorum.org/Publications/Index%20Fungorum%20no.441.pdf.
10. Saba M, Haelewaters D, Pfister DH, Khalid AN. New species of *Pseudosperma* (agaricales, *inocybaceae*) from pakistan revealed by morphology and multi-locus phylogenetic reconstruction. MycoKeys 2020;69:1 – 31. https://doi.org/10.3897/mycokeys.69.33563.
11. Bandini D, Oertel B, Eberhardt U. Noch mehr risspilze (3): einundzwanzig neue arten der familie inocybaceae. Mycol Bavarica 2022;22:31-138. https://www.researchgate.net/publication/360823313_Noch_mehr_Risspilze_3_Einundzwanzig_neue_Arten_der_Familie_Inocybaceae.

SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Mushroom species implicated in cases of poisoning and their spatial and temporal distribution in China, 2023.

Mushroom species	Number of incidents	Number of patients	Deaths	Case fatality (%)	Spatial and temporal distribution
Acute liver failure					
Amanita exitialis	9	20	0	0.00	April 7 to 8, Guangdong; June 13 to August 20, Yunnan
Amanita exitialis, *A. zangii* [U] and *Amanita* sp. [U]	1	1	1	100.00	June 16, Yunnan
Amanita cf. *exitialis*	1	5	0	0.00	September 2, Yunnan
Amanita fuliginea	2	4	0	0.00	June 26 and July 10, Sichuan and Hunan
Amanita fuligineoides	1	15	5	33.33	May 1, Guangdong
Amanita fuligineoides, *A. pseudoporphyria*[ARF], *A. kotohiraensis*[ARF], *A. fritillaria*[P], *Russula compacta* [E], *Russula* spp. [U] and *Amanita* sp.[U]	1	3	2	66.67	May 2, Guangxi
Amanita pallidorosea	4	9	0	0.00	July 2, Guizhou; July 29, Shandong; August 12, Yunnan; September 3, Shanxi
Amanita subfuliginea	1	3	0	0.00	June 4, Chongqing
Amanita subjunquillea	6	17	1	5.88	July 23 to September 3, Shandong, Hebei
Amanita subjunquillea, *Gymnopus densilamellatus* [G], *Tricholoma sinoportentosum* [G], *Amanita orsonii*[P], *Pholiota spumosa* [U], *Hydnum vesterholtii* [E], *Suillus sibiricus* [U] and *Russula* spp.[U]	1	6	0	0.00	August 4, Sichuan
Amanita subpallidorosea	1	2	0	0.00	October 3, Hubei
Amanita subpallidorosea, *A. subfuliginea*[ALF], *Tapinella atrotomentosa*[G], *Suillus pinetorum*[G], *A. sinocitrina*[P], *Pleurotus pulmonarius*[E] and *Lactarius vividus*[E]	1	2	2	100.00	October 28, Chongqing
Amanita spp.	3	6	0	0.00	June 5 to August 10, Hubei, Yunnan, Shandong
Galerina sulciceps	3	6	1	16.67	March 30, Sichuan; April 23, Hunan; November 4, Yunnan
Lepiota brunneoincarnata	9	29	0	0.00	June 9 to 26, Jiangsu, Guizhou, Hubei; July 23, Jiangsu; August 29 to September 25, Xinjiang, Ningxia
Rhabdomyolysis					
Russula subnigricans	12	35	2	5.71	June 15 to August 17, Yunnan, Jiangxi, Guizhou, Chongqing and Hunan
Russula subnigricans, *R. japonica*[G] and *R. punctipes*[G]	1	2	0	0.00	June 24, Hunan
Russula subnigricans and *Russula* sp.[U]	1	1	0	0.00	August 17, Fujian
Acute renal failure					
Amanita oberwinklerana	10	19	0	0.00	June 2 to October 11, Guizhou, Chongqing, Henan, Shanxi, and Hubei
Amanita oberwinklerana and *A. pseudoporphyria*	1	3	0	0.00	June 8, Chongqing
Amanita oberwinklerana and *A. subjunquillea*[ALF]	1	2	0	0.00	August 31, Hebei
Amanita oberwinklerana, *A. fritillaria*[P], *Agaricus luteofibrillosus*[U] and *Lactarius subzonarius*[E]	1	2	0	0.00	June 18, Guizhou
Amanita pseudoporphyria	5	17	2	11.76	August 31 to September 17, Hunan, Guangxi
Gastroenteritis					
Agaricus xanthodermus	1	2	0	0.00	September 20, Jiangsu
Baorangia major	2	5	0	0.00	June 29, Fujian; December 25, Hunan (dried boletes bought from Yunnan market)
Chlorophyllum globosum	8	24	0	0.00	May 3 to August 18, Guangdong, Hubei, Hainan, Yunnan, Sichuan
Chlorophyllum aff. *globosum*	2	7	0	0.00	August 7 to September 26, Sichuan

Continued

Mushroom species	Number of incidents	Number of patients	Deaths	Case fatality (%)	Spatial and temporal distribution
Chlorophyllum hortense	7	19	0	0.00	May 2 to September 4, Zhejiang, Hubei, Sichuan, Hunan
Chlorophyllum molybdites	149	302	0	0.00	April 6 to November 3, Guangdong, Hunan, Guangxi, Hainan, Hubei, Fujian, Anhui, Jiangsu, Sichuan, Yunnan, Zhejiang, Chongqing (2 patients in 2 incidents from Guangdong ate raw mushrooms; 4 patients in 1 incident from Hunan ate dried mushrooms collected in 2022)
Chlorophyllum molybdites and *Coprinus comatus*[E,G]	1	1	0	0.00	August 28, Hubei
Coprinopsis atramentaria	2	3	0	0.00	April 25 and May 6, Ningxia
Coprinopsis strossmayeri	1	2	0	0.00	June 19, Jiangsu
Entoloma caespitosum	1	2	0	0.00	July 14, Yunnan
Entoloma cf. *sinuatum*	1	5	0	0.00	June 15, Guizhou
Entoloma cf. *subsinuatum*	1	4	0	0.00	October 8, Guizhou
Entoloma cf. *subsinuatum* and *Descolea quercina*[U]	1	9	0	0.00	October 6, Guizhou
Entoloma omiense	20	82	0	0.00	June 14 to August 12, Hainan, Jiangxi, Guangxi, Guizhou, Sichuan
Entoloma omiense and *Amanita sinensis*[E]	1	7	0	0.00	June 26, Guangxi
Entoloma omiense and *Amanita sinocitrina*[P]	1	7	0	0.00	June 23, Guizhou
Entoloma omiense, *Amanita* sp.[U], *Russula viridicinnamomea*[U], *Lactarius* aff. *gerardii*[E] and *Russula crustosa*[E]	1	6	0	0.00	August 10, Sichuan
Entoloma omiense, *Calvatia craniiformis*[E,M], *Lactarius vividus*[E] and *Entoloma* sp.[U]	1	4	0	0.00	August 12, Sichuan
Entoloma omiense, *Pisolithus albus*[U], *Retiboletus fuscus*[E] and *Lactarius vividus*[E]	1	2	0	0.00	August 17, Yunnan
Entoloma omiense, *Marasmius maximus*[E] and *Leucoagaricus rubrotinctus*[U]	1	10	0	0.00	July 8, Jiangsu
Entoloma omiense and *Entoloma* sp.[U]	1	2	0	0.00	August 6, Sichuan
Entoloma omiense and *Gymnopus* sp.[U]	1	6	0	0.00	July 28, Guizhou
Entoloma omiense and *Russula viridicinnamomea*[U]	1	2	0	0.00	August 12, Sichuan
Gymnopus densilamellatus	1	1	0	0.00	July 5, Guizhou
Gymnopus cf. *densilamellatus*	2	5	0	0.00	February 18 and March 29, Hunan
Gymnopus dryophilus	1	2	0	0.00	March 26, Guizhou
Gymnopus dryophilus, *G. densilamellatus*, *Suillus pinetorum*[G], *Laccaria laccata*[E], *Infundibulicybe alkaliviolascens*[E], *Russula violeipes*[E], *R. cerolens*[U] and *Gymnopus* sp.[U]	1	3	0	0.00	June 14, Guizhou
Gymnopus dysodes	1	3	0	0.00	June 14, Yunnan
Gymnopus similis	2	3	0	0.00	April 25 and July 8, Hunan
Gymnopus sp. and *Agaricus* sp.[U]	1	2	0	0.00	August 3, Hunan
Gymnopus sp. and *Russula* sp.[U]	1	2	0	0.00	July 13, Yunnan
Heimioporus japonicus	1	2	0	0.00	August 19, Fujian
Lactarius laccarioides	1	10	0	0.00	October 18, Yunnan
Lactarius rubrobrunneus	1	1	0	0.00	July 2, Yunnan
Lactifluus aff. *glaucescens*	1	3	0	0.00	June 27, Guizhou
Lanmaoa sp.	1	2	0	0.00	June 30, Yunnan
Leucocoprinus cretaceus	1	1	0	0.00	July 16, Jiangsu

Continued

Mushroom species	Number of incidents	Number of patients	Deaths	Case fatality (%)	Spatial and temporal distribution
Neoboletus venenatus	3	5	0	0.00	August 10, Sichuan; September 10 to 24, Shandong, Hunan (dried boletes, bought from markets)
Omphalotus guepiniformis	3	7	0	0.00	March 20, Guizhou; October 9 and November 3, Hunan
Omphalotus yunnanensis nom. prov.	2	9	0	0.00	August 20 and October 14, Yunnan
Pholiota lubrica	1	3	0	0.00	November 13, Yunnan
Pulveroboletus subrufus, *Lactifluus* cf. *pseudoluteopus*[U], *L. subpruinosus*[E], *L. volemus*[E], *Pleurotus giganteus*[E] and *Russula crustosa*[E]	1	1	0	0.00	August 2, Hunan
Rubroboletus sinicus	1	2	0	0.00	July 16, Yunnan
Russula brevispora	1	1	0	0.00	July 18, Hunan
Russula brevispora, *R. punctipes*, *R. rufobasaliss*[G], *Tylopilus neofelleus*[G], *Suillus pinetorums*[G], *Boletellus indistinctuss*[G], *Xerocomus subtomentosus*[G], *Amanita pseudoporphyrias*[ARF], *Amanita fritillaria*, *Russula crustosa*[E], *Termitomyces* sp.[E], *Lactifluus subpruinosus*[E], *Pleurotus giganteus*[E], *Russula compacta*[E], *Russula aureoviridi*[U], *Russula purpureoverrucosa*[U], *Gyroporus longicystidiatus*[U], *Tylopilus pseudoballoui*[U] and *Lactarius atromarginatus*[U]	1	2	0	0.00	June 25, Hunan (dried mushrooms)
Russula brevispora, *R. punctipes*[G], *R. foetens*[G], *Amanita pseudoporphyria*[ARF], *Lactarius vitellinus*[U], *Lactifluus roseophyllus*[U], *Russula aureoviridi*[U], *Lactifluus* aff. *ambicystidiatus*[E], *Lactifluus* aff. *tropicosinicus*[E], *Lentinus squarrosulus*[E], *Russula lepida*[E] and *Russula vesca*[E]	1	2	0	0.00	July 31, Hunan (dried mushrooms)
Russula flavescens	1	3	0	0.00	November 8, Yunan
Russula flavescens and *Amanita* cf. *similis*[U]	1	1	0	0.00	August 31, Yunan
Russula japonica	20	49	0	0.00	May 5 to July 22, Hunan, Hubei, Guizhou, Yunnan, Zhejiang
Russula pseudojaponica	11	45	0	0.00	June 6 to November 7, Guangxi, Guizhou, Jiangxi, Yunnan, Fujian, Hunan
Russula pseudojaponica, *Amanita* cf. *princeps*[E] and *Russula* sp.[U]	1	1	0	0.00	July 30, Sichuan
Russula pseudojaponica, *R. punctipes*[G], *R. viridicinnamomea*[U] and *Russula* spp.[U]	1	2	0	0.00	August 11, Sichuan
Russula pseudojaponica, *R. densifolia*[E], *R. callainomarginis*[U] and *Russula* sp.[U]	1	6	0	0.00	June 19, Guizhou
Russula pseudojaponica, *R. densifolia*[E] and *Calvatia craniiformis*[E,M]	1	4	0	0.00	July 25, Sichuan
Russula pseudojaponica, *R. foetens*[G], *R. punctipes*[G], *Lactifluus pilosus*[G], *Suillus granulatus*[G] and *Russula virescens*[E]	1	5	0	0.00	June 17, Guizhou
Russula pseudojaponica, *Russula* sp.[U] and *Amanita* sp.[U]	1	2	0	0.00	August 4, Sichuan
Russula punctipes, *R. callainomarginis*[U], *Russula* sp.[U], *Amanita griseofolia*[U] and *A. fritillaria*[P]	1	2	0	0.00	August 7, Sichuan
Scleroderma cepa	3	15	0	0.00	June 27 to July 16, Guizhou, Yunnan
Scleroderma sp., *Clitocella* sp.[U], *Amanita melleiceps*[P] and *Agaricus atrodiscus*[G]	1	3	0	0.00	September 23, Sichuan
Suillus granulatus	2	3	0	0.00	August 10 and October 4, Guizhou, Shandong
Tricholoma olivaceum	1	2	0	0.00	September 5, Yunnan
Tricholoma olivaceum, *Entoloma* cf. *subsinuatum*[G] and *Amanita* sp.[U]	1	1	0	0.00	August 21, Yunnan
Tricholoma sinopardinum	1	2	0	0.00	November 9, Sichuan

Continued

Mushroom species	Number of incidents	Number of patients	Deaths	Case fatality (%)	Spatial and temporal distribution
Tricholoma stans	1	4	0	0.00	November 1, Yunnan
Tylopilus vinosobrunneus, *Lactifluus piperatus*[E,G], *Boletus reticulatus*[E], *Tylopilus pseudoballoui*[E], *Neoboletus obscureumbrinus*[E], *Retiboletus sinensis*[E], *Rugiboletus extermioirentalis*[E], *Lanmaoa angustispora*[U], *Neoboletus multipunctatus*[U] and *Lactifluus dwaliensis*[U]	1	2	0	0.00	November 14, Guizhou (dried mushrooms)
Psycho-neurological disorder					
Amanita collariata, *Russula sanguinea*[E]	1	4	0	0.00	April 18, Guangxi
Amanita concentrica	1	1	0	0.00	June 8, Yunnan
Amanita melleiceps	2	2	0	0.00	April 24, Jiangxi; August 26, Hunan
Amanita parvipantherina	3	11	0	0.00	May 23 to June 6, Guizhou
Amanita pseudosychnopyramis	1	4	0	0.00	April 15, Zhejiang
Amanita cf. *pseudosychnopyramis* and *A. rufoferruginea*	1	5	0	0.00	June 8, Fujian
Amanita rufoferruginea	4	10	0	0.00	May 26 to July 1, Hunan, Chongqing, Guizhou
Amanita siamensis	1	2	0	0.00	July 30, Sichuan
Amanita siamensis and *Termitomyces* sp.[E]	1	3	0	0.00	July 29, Sichuan
Amanita subglobosa	7	33	0	0.00	June 16 to July 2, Guizhou; August 6 to 15, Chongqing, Yunnan; September 30, Guizhou
Amanita subglobosa, A. pseudoporphyria[ARF], *Pisolithus arhizus*[U]	1	4	0	0.00	October 20, Sichuan
Amanita subglobosa and *Agaricus atrodiscus*[G]	1	3	0	0.00	October 7, Guizhou
Amanita sychnopyramis f. *subannulata*	8	24	0	0.00	April 25 to June 25, Guangxi, Hunan, Chongqing
Amanita sychnopyramis f. *subannulata* and *Chlorophyllum molybdites*[G]	1	1	0	0.00	June 27, Fujian
Amanita sychnopyramis f. *subannulata*, *A. castanea*[U] and *A. pseudoporphyria*[ARF]	1	5	0	0.00	July 15, Hunan
Candolleomyces candolleanus	1	3	0	0.00	June 19, Yunnan
Clitocybe dealbata	1	1	0	0.00	October 7, Hunan
Collybia subtropica	3	3	0	0.00	October 9 to November 17, Hunan
Gymnopilus dilepis	3	6	0	0.00	May 14 to August 9, Guizhou, Yunnan
Gyromitra venenata	1	1	0	0.00	March 31, Guizhou
Inocybe serotina	1	1	0	0.00	September 29, Ningxia
Inosperma cf. *virosum*	1	1	0	0.00	September 4, Yunnan
Inosperma sp.	2	16	0	0.00	September 1 and 2, Yunnan
Lanmaoa asiatica	3	3	0	0.00	July 5 to November 6, Guangdong, Jiangxi (bought from Yunnan market)
Ophiocordyceps sobolifera	1	1	0	0.00	September 17, Chongqing
Panaeolus cyanescens	2	4	0	0.00	October 11 and 31, Guangxi, Guizhou
Pseudosperma arenarium	1	1	0	0.00	October 14, Ningxia
Pseudosperma conviviale	1	2	0	0.00	October 8, Anhui
Pseudosperma triaciculare	1	2	0	0.00	September 15, Beijing
Pseudosperma umbrinellum	2	4	0	0.00	July 28 and September 9, Ningxia
Pseudosperma umbrinellum, *P. arenarium*[P], ***Inocybe amelandica***[P], *I. serotina*[P] and *Hebeloma dunense*[U]	1	2	0	0.00	October 7, Ningxia
Pseudosperma yunnanense, *Tylopilus neofelleus*[G] and *Collybiopsis subnuda*[U]	1	6	0	0.00	August 9, Guizhou

Continued

Mushroom species	Number of incidents	Number of patients	Deaths	Case fatality (%)	Spatial and temporal distribution
Psilocybe cubensis	7	16	0	0.00	May 4 to June 15, Hunan, Guizhou; November 6, Guangxi
Psilocybe cubensis and *Chlorophyllum hortense*[G]	1	11	0	0.00	April 29, Guangxi
Psilocybe papuana	1	4	0	0.00	August 9, Yunnan
Tolypocladium dujiaolongae	1	3	0	0.00	September 21, Guangdong
Photosensitive dermatitis					
Cordierites frondosus	2	4	0	0.00	June 20, Yunnan
Unclassified					
Agaricus albovariabilis[U]	1	1	0	0.00	August 21, Fujian
Agaricus beijingensis[U]	1	1	0	0.00	October 3, Shandong
Agaricus campestris[E]	3	3	0	0.00	March 13 to April 3, Hunan
Agaricus sp.[U], *Oudemansiella orientalis*[E], *Lactarius cinnamomeus*[E]	1	1	0	0.00	May 29, Guizhou
Agaricus sp.[U], *Russula* sp.[U]	1	1	0	0.00	June 18, Guizhou
Amanita cf. *princeps*[E]	1	2	0	0.00	July 15, Sichuan
Amanita manicata[U]	1	1	0	0.00	June 28, Guangxi
Amanita pseudoprinceps[E]	1	1	0	0.00	August 16, Yunnan
Calvatia cyathiformis[U]	1	1	0	0.00	September 3, Guangdong
Calvatia gigantea[U]	1	1	0	0.00	June 7, Chongqing
Cortinarius saturninus[U]	1	1	0	0.00	September 25, Inner Mongolia
Cortinarius saturninus[U], ***Pseudosperma ushae***[P]	1	2	0	0.00	October 3, Jilin
Hygrophorus yunnanensis[U] and *H. pseudopurpurascens*[U]	1	2	0	0.00	November 9, Yunnan (bought from market)
Leucoagaricus lacrymans[U] and *Agaricus* sp.[U]	1	1	0	0.00	May 18, Guangdong
Neoboletus flavidus[E]	1	1	0	0.00	July 2, Yunnan
Neoboletus flavidus[E] and *Albatrellus ellisii*[E]	1	2	0	0.00	July 3, Shandong (dried boletes)
Neofavolus alveolaris[U] and *Tyromyces chioneus*[U]	1	1	0	0.00	December 25, Chongqing
Pisolithus arhizus[U]	1	4	0	0.00	October 4, Sichuan
Pleurotus pulmonarius[E]	1	1	0	0.00	April 18, Hubei
Russula pulchra[U]	1	3	0	0.00	August 10, Chongqing
Scleroderma yunnanense[E]	1	4	0	0.00	October 26, Guizhou
Trametes hirsuta[U]	1	1	0	0.00	July 10, Guangdong
Trichaptum byssogenum[U]	1	4	0	0.00	September 17, Hubei
Turbinellus cf. *parvisporus*[U]	1	2	0	0.00	June 30, Yunnan

Abbreviations used for mushroom poisoning incidents involving more than two species: ALF=Acute liver failure, ARF=Acute renal failure, G=Gastroenteritis, P=Psycho to neurological disorder, M=Medicinal, U=Unclassified, E=edible.

Note: Species newly recorded as poisonous mushrooms in China are in italics and bolded.

Vital Surveillances

Relationship Between Climate Change and Marmot Plague of *Marmota himalayana* Plague Focus — the Altun Mountains of the Qinghai-Xizang Plateau, China, 2000–2022

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ABSTRACT

Introduction: Plague is a zoonotic disease that occurs naturally in specific geographic areas. Climate change can influence the populations of the plague host or vector, leading to variations in the occurrence and epidemiology of plague in animals.

Methods: In this study, we collected meteorological and plague epidemiological data from the *Marmota himalayana* plague focus in the Altun Mountains of the Qinghai-Xizang Plateau. The data spanned from 2000 to 2022. We describe the climatic factors and plague epidemic conditions and we describe their analysis by Pearson's correlation.

Results: During the period from 2000 to 2022, the isolation rates of *Yersinia pestis* (*Y.pestis*) from marmots and fleas were 9.27% (451/4,864) and 7.17% (118/1,646), respectively. Additionally, we observed a positive rate of F1 antibody of 11.25% (443/3,937) in marmots and 18.16% (142/782) in dogs. With regards to climate, there was little variation, and a decreasing trend in blowing-sand days was observed. The temperature in the previous year showed a negative correlation with the *Y. pestis* isolation rate in marmots ($r=-0.555$, $P=0.011$) and the positive rate of F1 antibody in marmots ($r=-0.552$, $P=0.012$) in the current year. The average annual precipitation in the previous two years showed a positive correlation with marmot density ($r=0.514$, $P=0.024$), while blowing-sand days showed a negative correlation with marmot density ($r=-0.701$, $P=0.001$). Furthermore, the average annual precipitation in the previous three years showed a positive correlation with the isolation rate of *Y. pestis* from marmots ($r=0.666$, $P=0.003$), and blowing-sand days showed a negative correlation with marmot density ($r=-0.597$, $P=0.009$).

Conclusions: The findings of this study indicate that there is a hysteresis effect of climate change on the prevalence of plague. Therefore, monitoring climate conditions can offer significant insights for implementing timely preventive and control measures to combat plague epidemics.

INTRODUCTION

Plague is a zoonotic disease that can persist in natural foci even without human hosts (*1*). Climate changes in these foci can disrupt plague hosts and vectors, leading to outbreaks in animals and humans. Studies have demonstrated that climate warming can promote the spread of plague (*2*). The frequency of plague outbreaks significantly increases during dry seasons (*3*), and the effects of rainfall on plague intensity differ between northern and southern regions of China (*4*). Therefore, it is important to conduct detailed studies on local climate factors to better prepare for epidemics. The Altun Mountains region, located in the *Marmota himalayana* (*M. himalayana*) plague focus of the Qinghai-Xizang Plateau, has a relatively stable ecological environment with fewer human settlements. This makes it less susceptible to human activities but more vulnerable to ecological changes (*5*). Consequently, climate change is expected to impact animal plagues in this region.

In this study, we examined meteorological data and plague monitoring data in the Altun Mountains region of the *M. himalayana* plague focus of the Qinghai-Xizang Plateau from 2000 to 2022. Our objective was to understand the plague epidemic and climate conditions in this region. We aimed to analyze the relationship between climate change and marmot plague in the Altun Mountains of the Qinghai-Xizang Plateau from 2000 to 2022, in order to provide a theoretical foundation for developing an early warning system for effective plague prevention and control.

METHODS

Data Collection

Meteorological and plague epidemiological data were collected from the *M. himalayana* plague focus in the Altun Mountains of the Qinghai-Xizang Plateau between the years 2000 and 2022. Meteorological data were obtained from the Meteorological Bureau of Aksai Kazakh Autonomous County, Gansu Province, China. Plague surveillance data were obtained from Aksai CDC, with the exception of the years 2003, 2011, and 2016 due to legitimate reasons.

Analysis Indicators

The meteorological data utilized in this study comprise temperature (°C), relative humidity (% RH), precipitation (mm), occurrences of strong wind days (day), floating-dust days (day), blowing-sand days (day), sandstorm days (day), and sunshine hours (h). Plague surveillance data consist of marmot and vector counts, isolation rates of *Y. pestis* from marmots and fleas, positive rates of F1 antibody in marmots and dogs, as well as the marmot flea index.

Statistical Analyses

Statistical analyses were conducted using SPSS software (version 26.0, IBM, Armonk, New York, USA). The study described the prevalence of plague in animals and climate change in the Altun Mountains, which is the natural focus of *M. himalayana* plague, from 2000 to 2022. A Chi-square test was utilized to compare the isolation rates of *Y. pestis* from marmots and fleas in different years. Pearson correlation analysis was performed to examine the correlation between climate change and plague prevalence in the current year, as well as the previous year, previous two years, and previous three years (relative to the current year). The previous 1, 2, and 3 years were considered in relation to the current year as a reference. A P value of <0.05 was considered statistically significant.

RESULTS

Epidemiological Characteristics of Plague During 2000−2022

Figure 1 depicts the detection of 4,864 marmots, the primary host animal, from 2000 to 2022 (excluding 2003, 2011, and 2016). During this period, 451 strains of *Y. pestis* were isolated, resulting in an isolation rate of 9.27% in marmots. A significant difference was observed in the isolation rate of *Y. pestis* from marmots each year (χ^2=103.00, P<0.05). The lowest isolation rate was recorded in 2001 (3.54%, 8/226), while the rate displayed an increasing trend from 2019 (6.47%, 15/232) and reached 22.05% (58/263) in 2022. The isolation rate of *Y. pestis* from fleas was 7.17% (118/1,646). Similarly, the isolation

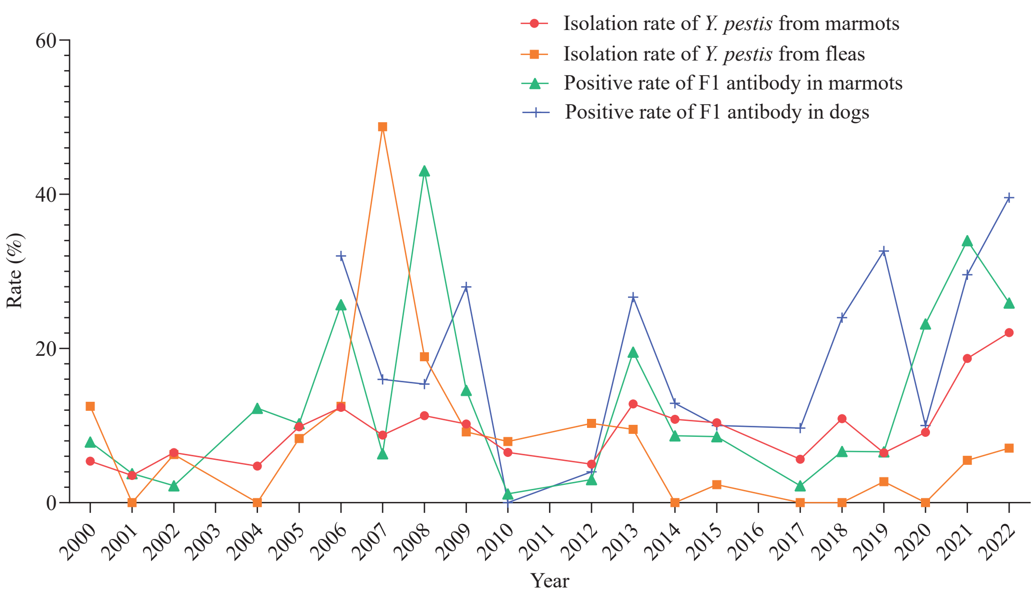

FIGURE 1. Epidemiological characteristics of plague in *M. himalayana* plague foci in the Altun Mountains on the Qinghai-Xizang Plateau, China, 2000−2022.

rate of *Y. pestis* from fleas exhibited a significant difference each year (χ^2=117.17, P<0.05). The isolation rate from fleas increased from 2.73% (2/73) in 2019 to 7.09% (28/395) in 2022, mirroring the findings from marmots, except for a high rate in 2007 (48.78%, 20/41) (Figure 1).

The F1 antibody positive rate in marmots was 11.25% (443/3,979). The highest rate was observed in 2008 at 40.06% (59/137). There was a statistically significant difference in the positive rate of F1 antibody in marmots between different years (χ^2=350.36, P<0.05). The positive rate of F1 antibody in dogs from 2006 to 2022 was 18.16% (142/782). There was also a statistically significant difference in the positive rate of F1 antibody in dogs between different years (χ^2=59.37, P<0.05). Additionally, both the positive rate of F1 antibody in marmots and dogs exhibited zigzag interannual changes.

Climate Change During 2000−2022

The *M. himalayana* plague foci in the Altun Mountains on the Qinghai-Xizang Plateau had an average annual temperature ranging from 16.63 °C to 18.51 °C. The RH ranged from 28.10% to 42.86%. The average annual precipitation varied from 18.7 mm to 203.30 mm. Sunshine hours ranged from 1639.30 h to 2063.50 h per year. The number of strong wind days varied from 0 to 7, blowing-sand days ranged from 1 to 20, floating-dust days ranged from 2 to 39, and sandstorm days ranged from 0 to 9 annually. These data exhibited slight variability with minimal fluctuation (Figure 2).

Correlation Between Climate and Plague

The indicators used for correlation analysis met the criteria of normal distribution (P>0.05), and there were significant linear relationships between climate factors and plague epidemic indicators (P<0.05) (Supplementary Figure S1, available at https://weekly.chinacdc.cn/). In terms of the relationship between current climate change and current plague epidemic, the number of blowing-sand days showed a positive correlation with the isolation rate of *Y. pestis* from fleas (r=0.463, P=0.04), while temperature was

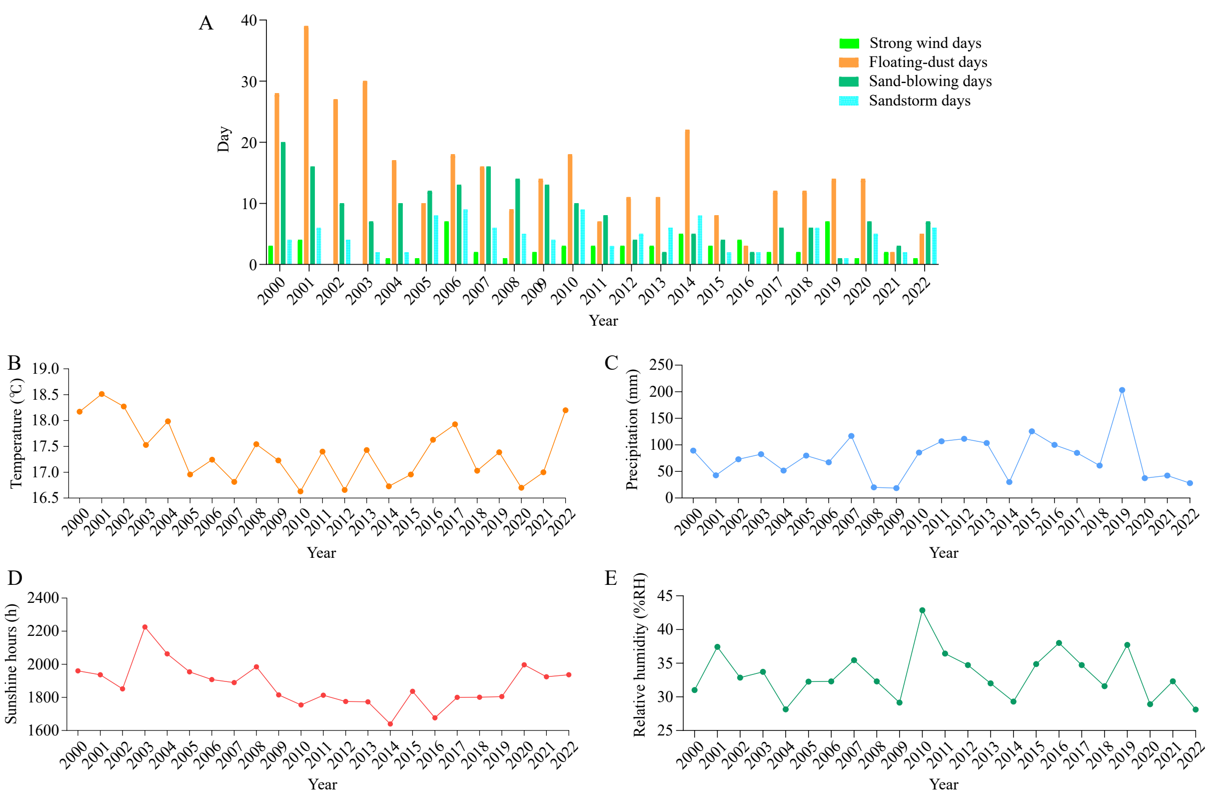

FIGURE 2. Climate change in *M. himalayana* plague foci in the Altun Mountains on the Qinghai-Xizang Plateau, China, 2000−2022. (A) The average annual number of unusual weather days; (B) The average annual temperature; (C) The average annual precipitation; (D) The average annual sunshine hours; (E) The average annual relative humidity.

positively correlated with the positive identification of F1 antibodies in dogs (r=0.575, *P*=0.025). Regarding the relationship between climate change in the previous year and plague prevalence in the current year, there was a negative correlation between temperature and the *Y. pestis* isolation rate from marmots (r=−0.555, *P*=0.011), as well as the positive F1 antibody rate in dogs in marmots (r=−0.552, *P*=0.012). Additionally, there was a positive correlation between average sunshine hours and the positive F1 antibody rate in dogs (r=0.550, *P*=0.034) (Table 1).

The correlation between climate change in the previous two years and the plague epidemic in the current year was examined. The results showed a positive correlation between average annual precipitation and marmot density (r=0.514, *P*=0.024). On the other hand, there were negative correlations between the number of blowing-sand days (r=−0.701, *P*=0.001) and sunshine hours (r=−0.593, *P*=0.007) with marmot density. Additionally, a negative correlation was observed between temperature in the previous two years and flea index in the current year (r=−0.577, *P*=0.010). Furthermore, the relationship between climate change in the previous three years and plague prevalence in the current year was examined. The findings revealed a positive correlation between average annual precipitation in the previous three years and the number of self-destructed marmots (r=0.699, *P*=0.005), as well as the isolation rate of *Y. pestis* in marmots (r=0.666, *P*=0.003). Conversely, the number of blowing-sand days showed negative correlations with the number of dead marmots (r=−0.676, *P*=0.008), marmot density (r=−0.597, *P*=0.009), isolation rate of *Y. pestis* from marmots (r=−0.505, *P*=0.032), and positive F1 antibody rate in dogs (r=−0.527, *P*=0.043). Moreover, average sunshine hours were negatively correlated with marmot density (r=−0.611, *P*=0.007), and positively correlated with the isolation rate of *Y. pestis* from fleas (r=0.521, *P*=0.027) (Table 1).

CONCLUSIONS

The *M. himalayana* plague focus in China is a highly prevalent region for animal and human plague. Animal plague occurs every year (*6*), with occasional transmission to humans (*7–8*), highlighting the importance of monitoring animal plague. In recent years, the isolation rate of *Y. pestis* in marmots has continuously risen from 6.46% in 2019 to 22.05% in 2022. Similarly, the isolation rate of fleas carrying *Y. pestis* has also increased. *Y. pestis* was detected in both deceased marmots and the fleas they carried, indicating persistent infection and the widespread presence of plague among animals. The fluctuation in the positive rate of F1 antibody suggests a shift in the active and silent state of the plague foci.

The Altun Mountains in the *M. himalayana* plague focus area have undulating basins formed by the foldings of the Qilian Mountains and the Tianshan Mountains. The main types of terrain in this area are deserts and semi-desert grasslands (*9*). The climate in this region is characterized by high altitude, cold temperatures, large temperature variations, and dryness. From 2000 to 2022, the climate in this region has remained relatively stable in terms of change.

In analyzing the relationship between climate and plague prevalence in the current year, we observed that an increase in the number of sand-blowing days led to a higher isolation rate of *Y. pestis* from fleas. This is attributed to reduced marmot activities during blowing-sand days, causing them to spend more time in caves. The cave environment provides favorable conditions for flea parasites on marmots and the propagation of *Y. pestis* in fleas (*10*). Consequently, this increases the risk of plague epidemics. Previous sand-raising events in the two to three years prior have adversely affected marmot foraging, resulting in lower marmot density, decreased number of *Y. pestis* hosts, and reduced isolation rates of *Y. pestis* from marmots.

Regarding the analysis of climate and plague prevalence in the current year, we found that higher temperatures created warmer conditions for marmot hibernation. This leads to earlier hibernation periods and increased activities outside, thereby increasing the likelihood of marmots being preyed upon by dogs. Furthermore, marmots may hibernate with bacterial infections (*11*), and predation of infected marmots by dogs can elevate the positive rate of F1 antibodies in dogs. Rising temperatures also cause drought, resulting in food scarcity for marmots and decreased resistance, making them more susceptible to *Y. pestis* infection and predation by dogs. Thus, these factors contribute to the outbreak of plague epidemics. Through our study on the relationship between climate and plague prevalence in the previous year, we discovered that increased temperature led to enhanced development and reproductive ability of marmots. As a result, the current year saw a rise in the marmot population, improved healthy survival rates, and decreased isolation rates of *Y. pestis* and F1 antibody positive rates in marmots. These findings align with previous researches

TABLE 1. Correlation analysis of climate factors and plague epidemic indicators in the Altun Mountains on the Qinghai-Xizang Plateau, China, 2000–2022.

Plague epidemic indicators		Current year		Last year		Previous two years				Previous three years		
		Temperature	Number of sand-blowing days	Temperature	Number of sunshine hours	Temperature	Precipitation	Number of sand-blowingdays	Number of sunshine hours	Precipitation	Number of sand-blowing days	Number of sunshine hours
Number of self-dead marmota	r	0.430	0.103	0.030	0.266	0.052	0.070	−0.287	0.135	0.699	−0.676	0.122
	P	0.125	0.725	0.919	0.359	0.860	0.813	0.320	0.645	0.005*	0.008*	0.679
Marmot density	r	−0.017	−0.314	−0.017	−0.273	−0.379	0.514	−0.701	−0.593	0.436	−0.597	−0.611
	P	0.943	0.177	0.944	0.245	0.110	0.024*	0.001*	0.007*	0.071	0.009*	0.007*
Isolation rate of *Y. pestis* from marmots	r	−0.147	−0.300	−0.555	−0.019	−0.387	0.380	0.001	0.007	0.666	−0.505	−0.009
	P	0.536	0.198	0.011*	0.935	0.101	0.108	−0.433	0.023	0.003*	0.032*	0.973
Isolation rate of *Y. pestis* from fleas	r	−0.189	0.463	−0.135	0.132	−0.253	−0.175	0.064	0.925	−0.190	0.186	0.521
	P	0.424	0.040*	0.572	0.579	0.297	0.473	0.262	0.271	0.449	0.460	0.027*
Positive rate of F1 antibody in marmots	r	−0.027	−0.015	−0.552	0.195	−0.167	0.208	0.279	0.261	0.214	−0.216	0.181
	P	0.911	0.950	0.012*	0.411	0.494	0.392	−0.182	0.042	0.394	0.388	0.471
Positive rate of F1 antibody in dogs	r	0.575	−0.069	−0.283	0.550	0.278	0.233	0.455	0.864	0.452	−0.527	0.117
	P	0.025*	0.807	0.306	0.034*	0.316	0.404	−0.119	0.220	0.091	0.043*	0.677
Marmot flea index	r	−0.399	0.283	−0.255	0.018	−0.577	−0.187	0.672	0.430	0.051	0.229	0.401
	P	0.082	0.227	0.278	0.940	0.010*	0.444	0.205	0.290	0.841	0.361	0.099

Note: r=pearson correlation coefficient; *P*=*P* value.
* Indicates statistical significance; grey base color indicates correlation.

highlighting the impact of temperature on plague host animals (*12–13*).

Higher levels of sunshine in the previous year are associated with increased detection of F1 antibodies in dogs, indicating a greater likelihood of dogs being exposed to marmots. The increased sunshine in the previous two and three years also promotes vegetation growth, leading to a higher marmot density in the endemic area. This, in turn, results in greater competition for resources and territory, increasing the risk of plague outbreaks. In contrast, a decrease in marmot density in the current year may be attributed to these factors. Additionally, increased precipitation in the previous two to three years provides favorable conditions for marmot survival and reproduction, leading to higher population density in the current year. However, when marmot density exceeds a certain threshold, the risk of plague transmission and self-dead marmots increases. It is important to note that previous studies have reported an association between increased marmot density and the presence of plague in marmots (*14–15*).

This study focused solely on examining the correlation between climate change and the occurrence of plague epidemics. However, further analysis is necessary to assess the specific impact of individual climate factors on the prevalence of plague. It is important to note that the prevalence of plague is influenced by multiple factors, and this study only explores the role of climate factors. Future research should consider integrating other relevant factors when analyzing the prevalence of plague.

In this study, we observed variations in the influence of temperature, precipitation, sand-blowing days, and sunshine hours on the prevalence of plague. Specifically, an increase in temperature in the current year increases the risk of plague transmission in the same year. However, temperature increases in the previous one and two years decrease the risk of plague outbreaks in the current year. We also found that an increase in average annual precipitation in the previous two and three years elevates the risk of plague outbreaks in the current year. Moreover, an increase in the number of sand-blowing days in the current year increases the risk of plague outbreaks in the same year, while increases in the previous two and three years reduce the risk in the current year. Additionally, our findings indicate that an increase in average annual sunshine hours in the previous year raises the risk of plague outbreaks in the current year. Conversely, increases in sunshine hours in the previous two and three years decrease the risk in the current year. Generally, the impact of climate on plague epidemics exhibits a hysteresis effect, in which the effects of climate change in a specific year manifest in subsequent years. Consistent with previous researches on the nature focus of Rattus flavipectus plague, we also identified a delayed influence of meteorological factors (*15*). Long-term climate monitoring can be utilized as a control strategy to provide early warning of future plague epidemics.

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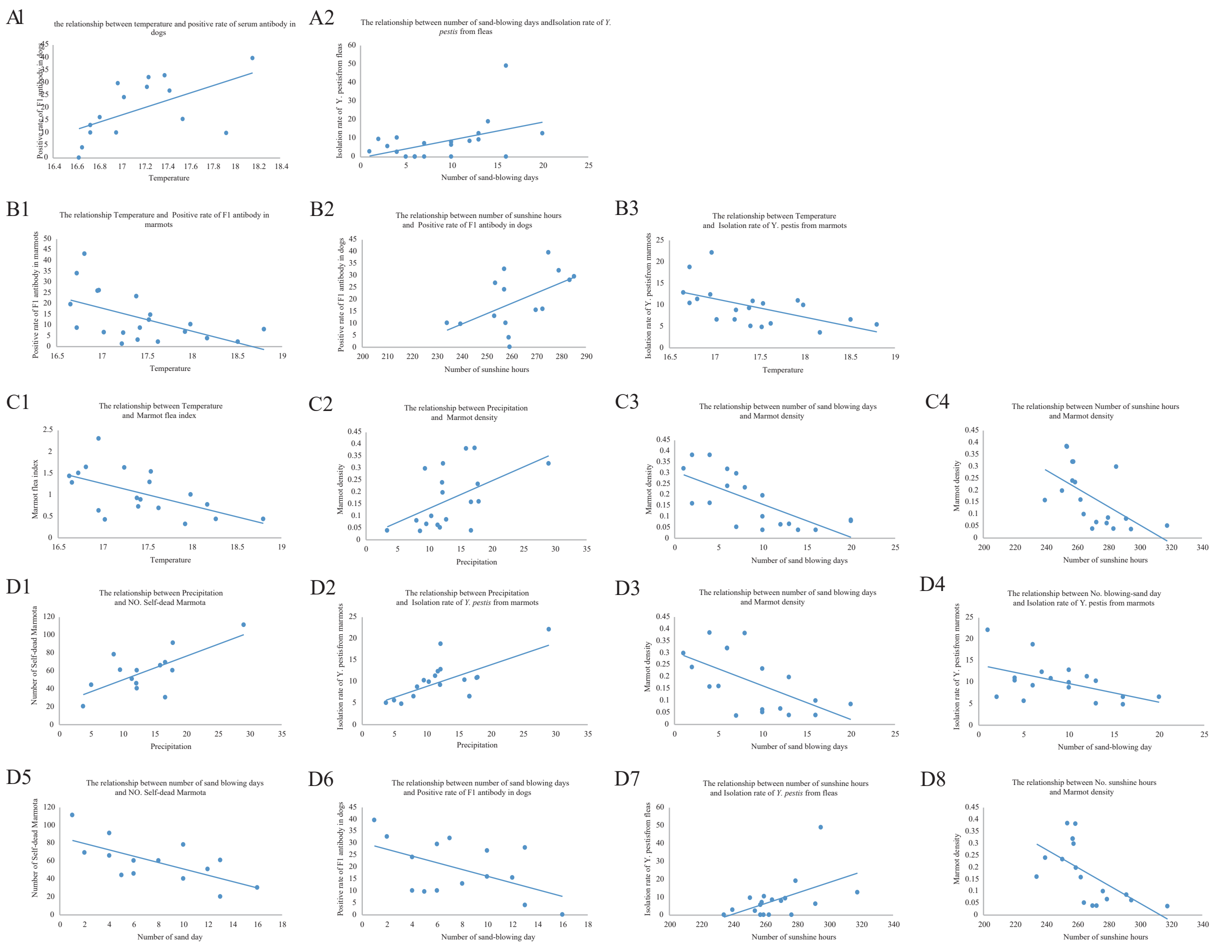
REFERENCES

1. WHO. Plague. Wkly Epidemiol Rec 2005;80(15):138-40. https://pubmed.ncbi.nlm.nih.gov/15875712/.
2. Stenseth NC, Samia NI, Viljugrein H, Kausrud KL, Begon M, Davis S, et al. Plague dynamics are driven by climate variation. Proc Natl Acad Sci USA 2006;103(35):13110 – 5. https://doi.org/10.1073/pnas.0602447103.
3. Pham HV, Dang DT, Tran Minh NN, Nguyen ND, Nguyen TV. Correlates of environmental factors and human plague: an ecological study in Vietnam. Int J Epidemiol 2009;38(6):1634 – 41. https://doi.org/10.1093/ije/dyp244.
4. Xu L, Liu QY, Stige LC, Ben Ari T, Fang XY, Chan KS, et al. Nonlinear effect of climate on plague during the third pandemic in China. Proc Natl Acad Sci USA 2011;108(25):10214 – 9. https://doi.org/10.1073/pnas.1019486108.
5. Wang X, Wei XY, Song ZZ, Wang ML, Xi JX, Liang JR, et al. Mechanism study on a plague outbreak driven by the construction of a large reservoir in southwest China (surveillance from 2000-2015). PLoS Negl Trop Dis 2017;11(3):e0005425. https://doi.org/10.1371/journal.pntd.0005425.
6. He ZK, Wei BQ, Zhang YJ, Liu J, Xi JX, Ciren D, et al. Distribution and characteristics of human plague cases and *Yersinia pestis* isolates from 4 *Marmota* plague foci, China, 1950-2019. Emerg Infect Dis 2021;27(10):2544 – 53. https://doi.org/10.3201/eid2710.202239.
7. Tang DM, Duan R, Chen YH, Liang JR, Zheng XJ, Qin S, et al. Plague outbreak of a *Marmota himalayana* family emerging from hibernation. Vector Borne Zoonotic Dis 2022;22(8):410 – 8. https://doi.org/10.1089/vbz.2022.0010.
8. Wang YM, Zhou L, Fan MG, Wang QY, Li JY, Li Q, et al. Isolated cases of plague - Inner Mongolia-Beijing, 2019. China CDC Wkly 2019;1(1):13 – 6. https://doi.org/10.46234/ccdcw2019.005.
9. Abedi AA, Shako JC, Gaudart J, Sudre B, Ilunga BK, Shamamba SKB, et al. Ecologic features of plague outbreak areas, democratic republic of the Congo, 2004-2014. Emerg Infect Dis 2018;24(2):210 – 20. https://doi.org/10.3201/eid2402.160122.
10. Wang DS, Ge PF, Xi JX, Su YQ, Xu DQ, Gai YZ, et al. Non-linear effects of meteorological factors on plague epidemics in the plague foci of Subei and Sunan counties of Gansu Province. Chin J Endemiol 2020;39(1):27 – 32. https://doi.org/10.3760/cma.j.issn.2095-4255.2020.01.006.
11. Xi JX, Duan R, He ZK, Meng L, Xu DQ, Chen YH, et al. First case report of human plague caused by excavation, skinning, and eating of a hibernating marmot (*Marmota himalayana*). Front Public Health 2022;10:910872. https://doi.org/10.3389/fpubh.2022.910872.
12. Gage KL. Factors affecting the spread and maintenance of plague. In: De Almeida AMP, Leal NC, editors. Advances in Yersinia research. New York: Springer. 2012; p. 79-94. http://dx.doi.org/10.1007/978-1-4614-3561-7_11.
13. Schmid BV, Büntgen U, Easterday WR, Ginzler C, Walløe L, Bramanti B, et al. Climate-driven introduction of the Black Death and successive plague reintroductions into Europe. Proc Natl Acad Sci USA 2015;112(10):3020 – 5. https://doi.org/10.1073/pnas.1412887112.
14. Xu L, Schmid BV, Liu J, Si XY, Stenseth NC, Zhang ZB. The trophic responses of two different rodent-vector-plague systems to climate change. Proc Biol Sci 2015;282(1800):20141846. https://doi.org/10.1098/rspb.2014.1846.
15. Ju C, Liu ZC, Zhang GJ, Yao XH, Xu C, Duan TY, et al. Relationship between human plague epidemic and meteorological factors in China. Chin J Endemiol 2014;33(5):488 – 91. https://doi.org/10.3760/cma.j.issn.2095-4255.2014.05.005.

SUPPLEMENTAL MATERIAL



SUPPLEMENTARY FIGURE S1. Linear relationships between climate factors and indicators of plague epidemics. (A1–A2) The relationship between climate factors and plague epidemic indicators in the current year; (B1–B3) The relationship between climatic factors in the previous year and plague epidemic indicators in the current year; (C1–C4) The relationship between climatic factors in the previous two years and plague epidemic indicators in the current year; (D1–D8) The relationship between climatic factors in the previous three years and plague epidemic indicators in the current year.

Notifiable Infectious Diseases Reports

Reported Cases and Deaths of National Notifiable Infectious Diseases — China, December 2023*

Diseases	Cases	Deaths
Plague	0	0
Cholera	0	0
SARS-CoV	0	0
Acquired immune deficiency syndrome†	5,295	2,068
Hepatitis	143,778	428
Hepatitis A	975	0
Hepatitis B	121,415	32
Hepatitis C	18,085	393
Hepatitis D	23	0
Hepatitis E	2,668	3
Other hepatitis	612	0
Poliomyelitis	0	0
Human infection with H5N1 virus	0	0
Measles	69	0
Epidemic hemorrhagic fever	1,122	1
Rabies	13	16
Japanese encephalitis	4	0
Dengue	154	0
Anthrax	21	0
Dysentery	1,727	0
Tuberculosis	52,826	416
Typhoid fever and paratyphoid fever	358	0
Meningococcal meningitis	21	0
Pertussis	9,126	1
Diphtheria	0	0
Neonatal tetanus	3	0
Scarlet fever	5,826	0
Brucellosis	3,743	0
Gonorrhea	9,414	0
Syphilis	50,823	1
Leptospirosis	11	0
Schistosomiasis	7	0
Malaria	245	1
Human infection with H7N9 virus	0	0
Monkey pox§	102	0
Influenza	4,113,326	6
Mumps	7,092	0

Continued

Diseases	Cases	Deaths
Rubella	74	0
Acute hemorrhagic conjunctivitis	3,873	0
Leprosy	24	0
Typhus	102	0
Kala azar	29	0
Echinococcosis	354	0
Filariasis	0	0
Infectious diarrhea[¶]	67,461	0
Hand, foot and mouth disease	46,150	0
Total	4,523,173	2,938

* According to the National Bureau of Disease Control and Prevention, not included coronavirus disease 2019 (COVID-19).

[†] The number of deaths of acquired immune deficiency syndrome (AIDS) is the number of all-cause deaths reported in the month by cumulative reported AIDS patients.

[§] Since September 20, 2023, Monkey pox was included in the management of Class B infectious diseases.

[¶] Infectious diarrhea excludes cholera, dysentery, typhoid fever and paratyphoid fever.

The number of cases and cause-specific deaths refer to data recorded in National Notifiable Disease Reporting System in China, which includes both clinically-diagnosed cases and laboratory-confirmed cases. Only reported cases of the 31 provincial-level administrative divisions in Chinese mainland are included in the table, whereas data of Hong Kong Special Administrative Region, Macau Special Administrative Region, and Taiwan, China are not included. Monthly statistics are calculated without annual verification, which were usually conducted in February of the next year for de-duplication and verification of reported cases in annual statistics. Therefore, 12-month cases could not be added together directly to calculate the cumulative cases because the individual information might be verified via National Notifiable Disease Reporting System according to information verification or field investigations by local CDCs.

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