Wildlife resource conservation and utilization for achieving sustainable development in China: main barriers and problem identification

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Abstract

The rapid growth of the industrial economy has affected the survival of wildlife, and the decline in wildlife resources will in turn have some negative impact on the industrial economy. For the sustainable development of the industrial economy, human beings began to reflect on traditional development thinking and strive to find a development strategy that harmonizes industrial economic development and resource protection, and wildlife protection gradually attracted people's attention. "Protecting wild animals, maintaining ecological balance, and promoting economic development" has become a hot topic in the new century. Wildlife resources are valuable natural resources and play an important role in the ecosystem, which is related to the well-being and future of human beings. In recent years, China has made great progress in wildlife protection, while protecting and expanding wildlife habitats, introducing relevant laws and regulations, and other measures which have been implemented recently. However, there are still shortcomings in the protection of wildlife in China. Over-utilization, habitat loss and degradation, environmental pollution, climate change, weak legal awareness, and indiscriminate hunting all pose serious threats to wildlife in China. In this regard, this paper summarizes the main problems and barriers to wildlife resource conservation and utilization in China. Based on the analytic hierarchy process (AHP), the main technology factors influencing wildlife resource conservation and utilization in China are identified. Finally, the future research development direction of wildlife conservation is discussed based on the critical factors. This can provide some guidance for developing wildlife resource conservation and utilization for a sustainable ecosystem in China.

Keywords Sustainable development · Sustainable ecosystem · Sustainable environment · Wildlife resource conservation · Analytic hierarchy process

Introduction

The development of the industrial economy affects the survival and development of wildlife, while wildlife resources and the industrial economy interact with each other (Wilkinson 2023), and the protection of wildlife resources is an important link in promoting the sustainable development of the industrial economy and can provide a new impetus to the industrial economy (Dong and Lyu 2022). With the comprehensive implementation of the sustainable development strategy and the deepening of the concept of sustainable development, wildlife protection has attracted widespread attention. The development of wildlife protection is one of the important symbols of the degree of scientific culture and spiritual civilization worldwide at present. Wildlife is a very

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valuable natural resource, an important part of biodiversity and natural ecosystem, a mountain, water, forest, lake, and grass. Therefore, we can say that it is the key to the community of life.

The existence of wild animals is of great importance to stabilize the ecological chain and maintain the ecological balance. On the contrary, when the balance of species is destroyed, the human living environment will deteriorate drastically and various natural disasters will come (Tian et al. 2022). Strengthening the protection of wildlife resources, maintaining ecological security, and biosecurity, promoting sustainable economic and social development, and promoting the construction of ecological civilization is of great significance. At present, due to the change and destruction of the living environment. Population growth and economic development, more and more demand for natural resources, excessive deforestation, grassland reclamation, overgrazing of grasslands, and the construction of lakes, etc., destroying the living environment of wildlife, thus making much wildlife on the verge of extinction Now, on average, there is a wildlife extinction on earth in less than two years, and many animals are on the verge of extinction, according to the latest report of the World Wide Fund for Nature The latest WWF report shows that in the past 50 years, the global wildlife population has been reduced by more than two-thirds (Yu 2020); According to the world's "Red Book," 110 species and subspecies of mammals and 139 species and subspecies of birds have disappeared from the earth in the twentieth century. Nowadays, there are 593 species of birds, 400 species of beasts, 209 species of amphibians and reptiles, and 20,000 species of higher plants endangered in the world. China is one of the richest countries in the world in terms of biological diversity, with about 10% of the world's higher plant and wildlife species (Editorial Board of this journal 2020). However, environmental pollution and ecological damage have led to the destruction of the living environment of plants and animals, the number of species has decreased dramatically, and some species have become extinct. According to statistics, about 200 species of higher plants have become

extinct in the past 50 years, an average of 4 species per year; about 400 species of wild animals are in an endangered or threatened state (Ye 2014). Table 1 shows the percentage of wildlife operating in different classifications.

Nowadays, the form of wildlife conservation has become very serious. To maintain the biodiversity of the earth and to protect wildlife resources, each country attaches great importance to the protection of wildlife (Cheng et al. 2013). In 1959, China made provisions for the protection of giant pandas and golden monkeys, and in 1962, it was stipulated that 83 kinds of cherished wild animals should be protected, and the Wildlife Protection Law was promulgated in 1988. Later in 2018, the revision of the Wildlife Protection Law was presented to clearly state that wild animals must be protected preciously and endangered wild animals should be saved, biodiversity and ecological balance should be maintained, and the construction of ecological civilization should be promoted. In 2020, the implementation of regulations on the protection of terrestrial wildlife in the People's Republic of China was revised to promote the development of terrestrial wildlife protection. In 2021, the new list of key national wildlife protection was officially announced. The adjusted list includes 980 species and 8 categories of wildlife, including 234 species and 1 category of wildlife protected at the national level and 746 species and 7 categories of wildlife protected at the national level (Nature Editorial Board 2021). It promotes us to assess the role and value of wildlife from the perspective of a complete and healthy ecosystem and further promotes the harmonious coexistence of humans and nature.

To sum up, China's efforts to protect wildlife are increasing and the awareness of protection is rising. However, at the present stage, there are some problems in the protection of wildlife, such as insufficient supervision, law enforcement facing difficulties in identification, high cost, long time, insufficient standardization and systematization, etc. Cracking these problems requires the joint efforts of all sectors of society while attracting people's attention. In this regard, this study applies a strong decision-making method, namely, the

Table 1 China wildlife endangerment classifications

Evaluation level	Mammals	Birds	Amphibians	Reptiles	Fish	Total number	Total ratio (%)
Extinction	0	0	1	0	3	4	0.1
Extinction in the wild	3	0	0	0	0	3	0.1
Regional extinction	3	3	1	2	1	10	0.2
Critically Endangered	58	15	13	34	65	185	4.2
Endangered	53	51	46	37	101	288	6.6
Vulnerabled	67	80	117	66	129	459	10.5
Near critical	153	190	76	78	101	598	13.7
No risk	262	876	102	175	454	1869	42.9
Lack of data	74	157	52	69	589	941	21.6
Total	673	1372	408	461	1443	4357	100

analytic hierarchy process (AHP) for identifying the main technology factors influencing wildlife resource conservation and utilization in China. This paper aims to maximize the development of wildlife conservation in China in the industrial era, identify the main factors currently affecting wildlife conservation in China among multiple complex factors, further promote the harmony between human industry and nature, and maximize the rational use of wildlife resources, and tries to provide useful insights to managers in the field of wildlife conservation.

Compared to the previous work, the main contributions of this paper are as follows:

- A comprehensive summary and review of research in this key area of wildlife conservation.
- Factors affecting the development of wildlife conservation in the current context are summarized, and the index system of factors affecting its development is framed in a comprehensive and multi-level manner.
- Effectively identified key factors affecting wildlife conservation development and provided our management insights to promote a virtuous cycle in which wildlife conservation and industrial development complement each other.

The rest of this paper is summarized as follows: the "Literature review" section is a literature review to study the relevant fields and potential research gaps. The "Problems and barriers" section is an overview of existing problems and barriers to the field. The "Proposed China's wildlife legal system" section is the proposed legal wildlife system for achieving a sustainable ecosystem in China. The "Evaluation of the Chinese wildlife protection system using AHP" section is the implementation of AHP for our sustainable ecosystem. The "Managerial insights and future research trends" section is a comprehensive discussion of the main extracted managerial insights and future research trends from our results. Finally, conclusions, limitations, and findings are provided in the "Conclusions and suggestions" section.

Literature review

The literature on wildlife protection in China is not a new topic and it is rich in using analytical tools. For example, Wang et al. (2022) took Qinling as an example and pointed out the problems of the public interest litigation mechanism for wildlife protection in China, and make suggestions for improvement. For the improvement of wildlife protection public interest litigation mechanism brings guidance. Li (2022) studied and analyzed China's wildlife protection law, pointing out its lack of independence, the existence

of legislative punishment loopholes, and the lack of sound criminal law sanctions, and made corresponding recommendations. Niu et al. (2022) analyzed four dimensions of education objectives conservation, content, format, and project animals, using 295 offline education programs conducted by 34 zoos and aquariums in WWF's Asian members[1] as examples, and discuss some representative online outreach education resources in zoos in the context of the epidemic. Yao et al. (2022a, b) elaborated and analyzed the current situation of wildlife protection management in Zibo City, put forward problems for its wildlife protection work, and give corresponding improvement policies. Their research results provide certain significance for wildlife conservation work in other regions, and their research content can be used as a basis to promote the development of wildlife conservation by combining regional characteristics. Sun et al. (2023) analyzed the impact on the survival of wildlife caused by the implementation of forest and grass protection projects, and further, proposed an effective plan for the implementation of forest and grass protection projects to provide a good basis for wildlife protection. Gao et al. (2023a, b) assessed the main threats and conservation strategies for bats in China using a questionnaire for a global population, and similarly, their research strategies and methods can be effectively extended to other animals. Gao et al. (2023a, b) analyzed the impact of mass media coverage on public opinion, using ivory conservation as an example, and analyzed 2000 articles published in Chinese newspapers to understand the impact of wildlife policy on public opinion. Sun et al. (2023) investigated the spectrum of viruses carried by an animal endemic to China, the oriental roe deer, to promote effective conservation of this animal. Wang et al. (2023) studied the negative effects of human-wildlife conflict on both humans and wildlife, and provided guidance on how to mitigate this conflict.

China safeguards the safety of wildlife by establishing relevant wildlife protection laws. However, there are some problems in the legislation and law enforcement links, which do not give full play to the role of protection laws. Yin and Yang (2022a) analyzed the current situation of wildlife protection legislation and law enforcement in China and proposed effective measures to improve the management of wildlife legislation and law enforcement in China. Effectively enhance the important role played by laws and regulations in the protection of wildlife in this issue. Wildlife identification plays an important role in the protection of endangered species, species diversity analysis, and combating commercial meat food adulteration. Yu et al. (2022) reviewed the basic principles and specific applications of wildlife morphological

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[1] https://www.worldwildlife.org/species/asian-elephant

identification, physical and chemical identification, and molecular identification, to provide a reference for wildlife identification. Zhang et al. (2022a, b) summarized the application of deep learning in wildlife monitoring and identification, analyzed and discussed the problems of deep learning in wildlife conservation and utilization, and made an outlook on its future development trend. Deep learning is an important tool for wildlife conservation, and researchers can expand on it and continue to study it in depth. Sheng et al. (2022) conducted a study to analyze the wildlife conservation awareness of indigenous people in Guizhou's Leigongshan National Nature Reserve and its influencing factors. This analysis shows that with the promotion of the management and construction of the local nature reserve, the cultural and educational levels of residents must be strengthened where ideological education and propaganda must be conducted. At last but not least, excellent traditional culture should be inherited or developed, and economic development must be promoted in a sustainable direction to mobilize the conservation motivation of indigenous people.

From the basic concept of wildlife resources, Tang and Fan (2021) conducted a study and analysis on how to protect and utilize wildlife in the new era and offered opinions on achieving socio-economic progress and sustainable development of human civilization. Their research combines the context of the times and highlights even more the important role of wildlife resources in today's era. Guo et al. (2021) analyzed the relationship between epidemic outbreaks and wildlife while making suggestions on how to carry out wildlife conservation in the current situation. At present, the legal system of biodiversity compensation for wildlife habitats in China is inadequate, resulting in the lack of enthusiasm of farmers for wildlife habitat protection. Zhao and Wang (2021) have conducted an in-depth study and analysis of this issue, and believe that we should actively explore the combination of public and private sectors, innovate multiple forms of ecological compensation, broaden the sources of funds, establish scientific ecological compensation standards, and realize the dual benefits of biodiversity conservation and farmers getting out of poverty to achieve a win–win situation. Li (2018) constructed a large primate facial dataset, proposing strong support for intelligent and digital wildlife conservation protection, and also conducted research and analysis on monkey facial recognition methods around the dataset. Their findings provide a foundation for subsequent intelligent data for wildlife conservation.

Drawing on the experience of wildlife conservation in Tanzania, Zhang et al. (2022a, b) discussed the feasibility of specific practices for wildlife viewing, nature experience, and scientific research activities in China. They proposed relevant suggestions in the context of domestic practice, which can provide new methods and ideas for realizing their ecological value. Aquatic wildlife has an irreplaceable role in protecting water resources and protecting the ecological security of water bodies, etc. In this regard, Shi (2022) made an in-depth analysis of the current situation of aquatic wildlife protection in Beijing, the requirements of the new era, and the future work ideas while measuring and providing a basis for the relevant regions to carry out aquatic wildlife protection.

One key way of protecting forest ecosystems and wildlife is to establish nature reserves while increasing their impact. Due to the ecological environment, most wildlife reserves are located in remote areas with low levels of economic development, severe resource shortages, and difficult management. In this regard, Zhang (2022a) discussed how to strengthen conservation management and proposed corresponding measures through research on the current situation and conservation management of nature reserves.

The development of the social economy, especially the rapid development of industry, causes serious harm to the ecological environment and the survival of wild animals and plants. With the gradual increase of environmental protection awareness, how to better protect their homes and maintain ecological balance has become a hot issue in the current environmental protection field. Jiang (2022) discussed the necessity, importance, and countermeasures of grassroots wildlife conservation work. In another study, Lv and Li (2022) combined active and passive remote sensing images to give full play to the advantages of various information. They monitored the dynamics of nature reserves, detected ecological damage promptly, and evaluated the ecological restoration and protection status while improving the quality and change trend of suitable habitats for wildlife in the corresponding nature reserves as well as the risk-causing factors and influencing factors. Finally, they formulated scientific and reasonable planning and protection measures to provide important information guarantees and decision-making for effective and scientific wildlife protection. Jiang (2022) proposed a decision-making method to identify wildlife species in airborne thermal imaging, focusing on monitoring the ecological behavior of the Northeast tiger and its main prey (horse deer, roe deer, plum deer, reindeer), acquiring wildlife images in different seasons, constructing a wildlife monitoring image database, using YOLO V5s model to identify wildlife species in airborne thermal imaging. They analyzed the main difference in the recognition effect of the YOLO V5s model before and after the improvement. Their experiments show that the recognition time is greatly shortened while the accuracy of the method is higher.

The use of infrared imaging technology for wildlife target recognition is helpful for effective research and conservation of

wildlife. However, due to the number of wildlife species varying greatly, the wildlife data set collected by infrared cameras has the problem of long-tailed data with uneven distribution of the number of species, which affects the overall performance of the target recognition system. To address the problem of low target detection accuracy due to long-tailed data of wild animals, Cai et al. (2022) used a combination of two-stage learning and weighting methods to solve the problem of long-tailed data.

Since 2020, the COVID-19 disease has had a very high impact on human life and ecosystems around the world. There are legal frameworks that have serious gaps in protecting the health of wildlife and protecting human health, and there is a relationship between wildlife farming in China and the spread of the COVID-19 pandemic. However, China has not introduced any kind of health protection measures for wildlife used for human consumption.

Another major concern in wildlife protection is that wild long-distance migration has become an important biological phenomenon and conservation of long-distance migrating wildlife. In this regard, Kaczensky et al. (2021) used historical and current ranges, population genetics, and telemetry data to assess the connectivity of wild ass populations in the context of natural and anthropogenic landscape features and existing protected area networks.

During last decades, a lot of work has been done to evaluate and improve the area of biodiversity conservation. However, little is known about the various management strategies implemented within protected areas. Vimal et al. (2021) used a large database of 175,000 global terrestrial protected areas with data on non-marine mammals, amphibians, and avian species as a way to evaluate the share of areas within the IUCN[2] management boundaries contributing to the conservation of biodiversit. Protected area networks are important for the sustainable existence of species, but their size and extent are limited by available land and conservation resources. Donaldson et al. (2021) conducted a research analysis on how to construct the most efficient network of protected areas, estimating how each strategy is chosen based on the priority of species size, quantity, quality, and connectivity. Lavery et al. (2019) analyzed the current threats to Australian rock wallabies. Their study suggests that the main threats to rock wallabies include predation by exotic cats and foxes, competition between exotic herbivores and excessive native herbivores, changes in fire conditions, and loss of genetic diversity. Finally, they suggest key directions for effective monitoring, which has certain implications for the conservation of other species of wildlife.

In addition, protected areas are one of the most effective ways to conserve biodiversity, and large protected area systems have been established in many parts of the world. However, existing protected area networks are inadequate in coverage and biased toward many species in a variety of biomes and ecosystems. Guo et al. (2019) used gap analysis to assess the contribution and effectiveness of China's wetland protected area network to conservation by focusing on 216 national priority species and 129 endangered species. Roper et al. (2018) examined the multiple-use management of national forest system lands in the context of conducting a study of aquatic biodiversity conservation. Evaluating the context of multiple-use management of National Forest System lands, they found that if the United States Department of Agriculture Forest Service (USFS) can successfully conserve and restore aquatic biodiversity, it must continue to address traditional challenges such as minimizing the impacts of timber harvest, roads, grazing, and mining on aquatic systems while improving policies and practices that address contemporary challenges such as climate change and invasive species (Roper et al. 2018). Another important aspect of wildlife conservation is wetland conservation to promote wetland conservation and wildlife sustainability. Tozer et al. (2018) conducted a study on wetland conservation issues and proposed multi-species benefits of wetland conservation for wetland birds, frogs, and endangered species.

Given the need to better align protected area boundaries with biodiversity at risk, Button and Borzée (2021) assessed the importance of various factors in identifying priority areas for conservation at the global and biome levels, particularly for amphibians. A new comprehensive tool is used to identify, map, and rank important conservation areas for all amphibian species on the earth, scoring the urgency of protecting each species and site at the ecoregional level based on species characteristics and human impact. In another relevant study, Guo et al. (2021) analyzed the relationship between epidemic outbreaks and wildlife. They made suggestions on how to carry out wildlife conservation work under the current situation. At last but not least, Zhou et al. (2013) studied and analyzed the balance between the economic benefits of ecotourism and its potential negative impacts on wildlife conservation.

Looking at the aforementioned pieces of literature, there is no comprehensive study to identify all the main barriers and problems to achieving a sustainable ecosystem in China. As far as we know, all economic, social, technical, and policy factors have not been studied for studying the ecosystem in China. The literature was not successful to solve some problems in the protection of wildlife, such as insufficient supervision, law enforcement facing difficulties in identification, high cost, long time, and insufficient standardization and systematization. In this regard, this study proposes an AHP for identifying the main technology factors influencing wildlife resource conservation and utilization in China.
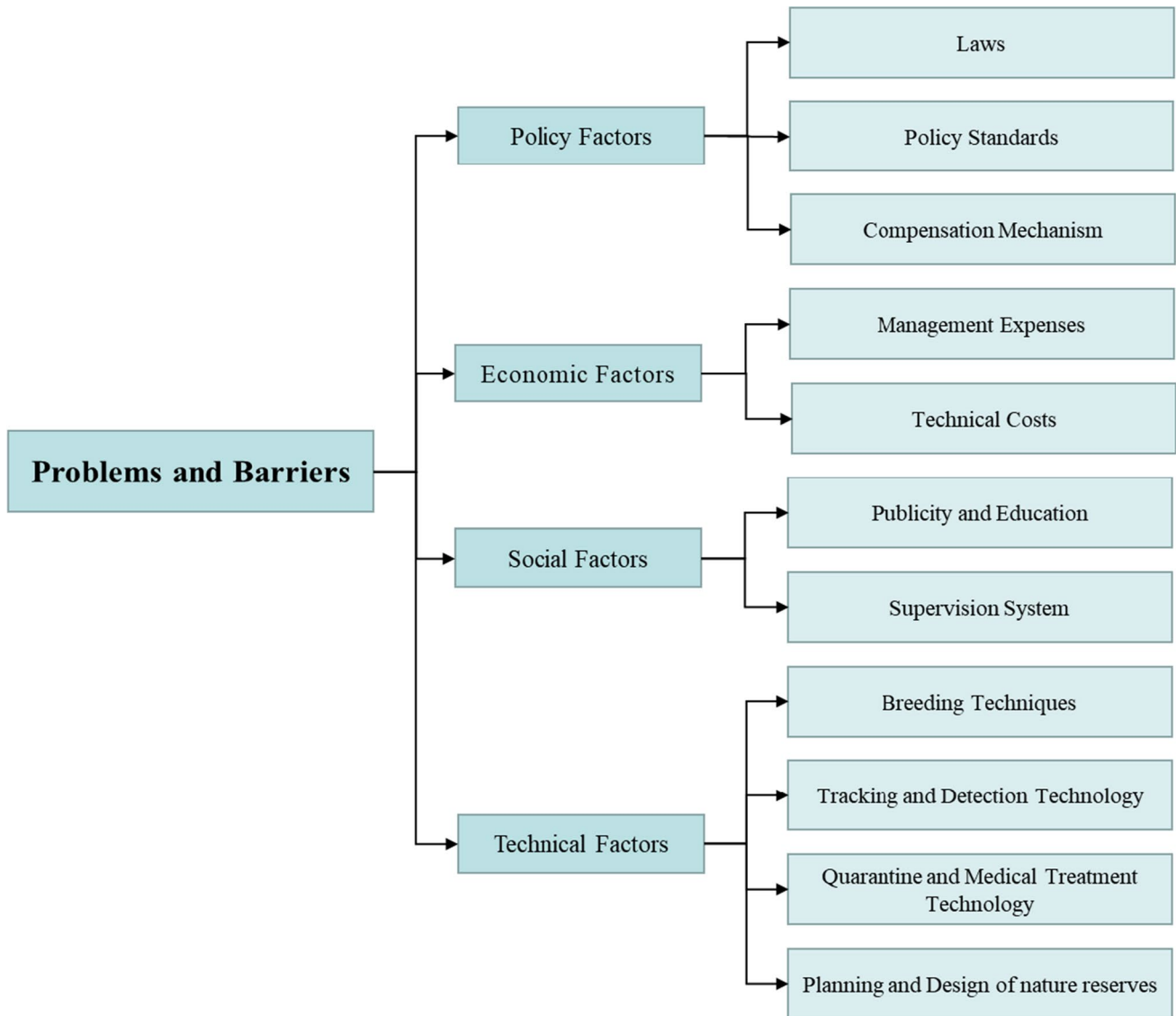
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[2] https://www.iucn.org/our-work/protected-areas-and-land-use

Fig. 1 Restricting factors of wildlife resource conservation

Problems and barriers

In order to realize the good protection demand for wildlife, it is necessary to establish a comprehensive and coordinated wildlife protection system from four aspects: policy factors, economic factors, social factors, and technical factors. The system should be well-established, balanced, and efficiently coordinated. However, at present, Chinese wildlife protection is mainly implemented from legislation and delineation of wildlife reserves, and there is a lack of an efficient system to reasonably control Chinese wildlife protection in China. With the purpose of establishing the above system, the existing wildlife protection system in China needs to analyze and extract the current defects and the reasons hindering the development of all levels.

Generally, our problems and barriers obtained from the analysis of related studies are shown in Fig. 1.

Policy factors

Although wildlife protection has been a topic of social concern for a long time, it has not been very controversial (Mu 2020). One of the controversial reasons is that the Chinese legal system and policies on wildlife protection are imperfect. In the context of the COVID-19 epidemic outbreak, most of the pathogens that caused the outbreak come from or are related to wildlife. Subsequently, wildlife protection has entered a new wave, generating the Chinese people's urgent hope to improve the relevant wildlife protection policies. Based on the analysis of the relevant data and literature,

this paper mainly analyzes the existing problems from three aspects: legislation (Yin and Yang 2022b), protection norms, and wildlife damage compensation mechanism policy.

Laws

Since the Wildlife Protection Law was promulgated in 1988, it has been revised many times. However, it has not been greatly adjusted and revised to have no problems and barriers (Yao et al. 2022a, b). There are still some loopholes in Chinese criminal law on the intentional killing, trafficking, and transportation of wildlife crimes, allowing criminals to take advantage of it. Wildlife has a great market and huge benefits. Thus, the severe crackdown on criminals needs to improve the criminal legislation to play the minimum protection role. Next, the difficulty of Chinese criminal legislation on wildlife lies in the difficulty in determining the intention of people who harm wildlife and the disagreement between wildlife and artificial breeding "wildlife" and the difficulty to distinguish between wild and artificial breeding (Liu 2021). The fuzzy boundary of these criminal laws for wildlife has also become a factor limiting the further improvement of criminal law (Chen et al. 2021). At the same time, the lack of a rare classification of wildlife in China's criminal law leads to the limitation of the protection scope of wildlife (Duan 2022). Finally, there is a conceptual deviation in the Chinese legislative concept. In the legislation of wildlife protection in China, people are regarded as the center for the protection and management of wildlife. There are class differences between people and wild animals, and people can control wild animals, which brings obstacles to the protection of wild animals. As a result, Chinese wildlife protection is only based on species protection, while the Chinese legal system lacks ethical animal protection norms in the pursuit of value or legal interests (Chen 2022). Not only by adding ethical protection to the criminal law legislation can China's wildlife protection be further strengthened, but also the inclusion of ethical protection will limit the basic rights of many citizens. Hence, it leads to the Chinese dilemma in wildlife protection.

Policy standards

China's lack of reasonable and unified normative documents makes the implementation of wildlife protection inconsistent, uncoordinated, and impractical (Zhong 2008). China's failure to establish a set of unified and scientific protection standards for wildlife protection has led to inconsistent standards of local governments in the process of law enforcement and protection. This is also an urgent problem and obstacle to be solved in the process of wildlife protection. In addition, China lacks specialized standards for specific and precious wildlife to effectively protect a specific kind of wildlife protection, making the protection objects specific and

making the protection norms reasonable. For example, in 2021, Yunnan first set special protection standards for three rare and endangered wildlife, including the Asian elephant, the Yunnan golden monkey, and the green peacock. Finally, due to the lack of systematic and scientific rescue standards and interactive systems as a reference, there are inconsistent standards in the process of wildlife rescue, which often increases the difficulty coefficient of wildlife rescue.

Compensation mechanism

In the process of dividing the nature reserves, due to the lack of relevant financial input support, land acquisition can only be adopted for free or at low compensation. As such, the adoption of administrative coercion to promote the implementation of nature reserve management policies. This approach plays a role in wildlife protection at a certain level, but at the same time, it also harms the interests of the people near the nature reserves. It is extremely easy to cause human and animal conflict and violates the concept of protecting the ecological environment and promoting the harmonious development between man and nature, which is not conducive to good wildlife protection. At the present stage, the imperfect compensation mechanism makes the residents have dissatisfaction, and even have rebellious psychology. Once the situation of wildlife destruction occurs, the wild animals will be violently killed, which will only have a serious negative impact on the protection of wild animals and plants (Li 2022).

Economic factors

With the proposal of ecological civilization construction, the proportion of Chinese investment in wildlife protection is also increasing. However, good wildlife protection needs a lot of financial support, and Chinese financial investment is a small drop in the ocean for wildlife protection at this stage. As such, the financial shortage of the protected areas pays more attention to the economic construction and livelihood construction in their area, and the financial investment in wildlife is very little. Due to the influence of economic factors, the management funds and technology investment in wildlife protection are seriously insufficient, which is not conducive to maintaining a good protection state. In this regard, the problem of too low financial investment leads to the lack of drive for the entire wildlife protection system.

Management expenses

The lack of national and regional financial input will lead to the insufficient investment of the management and supervision departments in law enforcement and publicity, which will then lead to the inability to convey the purpose of the

government to all the residents. The lack of management funds will seriously lead to the loss of the original management situation of the wildlife protection of nature reserves, and it is also easy to reduce the standards for the treatment and prevention of various wildlife in nature reserves, which is not conducive to the protection of wildlife. As the situation of wildlife protection in China is gradually improving and the biodiversity is constantly increasing, the corresponding management of wildlife cannot be maintained normally without sufficient management funds. Hence, it is easy to lead to the lack of funds, resulting in the situation of wildlife protection has turned sharply down.

Technical costs

Lack of government and associated funding input will lead to the office equipment cannot be updated in time and the wildlife protection information technology equipment being too backward (Tian 2020). Furthermore, with the advent of the information age, but lack of the supervision equipment, treatment equipment, and information equipment, unable to implement the supervision of wildlife protection and cannot be timely and accurate access to the physical condition of wildlife, resulting in the abnormal death of many wild animals. Wildlife protection requires extremely high the professional wildlife knowledge and rich wildlife protection work experience of the relevant staff (Ma 2022), but many practitioners engaged in wildlife conservation lack professional technical quality. And with the proposal of ecological civilization construction, more and more attention to wildlife protection and the number of wildlife is increasing, and the demand for staff is gradually increasing, especially professional talents. Therefore, a large amount of technical personnel capital investment is needed, but the government's capital investment in the introduction of relevant technical personnel is just opposite to the demand for the introduction of technical talents. In addition, nature reserves are generally located in remote and poor mountainous areas, accelerating the drain of outstanding talents for wildlife conservation.

Social factors

The construction of nature reserves in China has been developed rapidly developed, accumulated valuable experience, and the achievements of wildlife protection are more remarkable than before. However, social factors such as generally low levels of social supervision and management and poor handling and prevention of wildlife areas often lead to the low efficiency of wildlife conservation. To make the coordinated operation of the wildlife protection system, it is necessary to analyze the problems related to wildlife protection in our society.

Publicity and education

Unfortunately, many precious wild animals were killed because of people who fundamentally do not know what animals are the object of national key protection. The reason is that the relevant administrative departments do not sufficient the social publicity work of wildlife protection, which is a common phenomenon in the process of wildlife protection work. Besides, the publicity and management work of the administrative department is not enough, resulting in the weak awareness of environmental protection of the people in the protection area (Zhao 2020). Citizens cannot deeply realize the profound significance of wildlife protection, and in the process of management and law enforcement, there are often conflicts of interest with the public, which hinder wildlife. In addition to the legal education for the people in the protected areas, the protection of wildlife is currently only kept at the level of the state and relevant departments and fails to fully mobilize the people to form a national management mode of wildlife protection.

Supervision system

The improvement of the supervision system is an important measure to further strengthen wildlife protection, but at present, there are many deficiencies in China's supervision system on wildlife protection. First, in terms of supervising crime, Chinese supervisory authorities are miscellaneous and the power coverage between supervisory departments overlaps. As a result, in the process of supervision, each department has its supervision methods, lack of overall coordination, and unclear rights and responsibilities (Zhang 2022b).

The division of the supervision departments of the supervision system is not meticulous, which makes the criminals' crimes more wanton. In addition, the continuous development of information technology should provide more efficient monitoring for wildlife protection. However, the support of this information equipment has not been covered in a large area, leading to the backward level of information supervision for wildlife protection crimes, which is also one of the reasons for the current ineffective supervision. At the same time, in addition to poaching and trafficking by criminals, wild animals are also affected by natural diseases. Unfortunately, the Chinese wildlife testing system lacks a special management and supervision department and a professional management knowledge system, which cannot test the growth of wild animals, which is easy to cause many unnatural deaths and is not conducive to the development of wild protected animals. The perfect supervision system is only the national department level supervision effect is also insufficient, but also needs the supervision of the whole people (Yin and Yang 2022b). However, the Chinese government

has not taken corresponding measures to enhance the public's willingness to supervise wildlife criminal activities, and the role of public supervision has not been fully played.

Technical factors

During the situation of COVID-19 pandemic, the number of nature reserves under wildlife protection is increasing. An increase in biodiversity and the continuous improvement of information technology have also increased the technical requirements required for wildlife protection. However, at present, China's technical conditions for wildlife are still backward and seriously lack information technology and equipment, and professional theoretical knowledge. Therefore, wildlife problems and obstacles at the technical level are analyzed and provide basic information for subsequent improvements.

Breeding technology

The breeding of many rare and endangered wildlife has seriously hindered the growth of wildlife, and many lower grades of wildlife protection technology are also relatively immature (Zeng 2015). The lack of scientific domestication technology is one of the biggest bottlenecks that hinder the growth of wildlife populations. Moreover, the current lack of wildlife breeding proficiency and backward technology, the lack of long-term planning, and the lack of corresponding animal lineage archives. The reproduction of wild relatives is serious, which is easy to cause new wild animals to have more congenital and diseases, single genetic genes, poor ability to adapt to the environment, which is not conducive to the development of the population (Zhao 2016).

Tracking detection technology

With the continuous development of information technology, wildlife protection must also use the benefits of these new technologies. However, at present, the detection of wildlife in China is mainly based on traditional manual tracking and monitoring. These monitoring methods are not only low efficiency, heavy workload, but also prone to data inaccuracy and insufficient real-time problems, but also have a serious impact on the real-time tracking of wild animals by the wildlife reserve staff. At present, the monitoring method of remote sensing technology is relatively modern, On the one hand, its cost is relatively high, affected by the environment, and has limited monitoring range, lagging data acquisition, low acquisition of low image resolution; on the other hand, remote sensing technology has relatively low storage and management ability of monitored data, resulting in insufficient data sharing and low utilization rate (Sumthane and Vatti 2017). In addition to the technical limitations, there are also objective factors of complex terrain, changeable climate, the difficulty of manually retrieved the shooting data and high risk. Therefore, under the relatively difficult primeval forest and a large number of artificial obstacles, to develop a new information equipment to conduct real-time tracking and detection of wildlife to make timely corresponding decisions.

Quarantine and medical treatment technology

Due to the outbreak of the COVID-19 pandemic, the Chinese people have gradually paid more attention to wildlife quarantine. At the present, there are many obstacles to the quarantine and treatment of wildlife protection in China. One is that there are few professionals specialized in veterinary medicine, which cannot carry out regular quarantine and epidemic prevention of wild animals. Moreover, the too-traditional nature of wildlife treatment technology leads to the low efficiency of protection, especially for the quarantine and treatment technology of rare wild animals (Wu 2021).

Planning and design of nature reserves

As the scale of cities expands, the urbanization process accelerates, leading to the reduction of wildlife habitats (Zhang 2021) and the continuous expansion of human demand for resources to cause damage to the ecological environment. which seriously affects the survival of wildlife. The ultimate goal of wildlife conservation is to increase the number of wildlife populations to ensure species diversity, and as the number of wildlife increases, the demand for habitat and natural resources increases. Therefore, how to carry out reasonable planning of wildlife reserves has become an urgent problem to be solved after achieving the phased results of wildlife protection. Accelerating the solution of the unbalanced blind construction and development of nature reserves, unreasonable planning emphasizes quantity over quality (Northeast Industry and People's Studies Publishing House, 1992), and the reasonable planning of nature reserves can alleviate the expansion of wildlife populations and insufficient resources to a certain extent.

Proposed China's wildlife legal system

Since the 1980s, China has promulgated the "Wild Animal Protection Law" and taken it as the main support and complimented it to other relevant laws. The framework for wildlife legal regulation has begun to take shape, with the "Constitution" as the basis, the "Wildlife Protection Law" and other related laws as the backbone, and at the same time play the functions of "Civil Law|," "Criminal Law," "Administrative Law" and other related laws, supplemented by several local laws and regulations. The specific laws and regulations are shown in Table 2.

Constitution

With a reference to the article (Wang et al. 2022), the "Constitution" clarifies that the state has the responsibility to protect precious wild animals and plants, and has the task of maintaining the rational use of natural resources. At the same time, in the current legal provisions, wild animals have the right status of natural resources. Therefore, the "Constitution" should have the responsibility to regulate the use of wild animals. With a reference to the article (Lv and Li 2022), the "Constitution" stipulates that the state shall be responsible for maintaining the stability of the ecosystem, aiming at creating a good natural environment and indirectly regulating the use of wild animals and the encroachment of their living space.

National laws

The "Wildlife Protection Law" has detailed regulations on the management of wild animals, mainly including hunting, scientific research, and artificial breeding. The government has the responsibility to manage wild animals and maintain their survival.

As supporting administrative regulations, the State Council approved the formulation of the "Regulations on the Implementation of the Protection of Terrestrial Wildlife" and the "Regulations on the Implementation of the Protection of Aquatic Wildlife."

The "Fisheries Law" regulates aquatic wild animals and makes up for the deficiencies of the "Wildlife Protection Law." However, due to the economic needs of the aquatic market, the law focuses on sustainable utilization and development and economic industries.

Laws such as the "Environmental Protection Law," the "Grassland Law," the "Forest Law," the "Water Law," and the "Entry-Exit Animal and Plant Quarantine Law" are all related to the protection of wild animals and their habitats and managing the use of wild animals from different angles to maintain a good living environment for wild animals.

The "Decision on Comprehensively Banning Illegal Wildlife Trade, Eradicating the Habit of Overeating Wildlife and Effectively Protecting people's Lives and Health," issued by the Standing Committee of the National People's Congress, further establishes the intensity of punishment for illegal wildlife trade and enriches the connotation of wildlife. It also stipulates that the State Council, its relevant departments and provinces, autonomous regions, and municipalities directly under the Central Government should adjust the relevant lists and supporting regulations.

The "Administrative Measures for the Domestication and Breeding Licenses of Wild Animals under National Key Protection" implemented by the former competent forestry department of the State Council stipulates that the forestry department may review the applicants and decide whether to issue a license to control the use of wild animals.

The "Chinese Herbal Medicinal Development Plan (2015–2020)" clarifies the development plan for wild animal medicinal materials to standardize the collection and use of Chinese herbal medicines.

The "Regulations on the Administration of Import and Export of Endangered Wild Animals" is the only legal document that specifically manages endangered species, and is aimed at import and export management.

The "Regulations on Nature Reserves" divides the protection work of nature reserves into comprehensive management and departmental management, which has played an important role in the protection of wildlife habitats. Articles 341 and 346 of the "Criminal Law" provide criminal protection for wildlife protection.

The Supreme People's Court, the Supreme People's Procuratorate, the Ministry of Forestry, the Ministry of Public Security, and the State Administration for Industry and Commerce jointly issued the "Notice on Severely Combatting Illegal Hunting, Killing, Purchasing, Reselling, Smuggling, and Smuggling Wild Animals" to protect wild animals and maintain natural ecological balance.

Local laws

Local laws combine their characteristics and integrate local value needs in the process of implementation. Most of the revisions of local laws are optimized and implemented by coordinating national and local interests.

The "Gansu Wildlife Protection Law" promulgated by Gansu Province has more detailed regulations on the use of wild animals in the "Wild Animal Protection Law." For example, it is stipulated that when trading marmots, there should be a test report from the epidemic prevention department.

The "Several Regulations Prohibiting the Eating of Wild Animals in Shenzhen Special Economic Zone" promulgated by Shenzhen prohibits the consumption of wild animals, and at the same time stipulates that the artificially bred wild animals that have passed the inspection can be eaten.

The "Guangdong Province Wildlife Protection Management Regulations" revised and passed by the Standing Committee of the 13th People's Congress of Guangdong Province has newly established relevant penalties for the illegal consumption of wild animals.

The "Interim Regulations on the Protection and Management of Wild Animals and Plants in Jilin Province" is the first local law on wildlife protection in China.

Table 2 Laws and regulations

Type	References	Year	Act	Legislation
Constitution	National People's Representative Meeting (Standing Committee of the National People's Congress 2018)	Issued 1949, Revised 1954, 1975, 1978, 1982, 1988, 1993, 1999, 2004, and 2018	Nation's responsibility for wildlife protection (Article 9) Nation's responsibility for ecosystem stability (Article 26)	• The state has the responsibility to protect the precious wild animals and plants • The state has the task of maintaining the rational use of natural resources • The state shall be responsible for maintaining the stability of the ecosystem, creating a good natural environment
National laws	Standing Committee of the National People's Congress (State Council of China 2016)	Issued 1988, Revised 2004, 2009, 2016, and 2018	Wildlife Protection Law	• Detail regulations on the management of wild animals, mainly including hunting, scientific research, and artificial breeding • The government has the responsibility to manage wild animals and maintain their survival • Adapt to the new situation and new requirements of wildlife protection, especially to fully demonstrate the concept of ecological civilization
	State Council of China (State Council of China 2013)	Issued 1992, Revised 2011 and 2016	Regulations on the Implementation of the Protection of Terrestrial Wildlife	• Governments should carry out publicity and education on the protection of wild animals to raise citizens' awareness of wild animal protection • Hunting and killing of wildlife under special state protection is prohibited • Those who need to hunt wild animals under national key protection must apply for a special hunting license
	State Council of China (Standing Committee of the National People's Congress 2004)	Issued 1993, Revised 2011 and 2013	Regulations on the Implementation of the Protection of Aquatic Wildlife	• Any unit or individual is forbidden to damage the waters, places, and living conditions where the aquatic wild animals live and reproduce under national key protection and local key protection • Those who accidentally catch aquatic wild animals during fishing operations shall release them immediately and unconditionally
	Standing Committee of the National People's (Standing Committee of the National People's Congress 2020a, b)	Issued 1986, Revised 2000 and 2004	Fisheries Law	• Regulate the fishing of aquatic wild animals, making up for the deficiencies of the Wildlife Protection Law • The law focuses on sustainable utilization and development and economic industries
	Standing Committee of the National People's Congress (Forestry Department 2015)	Issued 2020	Decision on Comprehensively Banning Illegal Wildlife Trade, Eradicating the Habit of Overeating Wildlife and Effectively Protecting people's Lives and Health	• The "Decision" made targeted reinforcements to the "Wild Animal Protection Law" from the values of maintaining biosecurity and ecological security, preventing major public health risks, and promoting the harmonious coexistence of man and nature • The "Decision" greatly expands the scope of wildlife protection
	Forestry Department (Ministry of Industry and Information Technology 2015)	Issued 1991, Revised 2011 and 2015	Administrative Measures for the Domestication and Breeding Licenses of Wild Animals under National Key Protection	• The forestry departments can review applicants and decide whether to issue permits to control the use of wild animals • Establish a file and statistical system for domestication and breeding of wild animals
	Ministry of Industry and Information Technology, State Administration of Traditional Chinese Medicine (State Council of China 2019)	Issued 2015	Chinese Herbal Medicinal Development Plan (2015–2020)	• Implement the wild Chinese herbal medicine resource protection project and establish the Chinese herbal medicine resource conservation system • Break through the breeding technology of endangered and scarce Chinese medicinal materials
	State Council of China (State Council of China 2017)	Issued 2006, Revised 2018 and 2019	Regulations on the Administration of Import and Export of Endangered Wild Animals	• Strict regulations on the import and export of endangered species
	State Council of China (Standing Committee of the National People's Congress 2020a, b)	Issued 1994, Revised 2017	Regulations on Nature Reserves	• Divide the protection of nature reserves into comprehensive management and departmental management • The government shall give awards to the units and individuals who have made remarkable achievements in the construction and management of nature reserves and related scientific research
	Standing Committee of the National People's Congress (Supreme People's Court 1990)	Issued 1979, Revised 1997 and 2020	Criminal Law (Articles 341 and 346)	• Those Articles provide criminal protection for wildlife conservation
	Supreme People's Court, Supreme People's Procuratorate and Ministry of Public Security (Standing Committee of the People's Congress of Gansu Province 2018)	Issued 1990	Notice on Severely Combatting Illegal Hunting, Killing, Purchasing, Reselling, Smuggling and Smuggling Wild Animals	• Timely investigate and deal with cases of indiscriminate hunting of wild animals, and severely crack down on illegal and criminal activities that destroy wild animal resources • Strictly manage shotguns and ammunition

Table 2 (continued)

Type	References	Year	Act	Legislation
Local laws	Standing Committee of the People's Congress of Gansu Province (Standing Committee of the People's Congress of Shenzhen City 2018)	Issued 1990, Revised 2018	Gansu Wildlife Protection Law	• when trading marmots, there should be a test report from the epidemic prevention department • The provincial government can organize and carry out the work of releasing wild animals under national and provincial key protection into the wild according to the needs of protecting wild animals
	Standing Committee of the People's Congress of Shenzhen City (Standing Committee of the People's Congress of Guangdong Province 2020)	Issued 2003, Revised 2018	"Several Provisions on Prohibition of Eating Wild Animals in Shenzhen Special Economic Zone"	• It is forbidden to eat wild animals but artificially bred wild animals that have passed the inspection can be eaten • Catering operators shall not use the names, nicknames, or patterns of wild animals and their products to make signboards or recipes
	Standing Committee of the People's Congress of Guangdong Province (Standing Committee of the People's Congress of Jilin Province 1985)	Issued 2001, Revised 2004, 2012, and 2020	Guangdong Province Wildlife Protection Management Regulations	• New penalties are set for illegally consuming wild animals • Internet information service providers shall not produce, reproduce, publish, or disseminate illegal wildlife trade information • Wild animals that have risks endangering public health safety, ecological safety and public order shall not be kept as pets
	Standing Committee of the People's Congress of Jilin Province	Issued 1985	Interim Regulations on the Protection and Management of Wild Animals and Plants in Jilin Province	• Provide the list of protected wild animals in Jilin Province in detail (393 in total) • The special allocation of the financial department is used for the protection and development of wild animals and plants • For hunting wild animals and plants for breeding, scientific research and teaching purposes, the approved competent department shall charge corresponding fees

International laws China participates

China has always adhered to the concept of a community with a shared future for mankind, and actively participated in international activities to manage the use of wildlife.

Moreover, China has participated in inter-governmental cooperation for many times and signed agreements with governments of various countries to jointly protect the survival of wild animals, such as the "CITES Convention," the "Convention on Biological Diversity," and the "Convention on the Protection and Analysis of Wild Animal Species," involving the use of wild animals in all aspects, which strictly cracks down on smuggling and reduces damage to wildlife.

The "Convention on International Trade in Endangered Species of Wild Fauna and Flora" to which China has joined is an important legal document on the import and export of wild animals. It stipulates the import and export species list of wild animals, prohibits import and export species, and endangered wild animal import and export species, and imposes strict restrictions on the import and export of wild animals.

Evaluation of the Chinese wildlife protection system using AHP

To analyze the key factors affecting the development of wildlife conservation in China, this paper proposes the AHP method to rank the relevant factors in the current Chinese wildlife conservation system.

AHP method

The AHP method is a widely used factor ranking method in various fields (Li et al. 2012), which obtains the weight of the relevant index factors by comparing the factors in pairs. This method can decompose a complex problem into easy-to-handle sub-problems by breaking the problem into multiple levels, each of which contains multiple factors and criteria, making the decision problem more specific and clear, allowing the weights and relative importance of multiple factors to be taken into account. The main part of AHP is the hierarchical structure, which is generally divided into three-level structure model of goal level, criterion level, and factor level. For the established hierarchy, the experts express their personal preference for the alternative A_i and A_j by adopting the term a_{ij}. Therefore, the judgment matrix A will be expressed as follows:

$$A = [a_{ij}], i = 1, 2, ..., n; j = 1, 2, ..., n \tag{1}$$

where the a_{ij} indicates the preference relationship and the a_{ij} has the properties: $a_{ij} > 0$; $a_{ji} = 1/a_{ij}$, n represents the number of factors in each level.

Table 3 Random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI_n	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The weight of each factor $w = (w_1, w_2, …, w_n)$ is calculated by the eigenvector of the judgment matrix A [1]:

$$A_w = \lambda_{max} w \qquad (2)$$

where w is the weight of corresponding factors.

The judgment matrix we get is different due to the complex diversity of the objective world and the diversity of human cognition. Therefore, the feasibility of the judgment matrix A needs to be measured by consistency testing. The inconsistency of matrix A can be measured by the consistency ratio CR_A:

$$CR_A = \frac{CI_A}{RI_n} \qquad (3)$$

$$CI_A = \frac{(\lambda_{max} - n)}{(n - 1)} \qquad (4)$$
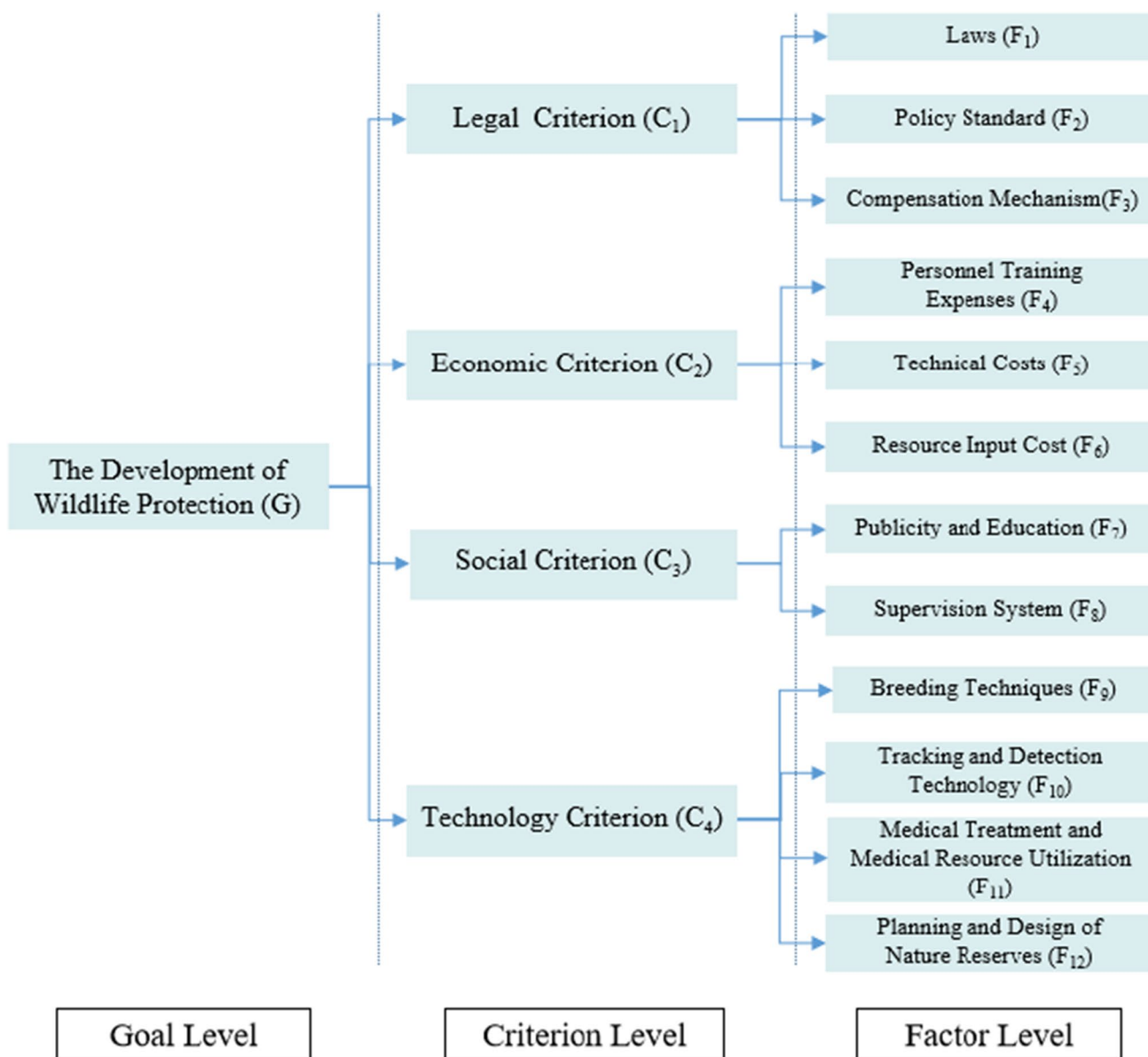
Fig. 2 The hierarchical structure of Chinese wildlife protection system

Table 4 Judgment matrix evaluation scale

Numerical scale	Definition
1	Equal significance of the two factors
3	Low significance of one factor compared to another
5	Strong significance of one factor compared to another
7	Confirmed dominance of one factor over another
9	Absolute dominance of one factor over another
2, 4, 6, and 8	Intermediate values between two neighboring levels
reciprocals ($1/x$)	A value attributed when factor i is compared to factor j becomes the reciprocal when j is compared to i

where RI_n is the random consistency index, which are shown in Table 3.

It is generally considered acceptable when the CR_A does not exceed one tenth of the average random consistency index, i.e., $CR_A < 0.1$. In particular, matrices of matrices of sizes 1 and 2 a real way consistent [2].

Case study

The paper uses the current situation of wildlife protection in China as an example to analyze the key factors affecting the development of wildlife protection in China. The specific implementation steps are shown as follows:

- Hierarchical structure of Chinese wildlife protection system

Based on the investigation and analysis of the key factors affecting the development of wildlife protection in China, we establish the hierarchical structure of Chinese wildlife protection system, as shown in Fig. 2, including goal level, criterion level, and factor level. Goal level (G) is the development of wildlife protection; criterion levels (C) is legal policy criterion (C_1), economic criterion (C_2), social criterion (C_3), and technology criterion (C_4). The legal policy criterion includes laws (F_1), policy standards (F_2), and compensation mechanism (F_3). The economic criterion includes personnel training expenses

Table 6 Pair-wise comparison matrix of C_1-F

C_1-F	F_1	F_2	F_3
F_1	1	2	4
F_2	1/2	1	2
F_3	1/4	1/2	1

(F_4), technical costs (F_5), and resource input cost (F_6). The social criterion includes publicity and education (F_7) and supervision system (F_8). The technology criterion includes breeding technology (F_9), tracking detection technology (F_{10}), medical treatment and medical resource utilization (F_{11}): Medical technology can maximize the treatment rate o*f* wildlife, and when the number of wild animals is enough, some wildlife resources can also be used for pharmaceutical and other human services. For example, forest frogs can extract forest frog oil to promote the metabolism of human skin and promote the anti-aging effect, and planning and design of nature reserves (F_{12}).

- Establishing the pair-wise comparison matrices

Experts will rate the key factors affecting wildlife conservation and development in China according to the criteria in Table 4, which establish the pair-wise comparison matrices.

Based on the analysis of the relevant status of a large number of wildlife conservation in China, we establish its pair-wise comparison matrix from the development of wildlife protection of view (G-C), which is presented in Table 5.

Similarly, we establish four pair-wise comparison matrices from legal policy point of view (C_1-F), economic point of view (C_2-F), social point of view (C_3-F), and technology point of view (C_4-F). The four pair-wise comparison matrices are shown in Table 6, 7, 8, and 9, respectively.

- Factor weight and consistency ratio test

Based on the Tables 5, 6, 7, 8, and 9, we can get the weight of every factor and the consistency ratio CR. The weight of each factor of the pair-wise comparison matrix and its consistency ratio of each pair-wise comparison matrix are shown in Tables 10, 11, 12, 13, and 14.

Through the hierarchy structure in Fig. 2 and the weights of the various factors given in Tables 10, 11, 12, 13, and 14, the influence weights of each factor on wildlife protection and

Table 5 Pair-wise comparison matrix of G-C

G-C	C_1	C_2	C_3	C_4
C_1	1	1/2	2	1/3
C_2	1/2	1	3	1
C_3	1/2	1/3	1	1/4
C_4	3	1	4	1

Table 7 Pair-wise comparison matrix of C_2-F

C_2-F	F_4	F_5	F_6
F_4	1	1/2	2
F_5	2	1	3
F_6	2	1/3	1

Table 8 Pair-wise comparison matrix of C_3-F

C_3-F	F_7	F_8
F_7	1	2
F_8	1/2	1

Table 10 Criterion weight rank and consistency ratio from G-C

Criterion	Weight	Rank
C_1	0.1474	3
C_2	0.3212	2
C_3	0.1041	4
C_4	0.4273	1
CR_{G-C}	0.0882 < 0.1	

development in China are calculated. The equation is as follows: $w_{G-C_j} = w_{G-F_i} \times w_{F-C_j}$ i = 1, 2, 3, 4; j = 1, 2, …, 12; Therefore, the weights of overall goal are shown in Table 15.

Based on the factor rank, we obtain the main key factors influencing Chinese wildlife protection system, which are F_{10} (tracking detection technology), F_5 (technical costs), and F_9 (breeding technology). It can be seen from the factor ranking results that to promote the development of wildlife protection in China, the first need to introduce wildlife tracking and monitoring technology and feeding technology. Chinese wildlife protection also needs sufficient technical financial support while introducing advanced technology. Overall, technical factors are the most key factor hindering the development of wildlife in China.

Managerial insights and future research trends

Wildlife is an important part of the natural ecosystem and a valuable resource given by nature to mankind. Protecting the safety of wildlife resources is related to the survival and development of mankind. Nowadays, the task of protecting wildlife resources in China is becoming more and more arduous, and there are still many problems. If we do not further strengthen the protection efforts and control the intensity of resource use more effectively, it will fundamentally affect the implementation of the whole social development and sustainable development strategy. At the same time, the development of information technology and big data technology has also brought new opportunities for wildlife protection. To better carry out wildlife protection, the importance of information technology in the process of wildlife conservation needs to be recognized. Therefore, this paper argues that the future development of wildlife conservation should focus on the following aspects, as shown in Fig. 3.

Big data and wildlife conservation converge

Wildlife conservation is gradually moving toward the era of big data. Through artificial intelligence, machine learning, neuro-linguistic processing, and other technical means, research on the ecological environment, animal populations, and individual animals can be realized. Ecologists can use computer vision to extract key features from images, videos, and other visual data to use large data sets to quickly classify animal species, count individual animals, and collect certain information. In wildlife rescue, information technology such as GPS positioning, the Internet of Things, QR codes, pictures, audio, and video can be used to assist in the rescue, treatment, breeding, and release of wild animals in the area. At the same time establish a timeline of the whole process of wildlife rescue digital files, to build a scientific and perfect, advanced means of wildlife rescue business management model. It can also actively promote the crackdown on wildlife trafficking through big data, drive species protection and research through big data and Internet security capabilities, cooperate with law enforcement agencies to crack down on cybercrimes in the field of wildlife trafficking, and help ecological governance.

Multi-channel intelligent protection and decision support system

Establishing a comprehensive management information platform covering all aspects of wildlife protection and considering resource sharing is of great significance to promote the continuous improvement of the wildlife protection business system and to continuously promote the development of regional ecological civilization construction. Through intelligent protection and decision support for the integration of geographic information, map impact, wildlife resource distribution and other resources, the monitoring and control

Table 9 Pair-wise comparison matrix of C_4-F

C_4-F	F_9	F_{10}	F_{11}	F_{12}
F_9	1	1/2	2	3
F_{10}	2	1	2	4
F_{11}	1/2	1/2	1	3
F_{12}	1/3	1/4	1/3	1

Table 11 Factor weight and consistency ratio from C_1-F

Factors	Weight	Rank
F_1	0.5714	1
F_2	0.2857	2
F_3	0.1429	3
CR_{C1-F}	0.0001 < 0.1	

Table 12 Factor weight and consistency ratio from C_2-F

Factors	Weight	Rank
F_4	0.2970	2
F_5	0.5396	1
F_6	0.1634	3
$CR_{C2\text{-}F}$	0.0079 < 0.1	

Table 14 Factor weight and consistency ratio from C_4-F

Factors	Weight	Rank
F_9	0.2844	3
F_{10}	0.4279	1
F_{11}	0.2005	2
F_{12}	0.0872	4
$CR_{C4\text{-}F}$	0.0301 < 0.1	

of wildlife epidemic sources and diseases automatic early warning monitoring, sampling, and inspection, to promote the popularization of science and improve multimedia science and education channels on data mining and utilization, visualization, and analysis, the establishment of virtual scenarios to help staff make auxiliary decisions, the introduction of intelligent analysis tools, the establishment of prediction models based on neural networks, prediction models, etc., to simulate the dynamic evolution of wildlife resources in the region. From the auxiliary analysis of data to the main dynamic decision-making.

Improving the management of wildlife conservation legislation and enforcement

In recent years, wildlife protection has received more and more attention, and the government has issued many laws, regulations, and standards for wildlife protection. The local government or relevant authorities should actively promote the development of a "no wildlife list" or, where appropriate, formulate relevant local regulations and standardize them. It should strengthen law enforcement, improve the rules and regulations supporting law enforcement, increase public participation in the law enforcement process, improve public participation channels, and establish an effective reward reporting system to supervise and manage illegal wildlife or related departments. In addition, the scope of wildlife legislative protection should be expanded, legislation should be enacted to regulate wildlife trade and consumption behavior, and laws and regulations on wildlife habitats and protected areas should be strengthened.

Promoting the development of complex talents

Cultivate composite talents in wildlife conservation and strengthen theoretical research that can be applied to wildlife conservation. The training of composite talents should be strengthened under the beneficial cross-combination

of wildlife conservation with environmental science and information science, so that wildlife conservation personnel can become composite talents with both knowledge of wildlife conservation and good knowledge of environmental protection and the ability to use information science. The government should strongly support and guide scientific research on wildlife conservation. On the one hand, it should actively support the basic theoretical research of wildlife conservation, and on the other hand, it should strengthen the cooperation between wildlife conservation institutions, colleges, universities, and scientific research institutions to form a virtuous cycle of combining industry, academia, and research. In terms of wildlife talent training, a multi-level and diversified wildlife conservation education system is a decisive factor in ensuring the formation of a reasonable talent structure and improving the level of wildlife conservation. Colleges and universities should be encouraged to offer modern specialized courses in wildlife conservation, including environmental science related to wildlife conservation, and information science. Undergraduate, master's, and doctoral education at multiple levels should be carried out to train senior management personnel and professionals for modern wildlife conservation and promote stronger development of wildlife conservation.

Application of intelligent monitoring and identification

In terms of wildlife monitoring, the unmanned technology can be used to obtain images from all angles of the ground or cliffs from the air, and the UAV can also use the airborne infrared thermal imaging camera for monitoring, displaying animal body temperature hot spots on the digital map of the ground

Table 13 Factor weight and consistency ratio from C_3-F

Factors	Weight	Rank
F_7	0.6667	1
F_8	0.3333	2
$CR_{C3\text{-}F}$	matrix size is 2	

Table 15 Factor weight rank of overall factors

Factors	Weight	Rank	Factors	Weight	Rank
F_1	0.0842	6	F_7	0.0694	6
F_2	0.0421	10	F_8	0.0347	11
F_3	0.0211	12	F_9	0.1215	3
F_4	0.0954	4	F_{10}	0.1828	1
F_5	0.1733	2	F_{11}	0.0857	5
F_6	0.0525	8	F_{12}	0.0373	9

Fig. 3 Future trends of wildlife resource conservation
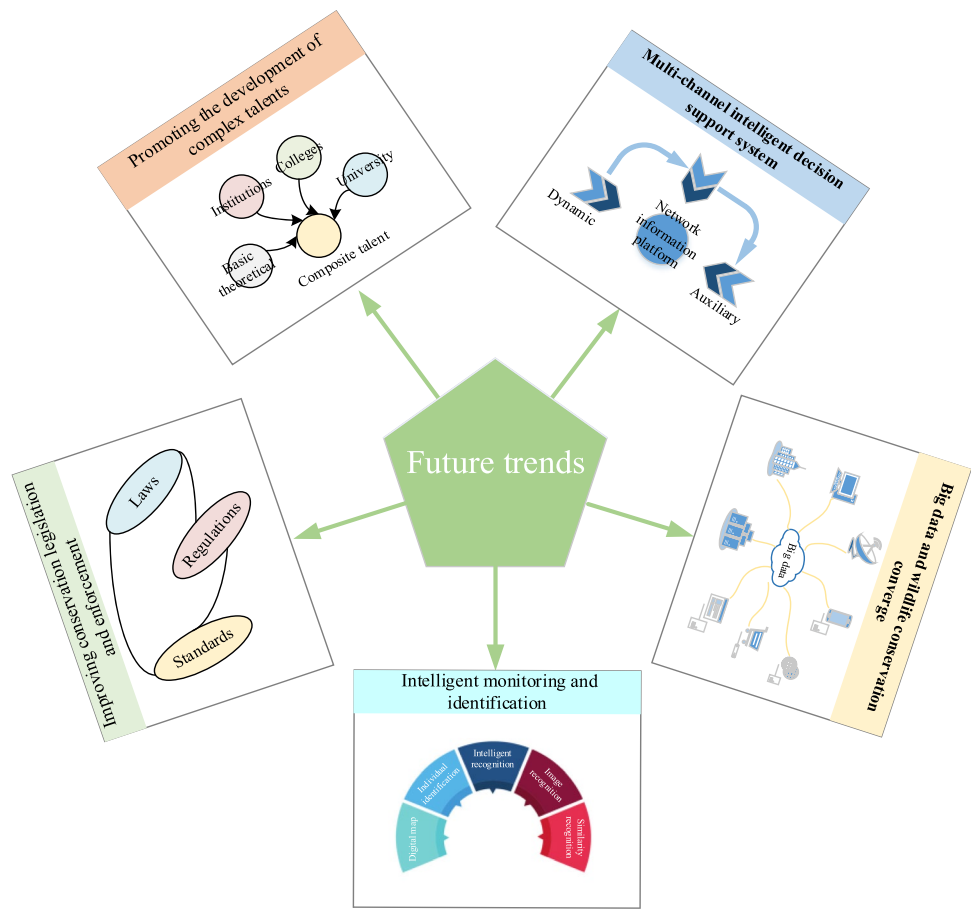
station, monitoring the population distribution, activity trajectory and behavior of different wild animals in the region such as water, land, and air, protecting the healthy development of wild animal populations and The ground station can monitor the distribution, activity trajectory and behavior of different wildlife populations in the region, such as water, land, and air, to protect the healthy development and reproduction of wildlife populations and prevent the spread of epidemic diseases carried by wild animals among people and domestic animals, causing large-scale economic and social losses. In terms of wildlife identification, we can establish an individual identification model with the basic characteristics of body posture, gait, color, and the fur pattern. It also performs intelligent individual recognition for static pictures and dynamic pictures, and image recognition for different kinds of wild animals, with the real-time marking of individual recognition results and similarity of individual recognition.

Conclusions and suggestions

As an important biological resource, wild animals and plants occupy a pivotal position in the natural world. They play a very important role in maintaining ecological balance,

improving the natural environment, promoting harmony between humans and nature, and maintaining biodiversity. This paper reviewed the latest research progress in the field of wildlife conservation, outlines the existing methods, and the obstacles in their development, and proposes future research directions and trends for the characteristics of wildlife conservation, such as strengthening the application of information technology, strengthening the training of complex talents, and promoting more standardized and reasonable laws and regulations. This study using the AHP method analyzed all these economic, social, technical and political criteria to provide practitioners and researchers. We hope our results and future research trends discussed earlier would be an inspiration for practitioners and researchers in this industry. It is hoped that the research in this paper can promote the benign use of wildlife resources, maintain ecological balance, improve the natural environment, and preserve biodiversity, and later promote the further development of industry through the healthy exploitation of wildlife resources, and promote better harmony between human and nature.

Although we have provided a comprehensive and integrated overview of the field of wildlife conservation, there were still some limitations that can be considered as our

suggestions for future research on wildlife conservation. First, there are many hybrid decision-making methods, such as gray correlation analysis (Tian et al. 2023), and fuzzy integration (Tian et al. 2018) for analyzing our criteria, which can be employed instead of our AHP. We can add more sub-criteria for the details of our main criteria for the classification of our research methodology and refinement of various wildlife conservation methods. Regarding the COVID-19 pandemic, there are many resiliency factors that can be added to our future work. The latest technologies regarding industrial informatics and high-tech can be used in our analyses for the integration of wildlife conservation. For example, neural network technology, big data support and data-driven. In addition, we can develop decision support systems to ease the decision-making process for selecting the weights of criteria based on the literature. Finally, although this paper is not an exhaustive study, we believe it will provide some new ideas for wildlife conservation research and it is a good reference for the future development and application of wildlife conservation in sustainable ecosystem and society.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Button S, Borzée A (2021) An integrative synthesis to global amphibian conservation priorities. Global Change Biol 27(19):4516–4529

Cai QZ, Zheng BC, Xiangyin Z et al (2022) Combining long-tailed data resolution methods for wildlife target detection [J]. Computer Applications 42(4):8

Chen HY (2020) Research progress and prospect of ecological protection and development in nature reserve [J]. Farmer Staff Officer 07:117–165

Chen ZM (2022) Wildlife rearing and rescue techniques [J]. China Livest Poultry Seed Ind 18(01):81–82

Chen JM, Hu CZ, Yang F et al (2021) Research on the governance strategies of illegal trade in wildlife and its products [J]. For Econ Probl 41(02):136–145

Cheng ZB, Zhang LY, Zhang W, et al. (2013). The scientific concept of wildlife conservation in China in the new era from biodiversity conservation [C]. Ann Conf Chinese Soc Environ Sci

Donaldson L, Bennie JJ, Wilson RJ et al (2021) Designing effective protected area networks for multiple species[J]. Biol Cons 258:109125

Dong J, Lyu Y (2022) Appraisal of urban land ecological security and analysis of influencing factors: a case study of Hefei city, China[J]. Environ Sci Pollut Res 29:90803–90819

Duan Q (2022) Constitutional animal protection: status quo, expectation, and response [J]. NTU Law 02:139–154

Editorial Board of this journal (2020) Reinforcing biosecurity regulation and saying "no" to the habit of indiscriminate wildlife consumption [J]. Environ Prot 48(5):1

Forestry Department. (2015). Measures for the management of permits for the domestication and breeding of wild animals under national key protection. http://www.forestry.gov.cn/main/3951/20170315/204774.html Accessed 09 Jan 1991.

Gao H, Xiang Z, He J, Luo B, Wang W, Deng Y,... Feng J (2023a). Using expert knowledge to identify key threats and conservation strategies for wildlife: a case study with bats in China. Global Ecol Conserv e02364

Gao Y, Liu Y, Luo Y, Biggs D, Zhao W, Clark SG (2023b). Tracking Chinese newspaper coverage of elephant ivory through topic modeling. Conserv Biol

Guo YM (2021) The conservation and sustainable utilization of wildlife resources in the new era [J]. Jilin Anim Husb Vet Med 42(02):87–88

Guo Z, Cui G, Zhang M et al (2019) Analysis of the contribution to conservation and effectiveness of the wetland reserve network in China based on wildlife diversity[J]. Global Ecol Conserv 20:e00684

Guo J, Song JQ, Li H (2021) An analysis of wildlife conservation under the new crown pneumonia epidemic [J]. Modern Rural Sci Technol 12:2

Harbin. (1992). Northeast Industry and People's Studies Publishing House. 339–340

Jiang SM (2022) Discussion on strengthening the construction of grassroots wildlife protection management team [J]. Modern Horticulture (6)

Jiang JZ, Xie YH (2022) Application of improved Yuru model for wildlife species identification in airborne thermal imaging [J]. J Northeast For Univ 50(3):5

Kaczensky P, Kuehn R, Lhagvasuren B et al (2021) Connectivity of the Asiatic wild ass population in the Mongolian Gobi [J]. Biol Cons 144(2):920–929

Lavery T H, Eldridge M, Legge S, et al. (2019). Threats to Australia's rock-wallabies (Petrogale spp.) with key directions for effective monitoring [J]. Biodivers Conserv 30(2)

Lee S, Kim W, Kim YM, Oh KJ (2012) Using AHP to determine intangible priority factors for technology transfer adoption. Expert Syst Appl 39:6388–6395

Li RJ. (2018). Research on the construction of primate animal face dataset and recognition methods [D]. Northwestern University

Li Y (2020) Research progress in ecological protection and development of nature reserve [J]. Henan Agriculture 17:63–64

Li X (2022) Criminal law protection mechanism of wild animals and its improvement [J]. Journal of Wildlife 43(02):538–546

Liu XL (2021) The system, defects and perfect path of wildlife legal protection in China [J]. Law J 42(08):123–135

Lv YL, Li F (2022) Research on wildlife habitat monitoring technology based on satellite remote sensing images [J]. China High-Tech 3:3

Ma ZH (2022) Wildlife status and research Direction in Taizi Mountain Nature Reserve [J]. Farmer Staff 06:132–134

Ministry of Industry and Information Technology (2015) Chinese Herbal Medicinal Development Plan (2015–2020). https://jxt.

hubei.gov.cn/fbjd/xxgkml/jgzn/nsjg/yycyc/yycy/201912/t2019 1226_1794784.shtml. Accessed 16 Dec 2015.

Mu L (2020) Criminal law protection of animals [D]. Chongqing University

National People's Representative Meeting (2018) Revise the Constitution of the People's Republic of China. http://www.gqb.gov.cn/node2/node3/node5/node9/userobject7ai1273html. Accessed 04 Apr 1982

Nature Editorial Board. (2021). New List of National Key Wildlife Protection [J]. Nature

Niu MJ, Liu Q, Zhou N et al (2022) Study and analysis of the current situation of conservation education in WAZA Asian zoos [J]. Journal of Wildlife 43(02):547–556

Roper BB, Capurso JM, Paroz Y et al (2018) Conservation of aquatic biodiversity in the context of multiple-use management on National Forest System lands [J]. Fisheries 43(9):396–405

Sheng S, Zhu Y, Zheng JF et al (2022) Influencing factors of indigenous wildlife conservation awareness in Guizhou Leigongshan National Nature Reserve [J/OL]. J Ecol 06(13):1–11

Shi X (2022) Exploration of aquatic wildlife conservation in Beijing [J]. China Fisheries 04:69–72

Standing Committee of the National People's Congress (2004). http://www.dayawan.gov.cn/hzdywhyyyj/gkmlpt/content/4/4058/post_4058442.html#4259. Accessed 14 Feb 1986

Standing Committee of the National People's Congress (2018) Law of the Wildlife Protection Law of the People's Republic of China. https://www.mca.gov.cn/article/zt_gjaqr2021/flfg/202104/20210400033207.shtml. Accessed 8 Nov 1988.

Standing Committee of the National People's Congress (2020a) Decision on comprehensively banning illegal wildlife trade, eradicating the habit of overeating wildlife and effectively protecting people's lives and health. http://www.npc.gov.cn/npc/c30834/2020a02/c56b129850aa42acb584cf01ebb68ea4.shtmlAccessed 24 Feb 2020.

Standing Committee of the National People's Congress (2020b) Criminal Law (Articles 341 and 346). http://www.gzasrd.gov.cn/flfg/cgfl/202203/t20220317_73026376.html. Accessed 17 Mar 2020b.

Standing Committee of the People's Congress of Gansu Province (2018) Gansu Wildlife Protection Law. http://www.tianshui.gov.cn/art/2022/5/6/art_368_308147.html. Accessed 6 May 2022.

Standing Committee of the People's Congress of Guangdong Province (2020) Guangdong Province Wildlife Protection Management Regulations. http://www.gd.gov.cn/gdywdt/zwzt/fkyq/pfzl/content/post_2962738.html. Accessed 31 May 2001.

Standing Committee of the People's Congress of Jilin Province (1985) Interim regulations on the protection and management of wild animals and plants in Jilin province. https://code.fabao365.com/law_106880.html. Accessed 12 Jun 1985.

Standing Committee of the People's Congress of Shenzhen City (2018) The Shenzhen Special Economic Zone prohibits the consumption of wild animals in a number of regulations. http://www.sz.gov.cn/zfgb/2003/gb1064/content/post_4973433.html Accessed 27 Aug 2003.

State Council of China (2013) Emergency regulations for major animal outbreaks. http://nyncj.lsz.gov.cn/x xgk/fdzdgknr/lzyj/nyflfg/202109/t202109272023062.html. Accessed 09 Apr 1993

State Council of China (2016) Implementing regulations of the People's Republic of China on the protection of terrestrial wild animals. https://www.mca.gov.cn/article/zt_gjaqr2021/flfg/202104/20210400033246. shtml. Accessed 1 Mar 1982

State Council of China (2017) Regulations on nature reserves. http://www.bjfsh.gov.cn/ztzx/2022/ld2022/xgwj/202203/t20220324_40041237.shtml. Accessed 24 Mar 2020.

State Council of China (2019) Emergency regulations for major animal outbreaks.http://nyncj.lsz.gov.cn/xxgk/fdzdgknr/lzyj/nyflfg/202109/t202109272023056.html Accessed 16 Nov 2005.

Sumthane M Y, Vatti R A. (2017). Wi-Fi interference detection and control mechanism in IEEE 802.15.4 wireless sensor networks[C] 2017 Fourth International Conference on Image Information Processing (ICIIP)

Sun WM, Ma D (2022) Effects of forest and grass conservation project implementation on wildlife [J]. New Agriculture 09:52

Sun Y, Sun L, Sun S, Tu Z, Liu Y, Yi L, He B (2023) Virome Profiling of an Eastern Roe Deer Reveals Spillover of Viruses from Domestic Animals to Wildlife. Pathogens 12(2):156

Supreme People's Court (1990) Criminal Law (Articles 341 and 346). http://www.lscps.gov.cn/html/17434. Accessed Mar 1990.

Tang GJ, Fan YL (2021) Exploring the conservation and sustainable utilization of wildlife resources in the new era [J]. Modern Agric Res 27(12):2

Tian ZH (2020) Discussion on the protection of wildlife resources in Nanhua Mountain National Nature Reserve [J]. Modern Rural Sci Technol 07:103–104

Tian G, Zhang H, Feng Y, Wang D, Peng Y, Jia H (2018) Green decoration materials selection under interior environment characteristics: a grey-correlation based hybrid MCDM method[J]. Renew Sustain Energy Rev 81:682–692

Tian G, Zhang C, Fatchollahi-Fard AM et al (2022) An enhanced social engineering optimizer for solving an energy-efficient disassembly line balancing problem based on bucket brigades and cloud theory[J]. IEEE Trans Industr Inform. https://doi.org/10.1109/TII.2022.3193866

Tian G, Lu W, Zhang X, Zhan M, Dulebenets MA, Aleksandrov A, Fatchollahi-Fard AM, Ivanov M (2023) A survey of multi-criteria decision-making techniques for green logistics and low-carbon transportation systems. Environ Sci Pollut Res :1–23. https://doi.org/10.1007/s11356-023-26577-2

Tozer DC, Steele O, Gloutney M (2018) Multispecies benefits of wetland conservation for marsh birds, frogs, and species at risk [J]. J Environ Manage 212:160–168

Vimal R, Navarro LM, Jones Y et al (2021) The global distribution of protected areas management strategies and their complementarity for biodiversity conservation [J]. Biol Cons 256:109014

Wang L, Wang BH, Xu WY (2022) The improvement of public interest litigation mechanism for wildlife protection: the case of Qinling [J]. J Shanxi Acad Polit Legal Manag Cadres 35(02):30–34

Wang J, Chen Y, Sun Y, Lyu Z, Shi K (2023). Inferring human-elephant coexistence based on characteristics of human-elephant interactions in Nangunhe, Yunnan, China. Chin Geograph Sci 1–14

Wilkinson CE (2023). Public interest in individual study animals can bolster wildlife conservation. Nat Ecol Evol 1–2

Wu Y (2021) Analysis of the existing problems and rescue methods of wildlife rescue [J]. Temperate For Res 4(03):54–56

Yao ZC, Zhang W, Xu HT et al (2022a) The current situation of wildlife protection management and countermeasures in Zibo City [J]. Jilin For Sci Technol 51(02):45–48

Yao ZC, Zhang W, Xu HT et al (2022b) Current situation and countermeasures of wildlife protection and management in Zibo City [J]. Jilin For Sci Technol 51(02):45–48

Ye SS (2014) The impact of climate change on wildlife [J]. Nature 4:2

Yin B, Yang HM (2022a) Improving the legislation and law enforcement management ofwildlife protection [J]. Anim Husb Vet Sci Technol Inf 03:16–18

Yin B, Yang HM (2022b) Improve the legislative law enforcement management of wildlife protection [J]. Anim Husb Vet Sci Technol Inf 03:16–18

Yu H (2020) wildlife decline by 2/3 in the last 50 years [J]. Ecol Econ 36(11):4

Yu KX, Hu E, Yao YA, Zhang SS, Feng G et al (2022) Advances in wildlife identification techniques[J]. Sci Technol Bull 38(02):1–10+18

Zeng YM (2015) The current status and development ideas of the domestication and breeding of wild animals [J]. Beijing Agric 02:64–65

Zhang P (2021) Current situation and conservation countermeasures of wildlife species diversity in nature reserves [J]. For Sci Technol Inf 53(04):81–82-85

Zhang ZG (2022a) Exploration of forest wildlife protection and nature reserve management [J]. China Forestry Specialties 1:3

Zhang ZG (2022b) Exploration on Forest Wildlife Protection and Nature Reserve Management [J]. Chinese forest sideline specialty 01:99–101

Zhang XY, Zhang HL, Han YY et al (2022a) Research progress of wildlife monitoring and identification based on deep learning [J]. J Wildl 43(01):251–258

Zhang H, Su KW, Ma L, Wen YL (2022b) Wildlife conservation and utilization in Tanzania and its inspiration [J]. World For Res 35(02):94–99

Zhang H, Peng Y, Tian G, Wang D Xie P (2017). Green material selection for sustainability: a hybrid MCDM approach[J]. Plos One 12(5) https://doi.org/10.1371/journal.pone.0177578.

Zhao W (2016) I Analysis of the domestication and reproduction status of terrestrial wild animals in Fuyang city [J]. Anhui For Sci Technol 42(Z1):42–45

Zhao ZZ (2020) Exploration on wildlife protection countermeasures in forestry protection area [J]. Southern Agric 14(36):171–172

Zhao N, Wang ZX (2021) The dilemma and way out of biodiversity compensation in wildlife habitats in China [J]. J Jiangxi Univ Technol 42(05):25–30

Zhong LC (2008) Research on the standardization and standard system of wildlife conservation in China [J]. For Sci Technol 03:28–30

Zhou Y, Buesching CD, Newman C et al (2013) Balancing the benefits of ecotourism and development: the effects of visitor trail-use on mammals in a Protected Area in rapidly developing China [J]. Biol Cons 165:18–24