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REVIEW ARTICLE

Natural resource management in American national parks: Principles, problems and enlightenment

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ABSTRACT

The natural resources of national parks in the United States are mainly divided into eight categories: biological resources, fire resources, water resources, air resources, geological resources, soundscape, lighting, chemicals and odors. The management procedures set by the National Park Administration include the formulation of natural resource management planning, the preservation and publication of natural resource information, the assessment of the impact of natural resources, the establishment of the extensive cooperative relations, the promotion of the restoration of natural ecosystems and the establishment of natural resources damage compensation system etc. Different management principles and methods are adopted for different types of natural resources. The "application–review–evaluation–permission" procedure for the development and utilization of natural resources is established and strictly implemented. However, there are also some problems, such as insufficient coverage of natural resources, dislocation of unified management and decentralized management, and serious shortage of financial investment. China's national parks should clearly define the types of natural resources, gradually expand the pilot scope of natural resource asset management system, establish and improve the natural resource management system, highlight the integrity of ecosystem, adhere to management according to law, and strengthen the control of land and space use.

Keywords: National Park; Natural Resources; Ecosystem Integrity; Resource Use Impact Assessment; Biological Resources; Damages

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1. Introduction

The reform task of perfecting the management system of natural resources assets is a significant reform task clearly defined in Overall Plan of Ecological Civilization System Reform, and it is also an important measure to implement the idea of Xi Jinping ecological civilization. Among them, the establishment of a hierarchical and unified natural resource asset management system is also an important task for the pilot of China's national park system[1,2]. Since 2017, as an independent natural resources ownership registration unit, China's national park pilot areas have made major headways in natural resources asset management system, property right system, ownership confirmation registration, accountability and other aspects, but there are also problems such as slow progress, unclear rights and responsibilities and unclear background[3,4]. In April 2019, the general office of the CPC Central Committee and the general office of the State Council printed *The Guiding Opinions on Comprehensively Promoting the Reform of the*

Property Right System of Natural Resource Assets, which clearly putting forward to speed up the unified ownership registration of natural resources, and focusing on promoting the ownership registration of important ecological spaces in various natural protection areas such as national parks. At the same time, it is proposed to carry out in-depth research on major issues, especially comparative research at home and abroad. In recent years, China has carried out some researches on the management of natural resources in the United States[5-8]. In contrast, there was less research on the management content of natural resources in American national parks, and the research mostly focused on management system and institutions, financial mechanism, mineral resources and other aspects[9-12]. The management of natural resources in American national parks started early and the system is relatively complete[13-16], which is worth further study. Based on the reality of our country, this paper focuses on introducing the experience of natural resource management in American national parks in detail from the aspects of natural resource types, principles and methods etc., and analyzing the existing problems in order to provide reference for the natural resource management of China's national parks and other natural protection areas.

2. Basic overview of natural resources management in American national parks

The natural resources of national parks in the United States are mainly managed by the National Park Administration. Its management of natural resources includes not only traditional natural resources, but also the evolution process, system and value of natural resources under the background of ecosystem integrity[17]. Natural resources in a broad sense include six kinds: (1) material resources, such as water, air, soil, topographic characteristics, geological characteristics, paleontological resources, natural landscape and clear sky day and night; (2) physical processes such as weather, erosion, cave formation and wildfire; (3) biological resources such as native plants, animals and communities; (4) biological processes such as photosynthesis, succession and evolution; (5) ecosystem; (6) Scenery and other high-value resources. Among the above natural resources, 8 categories including biological resources etc. are included in the specific management scope, with a total of more than 20 management priorities (see **Table 1**).

Table 1. Types of natural resources and management priorities of national parks in the United States

Type	Management priorities
Biological resources	Flora and fauna populations, genetic resources, invasive species, pests and diseases, etc.
Fire	Natural fire and man-made fire
Water resources	Water rights, water quality, wetlands, watersheds, etc.
Air resources	Air quality, weather and climate, etc.
Geological resources	Geological processes, coastlines, karsts, geological hazards, geothermal, soil, etc.
Soundscape	Natural sounds and their transmission carriers, etc.
Lighting	Natural lighting, artificial lighting, etc.
Chemicals and odors	Animal droppings, tree and flower secretions, pesticides, etc.

3. Laws and basic principles applicable to the integrated management of natural resources

3.1 Applicable law

The National Park Service of the United States carries out comprehensive management of natural resources according to a number of laws and regulations, mainly including *Organic Law of the Administration*, *Comprehensive Management Law of National Parks* and other special regulations, as well as *Clean Air Act*, *Clean Water Act*, *Endangered Species Act*, *National Environmental Policy Act*, *Wilderness Protection Act* and other applicable regulations such as *Sequoia Act*, *Migratory Bird Protection Act*, *Resource Protection and Restoration*

Act and *Federal Cave Resources Protection Act*. The right to manage the natural resources of the public park is exercised, so as to keep them in an unspoiled natural state, serving present and future generations. For example, *Law on Comprehensive Management of National Parks* clearly states that protecting park resources and their values from damage is the core of management. Therefore, the manager must specify in writing whether the activities in the proposed park will damage natural resources. In addition, the manager must take measures to ensure that the ongoing activities will not damage the natural resources of the park. If the impact of relevant activities on the natural resources of the park cannot be determined, the protection of natural resources should be the priority. In addition, *Code of Federal Regulations* requires the Forest Service Bureau, Land Administration Bureau, Fish and Wildlife Service and other institutions to consider the impact of their actions and decisions on the national parks and its surrounding land when preparing their own management plans. The above three bureaus cooperate with the National Park Administration to protect the natural resources of the national parks. According to the *National Environmental Policy Act*, when carrying out any relevant activities that may significantly affect the quality of human living environment, federal agencies need to analyze their environmental impact in detail. The development of natural resources in national parks must also comply with the above provisions, and reports of environmental impact assessment must be submitted when exploiting natural resources. It is stipulated in the *Clean Water Act* that the National Park is a class I area of air quality, and the most stringent emission standards of air pollutants is implemented to prevent significant deterioration of air quality and damage to atmospheric visibility and ensure the quality of air[18,19].

3.2 Management principles

The National Park Service implements comprehensive management of natural resources, focusing on the protection of basic physical and biological processes, as well as individual species, animal and plant communities and their related characteristics, rather than static and mechanical single management. The concepts and principles of natural resource management in American national parks have changed greatly in practice. In 1963, the *Leopold Report* submitted by the special advisory committee on wildlife management pointed out that the management of natural resources in national parks is a talisman to protect the primitive ecology of the United States. The 2012 *Leopold Revised Report* further pointed out that the ultimate goal of natural resource management in national parks in the United States should be to adapt to known and unknown changes and protect ecological integrity and cultural and historical authenticity[18]. Based on this proposal, the National Park Service formally proposed the management policy of “all native species are crucial to the mission of the national park” for the first time. In the late 1960s, the National Park Service officially abolished the policy of predation. In the mid-1970s, the policy of artificial feeding of wild animals was comprehensively stopped[20]. The above changes also show that the management object of natural resources in American national parks has changed from single resources to comprehensive resources based on ecosystem integrity, from land to land, sea and air three-dimensional management in space, and from scattered mode to networking. The main reasons for this transformation are the large variety, large quantity, high concentration, cross distribution and difficult separation of natural resources in the national park[2,21-24]. When protecting a single natural resource, it must involve other resources associated with it. For example, the protection of forest resources involves biological resources such as land resources, water resources and animals, and vice versa. Natural resource management based on ecosystem integrity has gradually developed into one of the important principles of natural resource management in American national parks, and it is also the success of its natural resource management.

In the practice of working, the park authority attaches great importance to maintaining all components and processes in the park ecosystem in the process of natural succession, including the abundance, diversity, genetic and ecological integrity of

vivid plant species in these ecosystems. In addition, the following consensus has been reached: if the park area is managed as biogeographic islands, it is almost impossible to fully realize or maintain its physical and biological integrity. On the contrary, the park area must be managed in the context of a larger ecosystem, and all kinds of resources that need to be protected must be placed in an appropriate ecosystem environment to highlight the integrity of the ecosystem.

Specifically, implementing comprehensive management needs to consider the following six aspects.

3.2.1 Formulate natural resource management plan

The United States stipulates that each park with important natural resources base shall formulate and regularly update a long-term (at least 10–20 years in advance) comprehensive development strategy for natural resource management, and make provisions for inventory, research, monitoring, restoration, protection, education and resource utilization management. The strategy should also cover activities related to the protection and inheritance of natural heritage and history and culture with natural resources as the carrier, so as to realize the value of cultural resources (such as historical landscape) and meet the needs of tourists. The planning of operation, development and management activities that may affect the park's natural resources must be formulated on the basis of high-quality assessment, which should be based on scientific and detailed information and data.

3.2.2 Preservation and publication of natural resource information

The information collected or developed through resource inventory, monitoring, research and evaluation will be managed and kept for a long time according to the professional standards of archives and libraries of the authority. Most of the information about the park's natural resources will be widely disclosed to park employees, scientists and the public.

3.2.3 Conduct natural resource impact assessment

For proposed activities that may affect the park's natural resources, the authority needs to conduct a comprehensive and public assessment of the environmental costs and benefits of its operation, development and resource management. The assessment must include: appropriate participation of the public, the application of scientific and technological information to planning, assessment and decision-making processes, the professional knowledge used by interdisciplinary teams and processes, and the full integration of mitigation measures, pollution prevention technologies and other principles of sustainable park management. The environmental assessment and environmental impact report shall include an analysis of whether the proposed activities will damage the natural resources and values of the park. Each conclusion of "no significant impact", decision-making record and memorandum agreement under article 106 of *National Historical Protection Law* signed by the park authority shall include a separate certificate that the proposed activity will not damage the natural resources and value of the park.

3.2.4 Establish extensive cooperative relations

The United States believes that it may be difficult for a single manager to achieve the best results of resource management, and cooperation with other land and resource managers can achieve ecosystem stability and other resource management objectives. Therefore, the authority has reached agreements with the federal government, tribal, state and local governments and social organizations, other governments and social organizations, and private landowners to coordinate animal, plant, water and other natural resource management activities at discretion, and maintain and protect park resources and values. The scope of cooperation includes park restoration activities, research on natural resources in the park and the management of species in the park, and it may also involve coordinating management activities in two or more separate areas, integrating management measures to reduce conflict, assisting in research, sharing data and expertise, exchanging local biological resources and establishing wildlife corridors, and providing basic

habitat adjacent to or across the park boundary. In addition, the authority seeks cooperation to minimize impacts outside the park, including controlling noise and artificial lighting, maintaining water quality and quantity, eliminating toxic substances, protecting landscape, improving air quality, protecting wetlands, protecting threatened or endangered species, eliminating alien species, managing the use of pesticides, protecting coastlines, preventing fires, and managing border impacts, and other ways to protect natural resources.

3.2.5 Promote the restoration of natural ecosystem

Unless there are specified regulation made by Congress, the authority will strive to restore the natural ecological functions of the national park. When restoring the landscape disturbed by natural phenomena (such as landslides, earthquakes, floods, hurricanes, tornadoes and fires), natural restoration can be implemented except for special circumstances such as needing to take control measures to protect other park resources and public safety. Due to the impact of human disturbance on the natural system (including the introduction of alien species, air, water and soil pollution, accelerated erosion and deposition, etc.), the authority shall restore the disturbed area to the natural condition and process characteristics. The authority also uses the current advanced technology to restore the biological and material components in the system and accelerate the restoration of landscape and biological community structure and function. Specific measures include: elimination of alien species; removal of pollutants and non-historic buildings and facilities; repair abandoned mining areas, abandoned or unauthorized roads, areas where livestock are overgrazed, or damaged natural waterways and coastlines; restore areas disturbed by development activities approved by the authority (e.g. removal of dangerous trees, construction, mining of sand and gravel) or normal park management activities; restore the natural sound scene; restore the original vivid plants; restore natural visibility, etc.

3.2.6 Establish a compensation system for damage to natural resources

In case of any act that leads to the destruction or damage of park resources or values, the authority will use all measures to protect and restore natural resources to maintain the ecosystem and natural resource values. One of the most critical measures is damage assessment. Damage assessment is a milestone for the United States to achieve the ultimate goal of restoration, replacement and regeneration of public resources, which lays a foundation for restoring public losses and determining compensation. The specific implementation steps of damage compensation are as follows: (1) determine the damage of natural resources, evaluate all loss contents and assess the degree of damage; (2) assess the cost of resource losses, including direct and indirect costs of recovery and monitoring activities; (3) use the resource damage compensation to recover and replace the damaged resources.

4. Methods and principles of different types of natural resources management

4.1 Biological resource management

4.1.1 Basic principle

The authority maintains the number of all plants and animals in the park ecosystem from the perspective of the composition of the park's natural ecosystem. Specifically, it includes flowers, ferns, mosses, algae, fungi, bacteria, mammals, birds, reptiles, amphibians and other groups. Different management methods are adopted for different types of biological resources.

For flora and fauna, the important goal is to protect their lives and habitats, so as to prevent large fluctuations of population numbers and periodic disappearance of them. For faunas distributed in multiple habitats, national park as one of their habitats, the park management parties will actively cooperate with other habitat management parties to strengthen collaborative protection. Specific ways include: joint participation in scientific research and planning; developing mutually beneficial policies; sharing monitoring data; include information on the life cycle, range of activities and population dynamics of species in the interpretation project to

improve public awareness of all species in the park (including native and alien species); prevention and control of alien species invasion, etc. For genetic resources, the authority strives to protect all genetic types (genotypes) of native animal and plant populations in the park by continuing the process of natural evolution and reducing human interference with evolutionary genetic diversity. The authority uses organisms from populations that are genetically and ecologically as closely related as possible (especially organisms from adjacent or local similar habitats) to restore native animals and plants. In order to strengthen the gene exchange between locally bred populations and restore the genetic diversity of species, when native plants or animals are removed for some reason (such as hunting, fishing, pest management, etc.), the authority will explore and try biological transplantation, and control the natural genetic diversity at a reasonable level on the basis of evaluating the genetic compatibility of the population.

4.1.2 Managing native plants

The management focuses on three aspects. First, the restoration of native animal and plant species. When a large number of species are on the verge of disappearing, the authority may implement a recovery plan. The plan may include limiting animals to small enclosures during the resumption of work, provided that the animals have adapted to the new area or are mature enough and the authority can minimize predators, poaching, disease or other threats. Plans to restore animal species also include keeping animals in cages for captive breeding to increase the number of offspring released into the wild, or managing the gene pool of the population. The plan for restoring plant species includes breeding plants in greenhouses, gardens or other closed areas to develop breeding materials (propagules) for restoring species or managing the gene pool of populations.

The second is to manage threatened or endangered animals and plants. The authority will investigate, protect and strive to restore native species listed in *Endangered Species Act* in the national park system. Work with the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration to ensure that the actions of the National Park Service comply with the requirements and spirit of the act. Inventory, monitor, restore and maintain the habitats of listed species; control the invasion of harmful alien species; manage the admission of tourists to prevent tourists who may do harm to the park from entering. Manage designated important habitats, basic habitats and restoration areas to maintain and enhance their value for the restoration of threatened and endangered species.

Third, manage the natural landscape. The combination of natural restoration and artificial intervention is adopted to realize landscape management. There are two important tasks: landscape greening and landscape restoration. For landscape restoration, seeds, clonal cuttings or transplant materials that can represent the species and gene banks of local ecological components of the park under restoration can be used. When a natural area is degraded to the extent that the original gene bank of the park cannot be used for restoration, improved varieties or closely related native species can be used for restoration. Landscape restoration can use geological materials and soils permitted by geological and soil resource management policies, and properly add soil fertilizer or other soil improvers. However, such fertilizers and modifiers shall not have an irreversible impact on the physical, chemical or biological properties of soil and biological communities, nor shall they pollute the surface water or groundwater.

4.1.3 Manage the flora and fauna obtained by the public

Usually, the public can pick and hunt a certain amount of animal and plant resources within the specified list, such as fishing etc. The authority will consult and cooperate with state governments and tribes at their discretion to restore and maintain habitats for collectible plants and huntable animal populations in accordance with federal and state regulations. Management is to meet the needs of self-reproduction and development of collectible hunting species, not to increase the stock of plants or animals. In exceptional circumstances, the authority may store native or alien species for recreational picking or hunting, provided that such storage

does not adversely affect the natural resources or management of the park.

4.1.4 Management of alien species

In a few cases, the park will introduce or maintain alien species to meet specific management needs, and take prudent measures to minimize the risk of harm. Species that can be introduced include: (1) closely related races, subspecies or hybrids of extinct native species; (2) improved native species whose natural varieties cannot survive in the changing environment of mankind; (3) an alien species that has established for controlling another species; (4) an alien species needs to meet the ideal state of historical resources and is non-invasive; (5) domestic animals (such as cattle, sheep, horses, etc.). If livestock are alien species raised in some parks, they can be used for administrative purposes such as commercial grazing, recreation, maintaining cultural landscape and supporting park management. The authority will phase out commercial grazing of livestock and manage the recreational and administrative uses of livestock to prevent adverse effects on park resources.

In addition, if alien species interfere with the continuation of natural processes and natural characteristics, affect native species or natural habitats, or destroy the genetic integrity, cultural resources and landscape of native species, seriously hinder the management of parks or adjacent land and threaten public safety, the authority will carry out removal action. The prerequisite for the implementation of management is to determine that the target species are alien species and the management is feasible and effective, the administrator shall assess the current or potential impact of the species on the park resources, formulate and implement the alien species management plan according to the established planning procedures, and then consult with federal, tribal, local and state agencies and other relevant groups as appropriate and invite the public to review and comment as appropriate. The management scheme of alien species should avoid causing significant damage to local species, natural ecological communities, natural ecological processes, cultural resources and human health and safety.

4.1.5 Pest control

Integrated pest management must be developed for pest control, which includes when to implement pest management actions and which combination strategy is the most effective. Other measures include strict control over the use of pesticides. The intended users must submit applications before using pesticides, review them one by one, and the environmental impact, cost and manpower and other relevant factors are taken into account. All use of pesticides on land managed or controlled by the authority, whether authorized or not, must be reported annually. Pesticides may only be used by or under the supervision of an applicator certified or registered by a federal or state certification system.

4.2 Water resources management

4.2.1 Water right

The authority cooperates with the water resources management agencies of the state where the park is located to protect the water resources of the park, and participates in the negotiation of water rights stakeholders to seek solutions to conflicts. If there is no other water available, the authority shall purchase it by itself when using water. In addition, the authority may enter into water resource sales or leasing contracts with individuals, states or their government branches to provide public accommodation and services for park visitors who do not have alternative water sources, whether they live inside or outside the park.

4.2.2 Water quality

Surface water and groundwater pollution from point sources or non-point sources will damage the natural functions of aquatic and terrestrial ecosystems and weaken the effect of tourists' use and enjoyment of park waters. The authority shall determine the water quality of surface water and groundwater in the park and avoid the pollution of water areas by human activities inside and outside the park as far as possible. The authority also cooperates with relevant government agencies to protect park waters and meet the highest standards of *Clean Water Act*; take all necessary measures to maintain

or restore the quality of surface water and groundwater in the park in accordance with *Clean Water Act* and other applicable federal, state and regional regulations; enter into water quality protection agreements with the park or other agencies as appropriate.

4.2.3 Wetland

The protection objective of the authority is to lead and take actions to prevent the destruction, disappearance and degradation of wetlands, protect and enhance the ecological function and value of wetlands, and avoid new projects carried directly or indirectly in wetlands. Implement the "zero loss of wetlands" policy to realize the net growth of wetlands by restoring previously degraded or damaged wetlands. Carry out wetland survey to assist in formulating reasonable plans for wetland resource management and protection. Conduct more detailed wetland surveys in areas to be developed or vulnerable to degradation or loss due to human activities. On the basis of ensuring the ecological function of natural wetland, full play should be given to its functions of education, entertainment and scientific research as much as possible to improve the value of natural wetland. Implement "dynamic balance", namely every 1 hm^2 wetland is damaged or degraded, at least 1 hm^2 of wetland needs to be restored. For actions that may adversely affect wetlands, an environmental assessment must be conducted or an environmental impact statement issued. If the preferred alternative will also have an adverse impact on wetlands, a statement of findings must be prepared and approved in accordance with the order of the director of the National Park Service.

4.2.4 Watershed and stream management

The authority manages the basin as a complete hydrological system to minimize the impact of human activities on hydrological processes, including runoff, erosion and the impact of fire, insects, meteorological events and object movement on vegetation and soil. The authority will also protect streams and riparian vegetation that may form habitats, including flood plains, riparian buffers, accumulation of wood debris, terraces, gravel piles, shoals and pools. In addition, when infrastructure (such as bridges and pipelines) affects streams, displacement or redesign will be considered first, rather than changing the direction of streams. When river intervention is unavoidable, managers will use technical solutions that are not visually obvious and protect natural processes to the greatest extent.

4.3 Fire management

It is mainly divided into natural fire and man-made fire management. Natural fire and its smoke are part of the natural system that continues to exist in the park. The natural system includes plant and animal communities that can adapt to fire. The authority believes that they need regular fires to maintain ecosystem integrity. The frequency of natural fires in national parks is very low, but when natural wildfires are interfered by human beings, the ecosystem of the park may lose its integrity.

In addition, parks with vegetation combustibles should develop a fire management plan, which should be consistent with federal laws and departmental fire management policies, and be equipped with sufficient funds and personnel to support the plan. The plan must respond to the park's natural and cultural resource objectives while protecting public health and safety. The plan should also include the circumstances under which the ecosystem will be naturally renewed after the fire, when management action is required to stabilize or restore forest fire areas, and the impact of fire on air quality, water quality, human health and safety. All wildfires should be effectively managed with appropriate management schemes under the guidance of the park fire management plan. The selection of the scheme shall comprehensively consider the value of the resources to be protected, the safety of firefighters and the public, the cost, the available amount of fire resources, weather and fuel conditions, and design the monitoring scheme to record the fire, smoke status, fire-related decisions and the consequences caused by the fire. Wildfires may endanger other natural resources and personal and property safety in the park. Therefore, it is necessary to prevent the accumulation of dangerous combustibles in specific areas, strengthen strategic planning and multi sectoral and cross organizational

cooperation, and provide solutions for landscape adaptive management. These strategies should also include other activities, such as human, mechanical, biological, chemical treatment methods, etc.

4.4 Air resource management

The United States attaches great importance to the air quality of national parks. The administration has the responsibility to maintain the best air quality in the park, maintain the natural scenery and tourists' travel experience and health, and protect the vegetation, water quality, wild animals and plants, historical sites and other resources in the park that are very sensitive to air quality. Managers take actions in accordance with their responsibilities under *Clean Air Act* to protect resources closely related to air quality in class I areas (class I areas were designated in 1977, including more than 2,400 hm^2 of national parks and more than 2,000 hm^2 of national wilderness). The purpose of the act is to prevent visibility impairment caused by human activities to class I areas.

When the air pollution concentration in an area exceeds the limits of national or state air quality standards, the management personnel will inform tourists and employees in accordance with the regulations. In addition, since the air quality of the park is affected by human activities and work, therefore, the authority shall collect relevant information, conduct a general survey of the air quality and related values of the park (including animal and plant health status, visibility, historical buildings, cultural landscape, etc.), monitor and record the air quality and related values, assess the impact of air pollution and determine the root causes, and minimize the air pollution emissions generated by the operation of the park, including carrying out specified fire management and tourist recreational activities.

The administration needs to actively participate in the formulation of federal, state and local air pollution prevention and control regulations, seek remedies and prevent the impact of air pollution caused by external cooperative projects on park resources. Administration should review the application for administrative license of major air pollution sources and assess their potential impact. If it is determined that such new pollution sources may have an adverse impact on air quality and related values, the administration will recommend that the authorities prohibit construction or take improvement measures. Publicity and education are also very important，through educational or explanatory programs, we can deepen the public's understanding of air quality problems in parks and urge the authority to strengthen the management of air quality.

4.5 Geological resource management

Geological resources are the focus of natural resource management in national parks, mainly including geological processes and geological characteristics. The main responsibility of the authority is to assess the impact of natural processes and human activities on geological resources, maintain and restore the integrity of existing geological resources, and introduce geological resources to park visitors.

4.5.1 Geological process protection

The geological process includes but is not limited to stripping, erosion and deposition, ice erosion, karst development, coastline change, earthquake and volcanic activity, etc. Its protection focuses mainly on coastline and karst to protect the park from geological disasters. For the coastline, the protection focused on the nature and speed of natural coastline change; for karst terrain, the protection focused on maintaining its water quality, spring, drainage mode and the internal integrity of caves. Karst development (the process by which water dissolves limestone) creates areas such as limestone pits, underground runoff, caves and springs. If human activities or buildings change the above processes or characteristics, the authority will, in consultation with relevant state and federal agencies, develop alternative programs to restore natural conditions to mitigate the impact of such activities or structures. In addition, new project development is prohibited in areas subject to wave erosion or active coastline changes. Geological hazard prediction is the key and difficult point. The administration cooperates with the U.S. Geological Survey, lo-

cal/regional, state and federal disaster management departments to develop effective geological hazard identification and management strategies to avoid tourists and other facilities from entering the geological hazard area.

4.5.2 Geological feature management

Geological characteristics refer to the products and physical composition of geological processes. The geological features of the park include rocks, soils and minerals, geysers and hot springs in geothermal systems, caves and karst systems, canyons and arches in eroded landscapes, sand dunes, moraines and terraces in sedimentary landscapes, artistic or rare outcrop rocks and strata, paleontological and palaeoecological resources, such as fossil plants, animals or other traces. The administration focuses on four categories: paleontological resources, caves, geothermal and hydrothermal resources and soil resources.

(1) Paleontological resources. The manager shall formulate a paleontological resource survey plan, systematically monitor the newly discovered fossils (especially in the rapidly eroding area), carry out paleontological field survey, and record the fossil location and relevant geological data in detail to prevent fossil damage and unauthorized collection. In order to protect paleontological resources from damage, theft or destruction, ensure the confidentiality of information on the nature and specific location of relevant resources when necessary. The park formulates a fossil list and prohibits the sale of primitive paleontological specimens. These can only be exchanged with qualified museums and public institutions. At the same time, purchasing fossil specimens should be avoided. When carrying out national park construction projects in areas with potential paleontological resources, the impact assessment of paleontological resources must be carried out before construction. For the discovered or possibly discovered paleontological resources, construction shall be avoided or, if necessary, resources shall be collected and properly managed before construction.

(2) Cave. Including karst caves such as limestone and non karst caves such as coastal caves. The authority manages the caves according to the approved cave management plan and maintains the natural systems related to the caves, including karst and other seepage types, airflow, mineral deposition, animal and plant communities, etc. Wasteland and cultural resources and values will also be protected. Many caves or parts of caves contain fragile nonrenewable resources and cannot be restored naturally. Therefore, the authority implements strict management and prohibits any development and utilization, including public access (such as roads, lights and elevator shafts), inside, above or near the cave. Some caves or parts of them can be used for research and are only accessible to researchers.

(3) Geothermal and hydrothermal resources. It includes underground heat source, heat conduit rock formations and circulation in the bottom layer air and/or water that can be discharged on the surface. These resources create geysers, hot springs, mud pools, blowholes, mineral deposits and hydrophilic biological communities. The management focuses on maintaining the integrity of the thermal system, including air and water movement under the hot rock, cold water supply, hot or warm water around the heat source, hydrostatic pressure and high temperature. Measures should be developed to prevent serious impact of development on thermal resources, including loss of geothermal resources, ground subsidence, frequent earthquakes, release of toxic gases, noise and surface disturbance from drilling or power plants, and discharge of polluted water. Since the thermal system will go far beyond the park boundary, it is necessary to cooperate with the local government to determine the scope of the thermal system and protect the thermal system within the park. At the same time, the authority monitors specific important thermal resources.

(4) Soil resources. By carrying out soil investigation, drawing soil map, determining soil physical and chemical characteristics, and formulating plans to guide resource management and development, we can prevent unnatural erosion, physical loss, soil pollution and pollution to other resources. Soil can be introduced from outside the park or soil amendments can be used to restore damaged areas. When using materials outside the park, the park must develop plans to screen materials aimed at

restoring the physical, chemical and biological properties of the native soil to avoid the introduction of invasive species.

4.6 Soundscape management

Natural soundscape resources include all natural sounds occurring in the park and sound transmission carriers. The manager determines the appropriate natural sound level and type according to the management plan. In and around the park, the administration also monitors the noise of human activities that adversely affect the sound scene of the park, including the noise generated by machinery or electronic equipment, and takes action to prevent and minimize the noise that adversely affects the natural sound scene or other resources due to frequency, amplitude or duration.

4.7 Lighting management

Natural lighting is the natural resource and value existing in the environment of no man-made light. In areas where there is no light, such as caves or deep-water bottoms, natural scenery can affect biological processes and the evolution of species, such as blind eyed fish. Late at night, the sparkling light of waves helps newly hatched turtles adapt to the sea. The stars, planets and moon that can be seen on a clear night will affect humans and many other animals. Birds rely on stars to navigate for flight or predation. Improper outdoor lighting will affect the viewing and hinder tourists from enjoying the natural night sky. The administration will minimize the light emitted by the park facilities and prevent or minimize the damage of artificial lights in the park to the night view of the ecosystem. Gradually reduce and completely prohibit the use of artificial lighting when necessary to prevent interference with the night sky, natural cave development, biological physiological processes and similar natural processes.

4.8 Chemicals and odor management

The information transmitted by natural chemicals and odors will be received by organisms. Many animals can perceive and change their behavior to respond, such as mating, migration, feeding, avoiding predators, choosing prey and building social structure. The administration prohibits the use of man-made chemicals to affect the release, precipitation and animal perception of natural chemicals, as well as disturbing or mixing natural chemicals. Management measures include: (1) introducing pesticides and pheromones into the park as part of the comprehensive pest management plan; (2) build and operate intensive development zones and introduce non-natural chemicals; (3) changing vegetation, thereby changing the types of natural phytochemicals released into the air; (4) transfer water from one drainage system to another through a water supply or sewer system, or use exhaust motors in the air, on land and on water.

5. Question

Although the natural resource management of national parks in the United States has achieved remarkable results, there are also some problems that cannot be ignored, mainly in the following three aspects.

5.1 Insufficient type

The natural resource asset management of national parks in the United States mainly involves eight categories. Although ecosystems are defined as natural resources in a broad sense, there are no detailed management principles and methods for forests and grasslands in national parks. Therefore, in the long run, it may not be conducive to the protection of forests and grassland ecosystems. What is more serious is that once the forests and grasslands, as important habitats of wild animals, are damaged, the restoration process will be very long, which will aggravate the degree of protection of wild animals.

5.2 System division dislocation

Although the natural resources in the National Park are managed by the National Park Service, it is difficult to unify in the process of exercising the management right. The National Park Service should cooperate with the U.S. Forest Service, the Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, the Bureau of Land, the Geological Survey Bureau, the Environmental Protection Agency and other federal agencies, and

state-level agencies and private landowners, which has a long coordination cycle and wide range, making it difficult to quickly solve problems such as the reconstruction of mine wasteland[11], and hindering the effective utilization of natural resources. In addition, for the natural resources on state-owned land, the responsibilities of the National Park Service are unclear, in a certain way. To some extent, it is both the owner and the manager, and the separation of the two has not been realized, which is not conducive to the efficient management of natural resources.

5.3 Insufficient funds

In recent years, the National Park Service has gradually reduced its investment in natural resource management, with a budget of only US $7.6 million in fiscal year 2019, accounting for 0.23% of the total budget (US $3.22 billion), even lower than that of culture Budget input of resources (US $2,018 million)[10]. Insufficient funding leads to the untimely updating of natural resource management planning and monitoring equipment in the United States, and the quality of resource utilization evaluation is reduced, which may eventually seriously affect the protection of natural resources. In addition, insufficient funding has also limited the authority's research and substantive action on natural resources to address climate change.

6. Revelation

The above introduction to the principles and methods of natural resource management in American national parks and the analysis of existing problems offer the following enlightenment to the natural resource asset management of national parks in China.

6.1 Clearly define the types of natural resources

In accordance with the requirements of Constitution of the People's Republic of China and Measures for the Unified Confirmation and Registration of Natural Resources (Trial Version), on the basis of seven types of natural resources such as mineral resources, water flow, forests, mountains, grasslands, wasteland and beaches, and in combination with the current pilot progress and future development trend of China's national park system, natural resources are divided into eight types: land resources, mineral resources, water resources, forest resources, grassland resources, sea island resources, geological heritage resources and scenic spot resources[2]. Establish dynamic monitoring, regular assessment, early warning and prediction mechanisms for the above natural resources, and take into account the management of animals and plants, air, sound and lighting and other resources.

6.2 Gradually expand the pilot scope of national park natural resource asset management system

The effective management of natural resources in American national parks is based on clear property rights, clear responsibilities and rights and advanced ideas. On the basis of fully summarizing the pilot experience of state-owned natural resource asset management system in Sanjiangyuan and manchurian tiger and leopard national parks, China should carry out the above pilot in other national parks with mature conditions, clarify the property right system, establish the right confirmation registration system, establish a unified management system and accountability system, and establish the land and space use control system of national parks. Try to formulate the laws and regulations such as Measures for *Unified Confirmation and Registration of Natural Resources in National Parks*, *Measures for the Control of Land and Space Use in National Parks*, and *Regulations on the Administration of the Use of Natural Resources in National Parks*, so as to realize the use, management and accountability of natural resources in accordance with laws and regulations. In addition, pilot projects should be carried out to speed up the formulation of paid use systems and compensation systems for natural resources, and the development of natural resource assets assessment. Explore new use rights of natural resource complexes, including recreational management rights, franchise rights, etc.[2].

6.3 Establish and improve the natural resource management system and highlight the ecological integrity

National parks in the United States have established a complete natural resource management system and procedures, including formulating management plans, publishing resource information, conducting natural resource impact assessment, restoring natural ecosystems, establishing natural resource damage compensation system, etc. At the same time, they have established and strictly implemented the "application–review–evaluation–permission" system for the development and utilization of natural resources. This system has played a decisive role in the protection of natural resources. In contrast, the natural resource management of China's national parks is still in the stage of confirming the right, registering and finding out the background, and there is a lack of complete management procedures. Therefore, we should formulate natural resource management planning, speed up the establishment of natural resource management system including inventory, use, impact assessment and damage compensation, and improve the efficiency of natural resource management. In addition, maintaining ecological integrity is also one of the important principles in the management of natural resources in American national parks, that is, avoiding static and mechanical classification management, placing natural resources in the ecosystem, highlighting their integrity, and paying attention to the relationship between various natural resources. Ecological integrity includes not only the stability and integrity of the ecosystem, but also the integrity of the ecological process. The restoration and evolution of the natural ecosystem are regarded as the protection objects. Our country should also learn from this experience, fully implement the concept of "mountains, rivers, forests, fields, lakes and grasses are the common thread" in Xi Jinping's ecological civilization thought, and fully consider the ecosystem in the management of natural resources. Adopt ecosystem approach to realize efficient, high-quality and dynamic management of natural resources.

6.4 Adhere to legal management

The legal system of natural resources management in national parks in the United States has been improved, forming a complete framework in which federal regulations, special regulations and "one park, one law" complement each other. According to nearly 10 federal laws such as *Organic Law of the Administration*, *National Environmental Policy Act* and *Wilderness Act*, as well as a number of local laws, departmental rules and administrative orders, the administration and national parks have realized the legal management of natural resources, and any behavior detrimental to the protection of natural resources will be restricted by law. "One park, one law" consolidates the legal system of natural resource management. The park police, as a complete law enforcement team in America national park[9], severely punished illegal acts and safeguarded the dignity of the law. Protecting the ecological environment with the strictest system and the strictest rule of law is an important principle to Xi Jinping's ecological civilization thought, and it also provides a basis for the management of natural resources in China's national parks. China should accelerate the promulgation of the national park law, take the management of natural resources as an important content, explore a comprehensive law enforcement mechanism, grant the necessary law enforcement power to the national park management institutions, and effectively protect the natural resources in the national park from loss.

6.5 Strengthen the unified control of land and space use

Although the land ownership is complex, national parks in the United States have basically realized the unified control of land and space use in parks, and they cooperate with surrounding land owners to jointly protect natural resources and habitat of wild animals. The experience of the United States and the current problems in China show that the premise of centralized, unified and efficient management of natural resources is the unified control of land and space use. At the same time, scientific functional zoning should be established, so as to implement comprehensive management of natural resources based on functional zoning. National

parks belong to prohibited development zones, so it is necessary to promote the gradual withdrawal of existing mining rights and establish a classified withdrawal compensation mechanism. We should strictly restrict various construction activities in the park and establish a special purpose change permit system. The implementation of classified management based on functional zoning mainly adopts different management measures according to the ownership nature of land and its natural resources. For the collectively owned natural resources in the core reserve, the collective land can be transformed into state-owned by expropriation, and then the resettlement and withdrawal of mining rights can be implemented gradually. If it is unable to expropriate land or implement ecological resettlement, an easement agreement for natural resources complex can be signed. For the collectively owned natural resources in the general control area, on the basis of unified confirmation and registration, the separation of ownership, contracting right and management right shall be implemented, and the collective owners of natural resources shall be absorbed to participate in the operation and management of the national park by means of leasing and replacement.

Conflict of interest

The authors declared no conflict of interest.

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