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DISASTERS AND ENVIRONMENTAL MANAGEMENT IN THE DONGTING LAKE LOWLANDS

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ABSTRACT: Dongting Lake is one of the most important freshwater lakes in China. There is a dense population and rich resources in the lake region that is also an important natural ecological system. The Dongting Lake lowlands have always been a serious flood disaster region, and human activities have impacted negatively on the ecological environment. In response, the Chinese government has adopted a series of structural and non-structural measures, resulting in mitigation of flooding disasters and improving the environmental protection in the lake region.

Key words: Dongting Lake lowlands, flood disasters, relationship between the river and lake, environmental protection, flood disaster management

INTRODUCTION

Dongting Lake is one of the most important freshwater lakes in China. The lake area supports a dense population with an abundance of products, and is known for its rice and fish production. The lake area covers a wide, low lying area and plays an important role in flood regulation of the middle-lower Yangtze River. The Dongting lake area is also a serious flood disaster region, and since the founding of the New China, the government has paid particular attention to flood control for this region, building many dykes and constructing several flood diversion areas. These measures have, mitigated the effects of flooding disasters to some extent.

The Dongting Lake area is an important natural ecological system, with diverse ecological and environmental functions, such as climate regulation, water conservation and purification, and maintaining biodiversity. Because of an enclosing marsh used for cultivation and industrial wastewater discharge, the environmental conditions of the wetland and the water zone close to the lakes bank have deteriorated to a certain degree. The Chinese government is now taking measures to protect and improve the basic ecological processes and condition of the lake and the surrounding lowlands, in order to ensure sustainable development for the local population and economy.

CHARACTERISTICS OF WATER FLOW, SEDIMENTATION AND FLOODING DISASTERS IN THE DONGTING LAKE AREA

Characteristics of Water Flow and Sedimentation

The Dongting Lake, composed of Western Dongting Lake, Southern Dongting Lake and Eastern Dongting Lake, is located in the middle Yangtze River region, and connected to the Jingjiang reach of the Yangtze River (see Fig 1). Water from the Jingjiang flows into Dongting Lake through four river mouths (known as the Four-mouth region); the Songzi Mouth, Taiping Mouth, Ouchi Mouth and Tiaoxian Mouth. In addition, four rivers run into Dongting Lake (known as the Four-rivers); the Xiangjiang River, the Zishui River, the Yuanshui River and the Lishui River. At the outlet of the Eastern Dongting Lake, Chenglingji, water from the lake flows back into the Yangtze stem stream. Through these connections, the lake basin serves as flood detention area. There are longer flood diversion channels leading from four mouths to Dongting Lake with many branch channels, forming a complicated river network. Between the flood diversion channels and the end regions of the four rivers, there are a wide variety of polders providing homes for millions of people. The Lake area undertakes a considerable amount of flood diversion from the Jingjiang, with the well-known Jingjiang Flood Diversion Area located close to the Taping Mouth. Floods in the Yangtze valley are formed by storms, and there are five storm regions within the whole valley, three of which are located upstream of the Dongting Lake; the western

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Sichuan storm region, Dabashan storm region, and the western Hunan-Hubei storm region. In this respect, all floods formed by storms in these regions are a threat the Dongting Lake area. The annual average runoff into Dongting Lake is 301 billion m^3 of which, 164 billion m^3 comes from the four rivers, 111 billion m^3 from the four river mouths, and 26 billion m^3 from the local area. These are 54.4%, 37.0%, and 8.6% respectively of the total runoff flowing into the lake. Long term hydrological statistical data show that April through July of every year is generally the flood period for the Four-rivers, and July through September is the potential flood diversion period for the Four-mouths (Han 1999; HBCWRC 2000). During the flood period, the volume of water flowing into Dongting Lake is 225.2 billion m^3 on average, occupying 74.5% of the total annual lake influx.

It can be seen from Table 1 that in the last 50 years, the quantities of water and sediment flowing into Dongting Lake have been gradually decreasing. The quantity of sediment depositing in the lake basin has also been decreasing continuously.

Relationship between River and Lake

During the prehistoric ages, the Yangtze River ran out of the Three Gorges into the vast expanse of the Yunmeng Pond. Through sedimentation, many of the branching water systems gradually formed into the Yunmeng Pond of which, the present Jingjiang reach of the Yangtze River was a main waterway. The Dongting Lake was a very small pool, south of the Yangtze River and near the Laojun hill, at this time, and was connected with the Jingjiang reach. The Yunmeng Pond evolved as a vast sheet of sand shoal, with a large amount of smaller lakes scattered throughout, with 13 flood channels (also known as "mouths") between the Jingjiang reach and Dongting Lake. When the Jingjiang levee was formed in 1542, it prevented the Yangtze flood from releasing northwards. As a result, Taiping Mouth and Tiaoxian Mouth were formed, resulting in the Yangtze flood releasing southwards. With the flood level of the Jingjiang reach rising, the area of the Dongting Lake underwent continuous expansion. According to records available, by 1852, the lake area had expanded out to 6000 km^2 bringing much prosperity to the Dongting Lake area. Floods in 1860 and 1870 formed the Ouchi Mouth and the Songzi Mouth respectively (Lou and Le 1999), resulting in the present situation where the Yangtze floods divert into Dongting Lake through the four mouths, and flows back into the Yangtze stem stream at Chenglingji. This complicated relationship between the river and the lake is unique within China and the rest of the world (see Fig. 1).

The Jingjiang reach has a length of 340 km, is divided into the upper and lower Jingjiang, and has a boundary formed by the Ouchi Mouth. The lower Jingjiang is a typical meandering channel. This reach has many naturally formed cut-offs, two artificial cut-offs at Shangchewan and Zhongzhouzi constructed in 1967 and 1969 respectively; and a more recent natural cut-off that formed at Nianziwan in 1972. Through these three cut-offs, the length of the reach has been reduced by 78 km. Beyond these cut-offs, the gradients of the local reaches were steepened, causing scouring along the river and upstream, and resulting in a lowered water level upstream of these scoured reaches. Consequentially, the diverted discharges through Ouchi

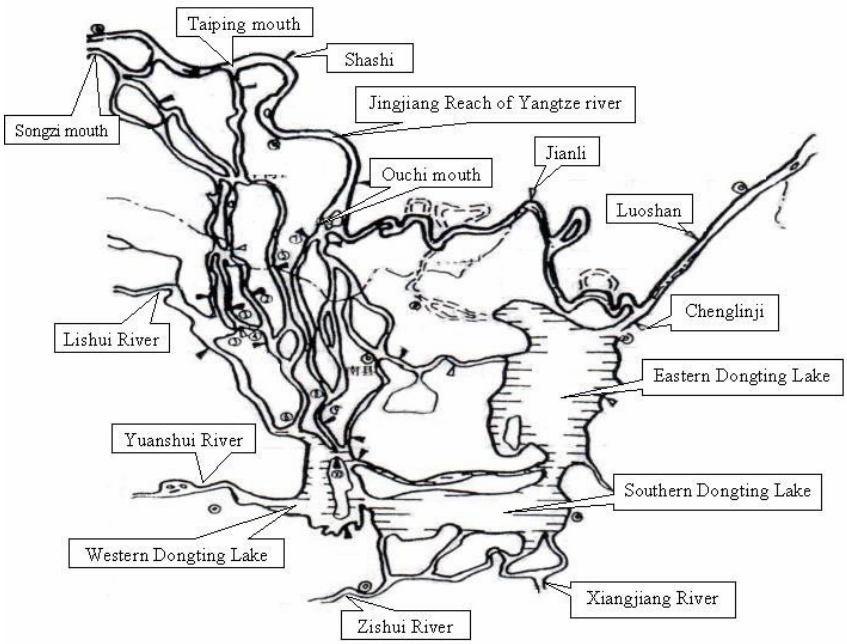

Fig. 1 Schematic of relationship between Jingjiang reach and Dongting Lake

Table 1 Quantities of water and sediment moving in and out of Dongting Lake

Description	Periods					
	Ⅰ 1951-1958	Ⅱ 1959-1966	Ⅲ 1967-1972	Ⅳ 1973-1980	Ⅴ 1981-1991	Ann. Avg. 1951-1991
Ann. lake influx water vol (10^8m^3)	3640	3100	2980	2790	2600	3010
Ann. lake influx sediment qty. (10^8t)	2.73	2.19	1.83	1.47	1.32	1.87
Ann. lake outflow sediment qty. (10^8t)	0.67	0.58	0.53	0.38	0.32	0.48
Ann. sedimentation qty. (10^8t)	2.06	1.61	1.30	1.09	1.00	1.39

Mouth, Taiping Mouth and Songzi Mouth were reduced, resulting in an increased discharge (and in turn water level) through the lower Jingjiang, downstream of these three mouths. Statistics performed by Han (1996) demonstrate that when the discharge at Yichang (upstream of Shashi) was 50000 m^3/s, the corresponding discharge at Shashi was 43750 m^3/s in 1966, and 45000 m^3/s in 1991, an increase of 1250 m^3/s. At Jianli, the corresponding discharge was 32000 m^3/s in 1966 and 39290 m^3/s in 1991, an increase of 7200 m^3/s. The corresponding water stage was 32.75 m in 1966, and 34.00 m in 1991, increasing by 1.25 m. In addition, because the diverted discharges from the Four-mouth region were reduced, the velocities of flow in the flood diversion channels decreased correspondingly, resulting in the sedimentation occurring in diversion channels and a reduced area of wetted cross-section of diversion channel. In turn, the diverted discharge from Four-mouth's was further reduced (Yin 2002). The changes in the diverted discharges and diverted sediments at Four-mouth are summarized in Table 2. It can be seen from Table 2 that, since 1967 there has been a trend of reduced run-off and sediment yield each year at Four-mouth. In addition, because the Jingjiang reach is scoured, the sediment content of the water flowing from the Jingjiang has increased, resulting in sedimentation at Chenglingji and in the reach below Chenglingji, and in turn, a raised flood level. Under the control of the water stage at Chenglingji, the flood level at Eastern Dongting Lake has also risen. Consequently, cutoffs formed in the lower Jingjiang reach, primarily due to both reduced water flow from the Yangtze stem stream into Dongting Lake and raised flood levels in the lower Jingjiang reach and in the outlet portion of Eastern Dongting Lake, have aggravated the risk of flooding disasters in the region. With such a complicated relationship between river and lake, local changes in flow and sedimentation can cause a change in the entire river and lake system.

Flooding Disasters in the Dongting Lake Area

The Dongting Lake area has always been a serious flood disaster region, and since the beginning of historical records, there have been many instances recorded where floods have threatened the Dongting Lake area (Shen 2000). The largest recorded floods occurred in 1788, 1860 and 1870, each time resulting in catastrophic damage; broken dykes and polders, collapsed houses, and countless lives lost. In 1896, the recorded peak flood discharge at Yichang reached 71100 m^3/s, resulting in serious damage to the Dongting Lake area. In 1931 the Yangtze River flood effected the entire valley, with most of the river levees and polders in

Table 2 Changes in flow and sediment diversions at Four-mouth

Period	1	2	3	4	5	Ann. average
	1951-58	1959-66	1967-72	1973-80	1981-96	1951-96
Zhicheng ann. avg. water volume (10^8 m^3)	4640	4580	4300	4440	4450	4500
Four-mouth ann. avg. water volume (10^8 m^3)	1610	1340	1020	834	690	1040
Four-mouth diversion ratio (%)	34.70	29.26	23.72	18.78	15.51	23.11
Zhicheng ann. avg. sediment runoff (10^8 t)	5.2	5.42	5.0	5.13	4.9	5.12
Four-mouth ann. avg. sediment runoff (10^8t)	2.3	1.91	1.42	1.11	0.92	1.43
Four-mouth sediment diversion ratio (%)	44.23	35.24	28.4	21.64	18.78	27.93

Note: Zhicheng is located upstream of the Four-mouth region. Flow and sediment from Zhicheng represents the total flow and sediment of the Yangtze River.

the middle-lower Yangtze region being breached. Many of the breaches occurred along the Jingjiang levee resulting in the districts along river and around the lake in the Hubei and Hunan provinces being inundated. Within the entire Yangtze valley, 28.87 million people were effected by the floods, 377.3 ha^2 of farmland was inundated, and 145.4 thousand people died. The Dongting Lake area was the most effected, with several counties around the lake suffering partial flooding. In 1935, a very large regional flood occurred in the middle Yangtze. The combination of this flood and the regular flooding of the Dongting Lake water system triggered a disaster in the Dongting Lake area. Because of these disasters, the government, since 1954, has paid particular attention to the problems of flood control, and although more floods have since occurred, causing a degree of economic loss, the effect on the population has been greatly reduced, particularly in regards to loss of life. One example is the 1998 Yangtze flood, affecting the entire valley. The flood volume was less than any previous flood barring that of 1954 Yangtze flood, while the maximum flood level at Chenglingji, the outlet of Dongting Lake, was 1.8 m higher than that of 1954 flood. In this flood, the Yangtze valley suffered serious property loss, particularly within the Hunan, Hubei and Jiangxi provinces, however, the loss of life was very low.

Because the Dongting Lake area is located downstream of three storm regions, has low terrain, and receives inflow water from the Four-rivers and Four-mouth areas, all storm floods from these regions can threaten the Dongting Lake area. Hence, the Dongting Lake area has always been regarded as a serious flood disaster region.

ECOLOGICAL CONDITIONS AND ENVIRONMENTAL PROTECTION IN THE DONGTING LAKE AREA

Ecological Conditions in the Dongting Lake Area

Water purification function of Dongting Lake

Dongting Lake not only acts as a natural reservoir, serving to regulate and control flooding within the middle Yangtze, but also serves the function of water purification. The quality of water from Dongting Lake is better on the whole, and basically meets the standards for Grade II water. Its main pollutants are nitrogen and phosphorus, accompanied by organic pollutants. The water in Dongting Lake is continually being refreshed, with an annual transit water volume of 301 billion m^3. The refreshment of the water is frequent, with replenishment of up to 17 times per year on average. In the upstream areas of the Four-river region, there are various non-ferrous minerals including mercury, lead, chromium and arsenic. These can be found in particularly high concentrations upstream of the Xiangjiang and the Yuanshui rivers. In water running from the carbonate rock region of the Three Gorges, there is a higher concentration of calcium and magnesium, making the water slightly alkaline. Water from the Four-river region reacts with water from the Four-mouth region, effectively neutralizing its pH, and the compounds deposit on the bottom of the lake basin resulting in better water quality within the lake basin.

Dongting Lake lowlands, an important habitat for fishes and birds

Dongting Lake is a very important winter habitat for migratory water birds. According to survey data, within the lake area there are 257 species of birds, covering 16 orders and 4 families of which, 7 belong to a species that are first-class state protected, 23 that are second-class state protected, and 53 that are third-class state protected., The lakes birds may be divided into four categories according to the features of their habitat; grassy marsh, shallow water, reed marsh and, hill and residential quarter. Through evolution, the birds of the wetland have developed characteristics that have adapted them to the wetlands ecology. There are ecological conditions suitable for the existence of rare birds in the grassy marshes and the shallow water area. These areas not only produce aquatic plants, but also have various mollusks that are used as a source of food by winter birds. In the Dongting Lake area, there are 173 types of migratory birds, of which, 88 kinds are winter birds, 49 kinds are summer birds, and 20 kinds are resident birds. Although there are a lot of species living in the wetland, each species has its own respective habitat, and exist without conflict over space.

Dongting Lake also has conditions suitable enough to provide a habitat for 114 species of fish, covering 11 orders and 23 families. The Dongting Lake fish originated from the Yangtze fish family, and are derived from several different breeds including Chinese plain breed, Indian plain breed, Chinese-Indian mountainous district compound, Chinese mountainous district breed, and sea water fish breed. A variety of different behavioral groups coexist in Dongting Lake And these can be classified according to their habitat and migration habits; (a) migratory fish such as the Chinese sturgeon and eels that regularly making spawning and feeding migrations between ocean and river or lake; (b) semi-migratory fish, such as Bighead and Silver carp that migrate between river and lake; (c) resident fish, such as carp and Crucian carp. In Dongting Lake there is a variety of rare species of which, under first-class state protection are Chinese Sturgeons, White Sturgeons and White-fin porpoises, and under second-class state protection are Rouge fish, lancelets and Black-finless porpoises.

Problems with the ecological environment

Eastern Dongting Lake is a state-level natural protection area. According to protection guidelines, the water area is

defined as a first-class protection region. However, the total nitrogen and phosphorus concentrations in the water exceed the standard for first-class water, and instead only meet the standard for second-class water. Within the Lake area, Eastern Dongting Lake ranks first in water quality, Southern Dongting Lake second, and Western Dongting Lake third. The water quality of the lake system is directly related to water level, it at its best during the high water period and at its worst during the low water season.

The water quality of Dongting Lake is good as a whole, however, there are local pollution zones close to the perimeter of the lake. During the low water season the volume of water from the Jingjiang reach into Eastern Dongting Lake decreases, and the volume of wastewater, mainly from the paper mills, discharging into the lake remains constant, resulting in an increased pollutant concentration. It is Eastern Dongting Lake that provides the habitat for winter birds and the feeding grounds for young fish during the low water season. In this respect, pollution levels pose a problem for the lakes ecology. In addition, the Dongting Lake area is one of China's schistosomiasis districts. Several large-scale preventive measures have been taken in this region with considerable success.

MEASURES FOR STRENGTHENING MANAGEMENT IN THE DONGTING LAKE AREA

Dongting Lake Evolutionary Processes and Trends

Changes in the area and volume of Dongting Lake have occurred continuously over time through natural evolutionary processes and human activity. Table 3 illustrates the changes that have occurred since the early 19th century, through to 1995. It can be seen from this table that during the 1820s, the area of Dongting Lake was approximately 6000 km^2, making it the largest lake in China. Over time,, the area and volume of the lake gradually decreased so that through the period 1949 to 1995 the area had been reduced by 40%, and the volume by 43%. This period saw the greatest and most rapid change within the Lakes history.

After the founding of the New China in 1949, the Chinese population increased very quickly and with it vigorous increase in various construction projects. One project called "Enclosing the lake for cultivation" was carried out, resulting in Dongting Lake's area and volume being reduced by 193 km^2 and $10 \times 10^8 m^3$ respectively during the period 1954 to 1958. Afterwards, it was found that this project reduced the lake's capability of regulating the floods, and was detrimental to flood control in the middle-lower Yangtze, and in turn causing damage to the ecological environment. The Chinese government prohibited enclosing of the lake for cultivation and strengthened lake management, greatly reducing the rate of lake shrinkage. In addition, reduction in the amount of sediment entering the lake also resulted in a slower rate of shrinkage. Table 2 shows that during the 1950's, the amount of sediment entering the Dongting Lake through the Four-mouth region was 230 million tons. By the 1990's, this was 92 million tons, a reduction of more than 50%. In brief, after the 1970's, the impact of both natural evolution and human activity on Dongting Lake was gradually reduced, resulting in a slower rate of lake shrinkage to the point where by 1995, there was very little additional change in the area and volume of the lake.

Strengthening Flood Disaster Risk Management

In China, flood control has always been an important issue, reflected in the amount of study performed in developing strategies and techniques for control and prevention, and in the wealth of experience accumulated. Early during the Ming Dynasty (1368 to 1644), the theory that humans should not contend for land with water, a principle in agreement with modern thought, was suggested. After the founding of New China, the Yangtze River was harnessed. A flood control plan was developed, based on analysis of the characteristics of the Yangtze floods and flooding disasters, and structural and non-structural flood control works were commenced. Flood control planning for the middle-lower Yangtze included flood-diversion channel regulation, and flood diversion and storage works planning for the Dongting lake area. In accordance, flood control works were constructed in the Dongting lake area.

Developing flood control planning

Based on an analysis of features of the Yangtze flood, and in the light of the complexity of flood control within the Yangtze valley, a control guideline whereby consideration is given to both storage and release, with principle importance placed on release,, and the guiding principles where equal importance is placed on the advantages to both river and lake, and to both left and right banks in coordination with the upper, middle and lower reaches, has been suggested in the development of flood control planning for the middle-lower Yangtze region. A flood control system based around the Three Gorges reservoir, principally using dykes, and other works, including reservoirs at the Yangtze stem stream and its tributaries, diversion and storage works, river regulation works, and other non-structural auxiliary measures, has been established in the Yangtze valley. Dongting Lake is a principal component in regulating floods in the middle-lower Yangtze. The Lake's basin is used for flood retention, while the Jingjiang Flood Diversion works and several

Table 3 Changes in area and volume of Dongting Lake

Time	Year No.	Area (km^2)	Reduced area (km^2)	Ann. ave. reduction (km^2)	volume (10^8m^3)	Reduced volume (10^8m^3)	Ann. ave reduction (10^8m^3)
1825		6000					
	71		600	8.54			
1896		5400					
	36		700	19.45			
1932		4700					
	17		350	20.6			
1949		4350			293		
	5		435	87.0		25	5.0
1954		3915			260		
	4		774	193.5		40	10.0
1958		3141			228		
	13		321	24.7		40	3.08
1971		2820			188		
	6		80	13.3		10	1.67
1977		2740			178		
	6		49	8.17		4	0.67
1983		2691			174		
	12		66	5.5		7	0.58
1995	2625				167		
from1949 to 1995	46	40% reduction	1725	37.5	43% reduction	126	2.74

polders constructed near Chenglingji assist in flood diversion. After the 1998 floods, a new strategy was developed that involved restricting access to the hillsides and stopping cultivation to facilitate afforestation, removing polders to allow flood passage, and terminating the farming of the land in order to restore the lake was developed in order to improve the flood control system. In addition, the study of non-structural measures such as flood forecasts and warning systems, flood regulation, and flood disaster management has increased.

Constructing the flood control facilities

The Jingjiang Flood Diversion Works, including the Jingjiang Flood Diversion Area, were built in 1952, and played a very important role in flood control of the middle-lower Yangtze in 1954. In the early 1990s, the intake sluice gates of this project were reinforced, and its dykes raised and thickened. Safety buildings and platforms, and high roads for evacuation, were constructed in the flood diversion area, and, at the same time, the flood passages in the lake area were dredged to ensure an unblocked flood diversion flow.

In combination with the construction of new safety facilities in the flood storage polders and the elimination of farmlands, construction of new towns for relocation and resettlement of the local population will be implemented, with the planned lake restoration area covering 217 km^2. In addition, ten polders in the region will be cultivated during normal years, and used for flood storage in very high flow years, with a preference to evacuate the population during flood years and cultivate the land during regular seasons. Through such measures, the resulting restored lake area is 1629 km^2. After restoration, the total area of the lake is now 1846 km^2, with in increased flood storage capacity of 9 billion m^3. These measures not only adequately solve the problems of flood control in the Dongting Lake area, but also improve the Lakes ecological conditions.

Strengthening Environment Protection

Protecting shallow water habitats

The continuous growth of reeds in the marshes pose a threat to the shallow water habitats, making it necessary to adopt appropriate measures for the preservation of these areas. The core zone in the Eastern Dongting Lake protection district is a semi-closed shallow water depression, a habitat that is important for rare birds. To protect this environment during low flow periods, and in particular, during low flow years, an inflatable dam will be employed to maintain the required water level within the depression. In addition, management of the rare bird habitat will be improved, with human and livestock activities strictly controlled.

Management of wastewater discharging into Dongting Lake

The total amount of wastewater discharged into Dongting Lake, along with its pollutant concentration with

particular focus on the nitrogen and phosphorus concentrations, is strictly controlled. New sources of pollution are rigorously controlled, with old sources being subject to new guidelines that require an improvement of conditions over a specified time. Small paper mills, chemical plants and leather-making plants have all been banned from discharging wastewater into the lake.

Oncomelania extermination in combination with the hydro project

Schistosomiasis prevention has been achieved by combining the extermination of oncomelania with construction of a hydro project. The shoals of oncomelanias were eradicated during formation of the separation trench along the lake perimeter, and when the rip-rap slope protection was replaced with concrete.

The wetland environment can yield an immense amount of produce. Wetlands provide areas for grain production, habitats for fish and water birds, are a major component in water purification, and provide recreational areas and generally improve the environment. Wetlands, however, are also very weak ecological systems. Therefore, for the benefit of the population and for the promotion of sustainable development, it vital that such regions are managed scientifically with environmental protection in mind, both presently, and in the future.

CONCLUDING REMARKS

The wetland is one of environments with huge productive forces, because it provides the grain production, the fish culture, the water bird culture, the water purification, and recreation with favorable condition and good environment. The wetland, however, is also a very weak ecological environment system. Thus, for the purpose of human themselves existence and sustainable society development, scientific environment management is absolutely necessary, whether at present or in the future.

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