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China's Natural Wetlands: Past Problems, Current Status, and Future Challenges

Natural wetlands, occupying 3.8% of China's land and providing 54.9% of ecosystem services, are unevenly distributed among eight wetland regions. Natural wetlands in China suffered great loss and degradation (e.g., 23.0% freshwater swamps, 51.2% costal wetlands) because of the wetland reclamation during China's long history of civilization, and the population pressure and the misguided policies over the last 50 years. Recently, with an improved understanding that healthy wetland ecosystems play a vital role in her sustainable economic development, China started major efforts in wetland conservation, as signified by the policy to return reclaimed croplands to wetlands, the funding of billions of dollars to restore degraded wetlands, and the national plan to place 90% of natural wetlands under protection by 2030. This paper describes the current status of the natural wetlands in China, reviews past problems, and discusses current efforts and future challenges in protecting China's natural wetlands.

INTRODUCTION

Healthy natural wetland ecosystems play a vital role in sustainable development of China, which has been recognized by the Chinese government (1, 2). Natural wetlands occupy 3.8% of China's terrestrial area (1), with the total wetlands areas estimated at 8.0% (compared with 6.0% in the world). Natural wetlands in China provide 54.9% of the annual ecosystem services for the country (3, 4). In addition, 54% of endangered species of ducks and geese in Asia have been recorded in China's wetlands (2, 5). Despite their importance as natural resources and as natural regulators to environmental problems (3, 4); however, natural wetlands in China suffered great losses and degradation, not only because of wetland reclamation during the country's long history of civilization but also because of the severe population pressure and the misguided policies over the last 50 years (1, 5). In this paper, we will describe the current status of the natural wetlands in China, review past problems (especially over the last 50 years), summarize current efforts, and discuss future challenges in protecting China's natural wetlands. Our goal is to provide a synthesis and the basic information about the natural wetlands in China so that people from institutions of scientific research and organizations of conservation abroad can learn and join in our efforts of wetland protection and help us develop effective conservation strategies for the science-based decision making by the government. It should be pointed out that the Chinese government uses a broader definition of wetlands than the Ramsar Convention (6) in that deep lakes and large rivers are regarded as wetlands.

CURRENT STATUS OF NATURAL WETLANDS IN CHINA

Natural Geography

China is a large country (9.6 million km^2), with diverse geomorphology (7, 8). Her vast territory is marked by many unique geomorphological features: the Qinghai-Tibet Plateau in her southwest (2.5 million km^2; the highest and largest plateau, known as the "roof of the world"), the Tarim basin in her west (0.4 million km^2; the largest basin in the world), the Gobi desert in her north (1.3 million km^2; one of the largest hot deserts in the world), and the Huang Tu plateau in the midwest (0.3 million km^2; the largest loess plateau in the world) (Fig. 1) (7, 8). The aquatic system of China is composed of many rivers and lakes, and a long coastline (18 000 km) in the east and southeast, including the four largest rivers (and their associated lakes), i.e., the Yangtze River (Change Jiang) in central China (6300 km; the third longest in the world), the Yellow River (Huang He) in the northern China plains (5464 km; "the cradle of the Chinese civilization"), the Songhua River in the northeastern plain (2308 km), and the Pearl River (Zhu Jiang) in the south (2214 km) (Fig. 1) (7, 8). In general, the western part of China is dominated by highlands, mountains, and deserts, whereas the eastern part of China contains almost all low-lying areas and supports dense populations and industrial and agricultural bases of the country.

Main Types and Distribution Patterns

China has all of the 26 natural and 9 human-made wetland types delineated in the Ramsar Convention (1, 9). The natural wetlands in China are unevenly distributed among eight wetland regions (9, 10): *i)* the northeast region dominated by freshwater swamps; *ii)* the northwest region by saline lakes and swamps in dry climate; *iii)* the southwest plateau region by subalpine lakes; *iv)* the south and southeast region by rivers; *v)* the coastal region by tidal swamps, salt marshes, and mud-lands; *vi)* the middle-lower Yangtze River region by lake groups and river systems; *vii)* the middle-lower Yellow River region by lake groups and river systems; and *viii)* the Tibet plateau region by alpine lakes and swamp groups (Fig. 1). Freshwater swamp is the largest wetland type in area, most of which is located in northeastern China (68 000 km^2; dominated by species of *Carex, Phragmites, Juncus, Scirpus, Acorus, Cyperus*) and the Tibetan Plateau (55 000 km^2; dominated by species of *Kobresia, Carex, Pedicularis, Phragmites, Blymus, Cyperus*). Note that the Tibetan Plateau possesses specific wetland types where the average elevation is more than 3000 m. The top five largest freshwater lakes of China (10 800 km^2; dominated by species of *Potamogeton, Prgamites, Acorus, Juncus, Ranalisma, Brasenia, Miscanthus, Vallisneria, Cyperus*) are all distributed in the middle and lower tributaries of the Yangtze River (e.g., Poyang Lake, Dongting Lake), and many saline lakes exist in the Tibetan Plateau and northwestern China. The tidal wetlands (21 000 km^2; dominated by species of *Phragmites, Scirpus, Spartina, Imperata, Typha, Suaeda,* and *Zoysia*; with additional 850 km^2 of mangrove) are found along the coast, especially near the estuaries of big rivers (11).

Ecosystem Services

China's natural wetlands, occupying only 3.8% of the land, provide a significant amount of ecosystem services, including

Table 1. The losses of the natural wetlands and the associated ecosystem services in China over the last 50 years.

Wetland Type	Area in 1950 (10^3 km^2)	Area in 2000 (10^3 km^2)	Area loss (10^3 km^2)	Area loss (%)	Ecosystem services (10^3 USD km^{-2} y^{-1})	Value loss (10^9 USD y^{-1})
Freshwater swamps	178	137	41	23.0	1958.0	80.3
Lakes	143	120	23	16.1	849.8	19.6
Rivers	95	82	13	15.3	849.8	11.1
Coastal wetlands	43	21	22	51.2	2091.8	46.0
Total	459	360	99	21.6	—	157.0

The data for wetland area in 2000 came from the first national wetland inventory (1) and those in 1950 were reconstructed by the authors based on the refs. 1, 5, 9, 11, 14, 15, 17, 18, 19, 26, 28, 29, 31–35, and 40. The average estimates of ecosystem services in US dollars were cited from references 3 and 4, and the value loss was calculated as the product of the lost area and the average ecosystem service value. The freshwater swamps include typical swamps, wet meadows, and saline marshes of northwestern regions; the lakes include open water area at mean water level and the lacustrine swamps; the rivers include river courses and riverine swamps; and the coastal wetlands only include tidal swamps, salt marshes, and mud-lands. The shallow sea wetland was excluded from the coastal wetlands in this table because the data are questionable. The inventory data contain only those that are more than 1 km^2 in area for wetlands and 10 m in width for rivers.

rivers may have amounted to a reduction of water storage capacity by 237 km^3 (i.e., 8.5% of their total storage capacity) (12, 19, 20), whereas during the same time, the construction of 85 000 or so reservoirs increased water storage only by 36 km^3. In addition, the five largest lakes in the middle and lower tributaries of the Yangtze River alone lost 44 km^3 of their volumes and resulted in increased flooding frequency from once every 50 years to once every 10 years (18). Given that, on average, swamps (including lacustrine and riverine wetlands) can remove TN by 29.8 g m^{-2} y^{-1} and TP by 3.8 g m^{-2} y^{-1} and costal wetlands (including tidal swamp, salt marsh, and mud-land) remove TN and TP by 25.0 and 5.0 g m^{-2} y^{-1}, respectively (10, 13, 14), the loss of these wetlands may have led to an annual reduction of water purification capacity by 2.8 Tg TN and 0.4 Tg TP in China. These lost water purification capacities amounted to 151.4% of TN and 64.0% of TP discharged in 2000 from the industrial and domestic activities in China (21). The loss of wetlands also resulted in extinction of many species that required wetlands as their vital habitats (Table 2). Among the known animal species that became extinct over the past 100 years or so, most of them were wetlands species (Table 2), including Xinjiang big-head fish (*Aspiorhynchus laticeps*), estuary crocodile (*Crocodilus porosus*), phoenix-head sheldrake (*Tadorna cristata*), and wild David deer (*Elaphurus davidianus*). Most of the extinctions were because of the loss of habitats caused by wetlands destruction (22). Another extraordinary loss of wetlands species was the wild rice (*Oryza meyeriana*), which was discovered in the swamps of the Hainan Island of Southern China in 1970s and was used to create a hybrid rice; this new crop increased the rice production by 3.0 quadrillion gram (Pg) in China (23), but wild rice populations disappeared from its natural environments (10, 23).

In addition to direct destruction of wetlands, there were other problems associated with wetland health and conservation, such as water pollution, C storage loss, and biological invasion. These problems were just as severe as the wetland loss in China.

Water Pollution

Water pollution, from both point and nonpoint sources, presents serious problems that not only damage wetlands and other natural resources but also threaten public health and livelihood. One doggerel by local people vividly depicts the dynamics of water pollution in Eastern China over the last 50 years: "Cleaning rice and vegetable in the 1950s; washing cloth in the 1960s; becoming dirty in the 1970s; disappearing of fish and shrimp in the 1980s; causing bodily injury in the 1990s." In the early 1970s, water quality began to show effects of increased discharge of wastewater from industrial and domestic activities and runoffs from nonpoint sources, such as fertilizers used in agriculture. Over the period of 1980–2000, the wastewater discharge increased by 180% from industry and 380% from residential sources (24), and much of the wastewater was poorly treated or untreated and full of pollutants (21). During 1950–2000, the annual consumption of fertilizers in China increased by 530 times, whereas the area of aquatic culture increased by 6.3 times and its production by 125 times (Fig. 2) (25). Much of the fertilizers (50%–70%) ended up in the natural wetlands either by direct discharge or by accumulation of runoffs (21, 25). Excessive nutrient loading and poorly treated wastewater discharge greatly affected water quality of rivers and lakes. Among the 1200 monitored rivers, 70.8% was polluted and

Table 2. The numbers of species that live or are extinct in natural wetlands of China.

Taxon	No. species			Species lost or endangered		
	Wetland	China	Percentage	Wetland	China	Percentage
Plants						
Moss	270	2200	12.3	15	40	37.5
Fern	70	2400	2.9	25	110	22.7
Gymnosperm	20	250	8.0	5	65	7.7
Angiosperm	1200	30 000	4.0	75	1000	7.5
Subtotal	1560	34 850	4.5	120	1215	9.9
Animals						
Mammal	30	580	5.2	60	135	44.4
Bird	270	1250	21.6	85	180	47.2
Reptilian	120	380	31.6	15	20	75.0
Amphibian	280	280	100.0	10	10	100.0
Fish	1040	3860	26.9	170	200	85.0
Subtotal	1740	6350	27.4	340	545	62.4
Total	3300	41 200	8.0	460	1760	26.1

The species data for wetlands were based on the first national wetland inventory from 1996 to 2003 (2, 5), with minor corrections made based on recent publications (9–11, 15, 17, 18). The species data for China come from "*National Report of Biodiversity of China*" (1998) (22).

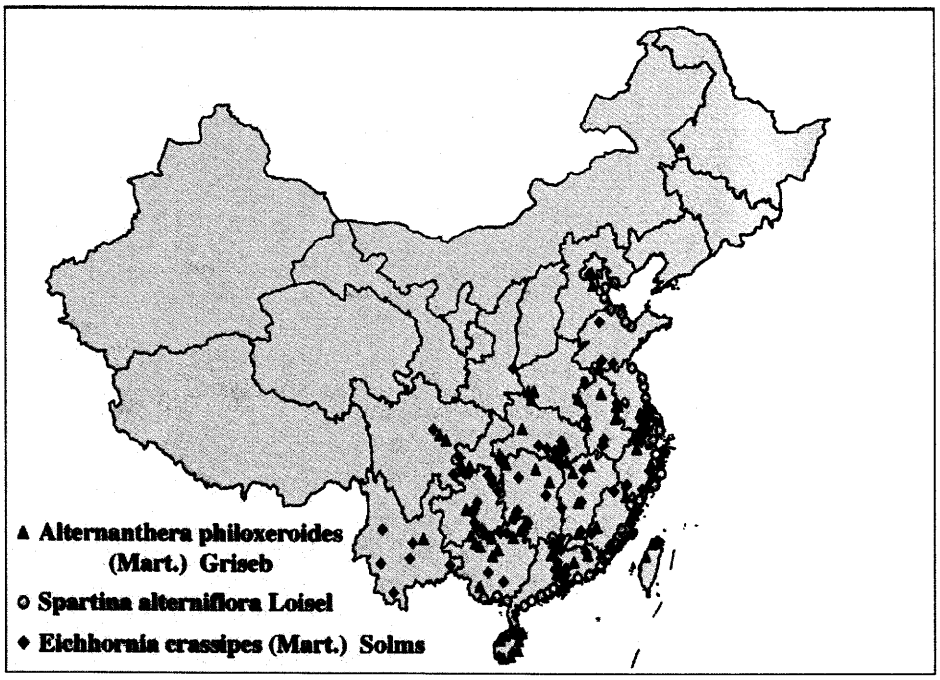

Figure 4. The distribution of three important invasive plant species in China's natural wetlands. The locations for the smooth cord grass are based on ref. 10, whereas the locations of both alligator weed and water hyacinth came from ref. 27, with minor corrections based on refs. 2 and 24.

Through history, additional waves of reclamation occurred during late Song (AD 1250–1276), Ming (AD 1470–1560), late Qing dynasties (AD 1780–1910), and the last century (mostly from 1950–2000) in the Dongting Lake, and during early Tang (AD 620–650), late Song (AD 1130–1270), late Qing dynasties (AD 1780–1910), and late last century (AD 1950–2000) in the Poyang Lake. The Dongting Lake, once the largest lake in China, shrank from the surface area of 18 730 km^2 1500 years ago to the current size of 2625 km^2 (Fig. 3) (28–30). The lakes lost a total area of 13 000 km^2 to reclamation during the last 50 years alone, with most of the loss occurring along the Yangtze River (e.g., 41.0% loss in Poyang Lake, 34.2% loss in the lake group of Jianghan-Dongting) (17, 19). Other wetland types also suffered a great loss. Coastal wetlands in the Northern Jiangsu Province, the largest in China, were reclaimed since the late Han dynasty (BC 202 to AD 220). In addition, much of the 30 000 km^2 coastal lands generated during the last 4000 years by the sediment buildup near the mouths of major rivers in Jiangsu Province was reclaimed; only 900 km^2 of these newly created wetlands remained undeveloped (31, 32). The largest swamps in China, the Sanjiang Plain, lost 83.7% of its total area during 1825–2000, with most of the reclamation taking place during the last 50 years (Fig. 3) (15, 33). It was estimated that a total of 133 500 km^2 of croplands, fishponds, salt ponds, and residential lands was obtained from the conversion of coastal wetlands in China (32). Overall, reclamation alone may account for 82% of the total wetland loss in China.

Misguided Policy

The accelerated loss of lakes, coastal wetlands, and swamps because of reclamation in the last 50 years (Fig. 3) was primarily the outcome of the reclamation policy by the Chinese government in that period (5, 10, 33, 34). As a country of agriculture, China has more people but less arable lands (122 million hectares) than the United States (638.8 million hectares) (35, 36). It was always (and still is) a struggle to produce enough grain for the population. As mentioned above, land reclamation had been regarded as a key solution, either from mountains (e.g., rice terraces) or from lakes and swamps. Thus, the strive for food security was the force that drove the reclamation policy of the Chinese government, and the large-scale reclamation during the last 50 years was sponsored by the government because building networks of levees and ditches required the kind of financial support and manpower that only governments could provide. However, recent natural disasters (e.g., the Yellow River dried up in 1997, the Yangtze River floods of 1998, Beijing's sandstorms of 2000s) brought the attention of the government and the public to the severe environmental problems caused by the policy of economic growth at all cost. The realization of environmental consequences of misguided policies also led to a change of attitude toward the environment in general and wetlands in particular (1, 2, 5). As a result, it is safe to say that large-scale reclamation will not be allowed, even though the coastal wetlands and natural swamps are still under threat, because many local governments continue to consider them as potential land resources.

Water Diversion

Decreased water recharge was another key cause for natural wetland loss in China (1, 10, 30). Water diversion to agricultural and industrial uses greatly reduced water flow into wetlands over the last 50 years. The area of the irrigated croplands increased by 340% from 1950 to 2000 (Fig. 2), and much of the water was lost because of low water use efficiency of irrigation (15%–35%) (12, 25, 35). The excessive use of water by agriculture and other industries resulted in the extremely low river flow in the lower sections of many rivers (e.g., Yellow, Talimu, Heihe); for example, a stretch of the lower Yellow River (704 km) had no water flow for 226 days in 1997 (12, 37). Meanwhile, more than 120 000 dams were constructed, with 46 000 dams and 7000 water gates along the Yangtze River alone (including the Three Gorges Dam, the biggest dam in the world) (12, 23). These dams and water gates not only isolated 70% of the natural lakes from rivers but also interrupted the migration routes of aquatic species and drastically changed the fauna of lakes (38, 39). In western China, lake areas are encroached by the desertification process caused by droughts and the loss of vegetation cover (1, 9, 17, 18). The lakes of

thousand million tonne of sediments into the estuaries each year, including 6.4 thousand million tonne from the Yellow River, 5.2 thousand million tonne from the Yangtze River, 1.6 thousand million tonne from the Haihe River, and 0.9 thousand million tonne from the Pearl River (12, 44, 45). From the sediments, 10 000 to 15 000 km^2 of new wetlands may originate in the estuaries of major rivers and nearby coasts in the next 50 years (31, 32, 37, 46). It is also estimated that over 100 000 km^2 of submerged alluvial deposits off the coast of the Yellow Sea may become terrestrial lands within 50–100 years if the current sedimentation rate remains unchanged (45). In addition, at the completion in 2008, the Three Gorges Dam will create a giant artificial lake of 1150 km^2 of surface area, with additional 460 km^2 of permanent wetlands and 4900 km^2 of transient wetlands near the lake shores because of high soil moisture (12, 23). The South-to-North Water Diversion project is also expected to contribute to the fresh wetland generation in Northern China (2, 21). The National Program of Wetland Protection Engineering calls for protection of the newly created wetlands by establishing natural reserves and wetland parks (2).

FUTURE CHALLENGES FOR CHINA'S WETLANDS

Despite all that has been done, many challenges remain in terms of wetland policy, management, and science. First, success in wetland conservation requires science-based policies and effective laws and regulations. China still needs a specific law for wetland protection, which is in a slow process of being established. Current laws and regulations can be effective in stopping wetland loss and water pollution at large scales, i.e., protecting wetlands from reclamation and point-source pollution. However, cleaning up of water pollution will take a long time, and the water-resource shortage will remain a problem for years to come. Therefore, it will be a major challenge to the Chinese government to maintain a consistent policy on and a long-term commitment to wetland conservation and water-quality control. In addition, a system for monitoring and assessing at the national scale will need to be developed to ensure the effectiveness of the implementation of the policies, laws, and regulations, and the accountability of the funded programs. Second, effective implementation of the national wetland action plan requires a concerted efforts at all levels. The policies, laws, and regulations may fail to produce the expected outcomes unless new ideas and incentives are developed to provide local people with alternative ways of livelihood that will not cause disturbances to wetlands. It will be a challenge to find a balance between protection of wetlands and revitalization of the local economy in wetland regions. Significant obstacles to wetland preservation, such as local bureaucracy, lack of trained managers, misuse of wetland funding, and lack of appreciation of the ecosystem management principle, will also need to be removed. Educational campaigns to increase public awareness about wetland-related issues just started, but it will take a long time to change peoples' attitudes. Third, science is needed to provide the information for decision making and for training wetland professionals to manage natural reserves and wetland parks, and to educate local people. China lacks the scientific expertise and technical know-how in wetland restoration and in water pollution control and clean-up. Efforts to enhance scientific exchanges and communications will be needed to narrow the gaps and to generate scientific advancements to solve many of the problems. Another major challenge is the lack of graduate programs for wetland sciences in universities, which is the main reason for the lack of trained researchers and managers. There are only a few such wetland graduate programs in China.

Sustainable development in China requires new attitudes, sound policies, and great efforts in protecting natural wetlands and preserving their valuable ecosystem services. The natural wetlands in China are still under great threats by the large population and rapid economic growth. In fact, the economic miracle of China in the last 20 years came at the huge expense of the environment, especially the natural wetlands (1, 21). To reverse the trends, China faces enormous challenges. However, significant actions are being taken, including the plan designed to place 90% of the natural wetlands under protection by 2030, the policy to return reclaimed croplands to wetlands (swamps, lakes), and the funding allocated to restore natural wetlands (2, 5, 17). These actions will ensure that natural wetlands are protected and damages to wetlands in the past are repaired so that the country receives the full benefits of the ecosystem services provided by wetlands in the years to come. The future of China's wetlands looks promising, because China understands that protecting wetland ecosystems is a national imperative to guarantee a sustainable development of the economy of the country.

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