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The Bayanbulak region, deep in the East Tienshan Mountains, is the southernmost and highest breeding area for swans anywhere in the world. As one of the few biodiversity hotspots in central Asia, it was listed in 1986 as a Chinese national swan nature reserve. The region is also the largest grazing area in Xinjiang as well as a tourist attraction. But in the last 25 years, the population of wild swans has decreased from about 20,000 to 2000, and approximately half of the pastureland now suffers from overgrazing and degradation. Moreover, the local government has been considering building a reservoir in the region. If this is done, the ecology of this region would be greatly altered, and almost all wild-swan habitats would disappear. The present study identifies alpine grassland types and concludes that it is urgent to protect the breeding areas of wild swans and control grassland degradation, and that any plan for reservoir construction should be rejected.

Keywords: *Tienshan; Bayanbulak; swan protection; pastureland degradation; China.*

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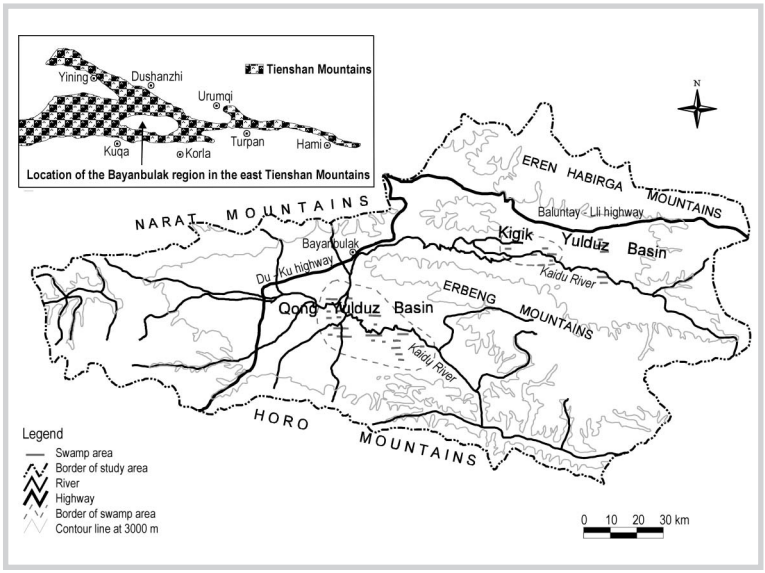


FIGURE 1 Sketch map of the Bayanbulak region in the East Tienshan Mountains.

The Bayanbulak region as a focus of study

The Bayanbulak region is located deep in the East Tienshan Mountains (Figure 1), between east longitude 82°27′–86°17′ and north latitude 42°18′–43°34′. There are many springs in the region, as its name implies: in Mongolian, *Bayanbulak* means "many springs." About 270 km long and 136 km wide, this region consists of 2 intramontane basins, the Qong Yulduz and the Kigik Yulduz Basins, covering an area of 2,383,500 ha. The bottoms of the 2 basins lie at an elevation of 2390–2500 m, whereas the surrounding high mountains are at an elevation of 4000–5000 m. The annual mean air temperature is –4.7°C, and annual mean precipitation is 276.2 mm in the basin bottoms. Administratively, this region is a district of Hejing County in the Bayingolin Mongol Autonomous Prefecture of Xinjiang, China.

The Bayanbulak region is well known for a large population of wild swans. In the early 1980s, about 20,000 swans were recorded (Jing et al 1992, 1993). Besides, over 120 species of other birds have been recorded, such as the black stork (*Ciconia nigra*), several species of buzzard (eg, *Buteo rufinus, Buteo hemilasius, Buteo lagopus*), and a few species of falcon (eg, *Falco tinunculus, Falco columbarius*). Two families, 4 species of fish (eg, *Aspiohynchus laticeps*), 2 species of amphibians, and 18 species of mammals (eg, *Cervus elaphus*) have also been recognized in the region (ACAX 1999). Conveniently, the central wetland (30,000 ha) of the Qong Yulduz Basin, where the breeding areas of swans are distributed, is called the "Swan Lake of China." Actually, the Bayanbulak region is the largest breeding and gathering area of swans in China and also the most extensive reproducing area of the whooper swan (*Cygnus cygnus*) in the world (Yuan and Zhang 1991; Yuan 1992; Yuan and Guo 1992; Ma 1993). In 1980, the government of the Xinjiang Uygur Autonomous Region declared it the Bayanbulak Swan Nature Reserve. In 1986, it was upgraded to a national swan nature reserve by the government of China.

With a vast extension of alpine steppe and alpine meadow as pastureland, the study region is also the largest stock-raising base in Xinjiang and even one of the most extensive, highly productive pasturelands in China. Since the 1970s, some 1.5 million sheep units of livestock have been grazing here every year. The local residents are Mongolian Turhut tribes that have lived here for about 230 years since they returned from Russia in 1772 (Hong 2000).

The Bayanbulak region has become a summer tourist site in Xinjiang, thanks to wild swans, the wandering Kaidu River, vast alpine grasslands, the cool summer climate, and the local Mongolian people and

TABLE 1 Grassland, main communities, and seasonal use in the Bayanbulak region.

Grassland	Main communities	Coverage (%)	Yield (kg/ha)	Area (10^4 ha)	Used in
Swamp meadow	1. *Carex* + mixed grass	>90	1650	3.45	Spring
	2. *Triglochin palustris* + *Batrachium* + *Carex*	80	1719	1.45	Summer
	3. *Carex* + *Polygonum viviparum* + *Kobresia*	90	1744	5.29	Summer/Autumn
	4. Herb + mixed grass	95	1600	1.35	Autumn
Subalpine steppe	1. *Stipa krylovii* + *Festuca sulcata*	50	378	92.78	Spring
	2. *F. sulcata* + *S. purpurea* + *Potentilla bifurca*	53	513	32.84	Spring
	3. *S. purpurea* + *Koeleria gracilis* + *Agropyron cristatum*	71	814.5	9.98	Autumn/Winter
	4. *F. sulcata*	48.7	289.5	9.59	Spring
	5. *F. sulcata* + *S. subsessiliflora* + *Artemisia frigida*	45–50	259.5	19.22	Spring
	6. *S. subsessiliflora* + *S. purpurea*	45	217.5	12.87	Spring
	7. *Aneurolepidium tianschanicum* + *S. purpurea* + *A. cristatum*	72.5	186	2.13	Spring
Subalpine meadow-steppe	1. *S. purpurea* + *A. cristatum* + *Carex*	50–60	513	13.66	Autumn
	2. *Carex* + *K. gracilis* + *F. sulcata*	60–70	723	6.33	Autumn
Subalpine steppe-meadow	1. *Carex* + *Poa* + *Stipa*	70–75	615	63	Autumn
	2. *Carex* + *A. cristatum* + *Stipa*	75	1057.5	38.13	Autumn
Subalpine meadow	1. *Geranium pratense* + *Poa*	84.5	2020.5	159	Summer
	2. Herb + mixed grass	75.3	1057.5	95.05	Winter
	3. *Carex* + *Kobresia* + mixed grass	75	990	13.64	Summer
	4. Mixed grass + *Carex* + *Kobresia*	80	950	23.5	Winter
	5. *P. viviparum* + mixed grass + *Kobresia*	80	1020	9.02	Winter
Alpine meadow	1. *Kobresia*	85–90	1812	243.78	Summer
	2. *Kobresia* + *Carex*	85	537	117.91	Autumn/Winter
	3. *Kobresia* + *P. viviparum* + *Carex*	90–95	2325	142.67	Summer
	4. *Carex* + *P. viviparum* + *Kobresia*	85–90	1522.5	107.47	Summer
	5. *P. viviparum* + *Kobresia* + mixed grass	90–95	2587.5	270.95	Summer
Alpine bog-meadow	1. Swamp *Kobresia*	91.1	1378.52	48.4	Summer
Shrub meadow	1. *Salix saposhnikovii* + mixed grass	82	2250	30.03	Summer
	2. *Caragana jubata* + mixed grass	80	1485	22.19	Summer
Interforest meadow	1. Mixed grass + herbs	92.5	7545	38.74	Summer
Planted grassland	*Elymus sibiricus*, *E. mutans*, *Avena fatua*, *Poa pratensis*, *Roegneria kokenorica*	>90	4500–7500	3.67	Spring

their lifestyle. Every year, growing numbers of tourists come all the way from other parts of China and even from abroad to the Swan Lake of China for sightseeing.

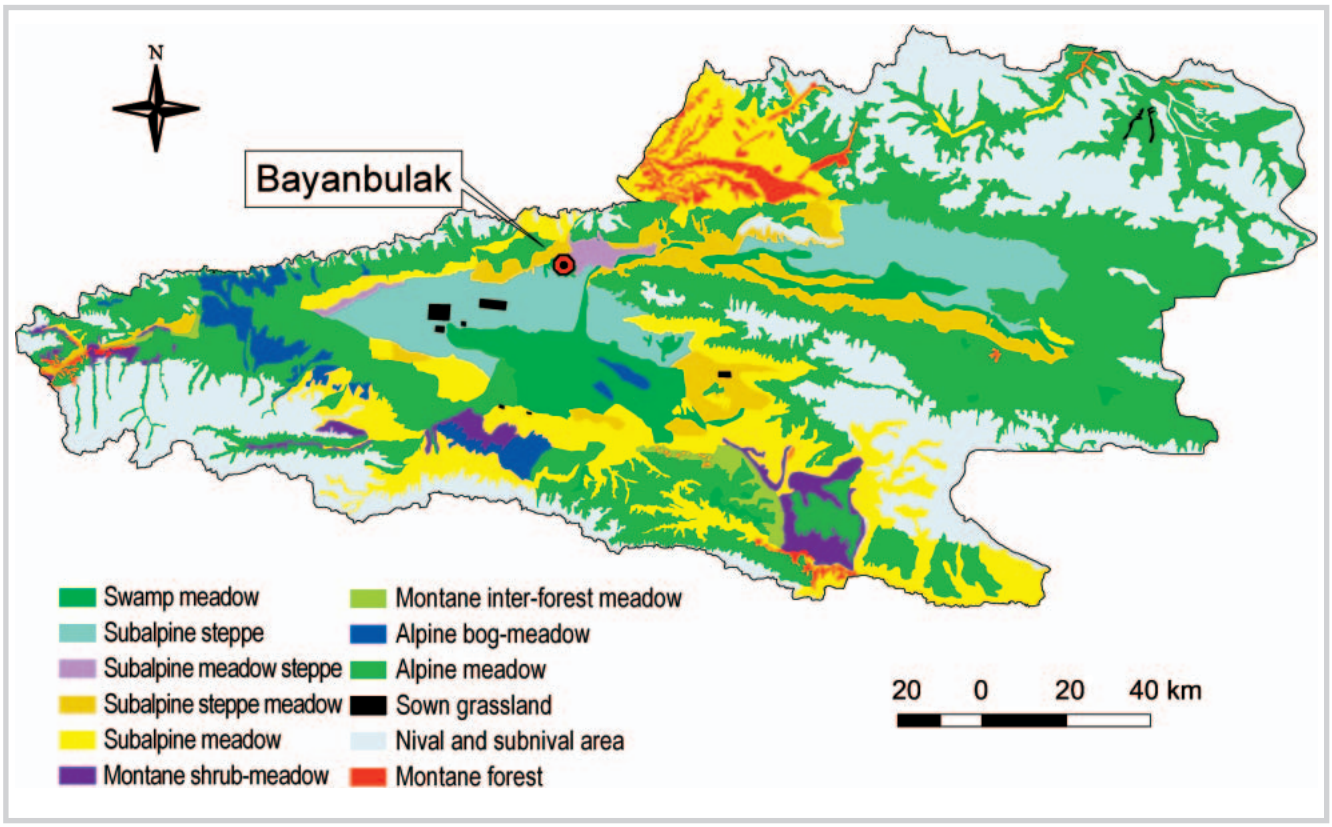
Before the early 1980s, the study region was almost closed to the outside world. The opening of the Du–Ku highway in 1982, which crosses the Tienshan range from north to south, greatly increased the accessibility of the Bayanbulak region. Since then, great changes have affected biodiversity and alpine pastureland (eg, pastureland degradation, swan habitat deterioration, and a decline in the number of swans). In recent years, there has been a plan to build a reservoir in Qong Yulduz Basin. If this is done, the Swan Lake of China would disappear, with fatal consequences for swan habitats and swans in the Bayanbulak region. In addition, local tourism and animal husbandry would also be greatly affected.

Classification of alpine grassland types and seasonal use

The landscape of the Bayanbulak region is dominated by subalpine and alpine meadow and steppe, with swamp and swamp meadow in the centers of the 2 Yulduz basins. A total of 50 families, 160 genera, and more than 260 species of alpine plants have been recorded (Islamkhan 1989). We identified 10 types of grassland and 30 types of communities and seasonal uses (Table 1). The distribution of grasslands is shown in Figure 2.

1. Swamp and swamp meadow occupy the lowest section (2380–2500 m), namely, along the upper reaches of the Kaidu River. In the swamps are such herbs as *Carex* spp, *Triglochin palustris, Batrachium,* and *Utricularia* spp, whereas steppe communities such as *Stipa subsessiliflora* + *S. purpurea, Festuca sulcata, Leymus secalinus,* and *Hordeum bogdanii* are found on the relatively high lands surrounded by swamps. Thanks to the very gentle slope (0.5–1%) in the basin bottoms, waters from the surrounding snow-capped mountains meander to form a series of oxbow lakes, springs, and swamps. This provides favorable habitats for swans and many other waterfowl.
2. Subalpine steppe surrounds the central swamp, usually on the alluvial and diluvial deposits. It shows continuous distribution at 2500–2800 m in the north (the southern piedmont plains of Mt Narat and Mt Eren Habirga), with a width of 16–20 km, whereas in the south (the northern piedmont plains of Mt Horo), it is intermittently distributed on elevations of 2450–2700 m, with a width of only 3–5 km. There are different steppe communities on different surface materials: *F. sulcata* communities are found on sandy or old riverbed ground, *Stipa krylovii* on thick soil and relatively high/dry ground, and *Stipa purpurea* close to the central swamp. Subalpine steppe covers a total area of nearly 200,000 ha. Most of the subalpine steppe serves as spring pastureland.
3. Subalpine meadow-steppe is a type of transitional grassland between subalpine steppe and meadow. On sunny slopes, it occurs between 2700 and 2900 m and on shady slopes between 2550 and 2700 m. It includes 2 communities and is used as autumn pastureland.
4. Subalpine steppe-meadow appears on some sunny slopes in the northern part of the study region. Its environment is characterized by frequent wind in spring and plentiful rainfall in summer. The ground is moderately wet with a thin layer of turf. It is also used as autumn grazing land.
5. Subalpine meadow consists of plenty of mesophytes, with dense grass and a multicolored appearance. *Geranium pratense* + *Poa* sp and herb + mixed grass are the 2 dominant communities. The other 3 communities listed in Table 1 are quite limited in area. This type of grassland is used in the winter season.
6. Alpine meadow usually makes its appearance above 3000 m on southern slopes and above 2700 m on some shady slopes. It includes 5 communities. The *Kobresia* community is generally found on sunny slopes above 3000 m; *Kobresia* + *Carex* communities appear on semishaded slopes above 3000 m; *Kobresia* + *Polygonum* + *Carex* communities grow on shady slopes above 2800 m with considerably wet soil; *Carex* + *Polygonum* + *Kobresia* communities are located on shady slopes above 3200 m with wet soil; and *Polygonum* + *Carex* + mixed-grass communities can be seen on semishady slopes or flat land above 3000 m. The total usable area of alpine meadow amounts to about 890,000 ha or 50.93% of the usable pastureland in the Bayanbulak region (Islamkhan 1989). It serves as summer grazing land and is the most extensive type of pastureland.
7. Alpine bog-meadow is situated at high elevations, where the frozen soil thaws from May to August and bog soil is formed. The dominant grass species is *Kobresia* sp. It serves as summer pasture but is very limited in area.
8. Shrub meadow appears below the montane forest belt in the northwestern mountains of the study region. It is used mainly in summer, within a limited area.
9. Interforest meadow is situated at the border of montane forest, between forest patches, or in the relics of forests, scattered in the southern and northern mountains. It has a very high yield of fresh grass of 7545 kg/ha. Shrub meadow mainly grows below the montane forest belt. Total area amounts to 91,000 ha, about 5.2% of the usable pastureland in the Bayanbulak region.

FIGURE 2 Grassland types and their distribution in the Bayanbulak region.



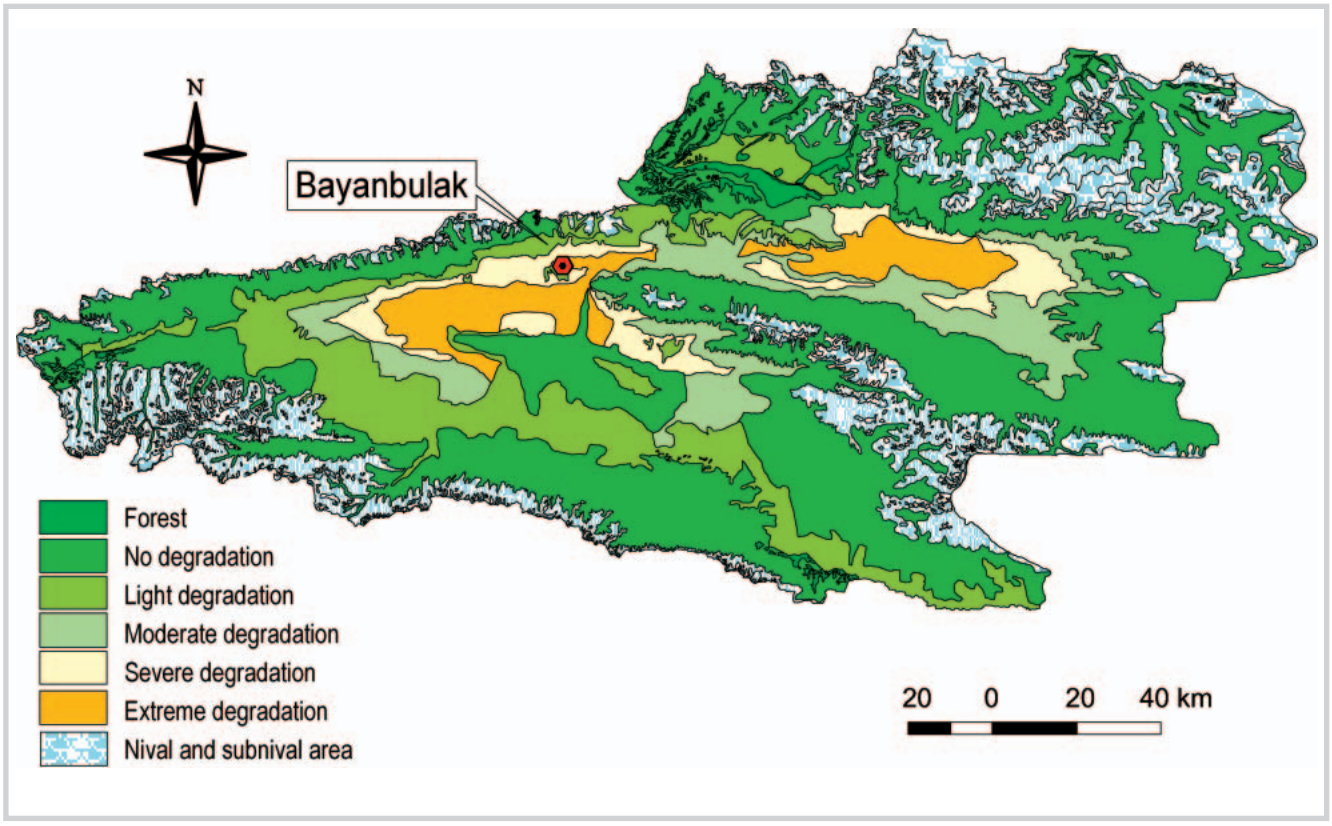


FIGURE 3 Distribution of degraded pastureland in the Bayanbulak region.

10. Sown grassland is generally located in the subalpine steppe belt. At about 3570 ha, it is quite limited in area.

Pastureland degradation

The extensive pastureland of the Bayanbulak region is virtually the only natural resource available to local communities, and animal husbandry has long been the only productive activity in the region. The livestock population has increased enormously since the early 1950s. For example, the domestic animal population was only 195,216 in 1949; this increased to 452,327 by 1989 and was as high as 517,349 by 1999 (Hong 2000). In other words, the number of livestock has more than doubled in the last 50 years. Pastureland degradation began to occur as a result.

Serious overgrazing began in the 1970s. During the period 1968–1977, annual local livestock numbers reached 1.545 million sheep units (1 horse = 5 sheep units, 1 sheep = 1 sheep unit). However, spring pastureland has a theoretical carrying capacity of only about 0.9 million sheep units (Islamkhan 1989). The same is true for autumn pastureland, although the situation is not as serious. Overgrazing results in pastureland degradation, especially on spring pastureland. This is manifested in at least 3 ways:

1. Gradual reduction of fresh grass yield. The alpine steppe pastureland about 10 km west of the town of Bayanbulak can be taken as an example. According to investigations at different periods, the grass yield was about 1200 kg/ha in the late 1950s, some 900 kg/ha in the early 1970s, and below 600 kg/ha in the late 1980s (Islamkhan 1989). On average, the coverage of subalpine steppe has decreased by 17.8–22.8% and the fresh grass yield by 62%.
2. Grassland degradation. Grassland degradation is serious around sheep production areas and water sources. Taking *F. sulcata* pastureland as an example, the most severe degradation occurs around the sheep production areas, light degradation about 1 km away, and no degradation about 4 km away. In general, serious pastureland degradation occurs largely around water sources, on flat land, and on easily accessible areas. The greater the distance from these sites, the less the pastureland is degraded.
3. Another form of grassland degradation is change of grass species composition, namely, good-quality grass species replaced by poor-quality grass species. The following degradation models can be identified:
   - When the *F. sulcata* grassland is overgrazed, *Carex stenophyloides* increases in the composition of the community. If overgrazing continues for 2–3 years, *Potentilla bifurca* begins to increase, and after 5–6 years, it becomes the dominant species. If overgrazing continues further, even *P. bifurca* begins to decrease and finally disappears, leaving barren land (Xiao and Hu 1991).
   - The degradation of *S. purpurea* grassland begins with increased patches of barren land and is followed by the invasion of *Aneurolepidium tianschanicum*.
   - The degradation of *S. krylovii* grassland appears differently: It begins with an increase of *Artemisia frigida*, followed by the expansion of barren patches, and finally the appearance of fine sand surfaces. Frequent nibbling at and trampling on the grass by livestock affect the dormancy of the tufty herbs, lower their segregation ability, and make it impossible for them to complete the growth cycle. The evaporation of soil water is then intensified, and the ground surface soil becomes dry and hardened; growth and development of the tufty herbs are affected, and grass coverage decreases. Later, antidrought *A. frigida* or *P. bifurca* with rhizome appears. If the process of desiccation continues, *A. frigida* and other plants disappear, and, finally, dry and hardened or even sandy ground results.
   - The degradation of *Kobresia* pastureland can also occur as a result of serious overgrazing. It begins with plants becoming shorter and with the increase of windflower (*Pulsatilla chinensis*), primrose, and Umbelliferae in the composition. Windflower then dominates the community. As a result, the grass yield is lowered, grass forage decreases, and poisonous and dicotyledonous herbs increase. But there is no obvious change in coverage.

According to grassland degradation criteria for the Bayanbulak region (Islamkhan 1989), about 10% of the pastureland is very seriously degraded, 1.4% seriously degraded, 28.6% moderately degraded, and 9.2% lightly degraded. In short, about 50% of the pastureland has experienced various degrees of degradation (Figure 3).

In addition to overgrazing, other human activities have led to pastureland degradation in the study region. Tourism development is one such activity. It has been widely acknowledged that tourism affects mountains in many ways (Mountain Agenda 1999). This is especially true in the Bayanbulak region. From the town of Bayanbulak, it is about 70 km to the swan-watching sites, and tourists have to take jeeps and cars to get there. But no fixed route is available. Cars and jeeps often use "open" routes for convenience, especially after rains. Usually, 7 or 8 routes can be found, each 8 to 10 m wide. This seriously destroys large areas of pastureland.

Human activities threaten biodiversity

The local Mongolians regard swans as the "Birds of God" and have a tradition of protecting them (Hong 2000). They worship swans, which serve as their "patron saint." Before the 1970s, swans and their habitats had been well conserved. But since the late 1970s, the biodiversity of the Bayanbulak region has been seriously threatened. This can be illustrated by the dynamics of wild swans. As mentioned previously, about 20,000 swans were recorded in the early 1980s. But in the early 1990s, only about 2000 were left (Jing et al 1992, 1993). On the basis of several field investigations, Professor Ma Ming, an ornithologist at the Xinjiang Institute of Ecology and Geography, even argued in 2001 that the number of swans in the Bayanbulak Swan Nature Reserve was very likely less than 1000. In other words, the number of wild swans decreased by at least 90%. This is an astounding decline at a time of global biodiversity conservation. The following human activities can be identified as responsible for this catastrophe:

- Grazing in the swan-breeding areas. In recent years, owing to pastureland degradation and carrying capacity reduction, livestock has been driven into the depths of the Yulduz basins, into the core area of the Bayanbulak Swan Nature Reserve. It is well known that swans are habitat specialists (Yuan and Zhang 1991). The incursion of livestock into swan-breeding areas forced some of the swans to emigrate. As a result of poor management, this nature reserve exists to a great extent only in law and on the map.
- The unlawful activity of poachers. Some people poach swans, collect swan eggs, and destroy swan nests. In 1978, even some of the staff of the Urumqi Zoo captured about 100 swans in the region using ropes. Thereafter, swans began to flee in panic when people approached. This interference with the normal life of wild swans is partly responsible for the decrease in the swan population.
- Inappropriate tourist activities. Some tourists approach swans too closely, and some even enter the depths of the "swan lake" on horseback. The swans often fly away in panic as a result.
- Spreading pesticides. Almost every year, locust invasions occur in the Bayanbulak region, and sometimes airplanes are used to spread pesticides to kill grasshoppers. This often adversely affects swans and their habitats.

An additional potential effect on swans and their habitats deserves special attention. Thanks to favorable geological conditions and visible economic benefits, the Qong Yulduz Basin has for years been considered an ideal site for a montane reservoir. The dam of the planned Hulstai Xil reservoir, 600 m long and 14 to 15 m high, would be located at the outlet of the Qong Yulduz Basin. The top of the dam would be at an altitude of 2400 m, and the water level would be at 2395.4 m. If the dam is constructed and water is stored, a water surface of 38,500 ha would be formed. This would have several adverse effects: (1) About 90% of the breeding area and about 70% of the swan habitats would be inundated. This would have fatal consequences for swan breeding in this region. (2) The number of swans would decrease enormously. Owing largely to reduced habitats, the swan population would decrease by 65% in the first year after water collection, and this would continue thereafter (Yuan and Zhang 1991). In short, building such a reservoir would completely change the ecology of the Bayanbulak region and would be fatal to wild swans.

Conclusions

The Bayanbulak region is significant in the Tienshan Mountains and even in the whole of central Asia for its rich biodiversity. But human activities have caused severe loss of biodiversity and degradation of grasslands.

Because the incursion of livestock into swan-breeding areas is the main factor in the loss of biodiversity, withdrawing livestock from the swan nature reserve is the principal measure that would foster conservation of biodiversity. To achieve this, the Management Bureau of the nature reserve will need to coordinate its relations with the local government to stop local livestock from entering the nature reserve as soon as possible. At the same time, degraded pastureland must be improved and planted pastureland expanded.

Nature reserve management should be strengthened. The Bayanbulak Swan Nature Reserve should come under Category IV (Habitat/Species Management Area) of the International Union for Conservation of Nature and Natural Resources protected area management categories (IUCN 1994). The Swan Lake of China is the home of wild swans, and it should be rendered safe for wild swans. Tourists should be strictly restricted to the watchtower and the natural observatory sites around the wetlands. Consideration could be given to fencing the swan lake near the observatory sites to make it a forbidden area, establishing more watchtowers, and providing telescopes for tourists. The natural state of the swan lake should be restored. In this way, the swans and their habitats could be strictly protected.

Any plan to build a reservoir in this region, whether in the Qong Yulduz Basin or in the Kigik Yulduz Basin, must be rejected. The negative effects of

building a reservoir in any of the basins will be serious and may be far greater than realized at present.

International cooperation is urgently needed. The immense Tienshan Mountain range, rich in biological and cultural diversity, has attracted the attention of Naturschutzbund Deutschland (NABU) in Germany (Dömpke and Succow 1998). NABU set up a project office for Eurasia in 1993 and initiated projects in the central and western Tienshan Mountains. However, little attention has been paid to the East Tienshan Mountains in the territories of China. Clearly, NABU projects should be extended eastward to the East Tienshan Mountains, and the experiences of Switzerland and Germany in mountain biodiversity conservation should be introduced to and applied in this range through international cooperation.

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