Synopsis

Sustainable Management of Alpine Meadows on the Tibetan Plateau: Problems Overlooked and Suggestions for Change

Many people know the Tibetan Plateau and its high-altitude animal husbandry; however, few people know the alpine meadows on the plateau. Widely distributed in the middle-east part of the plateau (roughly longitude 82–103°E, latitude 27–39°N) (Fig. 1), this alpine meadow is a unique natural landscape and an important grassland resource; not found anywhere else on earth (1, 2). It covers an area of about 700 000 km^2, accounting for nearly 50% of the total usable grassland area on the plateau (3). Animal husbandry, the backbone of the plateau's economy, is mainly dependent on the alpine meadows; however, growing economic development has placed pressure on these precious and fragile grasslands. In recent years, natural disasters, frequently occurring along the Yellow and Yangtze Rivers together with the construction of the plateau's railway have increased peoples' awareness of the alpine meadows. This is related to fact that *i)* the region of the Yellow River, the Yangtze River and the Lancang River, is regarded as "the water tower of China", where alpine meadows are widely distributed; and *ii)* the railway under construction is creating "a great corridor" which partly crosses the alpine meadows. Thus, the sustainable management of the alpine meadows is not only closely related to the survival and development of the herdsmen on the plateau, but also to the environmental protection of China.

Figure 1. Distribution of alpine meadows in China. Alpine meadows are mainly located on the Tibetan Plateau

NATURAL DEGRADATION OF ALPINE MEADOWS

Alpine meadows are periodically degraded together with its sod layer. The formation and the degradation of sod layer are closely related to the proportion of felty organic matter in topsoil. A high proportion of felty organic matter (the ratio of felty organic matter to soil mineral matter is greater than 1) hinders the release of soil nutrients, resulting in degradation of alpine meadows and the sod layer. The formation of a new healthy sod layer usually takes 14–17 years (2, 3). In areas with steep slopes and/or coarse soil texture, soil-forming conditions are unstable. Daily and seasonal freeze-thaw activity and wet and dry periods are frequent, leading to the destruction of sod layer. According to statistical analysis, freeze-thaw action often takes place over a long period in a year (3). Different swell-shrink characteristics between organic matter and soil usually lead to breakup between sod layer and the lower soil layer.

Regional climate change is not suitable for the growth of alpine meadows. According to climatic analyses on the South Qinghai Plateau since 1961, precipitation increased in the winter (December-February) and the spring (March-May), and decreased in the summer by 0.65 mm annually; and the duration of air temperature suitable for alpine meadow growth was shortened year after year. As a result, grass height decreased by 30–50%, and the fresh and dry yield of grass declined by 70–80% (4). The impact of regional strong winds is obvious. In most places, gales ($\geq$ 17 m s^{-1}) usually take place from December to April. This combined impact of freeze-thaw action and strong winds appears to accelerate alpine meadow degradation.

Rodents and insect pests are also a problem. About 130 000 km^2 of the plateau grasslands are seriously damaged by rodents. There are at least $6 \cdot 10^8$ of pikas and $1 \cdot 10^8$ zokors on the plateau. They consume about $1.5 \cdot 10^{10}$ kg fresh grass yearly, which would feed $1 \cdot 10^7$ head of sheep. The area affected by rodents generally has 0.27 rodent burrows m^{-2}, with seriously affected areas reaching 0.45 rodent burrows m^{-2}. Rodents eat grass all year round (3). In the area seriously damaged by rodents, useful grass has difficulty in growing, however some poisonous grasses can develop. Insect pests also seriously degrade alpine meadows. Nagqu Prefecture, for example, has 7300 km^2 of grassland seriously affected by insect pests (5).

HUMAN-INDUCED DEGRADATION OF ALPINE MEADOW

Overstocking gives rise to the export of soil nutrients and destruction of ground stability, seriously hindering the growth of grass. According to recent statistics, there were about $6 \cdot 10^7$–$7 \cdot 10^7$ heads of large and small livestock on the plateau, and the number of livestock on hand has increased 3-fold since the 1950s (2, 3).

There are seasonal contradictions between grass supply and livestock demand. Demand exceeds supply in the winter-spring season (withered grass period), but supply exceeds demand in the summer-autumn season (green grass period). In addition, unsuitable distribution of seasonal grasslands, lack of rotating grasslands on schedule, and lower market prices for fattened livestock not only greatly hinder the growth of grass in the cold season, but also lead to loss in livestock weight.

Irrational spatial distribution of livestock species results in irrational grassland use. For example, subpolar humid and subpolar subhumid regions are suitable for raising yaks and sheep; however, more sheep and goats have been fed in recent years. The tendency is for small livestock to replace large livestock. In addition, irrational droving structures also lead to a decrease in livestock growth capacity. The proportion of fertile female livestock is small, while that of old livestock is large.

Densely populated settlements, little fencing of grasslands, over-large areas of fenced grassland with different grazing conditions inside the areas, lack of adequate drinking water, and (or) inaccessibility of some grasslands, not only reduces the total grazing area, but also makes for some grassland being overutilized while others are not being developed. Reclamation of grasslands without consideration of natural conditions seriously limits both agricultural and animal husbandry development. Some grasslands have not yet recovered, which were irrationally reclaimed in the 1960s (3). Mining, road construction, gold mining, and collecting of herbal medicines have increased the loss of the protective layer of grasslands, greatly accelerating the degradation rate. In particular, some herdsmen usually dig sod layers to build fences, intensifying wind and water erosion, and rodent problems.

Slow-paced regional comprehensive development (referring to regional development of agriculture, industry, transportation, commerce, etc.) results in local people losing opportunities for livelihood. With lower education levels and larger populations, they are mainly dependent on the grasslands for a living. Decreased openness of the grassland systems and shorter contract periods for grassland use, hinder the exchange of information about grassland environments, and may lead to predatory, low-benefit grassland use and increasing degradation of alpine meadows.

OVERLOOKED PROBLEMS AND SUGGESTIONS

Based on the abovementioned degradation phenomena, scientific research and practical efforts have been carried out. However, the overall situation of degradation remains acute. This is because there are intrinsic and overlooked problems that need to be solved to combat alpine meadow degradation. Some suggestions are listed below.

Special grassland-use policies should be established. Grassland-use rights should revert to herdsmen, assuring the herdsmen that the grasslands belong to them and their offspring. Otherwise, herdsmen may use the grasslands without concern for their sustainable use, resulting in "tragedy of the commons". The following need to be taken into account to establish and perfect grassland-use policies: *i)* separate establishment of settlements should be encouraged to prevent livestock gathering and grazing in vulnerable places; *ii)* it is necessary to enlarge contracted grassland area for each family in order to establish satisfactory grazing in regions with poor living conditions.

China has established and implemented many related laws useful for alpine meadow protection. However, an effective Tibetan Plateau Protection Law is needed. It is only effective laws (not just slogans) that can prevent the destruction of the alpine meadows. The regions of the Yangtze River, the Yellow River and the Lancang River, the areas degraded by railway construction, and other seriously degraded alpine meadows should be completely protected by law. Otherwise, this fragile region could become the second Loess Plateau.

The effects obtained in combating grassland degradation needs to be taken into account in assessing governors' achievements in their posts. Elected governors must be acquainted with traditional experience in grassland protection, environmental sciences, and sustainable development ideas.

Scientific management systems and research need to be improved. Many scientists and scientific organizations in China are working on research projects related to alpine meadow protection. However, because of short-term research projects (3-yr periods) scientists tend to pay more attention to short-term scientific achievements and to publishing papers. Many research projects overlap and lack continuity. Governments should support long-term and rigorously organized research work relating to alpine meadows.

Located in the northeastern part of the plateau and established in 1976, the Haibei Alpine Meadow Research Station (longitude 101°12'–101°33'E, latitude 37°29'–37°45'N) has played a very important role in the protection and sustainable use of alpine meadows (6). To combat alpine meadow degradation, it is necessary to establish one more alpine meadow research station in the mid-eastern part of the plateau where alpine meadows are widely distributed. Scientists should also be responsible for the popularization and application of their scientific results.

Chemical methods used to control rodents, insect pests and poisonous weeds are detrimental to the sustainable use of alpine meadows. Chemical substances not only kill the rodent predators, but also seriously pollute the soil and water. Limiting the disadvantages and exploiting the advantages of rodents, insects and weeds by regarding them as environmental resources is important. In recent years, the fur and bones of some rodents have been used for ornaments and for medicines. Poisonous weeds are harmful in areas with animal husbandry, but help in binding soil and water, by covering fragile ground, and could therefore be seen as important resources for the future.

Sustainable management of the alpine meadows must also be based on capacity building and regional comprehensive development. Capacity building should include *i)* unforced control of brain-drain (trained personnel move eastwards because of the poor living and working conditions on the plateau) and attracting more competence; and *ii)* training local people in science and technology and intensifying their legal knowledge. Sustainable protection of competence is the first step to control grassland degradation. Regional comprehensive development needs both domestic and overseas investments. Regional development can increase the degree of mechanization and technology in grasslands, as well as increasing the grassland productivity and the marketing and commodity rate of livestock. Pressures on winter-spring grasslands can thus be reduced, and the exchange of resources, energy, and information between grassland systems can be intensified. With regional comprehensive development, a production base for ”pollution-free meat” may be established in alpine meadow zones, which will benefit people all over the world and lead to efforts to protect these fragile grasslands.

References and Notes

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Synopsis

Discovery of *Sphaeroma terebrans*, a Wood-boring Isopod, in the Red Mangrove, *Rhizophora mangle*, Habitat of Northern Florida Bay

Worldwide, the wood-boring isopod, *Sphaeroma terebrans* Bate, exploits the intertidal habitat created by mangrove prop roots (1, 2). In Florida, *S. terebrans* is found almost exclusively within free-hanging aerial roots of the red mangrove, *Rhizophora mangle* L. (2, 3) and is present only within the intertidal zone. The relationship between *S. terebrans* and the red mangrove is nonherbivorous, as *S. terebrans* does not actually ingest the excavated root material (4). Once constructed, the burrow is used for *i)* protection from both abiotic (exposure, desiccation) and biotic factors (2); *ii)* filter feeding activities (suspended sediment, algae, and bacteria) (5–7); and *iii)* reproduction along with maternal care (8). Burrowing by *S. terebrans* has important economic impacts due to the considerable damage it does to maritime structures (6, 9). Burrowing also has a controversial biological impact with discussions ranging from the damage caused by the isopod being described as “ecocatastrophic” to beneficial for the mangroves (see 10).

Isopod attack impacts the mangrove tree directly through root architectural changes (11, 12), reduced root production and increased root atrophy (13–15). Burrowing by *S. terebrans* also reduces root growth rates and increases root tip atrophy/breakage (13, 15–17). The red mangrove can respond to the tissue damage resulting from burrowing by either shunting energy to new material *via* the initiation of multiple lateral roots near sites of injury (11) or replacing root structure through repair (17). The changes to the root system as a result of isopod burrowing not only alter structural support (18) and nutrient provision for the tree itself, but may also indirectly affect other flora and fauna which utilize the mangrove roots as either substratum (16,19–21) or protective habitat (22). Thus the presence of *S. terebrans* within an area can have community-wide impacts.

Debatably, *S. terebrans* is not native to North and South America, but was introduced by humans from the Indo-Pacific through the shipping trade (23). *Sphaeroma terebrans* represents the only wood-boring sphaeromid in Florida. Historically, the distribution of *S. terebrans* has been documented to extend from just north of Tarpon Springs to Cape Sable on the west coast (3, 6, 24) and from New Smyrna Beach south to Biscayne Bay on the east coast of Florida (3). Curiously, the presence of *S. terebrans* has been documented in the canals of south Florida and along the shoreline of Long Sound but is reportedly absent from Florida Bay and the Keys (3, 6). The isopod is found further south, however, in the tropics of Central and South America (15). The distribution gap has been described by Conover and Reid (3) to represent an abrupt boundary. Herein, I report the results of a survey conducted 27 years later to determine if *S. terebrans* is still absent from Florida Bay.

THE STUDY

Eight mangrove stands ranging in salinity from 28–39 ppt were selected within Florida Bay as sampling points (Table 1). At each sampling point, a minimum of 25 m of red mangrove fringe was inspected for the presence of isopod burrows. The location of each stand was recorded using a Garmin GPS unit and the presence of any extensive root fouling was also noted. Additionally, at each sampling point the water-quality parameters of water temperature, salinity, dissolved oxygen, and pH were taken using a Yellow Springs Instruments (YSI) model 650 handheld, multi-function (model 600 sensor head) water-quality meter. If burrows were observed, several burrows were excavated to confirm the presence of *S. terebrans* and the size, sex, and reproductive status of all recovered individuals