Chapter 4

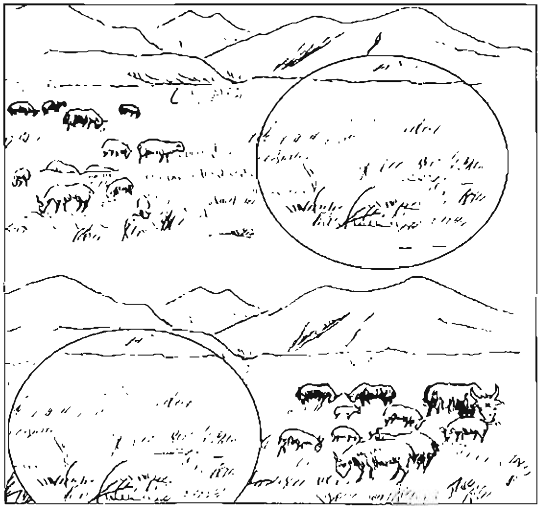
TECHNICAL INTERVENTIONS BY THE PROJECT

4.1 Rangeland Rehabilitation

A REVIEW OF RESEARCH CONDUCTED UNDER QLDP BY DENNIS SHEEHY

The majority of research on rangeland rehabilitation has been oriented towards developing techniques to rehabilitate black soil type degraded rangeland (commonly referred to as 'black beach'). According to Li (P30), the term 'black beach' first appeared in a 1976 report of the Bureau of Animal Husbandry. The Tibetan term for 'black beach' is sanaheta. The same author reports that 'black beach' only occurs at elevations of between 3,600 and 4,500m in areas affected by a combination of human activity and environmental factors. Black beach formation follows a sequence of sedge degradation, rodent burrowing, wind and water erosion, sedge mortality and increased amounts of bare ground, root shearing by frost heaving, and continued wind and water erosion. The paper describes the different levels of degradation and maps out the sequence of vegetation community changes in terms of changing species' composition, decreasing vegetation cover, and increasing cover of bare soil.

There are two theories regarding the formation of 'black beach' landscapes. The comprehensive factor theory sees over-grazing and rodent damage as the main factors initiating damage to *Kobresia* rangeland communities. Wind erosion of the damaged area begins with eroded away sand being blown on to and covering adjacent areas. This, together with frost heaving, destroys the vegetation until only bare soil remains. The climatic change theory believes that global warming has caused the formation of black beaches through a sequence of increase in temperature, degradation of vegetation communities, soil erosion, and decreases in precipitation. Supporters of the comprehensive factor theory maintain that the decline in *Kobresia* communities has occurred too rapidly to have been caused by climatic change (Ma, P44).



Ma (P44) reviewed research that has been carried out since 1970 to find ways of rehabilitating black beach. Experiments have addressed reseeding techniques and the suitability of species for revegetation. Approximately 20 species of grass have been found to be suitable for seeding black beach degraded grasslands. The best suited species have been *Elymus nutans* and *E. breviaristants*. In 1985, a review of previous research recommended that seriously degraded grasslands should be re-vegetated, whilst moderately degraded grassland should be disk-harrowed to loosen soil to allow natural regeneration. The recommendations for lightly degraded grasslands are that livestock grazing should be controlled. *Kobresia* spp., which make up most of the natural vegetation cover of alpine grasslands, have been successfully used to reseed degraded grasslands; however it has been less suitable as a rehabilitation species because of its low germination rate and slow development (Ma, P44).

Black soil type deteriorated grassland is mainly sandy loam and sandy soil over grit soil. The gritty soil only supports plants that are toxic to livestock and a few grasses. Coarse organic matter of the original meadow surface soil is 10% and contains 50-54% moisture. The surface soil of the black beach black soil type has 4% coarse organic matter and its moisture-holding capacity is only 4-18%. Li (P20) points out the benefits of rehabilitating 'black soil types'.

Most of the alpine meadow rangelands of Guoluo Prefecture are degraded. There are reportedly 2.86 million hectares of degraded grassland (49% of total usable grassland) in this prefecture (Li et al., P24) and black beach covers 1.23 million hectares of this. The total area of grassland reportedly degraded through pika and *Microtis* infestation is 2.56 million hectares (44% of usable rangeland). Ma et al. (P43) have estimated that the area of black beach rangeland in Qinghai Province in the 1990s was 2.13 million ha.

Systematic rehabilitation

The rehabilitation of grassland that has less than 30% vegetation cover, but with deep soils on relatively level topography, involves consecutively disking, harrowing, sowing seed of adapted perennial grass species, fertilising, and finally rolling. Rehabilitation by seeding should begin in May and June. The application of fertiliser is necessary during the plant growing season.

Two rehabilitation methods have been developed for areas with thin black soils where slopes make machine operation impractical and vegetation cover exceeds 30%. If vegetation cover is more than 50% and toxic weeds dominate the site, rehabilitation needs to involve fencing out large herbivores, controlling rodents, and the control of toxic plants by applying herbicides. On black soil slope sites with a vegetation cover of between 30 and 50%, rehabilitation should involve fencing, rodent control, reseeding, and fertilisation. Broadcast seeding should be carried out between May and June and animal hoof action can be used to set seed. Fertilisation is necessary for successful stand establishment and needs to be applied in subsequent years (Li, P24).

Black beach rehabilitation using these methods has a productive stand life of between five and eight years. Maximum yield is reached in two to three years and then decreases. After eight years, stands need to be revisited and re-treated if stand productivity is to be retained. The average annual yield of fodder over the eight-year life of the stand is 6,660

(DW) kg/ha. Pasture rehabilitation costs over the eight years of stand life use have been calculated by Li (Li, P24). The establishment of sown pasture is estimated to cost yuan 3,596/ha and semi-sown pasture yuan 352/ha. Assuming that sown pasture has an average annual yield of 6,660 kg/ha over eight years, it would accrue an economic value of yuan 10,656 (8 years x 6,660 kg/ha = 53,280 kg x yuan 0.2/kg = yuan 10,656). Therefore the benefit obtained from a combination of sown and semi-sown pastures over the eight-year life of the stand would therefore be yuan 1,621/ha.

Testing species adaptability

Shi et al. (P58) tested ten varieties of oats to determine their capacity to increase hay yields under plateau conditions. The three oat varieties, Qinghai 444, Bayan 5, and Xuan 18, were found to have significantly higher yields than the control (Bayan 3).

Ma (P44) reported on results of trials of 25 introduced plant species. Eleven species of grass and two species of legume did well in the Guoluo environment, whilst six species of grass and one legume species proved moderately suited, and three species of grass and one species of legume were unsuitable. Most species introduced from other areas of China appeared to have the potential to rehabilitate black beach.

Shi et al. (P58) reported on tests of 21 perennial grass species seeded in various mixtures to determine their over-winter survival potential and productivity under plateau conditions. Three grass species (*Elymus nutans* Griseb, *Elymus sibiricus*, and *L. perisicum* Boiss) that use above-ground seed reproduction strategies appeared well adapted. Eight grass species that use below-ground vegetative reproduction strategies also appeared to be well adapted. Stands of mixed grass species improved community structure and increased herbage yield more than stands of single grass species. The authors also suggested that germplasm of grasslike plants (*Cyperaceae*), which dominate turf communities, be tried out.

Black soil areas below 4,000m in elevation with slopes of less than 10 degrees were selected for rehabilitation. The application of fertiliser is necessary to ensure stand establishment and high biomass yields. Also, pest species must be controlled and the plant species used in seeding should be locally adapted. It is also crucial that site management continues after initial rehabilitation (Ma, P44).

The benefits of the rehabilitation of black beach include: 1) increase in above-ground biomass, 2) reduction in negative impacts associated with the severe physical environment (wind desiccation, wind speed reduction), 3) reduction in wind and water erosion, 4) reduction in soil moisture loss, 5) reduction in pest species' impacts, and 6) increased socioeconomic benefits to herders. The rehabilitation of degraded grassland and the prevention of further degradation are of vital importance for both improving pastoral livestock production and stabilising the environment (Li et al., P23)

Control of livestock grazing

Fencing can be important for rehabilitating moderately and lightly degraded black soil grasslands. Fencing allows herders to control livestock grazing to provide an opportunity for native forage species to restore their vigour (Ma, P44).

An enclosure trial was undertaken to study the effect of stopping livestock grazing on deteriorated alpine meadows. The yields, frequency, and cover of four classes of herbage (sedge, grass, palatable forbs, and poisonous forbs) were measured. Two years after fencing had excluded livestock grazing the plant cover had increased by 11%, the herbage yield of sedges, grasses and palatable weeds had increased by 65%, whilst the yield of poisonous weeds had decreased by 23%. Dong et al. (P12) suggest that fencing and control of livestock grazing can be used to improve deteriorated grassland. Ma (P41) notes that grass and grass-like plants had invaded deteriorated black beach grasslands that had been fenced to exclude livestock (Ma, P41).

Weed control

Four herbicides were tested to determine their effectiveness in controlling noxious and toxic plants growing on black beaches in which livestock grazing had been controlled. The mixed herbicide (80% metsuiifuron -methyl + 20% tribenuron-methyl) was most effective in controlling weeds after two years of treatment. The dry matter of beneficial species increased by 235%, the yield increased by 136%, and vegetation cover increased from 60 to 95%. Conversely, the dry matter of toxic plants decreased by 735%, their yield decreased by 87%, and the coverage of these species decreased from 90 to 10%. Three genera of toxic plants were completely controlled. The benefits in terms of increased dry matter for livestock were much greater than the costs of application (Ma, P42).

Improved fertility

Urea fertiliser was applied to deteriorated black soil type grassland in eight different treatments ranging from 0 (control) to 262.5 kg/ha. Urea fertiliser applied at the rate of 150 kg/ha provided the best results. After two years of treatment, the total aboveground biomass and biomass of high quality herbage was 827 kg/ha (53% higher than the control) and 584 kg/ha (106% higher than the control), respectively. More work is needed to determine the best timing for fertiliser application (Ma, P41).

Ma et al. (P42) have reviewed techniques for the rehabilitation of areas of black beach. They recommend establishing a seasonal livestock industry in which yak calves and lambs are fattened on sown perennial pastures as a technique for increasing the production of livestock and encouraging natural regeneration of grasslands. The basis for this suggestion is the high gain achieved by young animals over the relatively short grazing periods of the summer forage-growing season.

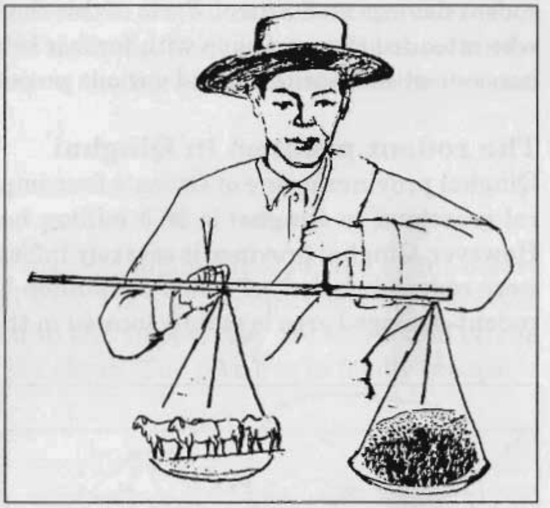
Recommendations

Livestock management and support

Liu and Zhou (P33) have developed the concept of an ideal Rangeland Livestock Industry System (RLIS). This would see an ecological system of livestock production based on the balance of energy transfers between soils, vegetation, and grazing animals with forage being the connecting link. If such a system was established as the basis for livestock production, they believe that the total vegetation productivity of Qinghai rangeland would increase by between 3.6 and 7.2 times.

Liu and Zhou (P33) recommend developing sustainable livestock production systems using RLIS as a guide to 1) developing an infrastructure that includes regulatory mechanisms, proper stocking rates, rangeland monitoring, rotational grazing, exclusion of livestock from degraded areas, and the revegetation of degraded areas; 2) increasing the use of grown fodder and crop by-products; and 3) organising herder livestock production units into family ranch operations.

Wang et al. (P63) assert that, by applying a set of optimum livestock production models, an ecological balance can be obtained between livestock needs and the grassland. The balance can be obtained by: 1) establishing a stable and highly productive artificial grassland to maintain feed and nutrient balance seasonally for livestock, 2) optimising seasonal animal production by using natural pasture for fattening young stock to create a fast turnover; 3) using hybrid livestock instead of native livestock, 4) developing a scientifically based rangeland monitoring and evaluation system, and 5) by developing scientifically based livestock production models that are a synthesis of traditional and innovative methods.



Li (P27) supports implementation of the government promoted Four-way programme of fencing, forage, and oat planting; animal shelter construction; and house construction, as a way for all families to overcome poverty.

Recommendations for overcoming livestock management problems in the project area include:

- using the grassland law to manage and protect the grassland — including preventing cultivation and the digging up of medicinal herbs;
- improving rodent control by concentrating control efforts in areas where populations are forecast to be high;
- controlling overstocking and overgrazing by extending grazing time on summer and fall pastures and reducing the time spent grazing winter and spring pastures;
- improving the effectiveness of techniques to rehabilitate degraded grasslands;
- finding ways to increase funding for rehabilitation and organisation of grassland use, including interest-free loans to herders, using poverty alleviation funds for grassland rehabilitation, and raising funds at provincial and local levels to implement improved management;
- developing ways to increase animal off-take rate through animal production mechanisms; and
- expanding household livestock production to include other animals.

As well as these measures the government should promote the establishment of alternative economic opportunities other than herding livestock.

4.2 Control of Rodents on Rangeland

A REVIEW OF DISCUSSIONS AND CONTRIBUTIONS TO THE WORKGROUP ON RODENT CONTROL, EDITED BY NICO VAN WAGENINGEN

Shortly before the Concluding Seminar, a separate expert meeting was held on the issue of rodent damage and control. Parts of this chapter have been written by the visiting experts[1] who attended the workshop with further information added by the editor, drawing on discussions at the workshop and various project sources.

The rodent problem in Qinghai

Qinghai province is one of China's four important grazing areas. The total area of natural grassland in Qinghai is 36.5 million hectares, of which 31.6 million ha are usable. However, Qinghai province is severely infested with rodents. In 1998 about 8.2 million ha were rodent infested, of which 6.8 million ha were classified as 'severely damaged'. The rodent-damaged area is mainly located in the south of Qinghai, accounting for 81% of the total area damaged by rodents in the province. The main pest rodent species are *Ochotona curizoniae*[2] or plateau pika and *Myospalax baileyi* or zokor. Other rodent species are the Daurian pika (*Ochotona daurica*), Plateau pine vole (*Pitymys irene*), and the Himalayan marmot (*Marmota himalayana*). The total area damaged by the pika in the south of Qinghai is 4.4 million ha, or 64% of the total damaged area in the province. The area damaged by the zokor is about 0.8 million ha (12% of the total damaged area).

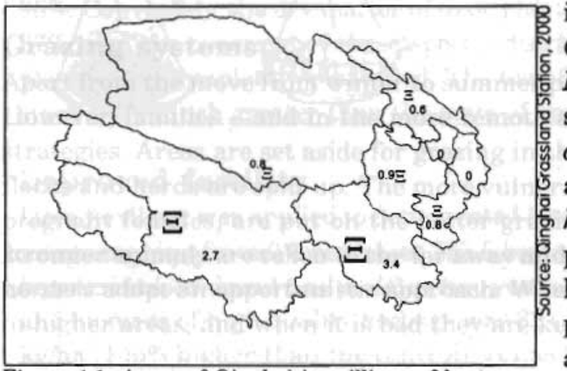


Figure 4.1: Areas of Qinghai in millions of hectares known to be colonised by pika

Nearly one million ha of Dari and Maqin counties (Guoluo prefecture) are colonised by large populations of pika. The area damaged by pika amounts to 74% of the total degraded area of rangelands in Dari and Maqin counties.

According to the calculations of Fan Nai-Chan (P14), there are at least 600 million pikas and 150 million zokors on the grasslands of the Qinghai-Tibet Plateau. It is estimated that they consume 50 billion kilogrammes of fresh grass each year, which is equivalent to the food intake of 30 million Tibetan sheep. The rodents compete with yaks and sheep for grass. They dig and destroy vegetation, and this causes soil erosion, a reduction in ecosystem biodiversity, and changes in the microclimate, which all lead to a reduction in the livestock carrying capacity. A large area of grassland has been degraded beyond the point at which it can regenerate by itself, radically changing the ecology of the environment in which animal husbandry operates.

[1] The workshop took place in Xining from 26 July to 31 July, 2000. The visiting experts are mentioned in Annex 2. Special mention is made here of Dr Pech, Dr Byrom, Dr Fan Naichang, Dr Wu Xiaodong and Dr Ma Yong.
[2] Pika is not a rodent but belongs to the order *Lagomorphae*

Posamentier (R1997) says that the habitat of pika is open land with short vegetation and therefore the occurrence of pika should be seen as an indicator of degraded rangeland and not as a cause. The areas invaded were already suitable as pika habitat.

From the end of the 1950s a number of Chinese research institutes and experts have studied these rodents. This has led to various control methods. The two main institutes studying rodents in Qinghai are the Grassland sections of the Bureau of Animal Husbandry, and the North-West Plateau Institute of Biology.

Ecology and damage of Plateau Pika

THIS SECTION IS FROM FAN NAI-CHANG (P14)

Pikas mainly inhabit the alpine steppe, steppe meadow, alpine meadow, and alpine desert steppe at elevations of between 3,100 and 5,100 masl. Pikas prefer open habitats and avoid dense shrub or thick vegetation. In areas of shrub and steppe, they are only found on the grassland around the shrub, and never enter the shrub. The pika live in family groups.

Pikas have two types of burrow system. Simple or temporary burrows are shallow and short and are mainly used in summer. They usually have only one or two surface openings. The other type is the complex burrow system which occupies larger areas. The average length of the tunnels is 13m, with a maximum of up to 20m. The average depth of the burrows is 33 cm, but they may be up to 60 cm deep. The burrow system has many branches that are connected to form a complex network. There are on average six openings, although some have up to 13. The diameter of the tunnels is between 8 and 12 cm. There is usually one nest in the burrow system about half a metre below the surface. It is bedded with soft dry grass and fur from yak and sheep and is where wintering and breeding occur.

Figure 4.2: Ochotona curizoniae or 'Plateau pika'

Pikas are typical herbivores. They feed on different plants and different parts of one plant selectively. Experiments have indicated that of 31 plant species available in their natural habitat, pikas prefer to feed on only 23 of them. These were mostly grasses, sedges, and legumes. Each pika consumes about 77 grammes of fresh grass per day, which is about 50% of its body weight. The grass consumption of 56 individuals of pikas is equal to that of one Tibetan sheep.

The pika is a diurnal non-hibernating animal. Its above-ground activities peak in the forenoon and afternoon. These peaks change with the seasons. In October the first activity peak occurs at 9 am and the second at 6 pm, while in July the activity peaks come at 8 am and 7 pm.

Close observation of marked individuals indicated that foraging is the dominant behaviour of pikas, comprising 63-78% of their total activity. Pikas have a special feeding pattern, termed as pecking, as after feeding for a moment they look around or move a short distance, and then feed again. Their feeding frequency is 5.7±1.3 pecking bouts per minute.

Social behaviour between individuals comprises 13% of all their behaviour. The most frequent types of social behaviour are intimate and play behaviour. Aggressive behaviour has seldom been noticed, suggesting that there is a weak tendency for exclusiveness. Where appropriate food and space are available, pikas tend to live in high densities, causing damage to grassland.

Pika studies in Himahe in China suggest that the average lifespan of a plateau pika is 120 days. The longest lifespan recorded has been 957 days.

Pikas live in family groups and their home ranges are relatively stable. Males and females exhibit territorial behaviour. During oestrus, the female holds no territory, but the male monopolises the female and drives away other invading males. The neonates of the current year also sometimes drive away invaders once they reach adult body weight.

The average litter size is 4.7±1.3 and an adult female can produce between one and nine offspring per litter. Each year an adult female can produce between three and five litters.

Whilst feeding pikas damage grass roots and also damage the primary grass and soil layers by burrowing, damage is related to the density of the animals. On one hand, an increasing pika populations increases the area of grassland suitable for habitation by rodents, on the other hand, the habitat restricts the size of the population when it gets to the carrying capacity. When the population increases to the carrying capacity, the population ceases to increase, but damage to the grassland still continues, and the grazing intensity increases.

Review of recent research in Qinghai

QLDP's four-year research programme on rodent control worked with Qinghai's Bureau of Animal Husbandry (BAH). The work was strengthened by experimental studies and recommendations by the project consultants and other BAH staff. Trials and investigation were mainly carried out in Wosai, Jainshe, and Dangluo townships (Dari and Maqin counties). The following section details the findings of the research programme and comments from the workshop.

The extent of the problem in Dari

Aiqi Gong et al. (P4) report that an area of 501,300 ha of the three townships is infested by rodents, causing a loss of around 16.1 million kilogrammes of forage each year.

Workshop comments

Here there is much information on the distribution, abundance, and impact of the economically significant rodent species, particularly the plateau pika (*Ochotona curzoniae*) and the zokor (*Myospalax baileyi*). No information was provided to the workshop on the status of the other approximately 45 species of rodents, including 12 other pika species which occur in Qinghai. Although monitoring stations have been established in seven prefectures to record changes in the abundance of rodents (see heading 'Population Monitoring and Forecasting'), it is a very difficult task to properly measure trends in rodent impact, and the sustainability of livestock grazing across huge areas of grassland. In future, remote sensing and GIS technology may be useful for broad monitoring.

The effect of rodents and livestock on herbage yield

A trial was conducted over three years to monitor the effect of the grazing of alpine meadow and resown pastureland by livestock and rodents (Aiqi Gong et al., P2). The result of grazing on herbage yield was as follows: no grazing: control; rodents graze freely, livestock grazing restricted: 45% yield reduction; and rodents and livestock graze freely: 58% yield reduction.

Workshop comments

The no-grazing control group made use of cages (exclosures) that excluded pika and yak from the experimental plots. The relatively small scale of the experiments meant that they were unlikely to represent a cross-section of major grassland types and ranges of levels of livestock grazing. The value of the experiments would have been improved by setting up replicated treatments and by measuring attributes of the pasture such as the biomass and the height and cover of palatable and unpalatable groups of plant species, as well as the abundance of pikas and the levels of livestock grazing.

Comparisons of rodenticides

Four years of rodent control trials compared the chemical poison 'Di Shu Na Yen' (sodium, chlorus, check translation) with the biological poison Botulin toxin C (Aiqi Gong et al. P3). Three different concentrations of the chemical were compared with one concentration of the botulism preparation. The result showed that a 0.09% concentration of the chemical and a 0.1% of the biological agent killed 95% of the rodents exposed to it. The biological agent is comparatively safer as it does not pollute the environment or the food chain and is recommended for use over large areas.

Workshop comments

There was some concern expressed about the experimental design as the timing of the assessment of population impact after baiting was not optimal. Botulin toxin C is a preferred lethal control agent in the grasslands because it does not affect livestock or predators. One problem is that it loses effectiveness at temperatures over 5°C. However a protective agent has been developed that maintains the performance of Botulin toxin C at temperatures higher than 5°C. Data from Qinghai and other provinces of China indicate that many 'rodent' species are susceptible to Botulin toxin C.

Population monitoring and forecasting

This study correlated a reproduction index with the capture rate. Regression analysis was used to forecast capture rates (an indicator for the rodent population) from a known reproduction index. Aiqi Gong et al. (P1) established that the reproduction index as estimated in April will forecast the capture rate in the month of September of the same year and of the next year. Similarly, September's reproduction index correlates with the capture rate of the following April. However, in this regression relation the number of factors is limited.

Workshop comments

The abundance of rodent populations was recorded over three years at nine monitoring stations in seven counties. In autumn of each of the three years the station staff recorded the extent of rodent infestation over the whole prefecture. Each station also used killed samples to collect monthly data on the demographic parameters for the major pest species. (It would have been better to have used live capture methods to monitor the abundance and survival of rodents, with a separate killed sample to measure reproduction.) The aim was to provide three and twelve monthly forecasts of the size of the rodent population. No data were reported to the workshop, although the paper referred to above did include the regression equations for making the forecasts. The predictions apparently have about 70% accuracy, but the predictive models require considerable improvement. For example, they fail to account for factors such as climate, the condition of the pasture, or the level of grazing by livestock. It was suggested that at least seven to eight years of data are required to establish the pattern of rodent population dynamics at the monitoring sites.

Control methods

An experiment compared bait application by machine with the traditional form of application by hand. Another experiment compared bait attractants with commercial, ready-made sterilants. The results indicated that, for rodent control over a large area, the machine-distributed bait is more economical as it saves time and labour, even though it requires an attractant added to the bait. The commercial sterilant did not work very well.

Workshop comments

Although aircraft and ground-based machinery can be used to distribute rodenticides, the project area's difficult terrain and climate necessitate that most rodent control measures are applied by hand. A trial has been conducted to measure the intensity of poison baiting required to effectively control rodents. This trial demonstrated that increasing the spacing of baited strips from every 25m to every 50m did not reduce the effectiveness of control. This led to recommendations to reduce the intensity, and hence the cost, of rodent control. Several types of attractants have been tested. This research is particularly relevant to the future use of control agents such as plant-derived sterility agents which pikas find unpalatable.

Research elsewhere

In many countries the focus is on integrated pest management (IPM). Viruses have been successfully used to reduce rabbit populations. Advances in gene engineering and immunocontraceptives hold great promise for the future.

Opportunities for development

A 'systems' approach to managing grasslands

The substantial findings from the research conducted over many years in Qinghai (Fan et al. 1999) needs to be made more widely available to policy-makers, technicians, field staff, and other people involved in grassland management. It is especially important to increase awareness of how to manage the total grazing system, which includes pasture, livestock, and rodents. Most attention is focused on managing rodents, with insufficient recognition of the strong ecological interactions between the pasture composition and livestock and rodent species for each of the major grassland types.

Rodent community composition and population dynamics

Studies suggest that the suite of rodent species present in an area is related to the habitat type. Also, the population dynamics of each rodent species is affected by environmental factors such as the condition of the pasture and the climate. However, current strategies exclusively focus on the control of the main rodent species. The management of pest species and the conservation of non-pest species could be improved by increased recognition that the whole community of rodent species in an area will respond to changes in the habitat, due for example to grazing by livestock.

Monitoring systems

The current monitoring system provides the basis for the collection of data and the forecasting of pika population dynamics. However, the value of this could be significantly enhanced if additional information was collected on other key aspects of the grazing system such as pasture condition, the abundance of rodents other than pika and zokor, and the level of grazing by livestock. The rodents data will have little use unless the environmental conditions are also measured. Reliable field data will provide essential 'ground truthing' calibration and verification for any future remote sensing monitoring system. Improvements to the monitoring system may require additional training and support for field staff.

Province-wide rodent survey data should be combined with other types of research to produce maps of the distribution and the levels of damage caused by rodents. These would provide better information to enable policy makers to adjust measures taken to suit the differing ecological types. Measures could be fine tuned according to locality. Such maps need producing soon to allow each prefecture to improve rodent management.

Predictive models for rodent population dynamics

The models used to predict changes in the abundance of pikas could be improved significantly. This may require collaboration with specialist scientists from other research institutions in China or overseas. Better predictive models will help to determine when rodent control is necessary. Also, being able to forecast rodent outbreaks would help to increase the effectiveness of rodent control measures by ensuring they are applied before high population densities of rodents are reached. Such modelling exercises are being used to predict outbreaks of Brandt's vole (*Microtus brandti*) in Inner Mongolia in a collaborative project between the Institute of Zoology (IOZ), the Chinese Academy of Sciences, and CSIRO Wildlife and Ecology (Australia).

The province's nine monitoring and forecasting stations should be strengthened to collect more data on grassland vegetation, climatic factors and rodent populations. They should progressively set up a monitoring system based on a geographical information system.

Integrated pest management

Byrom (2000) describes a new approach to rodent management using integrated pest management (Singleton et al. 1999). It recognises the importance of basing control measures on a good understanding of rodent ecology. These studies showed that in the project area further research is required on:

- compensatory responses following pika control which lead to increased survival or reproduction levels;
- the rates of re-invasion by pikas after control;
- the dependence of pika population dynamics on pasture conditions and climate; for example identifying the factors that determine the onset of breeding and survival over winter; and
- the value of controlling pikas compared to other measures such as managing livestock or re-seeding pastures.

Research should be conducted on a large enough scale to provide useful information for grassland management and experiments should include sufficient replication so that results are reliable. In addition, an ecological approach may find that there are conditions in which pikas have a beneficial impact on grasslands. An in-depth study based on work done until now should be carried out on the inter-relationships between rodents, livestock and grassland.

Rodent control technology

Rodenticides used to kill pikas also affect non-target species. Techniques that minimise the effects on other species, such as machines that place the baits in artificial burrows, however, increase the cost of rodent control. Research in Australia, and elsewhere, is developing a new species-specific, environmentally-benign method of sterilising pest species using an immuno-contraceptive vaccine that can be delivered using non-toxic baits[1]. Similar research is being carried out on Brandt's vole in Inner Mongolia. Immuno-contraceptive technology is only in the early stages of development, but there may be opportunities in the future for its application to pest species in Qinghai's grasslands.

Demonstration plots and management practices

Demonstration plots need to be established to show the effects of the Four-way programme interventions such as fencing, rotational grazing, adjustment of herd structure, and the reseeding of rangelands. Three to five areas should be set up covering 5,000–10,000 mu in different ecological zones.

Support for county and township

There is a need for improved support and facilities to county and township staff to allow for effective rodent control. The government should have relevant policies and ensure that adequate funding is made available to guarantee long-term, effective rodent control.

Suitable information towards herders

The knowledge of the herders about rodent control and grassland management also needs improving. A simply written and well-illustrated booklet should be produced. Such a booklet should be made to promote producers' skills.

[1]Details of the technique are described in Chambers et al. (1999).

Better cooperation between research, education and extension institutions
Qinghai province's large size and many types of grassland mean that the rodent pest problem is complex. Therefore for comprehensive rodent control the links between research institutes, universities, and extension agents should be strengthened to combine production, teaching, and research together to promote the effective control of rodents.

4.3 Cereal Fodders, Seeded Perennial Forage, and Rangeland Revegetation

A REVIEW OF RESEARCH CONDUCTED UNDER THE QLDP, BY ERIC LIMBACH

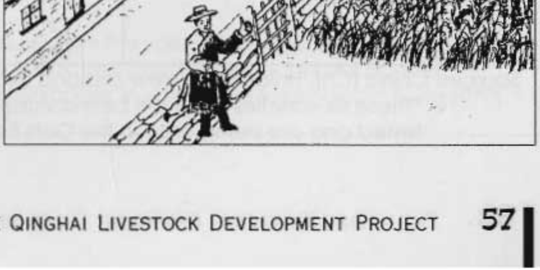
Herders have a difficult life in Guoluo province's harsh sub-alpine and alpine environments. Livestock production is hampered by low rangeland productivity on nutrient depleted soils, snow disasters in late winter and spring, no-to-little conserved fodders, and losses of young stock due to parasites and diseases. Scientists from the Qinghai Academy of Animal Science and Veterinary Medicine (QAASVM) have estimated that overgrazing by pikas has impacted the productivity and livestock production on 49% of the grazeable rangelands of Dari County and on 10% of the grazeable rangelands of Maqin County. Furthermore, black beach affects about 14% of the grazeable rangelands of Dari County and 29% of the grazeable rangelands of Maqin County.

These factors combine to render livestock production in Guoluo well below its potential. The livestock forage base must be improved to help herders to change to a more profitable livestock production system. A considerable impact on livestock health, survival, and production could be made by promoting the production of oat hay in sheep pens during the summer, by selecting adapted grasses to revegetate degraded sites, and by increasing revegetation efforts that have so far not gone beyond demonstrations.

This section reviews the accomplishments of QLDP to introduce improved oat hay varieties, to promote the growing of hay, to field screen improved forage grasses and legumes for revegetation, and finally gives recommendations for rangeland revegetation appropriate to Guoluo.

Cereal fodders for hay production

QLDP initiated a screening programme of cereal fodder varieties in 1996. These field trials were focused on hay production in herders' sheep pens and were enthusiastically carried out by QLDP personnel and scientists from QAASVM. They have been very successful (Jing, P16; Shi, P55; Shi et al., P58 and Yang, P70). Through QLDP's extension efforts, led principally by Yang Lijun, more than 2,200 herder households now grow oat hay for winter feed. Cereal fodder trials were extended from relatively low elevation sites at Xining (2,300m), intermediate elevation sites at Lajia (3,000m), and high elevation sites above 3,000m in Dari and Maqin counties to over 4300m at Sangrima in Dari County.



Introduction of new cereal fodder varieties

Table 4.3 lists the varieties of oats (*Avena sativa*), barley (*Hordeum vulgare*), and rye (*Seceale cereale*) that were screened as cereal fodder crops for growing in Guoluo. It was determined early on that neither barley nor rye did as well as the oat varieties; so further research and extension efforts focused entirely on oats. The growing season in most of Guoluo is generally too short and cool to produce seed from these fodder crops. Oat hay production, however, ranges between about 2,500 and 4,400 kg/ha at most sites, although a few sites were extremely productive, producing in excess of 6,000 kg/ha. At the lower to mid-elevations between Xining and Lajia, oat plants matured rapidly and made good seed production.

Growing oat hay in sheep pens

During part of the winter, especially during lambing season, sheep are kept in pens or corrals constructed of rammed-earth or sod-brick walls. The soils of these pens become well-manured and are high in nutrients. When sheep are herded to high elevation summer pastures, the pens lie dormant. These pens therefore offer protected, high nutrient sites for the production of oat hay in the summer.

Researchers carried out a number of experimental oat seedings in vacant sheep pens. Oats were grown in sheep pens by Jing (P17) in Maqin County (3,200-4,600m); by Li et al. (P28) at Dawu (3,719m); and by Yang (P72) at Lajia (3,650m) and Wusai (about 4,100m) and in a cultivated field in Xining (2,280m). According to the temperature and the length of the growing season, sowing rates ranged from 180 to 255 kg/ha and inter-row spacing from 10 to 20 cm between rows. Seeds were sown at between three and five cm (Jing, P17), three to four cm (Li et al., P28), and four to five cm (Yang, P70). The duration between planting and harvesting was 137 to 145 days at Maqin, 107 to 115 days at Dari, 134 days at Dawu, 150 days at Lajia, 140 to 170 days at Wusai, and 148 days at Xining. Generally, the frost-free period is about 120 to 130 days for areas where oats can be grown in Guoluo.

Table 4.3: Fodder cereals screened for hay production by QLDP

Name	Source	Name	Source
Oats, var. Aare	Fi	Oats, var. Canadian *	Ch
Oats, var. Kapp	No	Oats, Sweet	Ch
Oats, var. Katri	Fi	Xuan 18	Ch
Oats, var. Lena *	No	*Hordeum*, var. Strange	No
Oats, var. Veli	Fi	*Hordeum*, var. Tyra	No
Oats, var. YTA *	Fi	Ryecorn, var. Rahu	NZ
Oats, var. Wakieru	NZ	Spring Oats, var. Aberglen	Wa
Oats, var. Yongjiou 001 *	Ch	Spring Oats, var. Neon	Wa
Oats, var. Yongjiou 108	Ch	Spring Oats, var. Melys	Wa
Oats, var. Yongjiou 233	Ch	Winter Oats, var. Harpoon	Wa
Oats, var. Yongjiou 473 *	Ch	Winter Oats, var. Emperor	Wa
Oats, var. Qinghai 444 *	Ch	Winter Oats, var. Chamois	Wa
Oats, var. Bayan 3	Ch	*Seceale*, var. Norderaas tetra	No
Oats, var. Bayan 4	Ch	*Seceale*, var. Akusti	Fi
Oats, var. Bayan 5	Ch	*Seceale*, var. Anna	Fi
Oats, var. Bayan 6	Ch		

Sources: China (Ch), Finland (Fi), New Zealand (NZ), Norway (No), Wales (Wa)

*These six varieties were the best adapted and most productive of all the cereal fodders tested and are being used in the Oats Extension Campaign for Guoluo herders.

Typically, the sheep pens were shovelled or raked clean of the topmost layer of raw sheep manure. Then the underlying soil and manure were turned over and mixed by manual shovelling, were shallowly disked by small tractor or ploughed by yaks, and finally harrowed and levelled and then seeded (Jing, P17; Li et al., P28). The seed was broadcast at about 225 kg/ha for manual cultivation and 180 kg/ha in drill rows by tractor (Yang Lijun, QAASVM, personal communication).

Dry weight yields ranged between an equivalent of 1,140 and 8,907 kg/ha (Table 4.4). The latter value appears to be extremely high for oat production in Tibetan sheep pens in Guoluo. It is comparable to hay production under modern, intensive agriculture and is at the high

Table 4.4: A comparison of oat hay yields and nutrient content of improved oat varieties at sites in the QLDP area

Variety	Location	Site	Seeding rate (kg/ha)	Yield (kg/ha)	CP (kg/ha)	CP %	CF %
YTA[2]	Dawu	Pen	240	1140	na	11.2	na
YTA[2]	Dawu	Pen	180	**6002	2007	13.7	na
YTA[4]	Laj-Wus*	Pen	200	**5655	1758	na	na
YTA[5]	Dawu	Pen	na	**6640	2221	na	na
YTA[6]	Laj-Wus*	Field	188	2414	1837	11.9	28.0
YTA[7]	Lajia	Field	191	3783	na	na	na
YTA[8]	Lajia	Field	na	4770	na	na	Na
Lena[4]	Laj-Wus*	Pen	200	**5260	1794	na	Na
Lena[6]	Laj-Wus*	Field	188	2566	1682	10.8	27.2
Lena[7]	Lajia	Field	189	4484	na	na	na
Lena[8]	Lajia	Field	na	4970	na	na	na
Melys[4]	Laj-Wus*	Pen	200	**8907	2563	na	na
Melys[6]	Laj-Wus*	Field	188	4675	2102	12.3	23.0
Melys[7]	Lajia	Field	191	5885	na	na	na
Melys[8]	Lajia	Field	na	5283	na	na	na
Neon[4]	Laj-Wus*	Pen	200	**7844	2176	na	na
Neon[7]	Lajia	Field	191	5955	na	na	na
Neon[8]	Lajia	Field	na	4872	na	na	Na
QYJ 001[4]	Laj-Wus*	Pen	200	**5800	1837	na	Na
QYJ 001[1]	Dari	Field	250	4287	na	na	Na
QYJ 001[6]	Laj-Wus*	Field	188	4777	2314	11.8	29.0
QYJ 001[7]	Lajia	Field	202	**4844	na	na	Na
QH 444[1]	Dari	Field	250	5584	na	na	Na
QH 444[4]	Laj-Wus*	Pen	200	**4936	1246	na	Na
QH 444[6]	Laj-Wus*	Field	188	2871	1576	10.9	24.8
QYJ 473[1]	Dari	Field	250	4730	na	na	na
QYJ 473[6]	Laj-Wus*	Field	188	2823	1736	10.6	29.6
Bayan 3[1]	Dari	Field	250	3923	na	na	na
Bayan 3[7]	Lajia	Field	200	**8348	na	na	na
Bayan 4[1]	Dari	Field	250	4080	na	na	na
Bayan 5[1]	Dari	Field	250	5291	na	na	na
Bayan 6[1]	Dari	Field	250	3765	na	na	na
QYJ 108[1]	Dari	Field	250	3361	na	na	na
QYJ 233[1]	Dari	Field	250	4204	na	na	na
Xuan 18[1]	Dari	Field	250	5612	na	na	na
11Varieties[3]	Dari - Dawu	Pen	225-255	4730-5612	na	na	na

QH = Qinghai QYJ = Qing Yongjiu CP = crude protein CF = crude fibre
*Field trials at Lajia & Wusai
** These values were recalculated (multiplied by 0.3636) from the values reported by assuming that the reported values considered dry weight to be about 0.33 rather then 0.12. na = not applicable
[1] Shi Jianjun et al. (P58). [2] Li et al. (P28). [3] Jing (P17): only ranges in values were reported. [4] Yang (P70). [5] Li et al. (P28). [6] Shi et al. (P58). [7] Shi (P55). [8] Yang (P70).

end of such a production range. It appears safe to assume that oat production in sheep pens of Guoluo generally falls into the 1,000-4,000 kg/ha range in these studies, especially in high rainfall summers, like the summer of 1999.

Seed application rates and growth period

QLDP researchers have tested a variety of sowing techniques, sowing rates, and sowing dates. Li et al. (P28) investigated the yield of YTA oats and nutrient content using 60, 120, 180, 240, and 300 kg/ha sowing rates and a 107-day growing period (13 May–28 August) and one of 135 days (13 May–25 September). They determined that 240 kg/ha was the optimal sowing rate. The earlier (end of August) harvest date yielded a greater quantity of hay although it was not as nutritious as samples harvested at the mid-point between 28 August and 25 September. In a corroborative study, Li et al. (P28) demonstrated that 13 May was the best time to sow oats in sheep pens. Later sowing reduced the hay yields and the crude protein content.

In a similar trial Yang (P70) found that a seeding rate of 180 kg/ gave the highest hay yield (1,140 kg/ha). In this case the effects of competition for light at the higher sowing rates of 240 and 300 kg/ha caused lower leaf yields but taller plants. This also gave higher crude fibre yields and lower crude protein contents than the higher sowing rates.

In a separate study, Yang (P70) investigated the effects of hormone and fertiliser application, both alone and in combination, on the yield of hay. Interestingly, fertiliser had hardly any effect on yield compared to the high nutrient sheep pen control. However, growth hormone did increase yields but did not cause seed set and, ultimately, was not deemed appropriate.

Genetic characteristics of oat phenotypes

The isozymes of esterase of four introduced oats and six domestic oat varieties were investigated by Shi et al. (P55) using polyacrylamide gel electrophoresis. Isozyme biochemical characteristics are controlled at the gene level and the stability of esterase isozymes provides an effective means of determining genetic relationships between plant varieties. Six phenotypes were identified by comparing 16 bands of esterase isozymes. The 10 oat varieties were grouped as: 1) Melys and Neon phenotype, 2) YTA and Lena phenotype, 3) Yongjiu 108 and Qinghai 444 phenotype, 4) Canadian and Yongjiu 001 phenotype, 5) Canadian and Yongjiu 473 phenotype, and 6) Bayan 3 phenotype.

After being multiplied in Guoluo, the isozyme characteristics of the progeny of the four introduced varieties and Qinghai 001 did not change from the patterns of their parents. This genetic stability indicates that these varieties should breed true for at least four or five generations. It is important to classify the genetic characteristics of the about 600 oat varieties at QAASVM to better understand which varieties are related.

Seed production

Since 1996, the area in Guoluo producing foundation oat seed has increased from 225 ha to about 2,714 ha (Jing, P16). Growers are also producing seed on a further 12,540 ha (Jing, P16). This seed is supplied to Guoluo, Xinjiang, and Tibet. The most important oat varieties include YTA, Melys, Lena, Canadian, Yongjiu 001, Yongjiu 473, Xuan 18, Bayan 5, and Qinghai 444. Oat seed trials were established in Xining (Yang, P72) and Lajia, Maqin County (Shi, P57). Their results are presented in Table 4.5.

Table 4.5: Seed yields and ripening periods at Xining and Lajia for six oat varieties

Variety	Xining[1]		Lajia[2]	
	Yield (kg/ha)	Days to ripen	Yield (kg/ha)	Days to ripen
YTA	3560	102	4770	104
Melys	3750	118	5283	123
Neon	3600	117	4872	129
Lena	3630	115	4874	117
Yongjiu 001	3090	95	--	--
Qinghai 444	3630	101	--	--

[1] Yang 2000a
[2] Shi 2000

The yields were higher and the days to ripening longer in Lajia than in Xining. The fact that the Lajia plots received 405g ammonium phosphate and 105g of urea while the plots in Xining were not fertilised largely accounts for differences in seed yields. On the other hand, the site at Lajia is at an altitude of about 700m higher, which helps to explain the slightly longer period taken for ripening for all varieties there. At any rate, these varieties demonstrated their seed production capacities and the seed of these varieties is being multiplied and expanded across southern and eastern Qinghai.

Adoption by herder households

The oat hay campaign has been extremely successful across the QLDP project area. About 2,318 herder households are now growing oats in sheep pens over about 515 ha (Yang, P71). These pens have produced an accumulated production of about 4,414,500 kg of oat hay, an average of 8,543 kg/ha for each household. The statistics' bureau of Guoluo assumes that one kilogramme of hay has a value of about 0.4 yuan. This valued the oat production to be equivalent to about 1,759,858 RMB. As production costs average about 1,147.5 RMB/ha the surplus value of oat hay produced in the project township has been about 1.1 million RMB, or about 500 RMB per household. Jing (P16) estimates that production of oat hay in sheep pens benefits herders to the extent of about 480 RMB per household. Unless oat seed becomes very expensive, the enthusiasm with which the herders have taken to growing oats for winter hay should continue.

Introduced perennial forages

Perennial forages are required in Guoluo for the revegetation of degraded rangelands, to arrest the erosion of soil on black beach and other severely eroded sites, and to improve the rangeland forage base for sheep and yaks. At present, QAASVM has over 700 types of perennial forage grasses in its seed collection, but few have been tested under field conditions at high altitudes. Between 1996 and 1999, QLDP and QAASVM introduced 72 varieties of improved forages grasses to Guoluo (Limbach R1998, R1999, R2000; Liu, P31; Shi et al., P58). These introductions included 18 legume varieties and 54 perennial grass varieties from within and without China (Table 4.6).

Table 4.6: Perennial grass and legume forage varieties introduced by QLDP

Scientific Name	Source	Scientific Name	Source
Agropyron dasystachyum	Ca	*Lupinus luteus*	Ca
Agropyron intermedium	Ch	*Medicago falcata*	IM
Agropyron longatum	Ch	*Medicago falcata*	Ch
Agropyron smithii	Ca	*Medicago sativa var. Able*	Ca
Agrostis alba	Ca	*Medicago sativa var. Anik*	Ca
Agrostis hugoiana	Ch	*Medicago sativa var. orsa*	Ge
Alopecurus pratensis	Cn	*Onobrychis sativa var. Remont*	Ca
Astragalus cicer	Ca	*Oryzopsis munroi*	Ch
Bromus inermus	Ge	*Phleum pratense*	Ca
Bromus inermus var. hakari	NZ	*Phleum pratense*	Ge
Bromus inermus var. tiki	NZ	*Phleum pratense var. Engo*	No
Dactylis glomerata	Ca	*Phleum pratense var. hja*	Fi
Dactylis glomerata var. haka	Fi	*Phleum pratense var. tammisto*	Fi
Dactylis glomerata var. tatu	Fi	*Phleum pratense var. tuukka*	Fi
Deschampsia caespitosa	Ca	*Phleum pratense var. vega*	Fi
Deschampsia caespitosa	Ge	*Poa alpina var. mantelsaatgut*	Ge
Deschampsia flexuosa	Ge	*Poa annua*	Ge
Elymus nutans	Ch	*Poa compressa*	Ca
Elymus sibiricus	Cn	*Poa crymophila*	Ch
Elymus trachycaulus	Ca	*Poa poiphagorum*	Ch
Festuca arundinacea var. retu	Fi	*Poa pratensis var. alpina*	Ca
Festuca fascinata	Ch	*Poa pratensis*	Ge
Festuca kirilovii 01	Ch	*Puccinellia tenulflora*	Ch
Festuca kirilovii 02	Ch	*Roegneria pauciflora var. hylander*	Ch
Festuca ovina	Ca	*Stipa viridula*	Ca
Festuca ovina	Ch	*Trifolium hybridum*	Ge
Festuca ovina var. Karst	Ch	*Trifolium pratense var. jokionem*	Fi
Festuca ryloviana 01	Ch	*Trifolium pratense var. kolpo*	No
Festuca ryloviana 02	Ch	*Trifolium pratense var. pawera*	NZ
Festuca rubra var. America	Ch	*Trifolium pratense var. tepa*	Fi
Festuca rubra subspp. Rubra	Ge	*Trifolium pratense var. violetta*	Ge
Festuca rubra subspp. Rubra	Ca	*Trifolium repens*	Ge
Festuca sinensis	Ch	*Trifolium repens var. tooma*	Fi
Festuca rubra var. Tongde	Ch	*Trisetum flavescens*	Ge
Hordeum violaceum	Ch	*Vicia faba var. alfred*	Ge
Koeleria cristata	Ca	*Vicia sativa var. ebena*	Ge

Sources: Canada (Ca), China (Ch), Finland (Fi), Germany (Ge), Inner Mongolia (IM), New Zealand (NZ), Norway (No)

Tibetan Mixture (Ge): *Agrostis canina, A. gigantea, A. capilaris, Festuca rubra subspp. rubra, F. rubra subspp. Communtata, Poa alpina, Phleum pratense, Poa annua, Deschampsia flexuosa, Trisetum flavescens, Dactylis glomerata, Anthyllis vulneria, Lotus corniculltatus, Trifolium hybridum, Trifolium repens, Achillea millefolium.*

It is not for lack of knowledge or access to adapted plant materials that rangeland revegetation is yet to happen in Guoluo. A number of varieties of perennial forage grasses have been identified as suitable for rangeland revegetation at high altitudes in Guoluo. Of the 54 varieties of perennial grasses screened in field trials or used in rangeland reseeding efforts, at least 12 have proved well adapted to Guoluo's environment. These varieties include exotic introductions from outside China and introductions from other regions of China. All of these varieties are of species indigenous to the Qinghai-Tibetan Plateau. They include *Deschampsia caespitosa, Elymus nutans, E. sibiricus, Festuca kirilovii, F. ovina, F. rubra, F. ryloviana, F. sinensis, Poa compressa, P. crymophila, P. pratensis var. alpinum*, and *Puccinella tenuflora*. The real obstacles to enlarging rangeland revegetation efforts in Guoluo and Qinghai are the relatively high cost of mechanised reseeding operations and the availability of seeds. The seed production base of forage grasses has not been developed for large-scale reseeding operations.

Legumes are important for providing nutritious livestock forages that are high in nitrogen and crude protein. Furthermore, legumes that are inoculated with nitrogen-fixing bacteria, such as *Rhizobium* spp, help to enrich the fertility of the soil. However, hardly any of the legumes grown by Limbach (R1999, R2000) survived in the field, although two varieties of *Medicago falcata* did survive weakly and are persisting in a protected area at Dawu Seed Farm, Maqin Co. Yang (P73) also reported poor performance of legumes when sown at Lajia (3,700m) and Jianshe (4,100m). Dry matter yields have ranged from 40 to 410 kg/ha, averaging about 160 kg/ha. It is recommended that future legume introductions are limited to indigenous varieties collected on the Qinghai Tibetan Plateau.

Rangeland revegetation

This section focuses on rangeland revegetation to improve rangeland productivity and livestock production in Guoluo Prefecture in particular and Qinghai Province and western China, in general. Xung (P67) has reviewed range management and rangeland revegetation practices and policies carried out in Qinghai from the late 1950s.

A major caveat needs to be considered when considering rangeland revegetation. Restoring the productive capacity of degraded ranges is a major undertaking. It is expensive in terms of time, money, and manpower and is very risky. When the plant community has been degraded or transformed to a lower ecological-successional status, an ecological threshold has been crossed. This ecological threshold is a theoretical demarcation between plant communities of different successional status. It represents a dividing line between a more desirable plant community and a less desirable one. Degraded plant communities have a lower ecological status and provide poorer grazing. Once rangeland has moved over to the lower, less productive status, it is very difficult to return it to a more productive status. Direct manipulations, such as revegetation using modern equipment and rehabilitation techniques, are needed to restore a productive plant community. There will always be a risk that after all the effort and money invested the seeding fails.

A successful rangeland revegetation programme can produce the following benefits.

- Increased Forage Production - The seeding of desirable species into severely degraded ranges can increase forage production. However, reseeding is expensive and risky and should not be the first measure to be considered. A review of existing management and alternative options may suggest other ways of increasing forage production at less expense.
- Increased Forage Quality – Successful reseeding can lead to more palatable forage which has a higher nutrient content or a longer green growing period. Changes in management methods may be the most cost-effective means of accomplishing this goal.
- Increased Animal Production - This is a primary goal whether we are concerned with livestock or wildlife. Increased animal production translates into healthier new-born animals and lower mortality rates and greater prosperity for herder families.
- Control of Poisonous Plants - Poisonous plants may be routinely removed by pulling, spraying with herbicides, or burning provided that desirable species are present to re-

grow after the poisonous plants have been removed. If they are not present desirable species have to be seeded in. One of the main features of the overgrazed rangelands in Guoluo is the preponderance of poisonous species such as *Aconitum*, *Delphinium*, and *Ligularia*.

- Reduced Soil Erosion and Better Water Quality - Enhancing and promoting a denser vegetative cover will restore water quality on deteriorated watersheds. On severely eroded sites such as black beaches, soil stabilisation may justify restoration of the vegetative cover, with forage, and livestock production benefits being only the secondary consideration. For watershed improvement, the goal of revegetation should be to enhance the capture, storage, and slow release of water. A good vegetative cover aids the capture of precipitation by allowing it to infiltrate and be stored in the soil to be slowly released into streams. Enhanced watershed values also benefit wildlife and fish.

The counties, townships, and herders are sharing the costs of range revegetation projects in Guoluo. Once completed, the management of these restored rangelands needs changing to correct the problems that caused the original degradation. Part of this improved management strategy is already in place with implementation of the Four-way programme: Table 8 gives the perennial grass and legume forage varieties introduced by QLDP.

Reseeding of degraded rangelands

The successful reseeding of degraded rangelands requires considerable technical and financial inputs, good planning, and coordinated efforts. The following all need careful attention: site selection , selection of adapted plant materials, seedbed preparation, seeding techniques, fertiliser application, and control of rodents and weeds. After sowing the reseeded rangelands need to be continuously monitored and the grazing controlled. Reseeding efforts that initially appear to have only a low seedling density, such as one shoot in every one to one and a half square metres, can still be successful if plant reproduction and expansion occur in subsequent years. At present, the cost of reseeding degraded rangelands in Guoluo is about 120–150 yuan/mu (Ma Yushou, personal communication). This cost is considerably higher than in many other parts of the world. For example, the target costs for revegetation efforts in the Great Basin region of North America usually range from between 30 to 60 yuan/mu. One way of reducing the cost is to use a rangeland drill.

The rangeland drill

The rangeland drill has a number of features that make it superior to conventional seed drills for reseeding rangelands. (Note that direct seeding is variously referred to in the literature as 'inter-seeding', 'sod seeding', or 'over-sowing'). These features are as follow.

- Direct sowing: A no-till seed drill can seed directly into intact grassland sod, eroded soils or rough rangeland without prior mechanical preparation. The advantages are that it simplifies logistics and reduces the cost of reseeding. A chisel in the front of each planter unit opens a furrow in the sod, a delivery tube drops seeds into the furrow (with the depth band maintaining the proper planting depth) and a press wheel, behind, closes the furrow; fertiliser can be applied simultaneously with the seeds.
- Heavy duty design: The rangeland drill on the other hand is designed for use on rough, rocky terrain and hard, unploughed soils. It is stronger and more heavily constructed

than conventional seed drills. Each planter unit is separately hinged with a depth regulator band so that each planter unit works independently. Furthermore, end wheels on the back of the drill ensure that sod openers (see below) neither gouge the soil too deeply nor become airborne when working on rough ground.

- Less soil erosion: Direct seeding greatly reduces soil erosion problems associated with ploughing. It has the additional advantage of the seeding operation being performed in one operation.
- Cost effectiveness: A typical reseeding operation, using traditional agronomic techniques might consist of the six separate operations of woody plant removal, root-ploughing, harrowing, broadcast seeding, application of fertiliser, harrowing again, and roller packing. Direct seeding with a rangeland drill may require only one pass over the land. Consider the comparative costs in fuel and manpower between the two operations. At present, the cost of reseeding degraded rangelands in Guoluo is about 120–150 yuan/mu (Ma Yushou, personal communication). This cost could be reduced to perhaps 30–60 yuan/mu by using the rangeland drill.

Site selection

It is always best to choose revegetation sites that have the highest potential for recovery. Very degraded sites will often provide hardly any worthwhile returns on reseeding investment. A site's potential will often be indicated by the vigour or productivity of unpalatable plants growing on the site. Sites with high potential but current low production are the sites with the best potential.

Herbicides

Undesirable weeds can be eradicated by applying herbicides such as phenoxy herbicides (2,4-D or 2,4,5-T) or glyphosate 'Roundup'. Herbicides can be formulated to target either grasses or broadleaved plants forbs, shrubs, and trees. They can be sprayed or applied in the form of pellets. Spraying can be done from the air by plane or helicopter, or from the ground. Ground applications are usually done by 12–40 ft wide boom-sprayers mounted on tractors or caterpillar tractors or by hand-held pump, backpack sprayers. Application by backpack sprayers has the advantage of only effecting the target plants; but it is a very time consuming way of treating large areas.

Planting season

In Guoluo seeding is traditionally carried out early in the spring, whereas autumn seeding is practised on the rangelands of the Great Basin and in western Canada. Autumn sowing is preferable as it overcomes the following difficulties.

- When sowing is delayed until late spring or early summer, a significant portion of the growing season is lost for seedling growth, development, and establishment.
- The seeds of some species require stratification (cold period) to break dormancy and initiate germination.
- Seeds require a period of moisture inhibition to hydrate the seeds and initiate their physiological processes.

Autumn is the time when native seeds disperse and become part of the soil seed bank. Autumn seeding deposits seeds just prior to freezing and snowfall. This ensures that seeds go through freezing and thawing cycles to break dormancy or other germination requirements. Autumn seeding puts the seed in place so that the following spring, as soon as conditions of warmth and moisture are optimum, germination and emergence can immediately proceed. This gives seedlings the whole growing season to grow, develop, and establish. Spring seeding may miss the period of optimum germination for various reasons, but often because the site is not accessible until after optimum conditions occur.

However, if ranges are seeded too early in the autumn, the emergent seedlings need to be well established before winter sets in or there is a risk of losing them to frost heaving. This may be one of the reasons why seeding is typically delayed until spring in Guoluo. Another reason given by researchers at QAASVM is that they have no control over the reseeded area in autumn and winter as at this time the researchers are outside the area.

Seeding rates

Seeding rates tend to be too high in Guoluo. Typically, herders sow oats at 12.5–15 kg/mu (154–186 kg/ha), (Grassland Experiment Report 1997). This may be a consequence of poor seed quality. If seed is mixed up with an equal amount of inert materials and non-viable seeds, then these high seeding rates make some sense. Furthermore, if germination rates are correspondingly low, say <33%, then seeding at 170 kg/ha will be equivalent to using only about 28 kg/ha of pure live seed. Seeding rates for rangeland revegetation efforts elsewhere are about an order of magnitude lower than in Guoluo, typically between 9–17 kg/ha with seed quality much higher as it contains less than five per cent of inert materials and more than 90% of the seeds will be viable. Seeding rates could be significantly reduced and the limited seed supply more economically used if harvested seed materials were mechanically cleaned to increase quality.

Causes of reseeding failures

The most common causes of reseeding failures are the failure of seeds to germinate, the failure of seedling emergence, and the failure of plant growth and development. Generally, failures can be attributed to the wrong choice of species, poor seed quality, improper seedbed preparation and seeding techniques, predation of seeds and emergent seedlings by rodents, and improper management following reseeding.

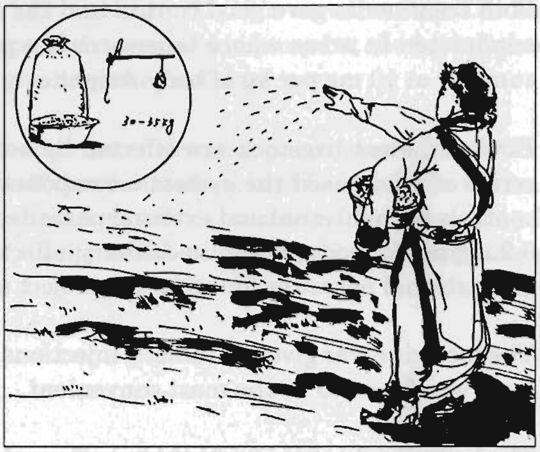
Germination and emergence fail due to poor seed quality, planting seeds too deeply, seed dormancy, soil crusting, low temperatures, drought and desiccation, insufficient soil moisture, wind and water erosion, seed predation, herbivory by rodents and insects, insufficient soil coverage of seeds, and poor seed quality.

Seedling establishment may fail due to drought, frost heaving, competition from weeds, poor drainage, low fertility, desiccation, herbivory by rodents and insects, wind and water erosion, failing to inoculate legumes, and grazing too soon.

Proper seedbed preparation should include: 1) the eradication of pikas, 2) removal of competing plants (by ploughing and letting the seedbed lie fallow or by applying herbicides), 3) ensuring there is firm soil below the seeding depth, 4) disking and harrowing to pulverise and mellow the topsoil, and 5) compaction by rolling or roto-tilling in the following seeding.

Seed may be either broadcast or planted in rows. Aerial broadcast seeding from a plane or helicopter can cover large areas of black beach on inaccessible steep mountain slopes.

The main problem with broadcasting seed is that the seed will not be covered for germination and the establishment of roots. However, some species do well when broadcast on to snow. With the spring snow melt they are carried down to the soil where they find very moist conditions suitable for germination. Planting in drill rows gives more control over seeding rates and planting depths. Drill rows are usually 15 to 40 cm apart. The wider the drill row spacing, the less the plants in adjacent rows will compete for soil water and nutrients.



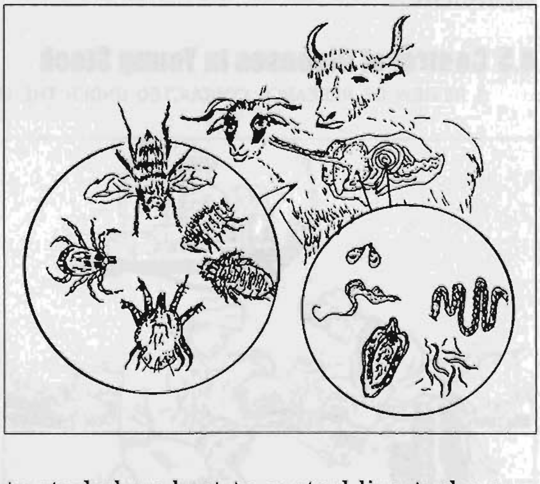
The job of revegetation is not finished when the new pasture or range becomes established. Established seedlings should only be exposed to grazing from the second year and a further year's deferrment is preferable. If the poor management practices that helped to previously degrade the site in the first place are not corrected, then the reseeding effort will be to no avail.

4.4 Control of Parasites in Sheep and Yaks

A REVIEW OF RESEARCH CONDUCTED UNDER THE QLDP, BY JOHN DAVIS

Parasite control

Investigations early in QLDP revealed that internal and external parasites caused a serious problem to livestock in southern Guoluo. Many of the livestock are infested, and since the privatisation of livestock and grazing land, the practice of parasite control is less rigorously implemented. The individual allocation of land has meant that many of the dip baths are no longer used because of access problems. Also, under the new system of individual responsibility, the government no longer supplies either anthelminthics or chemicals to control external parasites.



A series of trials was initiated by the project to study how best to control livestock parasites .One trial looked at the control of internal parasites using the standard anthelminthic, albendazole. It is relatively cheap and was found to give good control of common internal parasites found in the project area with significant increases in live weight gain and a greater survival of treated animals. The following two treatments were tested:

- one double dose of 20 mg per kg of body weight at the start of the winter; and
- two doses of 10 mg per kg of body weight with the first dose at the start of winter and the second in March.

Both treatments gave good control and the single dose is preferred because it is easier to administer. In areas where tapeworm is a problem the animals should be treated in late summer at 10 mg per kg of body weight.

However, most livestock are affected by both internal and external parasites. A second series of trials used the systemic compound, Avermectin. This is more expensive but it controls both internal and external parasites. In the trial, the drug, when administered at 0.2 mg per kg body weight in January, effectively controlled most of the common internal and external parasites found in the project area, including warble fly in yaks.

The medicine was given as tablets, injections, aerosol sprays, and in suspension. The tablet form was found to be the most convenient.

The body weight gains and increases in wool yield were recorded for animals that survived the winter. Increases in survival rates were: 17.9, 1.8, and 4.3% for yearling lambs, ewes, and calves respectively. Increases in body weight were 4.8 kg, 2.9 kg and 3.4 kg for the different groups. Extra wool production was on average 0.08 kg per ewe.

Assuming that, on average, the cost of medicines was 0.4 yuan per sheep and 1.0 yuan for yak calves, whilst labour cost 30 yuan per day per 100 animals with veterinary charges of 0.2 yuan per animal; and if the animals are valued at 50 yuan per lamb, 150 yuan per ewes, and 200 yuan per calf with wool worth 5 yuan per kg, then the cost benefit of the treatment would be 1:6.47. The benefits are worth more than six times the cost of the treatment.

4.5 Control of Diseases in Young Stock

A REVIEW OF RESEARCH CONDUCTED UNDER THE QLDP, BY JOHN DAVIS

Field data show that in the prefecture as a whole approximately 10% of the calves and 25% of the lambs die each year or before reaching maturity? The main causes of death are diarrhoea and in some cases pneumonia. The death rates in Dari are worse than the prefecture average whilst those in Maqin are better than average. A series of trials was initiated based on work undertaken by QAASVM. Firstly, the presence of pathogenic organisms was investigated. Four strains of *E. Coli* were found plus *Salmo-*

nella and *Clostridium*. One rotavirus was identified in lambs. The sensitivity of the bacterial strains to various antibiotics was then tested. A mixture known locally as 'Xu lilin' proved most effective.

The effectiveness of Xu lilin was tested in the field. The administration of 20 ml per day for calves and three ml per day for lambs over the first three days of their life increased the survival rate by nearly 10% in calves and by 13% in lambs. Xu lilin was also found to be effective as a treatment for animals that became ill if it was administered at the rate of one ml per kg of body weight, with a double dose given on the first day.

Following the success of these trials, a large-scale extension campaign started in 1998. Training courses were held for government staff, herder leaders, and herder technicians. Medicines were made available during the lambing and calving seasons. The provision of short-term credit for the herders to buy the inputs will be important to the long-term adoption of this technique.