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Rangeland Utilization and Biodiversity on the Alpine Grasslands of Qinghai Province, People's Republic of China

The Use of Regional and County-Level Datasets
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1 Introduction

It is important to understand the utilization of rangelands by pastoralists and, concomitantly, the potential effects of rangeland utilization on biodiversity, if efforts are to be made to ensure that such resources are managed sustainably. However, data on rangeland utilization and local biodiversity are often lacking, and it is not always clear how such data (when available) should be used to inform management decisions. Use of such data can even be more problematic when they were not gathered with the goal of evaluating sustainability or its relationship to biodiversity, or when they may be corrupted because of political forces. Nevertheless, on a regional basis and particularly in developing areas, broad-scale datasets that address rangeland issues may serve as the best starting point in any evaluation of such an area's natural resources. We examine series of provincial- and county-level datasets from the alpine grasslands of Qinghai Province, People's Republic of China, that describe rangeland utilization patterns and issues of sustainability that bear on continued use of this pastoral ecosystem and conservation of its native biodiversity. We evaluate these datasets and demonstrate their strengths and weaknesses toward the goal of assisting management decisions at the local, county, and provincial level.

We have chosen to focus on the alpine grasslands of Qinghai Province for several reasons. First, these high altitude grasslands constitute a large proportion of the province (385,873 km2, nearly 54% of the provincial area of 721,l97 km2, Jing 1986), and pastoralism impacts nearly all of the available grasslands (Hu et al. 1992, Wu 1997). Over 22 million head of livestock, mostly sheep and yak, utilize these rangelands in Qinghai (Drandui 1996). In a broader context, the high altitude grasslands of the Tibetan plateau extend over 2.5 million km2, and rangeland covers nearly 70% of this total land area (Miller 1995). Thus, although the Tibetan plateau is not homogeneous, our analysis of Qinghai will serve as a benchmark for understanding the demands of pastoralism upon Tibet's alpine grasslands and the extent to which the area can serve as a valuable refuge for wildlife. Second, this area has been grazed by domestic livestock going back at least 2,200 years (Zhao 199x) - thus it can be assumed that sustainable husbandry has been practiced throughout the region by the indigenous Tibetan pastoralists that occupy this part of the Tibetan plateau (Ekvall 1968, Clarke 1987, Goldstein and Beale 1990, Wu 1997). Most pastoralists belonged to one of the Tibetan tribes, but a few Mongol tribes also had significant impact in the area of present-day Qinghai, both in terms of their population and the land they occupied or controlled (Lattimore 1940, Schram 1954, Smith 1996). Third, there have been massive changes over the past several decades on the grasslands of Qinghai Province, and now there is every indication that the habitat in the region has been seriously degraded (Hu et al. 1992, NAS 1992, Lang et al. 1997). Only l% of the land area of the province currently has protected status (MacKinnon et al. 1996), thus any attempt to preserve biodiversity must include a comprehensive analysis of the condition of all pasturelands and their state of degradation. And fourth, the area possesses a distinctive mammal fauna that is fairly well-known and can be used as a measure of regional biodiversity (Hoffmann 1991 , Zhang 1991; Li 1989).

Many independent research programs have concluded that the average productivity of the rangelands on the Tibetan plateau is currently about 30% less than two-to-three decades ago (Hu et al. 1992; NAS 1992, Lang et al. 1997; Long & Ma 1997). From 1949 to 1994 the livestock population increased dramatically in Qinghai, while the ratio of pasture area per animal decreased substantially (from 4.2 to 1 .4 ha/animal, Long & Ma 1997). A recent sample of 111 villages in a relatively productive area of Qinghai found that "...degraded areas of temperate grassland, of alpine grassland, and of temperate desert grassland are 45.12%, 33.56% and 35.28% of their respective total utilizable areas" (Lang et al. 1997). This same report found that above-ground biomass decreased by over 73%, while prevalence of toxic plants increased 5.6 times. These trends have occurred simultaneously with several profound changes in the manner in which the land has been managed -- primarily through attempts by external forces to modernize production methods in the remote areas occupied by pastoralists. Unsustainable agriculture has been introduced to the grasslands (Wei 1986).

Husbandry was collectivized for most of the period between 1956 and shortly after the end of the Cultural Revolution (1966-1976) and then formally privatized in 1985 under the new Household Contract Responsibility System (Ho 1998). Traditional trade networks were disrupted (Goldstein and Beale 1990). And an insidious thrust to "settle down" many nomads has been undertaken with a corresponding reduction in the spatial mobility of livestock herds (Miller 1995). The most important ecological factor affected by changes in spatial mobility of herds is the differential use of seasonally important grasslands, namely summer and winter ranges (Cincotta et al. 1992; Miller 1995).

At the same time biodiversity on the plateau has been declining precipitously. The native ungulates used to present a specter similar to the Serengeti plain of Africa, yet now their numbers and distribution have been severely reduced (Schaller 1998). These declines may be due to a variety of factors, including illegal poaching, fencing, and increased degradation of the alpine meadow ecosystem. A key stone species on the grasslands, the plateau pika (*Ochotona curzoniae*) has been poisoned indiscriminately over huge areas to increase forage production for livestock (Smith et al. 1991). Between 1986 and 1994, insect and "rodent" control programs have affected an area of 74,628 km2, nearly one-fifth of the provincial grazing lands (Drandui 1996). Loss of pikas eliminates many symbiotic species that nest in pika burrows (i.e., the only lizard, *Phrynocephalus vlangalii*, Hume's ground jay, *Pseudopodoces humilis*, several species of snow finches, *Montifringilla* spp.), their mammalian predators (i.e., Asian polecats, *Mustela eversmanni*, mountain weasels, *M. altaica*, Tibetan sand and red foxes, *Vulpes ferrilata*, *V. vulpes*, Pallas' cat, *Otocolobus manul*), and their avian predators (i.e., Black kites, *Milvus migrans*, upland buzzards, Buteo *hemilasius*). Wolves (*Canis lupis*) and brown bears (*Ursus arctos*) also rely heavily on pikas for food (Prezewalski 1883; Koslov 1889; Schaller 1998). In addition, pika burrowing recycles nutrients and presents a micro-disturbance regime that enhances plant species richness (Smith et al. 1991).

Our analysis of provincial- and county-level data will give a detailed look at how contemporary changes in land use have affected the ability of the grasslands to support a viable pastoral way of life and still maintain the essential components of the region's biodiversity. Many important aspects of this subject are intertwined, and we show how these disparate data can be analyzed to allow informed policy decisions to be made concerning this vast and important ecosystem.

2 Methods

2.1 *Study Area*

The datasets analyzed comprise the alpine grassland counties of Qinghai Province, PRC, here defined by the exclusion of all counties of the low-lying, agricultural Haidong district and most counties of Haixi Mongolian and Tibetan Autonomous Prefecture (MTAP, i.e., the desert counties of the Qaidam basin area). Thus, all counties of the Huanguan Tibetan Autonomous Prefecture (TAP), Hainan TAP, Guoluo TAP, Yushu TAP, Haibei TAP, and Tianjun and Ulan counties of Haixi MTAP are included in the analyses, for a sample size of 27 counties (Fig. 1).
The area defined by these 27 counties lies almost exclusively at 3,000 m or higher in elevation, and the habitat ranges from mesic alpine meadow to alpine steppe (Hu et al. 1992).

2.2 *Rangeland Utilization*

The primary data set consists of rangeland population density, grassland quality, and season of use of rangeland (summer versus winter pastures) and was compiled from two sources: "Qinghai Province Today," (Jing 1986) and provincial census data (PCO 1992)(Appendices I and II). In these sources all grassland in Qinghai Province was classified according to season of use and to quality. Season of use is known for all grassland areas and is divided (at the provincial level) into two categories: summer grassland and winter grassland. This dichotomy may or may not reflect the reality of seasonal utilization, however, it represents the only data on seasonality available for the study area.

We obtained a standard measure of the relative areas of summer versus winter grassland in each county by multiplying the logarithm of the ratio of summer versus winter grassland areas times two. The resulting standard measure ranges from -1 (only winter grassland) to +1 (only summer grassland).

In its broadest sense, grassland quality is almost always qualified in government documents as "usable" (or "useful") versus "unusable" (or "wasteland"). A second level of classification of quality differentiates "usable" grassland into "high," "medium," or "low" quality grassland. This latter classification was introduced in the early 1980s as an important step toward a more equitable allocation of grazing lands to individual users (lease holders) as per the stipulations of the Rangeland Law, promulgated in 1985 (Ho 1998). Jing (1986) presents this second-level classification for the counties in the study area. We calculated a standard measure of the relative areas of high versus medium versus low quality grassland for each county, also with values ranging from -1 (low quality grassland) to +1 (high quality grassland). First, each area of grassland quality was weighted by the factors 3, 2 or 1 (from highest to lowest quality, respectively). Second, the sum of the weighted areas was divided by twice the unweighted total area. Finally, after 1 was subtracted from the total, the whole was multiplied by 2).

These standardized measures for season of use and for grassland quality were each derived using a logarithmic formula to convert ratios to more normal distributions, and a multiplication factor was used for each to increase the spread of the resultant values. In the case of grassland quality, simple weighting factors also were used to differentiate between each subjective quality class.

The effective population density of pastoralists on the rangeland area of each county was calculated by first determining the percentage of each county's workforce that is engaged in animal husbandry and then multiplying this percentage times the total county population to achieve an estimate of the total pastoral population. We then determined the density of this total pastoral population based on the area of each county's usable grassland (the same total area as used to obtain the standardized measures of seasonality and grassland quality).

2.3 *Mammalian Biodiversity*

A measure of biodiversity for the 27 grassland counties was derived from presence/absence data for 103 mammal species (Li 1989). Of the 103 species, our analyses include only those that 1) were reported in more than 25% of the grassland counties; 2) were identified as "Tibetan" fauna by Hoffmann (1991) or identified as "resident" or "characteristic" of the Tibetan fauna by Zhang (1991); and 3) are known or presumed to inhabit steppe or montane habitat. Twenty-one species were identified as comprising the characteristic mammalian fauna of the alpine grasslands of Qinghai province (Table 1). Biodiversity is taken to be the percentage of these 21 species reported (Li 1989) in each grassland county.

3 Results

3.1 *Rangeland Utilization*

There was a wide range of standardized values depicting season of use across the 27 county study site (Fig. 2). While most counties appeared relatively balanced in the use of summer versus winter pasturage (values close to 0), eight counties had highly skewed pattern of season of use. Six of these constitute primarily winter pastures, and overall 67% of counties were primarily used for winter pasture (Fig. 2).

Standardized values for grassland quality also ranged widely, one county registered in the lowest bracket for grassland quality, while three were represented in the highest bracket (Fig. 2). Most counties possessed an average to high value for rangeland quality.

Population density of pastoralists on the rangeland portions of the 27 counties was very evenly distributed from a low of 0.3 persons/km2 to a high of over 5.5 persons/ km2 (Fig. 3).

Simple (Person's product moment) correlation coefficients between pairs of these variables gives us a first-level understanding of their relationships (Fig. 4). Season of use tends (non-significantly) to shift towards more grassland area being used as winter pastures as grassland population density increases ($r = -0.17$, $p = 0.40$, Fig. 4), and conversely, range quality is lower in counties where more winter grazing occurs -- a relationship that approaches statistical significance ($r = 0.36$, $p = 0.06$).

As season of use is the only potential variable that can be managed directly (either by policy-makers or by pastoralists), it can be considered as the dependent variable in a multiple regression analysis with rangeland quality and pastoralist density serving as two independent, causal variables (Table 2). Both independent variables, when considered together, have a large impact on season of use. In addition, the analysis demonstrates the high level of interaction between season of use and grassland quality ($p < 0.01$), as well as with population density ($p < 0.05$).

3.2 *Mammalian Biodrversity*

Most counties in our survey currently support between 70 - 90% of those mammal species classified as characteristic of the alpine grassland fauna of Qinghai (Table 1; Fig. 5). None of
the 27 counties had a full complement of this mammalian assemblage, and one currently supports only 57% of these representative species. Thus, biodiversity on the grasslands of Qinghai has been seriously compromised.

Pastoralist population density affects biodiversity on the grasslands of Qinghai either directly and/or as a surrogate variable for livestock population density (or overall grazing pressure). As human population density increases by county on the rangelands, county-level biodiversity decreases ($R2 = 0.230$, $p = 0.011$; Fig. 5).

We investigated the causality of this relationship by further examining the relationship between biodiversity and both season of use and grassland quality. Although both relationships are not significant, their direction is the reverse from that expected: biodiversity tends to increase as season of use tends towards a greater proportion of winter pastures ($R2 = 0.0497$, $p = 0.264$), and biodiversity tends to increase as grassland quality decreases ($R2 = 0.0761$; $p = 0.164$).

These analyses indicate that pastoralist population density is likely only indicative of another correlated variable. One possibility is distance from Xining, the capital of Qinghai and its only major city (Xining is located in Haidong Distnct; see Fig. 1). Distance from Xining could possibly be a surrogate variable for hunting pressure as most poachers come from the Haidong district in northeast Qinghai. Indeed, distance from Xining and population density on the grasslands are very closely related ($R^2 = 0.177$, $p = 0.029$, Fig. 6). Further, there is a significant relationship between biodiversity and distance from Xining when these variables are examined directly ($R^2 = 0.249$, $p = 0.008$; Fig. 7).

Next, we examined the effect of rangeland density, grassland quality and season of use on biodiversity independently of the distance factor, that is after distance was removed statistically by henceforth examining only the standard residuals of biodiversity from the regression of biodiversity by distance. Neither rangeland population density ($R^2 = 0.097$, $p = 0.114$), nor grassland quality ($R^2 = 0.070$, $p = 0.182$) showed any significant impact on biodiversity. Season of use did have a significant association with biodiversity ($R^2 = 0.190$, $p = 0.023$, Fig. 8). This association, however, was in a direction opposite from that which we expected -- based on the assumption that a greater proportion of summer land should improve grassland quality, hence also biodiversity.

Finally, we examine the spatially explicit pattern of biodiversity in Qinghai (Figs. 9& 10). The first map (Fig. 9) portrays grassland biodiversity as calculated in Figure 8 (with the distance from Xining factor statistically removed). Figure 10 portrays grassland biodiversity with both distance and season of use factors statistically removed. Both maps indicate that there are three regions in the province where biodiversity is unusually low the area surrounding Qinghai Lake, the greater Tongren valley, and the Guoluo region.

4 Discussion

This survey of trends in pasture utilization patterns and biodiversity across 27 alpine grassland counties in Qinghai essentially represents a snapshot in time - and one that best reflects the current situation in the province. While it is necessary for managers and policy makers to make use of these contemporary data, it is also important to gain an understanding of historical trends that have led to the present situation so that these data, and management solutions to problems of degradation of the grasslands and concomitant loss in biodiversity, can be put into a proper context.

The decrease in Qinghai's biodiversity over the last few decades has occurred concomitantly with several important socio-political and "development" trends in the province. The first trend was founded in the socialist belief that crop cultivation is inherently superior to pastoralism because of its greater labor requirements. This ideology has led to many large areas of grassland being opened up for agriculture, both in the past and, to a lesser degree, in the present. For example, four decades ago it was recommended that 20,933 km2 of new land in Qinghai (5,587 km2 in grassland areas) should be opened up beyond the 4,367 km2 already under cultivation at the time (QSSJ 1958). However, because of the unsuitability of most land in Qinghai, only about one fifth of the above actual and proposed areas remains in use today (in the mid-1980S Qinghai had 5,789 km2 of "ploughed land"; Zhu, in Hu et al. 1989). Nonetheless, new lands continue to come under cultivation. In Gangcha County, a typical grassland county, the area of cultivated land was deliberately increased by 34% in 1996 alone (GXXNJ 1996). Tilled land is susceptible to rapid degradation due to increased rates of wind erosion, and disturbed land on the Tibetan plateau reverts to natural conditions only with great difficulty (CCICED 1996).

Another trend in the PRC has been periodic changes in land property and tenure rights. Initially livestock was privately owned and managed on common pasture within each tribal area. Grazing systems included seasonal grazing patterns, rotational grazing, deferred grazing and other well-defined practices (citation needed). In the period of communal ownership (1956-1978), however, livestock came under collective ownership. The main failing of the property rights structure of that period was that rights to the different components of the pastoral economy were not vested in one institution only, but in three: the primary resource, grassland, belonged to the commune (the present-day township), the secondary resource, livestock, belonged to the brigade (village), and labor, herders, was provided by the production team (natural village). Thus, direct users of natural resources felt no sense of responsibility towards the grassland since they did not perceive it as being their own and there was no incentive to use grassland resources sustainably (Ho, 1998). Finally, the communes were disbanded in the late 1970s and replaced progressively through the early 1980s with the Household Contract Responsibility System (HCRS), effectively a form of privatization. At the provincial level, Qinghai has established as a high priority enhancement of economic development of its agricultural (cultivated and pastoral) areas so as to strengthen the HCRS. New contract (lease) periods to pastoralists now extend 30 years, and in special circumstances to 50 years. By the early 1990s, a total area of 74,667 km2 (48 percent) of the provincial winter-spring grassland and 65,133 km2 (42 percent) of the provincial summer-autumn grassland had been assigned to private families and villages (Ma et al. 1995).

There is evidence, however, that the HCRS may be detramental to rangelands. Ho (1998) claims:."The reason that [the

HCRS] was expanded from agriculture to the livestock sector is probably that it had become the political norm for the reform strategy. It was applied to the livestock sector without consideration for local variations and the specific traits of the natural resource on which livestock production relies."Thus, the current institutional structure of rangeland management shows significant similarities to that of the communes, namely, "a two-level resource management whereby rights of usufruct are vested in individual households, but property rights remain with an external organization which is responsible for the enforcement of grazing regulations." (Ho 1998). What remains is a situation whereby an enduring, sustainable use of Qinghai's grassland resources still may not be the most "rational" option available to individual herders. If this is the case, then only two options are available in order to implement sustainable resource use practices and to protect biodiversity in the alpine grasslands of Qinghai. The first is a top-down approach stipulating a definite set of land use regulations that must be implemented, along with the means to enforce such regulations. This approach would require enormous cost and effort, and would be very difficult to implement on the sparsely populated grasslands. **The**
alternative approach is to address the institutional framework within which livestock grazing (and other components of grassland use) takes place at a local level. Here policy must favor entrusting pastureland natural resources to the direct resource users of these resources. The latter option requires that an institutional framework suitable to the resources in question be chosen, whether this be through so-called pnvate or common ownership. The key is to recognize the ecological realities of Qinghai's grassland regions, namely that they form a semi-arid to arid grassland system with highly variable climatic conditions (citation needed). These conditions dictate a pastoralist grazing strategy with inherent flexibility, allowing for seasonal (and occasionally annual) herd movement and overlapping grazing (Miller 1995, Wu 1997). Traditional pastoral responses to such ecosystem demands may indeed be the most appropriate responses, and they call into question some important aspects of the current drive to "modernize" the pastoral economy (Miller 1995; Wu 1997).
Another trend that has occurred in Qinghai is a decrease in the diversity of economic activities of the pastoral population. In the past, as bad years and good years came and went, pastoralists relied more or less heavily on alternate economic activities. A diversity of economic activities has always been a part of (even if relatively minor) the pastralist's annual cycle of activities. Trade networks to exchange livestock products for agricultural products have been an intrinsic part of the pastoral economy for centuries (Wu 1997). Such movements, however, have become more and more restricted in the last few decades. This change clearly has lead to a greater dependence on livestock-related occupations only, with a concomitant felt-need to increase this sector of a household's economy. This felt need (from the herders perspective) has been reinforced by prevailing political views that livestock quantity is of greater significance than quality. Limitation of regional movements, therefore, may be at least a partial reason for the observed overall increase in livestock numbers and degradation of grasslands throughout Qinghai in the several decades.

A final trend that has likely affected the productivity of rangelands in Qinghai relates to the "modernization" process promoted in the province. The primary development objective for the pastoral region of Qinghai is to encourage herdsmen to "give up their traditional nomadic herding and turn to modern production methods" (Xie 1997). In Mongolia, public policies of the 1960s and 1970s aimed to raise the standard of living of pastoralists (similar to those in present-day Qinghai -- construction of fences and winter animal shelters, provision of animal fodder, etc.), along with political-administrative constraints on traditional patterns of seasonal movements, have greatly reduced herder mobility (Meams 1996). Li, Ma and Simpson (1993) found that during the same period in inner Mongolia, the creation of new administrative boundaries, often unrelated to past geographic patterns, led to a change from long-distance nomadic herd movement to short-distance movement within brigade (village) boundaries.

Attempts to fence in rangeland impose even greater limits on herd mobility and remove nearly all flexibility inherent in traditional grazing strategies, to the detriment of the grasslands and the pastoralists (Ho 1998). Ho (1998) states:"The attempts to fence in rangeland do not only collide with the tradition of overlapped grazing, but are also unsuited to a natural resources with highly variable productivity, such as grasslands in China's semi-arid Northwest. ..[G]rasslands that are characterized by unstable productivity over time benefit more from flexible arrangements than from rigid ones. It should be no surprise that the experiments for dividing the rangeland into delimited plots have failed."

This approach to pastoral (animal husbandry) development is the result of policies focused only on increasing the number of livestock, rather than their productivity or quality, and a false hope that China can emulate the ranching systems of North America, Australia and New Zealand irrespective of underlying natural resource and ecosystem constraints.

In Qinghai, the conception of pastoral development has led to the formulation of the Four-In-One scheme to address one of China's top priorities -- poverty alleviation. This scheme, as adapted for the grassland areas of the province, has four essential components 1) build houses for the pastoralists; 2) construct winter livestock shelters; 3) fence grassland area; and 4) grow fodder for winter consumption (Qinghai Poverty Bureau 1996, personal communication). Each of these components has its individual pros and cons, but all focus primarily on the winter-spring grassland areas, as we will highlight below.

With these historic trends in mind, we now address specifically how the 27 county analysis adds to our understanding of the condition of alpine grasslands and biodiversity trends in Qinghai. Two main areas of interest emerge from our investigation of these provincial and county-level datasets. The first is a clarification of the pattern of pastoral land use, especially with regard to the contrast between summer and winter pastures. The second is the relationship between pastoral land use and loss of biodiversity on Qinghai's alpine grasslands.

There was a strong tendency for the pastoral population to rely more heavily on winter-spring pastureland with increasing human population density on the grasslands. In turn, quality of winter-spring pastureland decreased as human population density -- a surrogate variable for livestock density - increased. This pattern reflects the prevailing management paradigm -- that the livestock themselves should be the focus of management (a livestock- management perspective) rather than the condition of the pasture (a rangeland management perspective). Under the livestock management perspective, livestock numbers are of prime importance. As the winter-spring season is when most livestock die of starvation, an increase in the area of winter-spring pastureland is a rational response to ensure that more forage is available so that more livestock survive the harsh cold season. Our analysis indicates that this perspective is more likely to be adopted for areas that are closer "to the edge," whether due to poorer grassland conditions or to larger numbers of people and livestock utilizing a finite amount of grassland resources. The desire to increase over-winter survival of livestock has prompted virtually all government leaders in pastoral areas to focus their attention on the "problem" of winter-spring forage availability. At the policy level, the livestock-management view has played a key role in the development of the Four-In-One scheme (and its associated development activities) for modernizing the economy.

What are the implications of this "cold season" focus on pastureland development? First, summer-autumn rangelands may unintentionally be degraded further as artificially high winter populations of livestock are forced to graze on a "warm season" range of reduced size (see also Cincotta et al. 1992). While the official livestock-management perspective views technology as having great powers to overcome resource limitations, it fails to consider the mathematic reality that a greater proportion of winter-spring grassland area means a lesser proportion of summer-autumn grassland area, and the related biological reality that overgrazing becomes increasingly likely as more animals graze on a continuously decreasing area of a fragile ecosystem during its short vegetative growing season. Indeed, Lang et al. (1997) found that summer pastures in Hainan TAP were 3 to 4 times more degraded, primarily through overgrazing, than winter pastures. Clearly then, at least a partial shift toward a rangeland-management perspective is called for, if for no other reason than to mitigate grassland degradation in order to increase forage availability and hence livestock production and quality.

Another implication, related to the first, is that considerable development investment may be misdirected or inappropriately portioned between winter-spring and summer-autumn rangeland areas and associated projects. A case in point is the situation of Dari County where, despite over a decade of capital investments in "grassland construction" projects (e.g., fencing, houses, animal shelters, etc.), the total number of livestock has decreased, while grassland conditions continue to deteriorate (Foggin & Smith, unpublished data). County leaders are at a loss as to how to halt this downward spiral.

What is the link between pastoral land use and biodiversity? It was initially assumed that areas with lower quality grassland -- areas associated with higher population densities and smaller proportions of summer-autumn rangelands -- would harbor less biodiversity. This relationship, however, was not borne out statistically. In fact, the relationships between biodiversity and population density, biodiversity and season of use, and biodiversity and grassland quality are neither consistent, nor all in the directions expected. Only population density and biodiversity are significantly (negatively) related. Further, since internal consistency is lacking between the three variables (population density, season of use and grassland quality), they can not stand alone as sole causal variables associated with biodiversity. It is possible, therefore, that population density is a surrogate variable for another factor such as distance from Xining, this is borne out statistically, both between the variables of distance and population density and between distance and biodiversity. Poaching has often been suggested as a cause of biodiversity loss (Schaller 1998), and the above relationship is consistent with this position (most poachers come from Haidong District in the general vicinity of Xining). Another major contributing factor to loss of biodiversity in Qinghai is the loss of the keystone species, the plateau pika (*O. cursoniae*). Control programs directed to exterminate plateau pikas are more likely to be centered out of areas of high population density.

When the primary determinant of biodiversity -- distance from Xining -- is statistically removed, another single variable -- season of use -- becomes a primary determinant of biodiversity. However, again, this relationship is in a direction opposite than expected. It is possible that factors related to season of use - and there are many such variables, e.g., degree of nomadic movement, education, economic status, etc. -- are causal in this relationship, but data are lacking to undertake a detailed analysis of biodiversity and socio-ecomomic development factors. It is interesting to note, however, that a preliminary analysis of these variables has shown women's education, apart from the general educational status of the region, bears a significant relationship to biodiversity on the Tibetan plateau: the relationship

between biodiversity and the ratio of men to women with a formal education is statistically significant ($r = -0.546$, $p < 0.01$), while the relationship between biodiversity and general educational status is not ($r = 0.300$, $p = 0.12$). This analysis appears to indicate a primary role that women can have when given the opportunity, to impact positively the practice of sustainable natural resource utilization and biodiversity protection (Foggin, unpublished data) .

Apart from these socio-economic indicators, are there other land-use patterns that emerge as determinants of biodiversity in Qinghai's alpine grasslands? Or can one note only that patterns of seasonal use affect grassland quality, and that poaching and/or poisoning may play a significant role in reducing biodiversity in Qinghai? We approached these questions by examining the data in a spatially-explicit way.

When the distance from Xining factor is removed statistically (Fig. 9), and when both distance from Xining and season of use factors are removed statistically (Fig. 10), a similar spatial pattern of biodiversity emerges in Qinghai Province. Three areas in particular have unusually low levels of biodiversity the Qinghai Lake area (in Haibei and Hainan TAPs), the greater Tongren valley (Huangnan TAP), and parts of the Guoluo region (Guoluo TAP). What is the reason for this pattern of mammalian biodiversity? Part of the population density factor and most of the poaching/poisoning (distance from Xining) factor has been removed statistically. In addition, the season of use factor has been removed from Figure 10. These data indicate that it is possible for unique historic events (rather than traditional "causal" variables with degrees of impact spread along a continuum) to be the source the regional pattern observed -- in most cases "swamping out" patterns that may be caused by those variables more often assumed to be determinants of biodiversity loss. Therefore, scale appears to be an important consideration for explaining the loss of biodiversity throughout Qinghai.

At the regional scale, the scale at which data are most often readily available (such as the data analyzed in this paper), unique historic events may explain most variation in provincial biodiversity. Reflecting on their analysis of events in the Amazon rainforest, Hecht and Cockburn (1990) comment: "Once that political history and that political economy are understood, the genealogy of disaster stands forth." In the case of Qinghai's alpine grassland, this genealogy lies in three different areas, each exemplified by one of the geographic areas mentioned above. The Qinghai Lake area was one of the first areas of the Tibetan plateau to be opened up for agricultural production (crop cultivation), which led to the destruction of large areas of natural vegetation and also opened the region to an immigrant population unaccustomed to local conditions (QSRZ 1951; QSSJ 1958). The Tongren valley also has been affected greatly by the political winds of past decades (QSSJ 1958), and many potentially inappropriate "modernization" initiatives have been undertaken in this area. Even now, the pastoral population of the grassland area of Huangnan TAP is under enormous pressure to become fully sedentary through a massive drive to implement the Four-In-One scheme as soon as possible (Qinghai Poverty Bureau 1996, personal communication, Foggin, personal observation). This direction of development towards sedentarization is not unique to Huangnan TAP, but it is perhaps most actively pursued in this prefecture. Finally, the Guoluo region has both been subject to a variety of political hardships (Becker 1996), as well as to excessive land degradation (Foggin 1998, personal observation) the ultimate causes of which remain uncertain. In addition to high numbers of livestock, burrowing mammals (e.g., the plateau pika, *O. cursoniae*, Bailey's zokor, *Myospalax baileyi*) and very high spring winds all play a role (Gande and Dari county governors 1998, personal communication). In addition, a general pattern of desiccation reported to be occurring over much of the Tibetan plateau may be exacerbating the problem in this area (Miller and Craig 1996). Any final answer - if such can be found - for why so much land is degraded in Guoluo TAP has yet to be determined. Initial analyses of Dari County data suggest that livestock numbers may have exceeded the maximum sustainable numbers in the recent past, and the grassland there may have suffered (Foggin & Smith, unpublished data). From the above three scenarios, it is suggested that grassland conversion to agriculture, the Four-In-One scheme for poverty alleviation (and a consequent shift towards more sedentary lifestyles in formerly nomadic areas), and high livestock numbers are important factors affecting biodiversity in Qinghai's alpine grasslands. The challenge ahead is to find new ways that redress the issues for which agriculture, increased livestock numbers and the Four-In-One scheme were introduced in the first place -- namely, to promote provincial economic development and to help improve living standards -- while simultaneously ensuring that such initiatives can be sustained over many years and for future generations. Corrective action is needed to restore the quality of pasturelands and native biodiversity Qinghai to historic levels while ensuring sustainability of these resources in the future.

Cited literature

Bamett, A. 1993. China's Far West: xxx
Becker, J. 1996. Hungry ghosts: China's secret famine. John Murray, London.
CCICED. China Council for International Cooperation on Environment and Development. 1996. Proceedings: the fourth meeting (1995). CCICED, Beijing.
CSCPRC. Committee on Scholarly Communication with the People's Republic of China. 1992. Grasslands and grassland sciences in northern China. National Academy Press, Washington, D.C.
Cincotta, R. P., Y. Zhang, and X. Xingmin. 1992. Transhumant alpine pastoralism in northeastern Qinghai province: an evaluation of livestock population response during China's agrarian economic reform. Nomadic Peoples 30:3-25.
Clarke, G. E. 1987. China's reforms of Tibet, and their effects on pastoralism. University of Sussex, Brighton, United

Kingdom, Institute of Development Studies, Discussion Paper 237: 63-131.
Drandui, L. 1996. A comparative study on the animal husbandry of Qinghai and Tibet. China Tibetology 4:31-42. [in Chinese]
Ekvall, R. B. 1968. Fields on the hoof: nexus of Tibetan nomadic pastoralism. Holt, Rinehart and Winston, New York.
Foggin, J.M., and Smith, A.T. In progress. [Analysis of Dari County livestock numbers and productivity, in preparation for submission to Orxy] xxx
GXXNJ (*Gangcha Mian Xu Nong Ju*, Gangcha County Animal Husbandry and Agriculture Bureau). 1996. Agriculture and animal husbandry production report. Gangcha County, Qinghai province, PRC. [in Chinese]
GoldStein, M. C., and C. M. Beall. 1990. Nomads of western Tibet the survival of a way of life. University of California Press, Berkeley.
Hecht, S., and A. Cockburn. 1990. The fate of the forest: developers, destroyers and defenders of the Amazon. Penguin Books, London.
Ho, P. 1998. Ownership and control in Chinese rangeland management since Mao: a case study of the free-rider problem in pastoral areas in Ningxia. Pages 196-235 in E. B. Vermeer, F. N. Pieke, and W. L. Chong, editors. Cooperative and collective in China's Rural development: between state and private interests. M.E. Sharpe, New York.
Hoffmann, R. S. 1991 . The Tibetan plateau fauna: a high altitude desert associated with the Sahara-Gobi. Pages 285-297 in J. A. McNeely, and V. M. Neronov, editors. Mammals of the Palaearctic desert: status and trends in the Sahara-Gobian region. Russian Academy of Sciences, Moscow.
Hu, S.T., D.B. Hannaway, and H.W. Youngberg. 1992. Forage resources of China. Pudoc, Wageningen.
Jing S. (editor). 1986. Qinghai province today. Qinghai People's Publishing House, Xining. [in Chinese]
Koslov.P. 1889. Report. Page 143 in Proceedings of the lmperial Russian Geographic Society expedition to central Asia, 1893-1895, led by V. I. Roborovskiy. Imperial Russian Geographic Society, St. Petersburg. [in Russian]
Lang B., Huang J., and Wang H. 1997. Report on the pasture and livestock survey in Hainan IFAD project area. IFAD project report, xxcityxx. [need IFAD acronym]
Lattimore, O. 1940. Inner Asian frontiers of China. Beacon Press, Boston.
Li D. 1989. Annals of Qinghai's economic wildlife. Northwest Plateau Institute of Biology, Chinese Academy of Science, Qinghai People's Publishing House, Xining. [in Chinese]
Li D., Ma R., and J. R. Simpson. 1993. Changes in the nomadic pattern and its impact on the Inner Mongolian steppe grasslands ecosystem. Nomadic Peoples 33: 63-72.
Long R., and Y. Ma. 1997. Qinghai's yak production system. Pages 105-114 in D. J. Miller, S. R. Craig, and G. M. Rana, editors. Conservation and management of yak genetic diversity. International Centre for Integrated Mountain Development, Kathmandu.
Ma Y., [xx need et al. Authors]. 1995. Outline of Qinghai province's agricultural economy. Qinghai People's Publishing House, Xining. [in Chinese]
MacKinnon, J., M. Sha, C. Cheung, G. Carey, Z. Xiang, and David Melville. 1996. A biodiversity review of China. World Wide Fund for Nature, Hong Kong.
Meams, R. 1996. Community, collective action and common grazing: the case of post-socialist Mongolia. The Journal for Development Studies 32: 283-325.
Miller, D. 1995. Herds on the move: winds of change among pastoralists in the Himalayas and on the Tibetan plateau. International Center for Integrated Mountain Development, Kathmandu.
Miller, D. J., and S. R. Craig, editors. 1996. Rangelands and pastoral development in the Hindu Kush-Himalayas. International Center for Integrated Mountain Development, Kathmandu.
PCO. Population Census Office of Qinghai Province. 1992. Tabulation of the 1990 population census of Quinghai province-computer tabulation. China Statistical Publishing House, Beijing. [in Chinese]
Prezewalski, N. M. 1883. From Zaisan Lake through the Kham region of Tibet and the head of the Yellow River. Moscow.
QSRZ. Qinghai Sheng Renmin Zhengfu [Qinghai People's Government]. 1951. Guanyu Yinian lai sheng renmin zhengfu jijinhou renwu de baogao. Quinhai Zhengxu 8:4-15. [in Chinese]
QSSJ. Qinhai Sheng Shuili Ju [Qinghai Water Conservancy Office]. 1958. Qinghai sheng huagdi zilao. Qinghai Water Conservancy Office, Xinging, PRC. [in Chinese]
Schaller, G. 1998. Wildlife of the Tibetan steppe. University of Chicago Press, Chicago.
Schram, L. M. 1954. The Monguors of the Kansu-Tibetan frontier: their origin, history and social organization. Transactions of the American Philosophical Society, New Series 44:1-136
Smith, A.T., N.A. Formozov, R.S. Holffmann, C. Zheng, and M.A. Erbajeva. 1991. The pikas. Pages 14-57 in J.A. Chapman, and J.E.C. Flux editors. Rabbits, hares and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland.
Smith, A.T., and Foggin, J.M. In progress. [Tibetan Plateau environment-development framework paper, in preparation for submission to Ambio] xxx
Smith, W. W., Jr. 1996. Tibetan nation: a history of Tibetan nationalism and Sino-Tibetan relations. Westview Press, Boulder.
Wei Z. 1986. Intensifying desertification of the northern part of Qinghai Province. Environment of Qinghai 1:13-15
Wu N. 1997. Indigenous knowledge and sustainable approaches for the maintenance of biodiversity in nomatic society:

experiences from the eastern Tibetan plateau. Die Erde 128:67-80.
Xie L. 1997. Qinghai girding up against disasters. China Daily, 25 September 1997.
Zhang Y. 1991. Mammalian zoogeography and conservation of the endangered species in arid areas of China. Pages 269-284 in J.A. McNeely, and V.M. Nemorov, editors. Mammals of the Palaearctic desert: status and trends in the Sahara-Gobian region. Russian Academy of Sciences, Moscow.
Zhao S. 199x. The Qinghai-Xizang (Tibetan) plateau: its physical environment and economic development. Chinese Journal of Arid Land Research 5:203-222.
Zhu Y. 1989. Qinghai province's population distribution and natural conditions. Pages xx-xx in Hu H., [+other authors et al.], editors. Population, economy and ecologic environment of east China, middle China and west China. East China Normal University Press, Shanghai. [in Chinese]