RANGELAND DYNAMICS AND PASTORAL DEVELOPMENT IN THE HIGH ANDES:
THE CAMELID HERDERS OF COSAPA, BOLIVIA

by

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Current models of rangeland system dynamics were evaluated in Cosapa, a pastoral community on the Bolivian altiplano. Two specific models were tested: the "equilibrium" model, which assumes biotic interactions dominate rangeland dynamics and lead to system stability, and the "nonequilibrium" model, in which stochastic, abiotic factors control systems such that equilibrium is never attained. A livestock development project (called "Project Alpaca") working in the community was then assessed in terms of how its assumptions of system dynamics compared with empirical findings. The goal of Project Alpaca was to increase incomes for camelid (i.e., llama and alpaca) herders on the Bolivian altiplano by improving the processing, production, and marketing of alpaca wool. Project implementation was carried out by an indigenous herders' association, with funds provided for construction of a modern alpaca wool processing plant and technical interventions at the farm level.

Specific research objectives were to determine which conceptual model of system dynamics (equilibrium or nonequilibrium) best approximated the vegetation and livestock
dynamics in Cosapa, and determine the impacts of technical innovations introduced by Project Alpaca. Vegetation dynamics were assessed by comparing plant species composition and production between grazed and ungrazed sites. Pastoral management strategies, livestock population dynamics between 1982 to 1995, and project impacts were assessed using a household survey.

Results from the vegetation analyses showed that grazing protection had little impact on plant productivity, but reduced species diversity in wetland areas. The vegetation thus exhibited nonequilibrial characteristics. Regarding livestock dynamics, populations were relatively stable (over 13 years), although mortality was affected by severe drought, suggesting a combination of equilibrial and nonequilibrial interactions. Project Alpaca assumed an equilibrium model by emphasizing system stability and production maximization. The technical interventions showed positive, negative, and neutral associations with animal productivity. Construction of fenced exclosures on communal land has increased conflicts over land tenure rights, and may marginalize poorer households and increase social stratification. Development recommendations include shifting efforts away from intensification interventions that limit movement and flexibility, and strengthening social and economic networks that buffer the impacts of system variability.
DEDICATION

To the herders of Cosapa, who,

living under the vigilance of Tata Sajama,

offered tea and charque to this wayward visitor,

and taught me to dance at Carnival and

wrestle llamas at dawn.

May the llama and alpaca provide a constant source of

prosperity, autonomy, and well-being.

Yuspagarpuni.
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CHAPTER 1
INTRODUCTION AND OBJECTIVES

Introduction

Successful development projects require compatibility among tasks, environments, and organizational competencies (Passmore 1988). Defining the environmental context, organizational structure, and recommended interventions requires knowledge about how the target system functions. Often in development planning, however, models about system behavior are derived from other contexts and applied directly to new systems without being tested. For example, many livestock development projects in Africa have been based on models of Western U.S. commercial livestock production and range management (Abercrombie 1974). The failure of many of these range-livestock development projects can be attributed in part to the inapplicability of Western range models to subsistence pastoral systems (Sandford 1983, Moris 1991, Behnke and Scoones 1993). Although an adequate description of system dynamics does not guarantee project success (Moris 1991, Coppock 1994, Behnke and Scoones 1993), recognition of the conceptual models implied in a development plan, and use of models that better match a given situation, will at least provide a starting point from which appropriate interventions can be made.

This dissertation evaluates current ecological models of rangeland system dynamics in the context of a pastoral community on the Bolivian altiplano (or high plains). The community, called Cosapa, is one of several in the south-central altiplano that was the target of a livestock development project (Project Alpaca) aimed at improving the production and processing of alpaca wool. Unlike previous livestock development programs in the Andean region where development was imposed by government or outside organizations, funding for Project Alpaca
was given directly to an indigenous herders' association, called Asociación Integral de Ganaderos en Camélidos de los Andes Altos (AIGACAA). This association has been in existence since 1979, and was originally created to increase incomes for camelid (llama and alpaca) herders through direct marketing of their products, and to promote indigenous self-determination (Hale 1981).

The objective of this research was to examine the development approach used by AIGACAA and Project Alpaca in terms of current conceptual models of rangeland dynamics. These models are then compared to the system dynamics observed in the community of Cosapa, to determine how well assumed models fit empirical findings. Development interventions are then evaluated in terms of their impacts on land and livestock productivity, and the social relations that surround the use and management of rangeland resources.

Although much work has been done in Africa in both developing models of rangeland system dynamics (Ellis and Swift 1988, Coppock 1993, Scoones 1993a) and evaluating the performance of livestock development projects (Simpson and Evangelou 1984, Perrier 1991), very little work has been conducted in other pastoral systems. Andean pastoral systems may exhibit completely different characteristics compared to African systems. Testing models of rangeland dynamics in the context of the high Andes is important both in terms of devising more appropriate development interventions, as well as determining the extent to which current models can be applied. Development programs can provide a valuable means of observing and understanding the factors that govern the use and management of resources by altering some of the local constraints on production. By studying development projects, one can determine what types of actions strengthen local control over resource use and production.
Theoretical Framework

Historically, range-livestock development programs in the developing world have had two main goals: (1) increase animal productivity and commercial sales, and (2) reduce rangeland degradation. These goals were based on the premise that pastoralists are inefficient producers and poor land managers (Behnke and Scoones 1993). Although many other motives for "developing" pastoralists may often underlie these two objectives (e.g., sedentarization for purposes of greater social, economic, and political control by governments), many of the roots of these development goals are based on models of range ecology and range management. The following sections of this chapter outline these models.

Pastoral Ecosystem Models

The Equilibrium Model

Traditional range management theory is based on the notion that rangeland ecosystems, if managed correctly, are potentially stable systems. This idea originated from successional theory, first introduced by Clements (1916), that assumed vegetation communities replace one another, following a disturbance, in a predictable, unidirectional manner and eventually reach a stable climax or equilibrium state (Westoby et al. 1989). The climax vegetation community was assumed to have the highest productivity, and was self-sustaining as long as no disturbance (i.e., fire, grazing, cultivation) was introduced into the system. Range managers in the Western U.S. adopted this theory and applied it to rangeland systems. The goal of range management was to maintain a plant community at a certain subclimax via grazing by livestock that would result in a steady, sustainable off-take of animals without leading to further retrogression (i.e., a lower productive state--Dyksterhuis 1958, Stoddart et al. 1975, Heady
1975). It was assumed an equilibrium could be reached where both animal offtake and plant production could remain constant. This point was referred to as the carrying capacity or grazing equilibrium of the system (Heady 1975). Traditional range management was thus based on the assumption that

herbivore numbers are controlled by the availability of forage and...the availability of forage is controlled by animal numbers, a pattern of negative feedback which eventually produces a stable equilibrium between animal and plant populations. (Behnke and Scoones 1993:8)

Pastoral Development Based on the Equilibrium Model

Pastoral development based on the "equilibrium" model emphasizes interventions that attempt to reduce system variability. Common interventions include establishing watering points to create a more even distribution of grazing, privatization of communal grazing to prevent "the tragedy of the commons," reduction of stocking rates to improve animal condition and prevent overgrazing, and specialization and intensification of livestock production (i.e., emphasizing beef production, creating irrigated pastures, providing supplemental feed) (Sandford 1983, Ellis and Swift 1988, Moris 1988). Equilibrium-based development projects also emphasize a steady output of livestock products for commercial sale (Ellis and Swift 1988).

One assumption among development planners and range consultants has been that pastoralists overstock, and that overstocking results in rangeland degradation (Behnke and Scoones 1993). Since a negative association was assumed between stocking rates of livestock and vegetation standing crop, the role of development was to create interventions that encouraged a reduction in stocking to an appropriate carrying capacity. The carrying capacity concept, however, was based on the assumption that conditions for vegetation growth were
relatively constant (Behnke and Scoones 1993). In many pastoral systems forage production is highly variable from year to year, and is often unevenly distributed across the landscape. Movement of herds to different seasonal grazing pastures allows animals to take advantage of the spatial and temporal variability in forage production (Sandford 1983, Bartels et al. 1993). Calculations of stocking rates and carrying capacity, however, become difficult since a specific area is often difficult to delimit. Furthermore, carrying capacity is often based on the assumption that animals only graze on rangelands (Bartels et al. 1993). In many pastoral and agro-pastoral systems, nonrangeland areas (i.e., cropland, roadsides, banks of irrigation canals) provide important grazing areas for livestock (Scoones 1990, Bartels et al. 1993). Supplementation feeds also serve as important sources of forage for livestock. An additional problem with calculating carrying capacity is that it varies depending on production goals. Most calculations of carrying capacity are based on commercial beef production; however, the goals of pastoralists are often quite different, emphasizing higher animal numbers, mixed stock, and livestock production for milk, wool, blood, and animal traction (Behnke and Scoones 1993). Stoddart (1960:251-2) further acknowledges the problems of calculating carrying capacity (or grazing capacity) in the following statement:

Unfortunately range does not lend itself, as does a stack of hay, to exact formula conversion into cow-months potential. In the first place, range production is not the same each year, varying largely with annual precipitation and temperature characteristics. It is immediately evident that there is no single correct stocking rate for all years and that grazing capacity is not a constant feature of range land....This brings up the question of what is actually meant by grazing capacity. No satisfactory definition has ever been given for this term. The term "capacity" carried an unfortunate implication of permanence and lack of variation which is not justified....No one can examine a range and judge its capacity without knowing how it will be grazed. You cannot tell the production of range land by a look at the land alone any more than you can look at a cultivated land and forecast production without knowing whether the weeds will be
kept out, what fertilizers will be used, what implements are available, and similar management factors.

Despite these problems, livestock development programs in the Third World have made numerous attempts to estimate carrying capacity, assuming that once stocked at an appropriate rate, pastoral production systems could achieve rangeland conservation while maintaining a high and constant off-take of animals (Bartels et al. 1993). Highly variable and often unrealistic estimates of stocking rate and carrying capacity have been made, the outcome often being forced culling of livestock by pastoralists (Bartels et al. 1993). Bartels et al. (1993:100) state:

The enormous expense devoted to estimating carrying capacity in sub-Saharan Africa has contributed little to livestock development and has diverted resources from other priorities. Let us admit the problems with the carrying capacity concept in sub-Saharan Africa, and stop trying to apply it.

The Nonequilibrium Model: An Alternative Paradigm

There is now a substantial body of literature that illustrates environmental instability and disturbance as governing certain natural systems (Holling 1973, Noy-Meir 1973, Wiens 1984, DeAngelis and Waterhouse 1987, Gleick 1988, Botkin 1990, Pimm 1991). This is in contrast to the long-standing tradition in ecology that assumed nature was in balance and that systems tended towards stability and equilibrium through self-regulating feedbacks (Clements 1916, Odum 1969).

Within the field of range ecology and management, models of system instability and nonequilibrium have recently been proposed (Ellis and Swift 1988). Research conducted in the mid-1980's in dry-land Africa found that the equilibrium model did not explain rangeland dynamics in these systems. Rather than exhibiting strong negative feedback between vegetation
and livestock, climate appeared to determine both plant and animal production in these semi-arid and arid systems. Ellis and Swift (1988), based on 10 years of research conducted in Turkana, Kenya, were the first to propose a nonequilibrium model for some rangeland systems. They proposed that stochastic, environmental perturbations found in many semiarid and arid environments keep livestock populations below some maximum carrying capacity such that they never reach a density where they significantly impact vegetation. In contrast to equilibrial systems, in which density-dependent (or biotic) interactions predominate (Berryman 1989), nonequilibrial systems are characterized by high climatic variability or other abiotic factors that preclude any stable, equilibrium state from being attained (Ellis and Swift 1988). These systems are considered density-independent.

Pastoral Development Based on the Nonequilibrium Model

Proposed development interventions for nonequilibrial pastoral systems encourage flexibility and opportunism for producers (Sandford 1983, Behnke and Scoones 1993). Behnke and Scoones (1993:28) state that

pastoral land-use practices are an effective response to the exigencies of a difficult natural environment, and...the development of livestock production in dry Africa requires the refinement and adjustment of these practices to changing circumstances, not their outright elimination.

Thus, development recommendations for these environments include rapid and profitable stock removal in periods of drought, developing market systems that can accommodate massive and unpredictable shifts in levels of production, and land tenure policies that do not attempt to restrict pastoral movement (Behnke and Scoones 1993).
Several methods of determining whether a system is equilibrial or not have been proposed. Caughley et al. (1987) suggest that when the coefficient of variation for interannual precipitation is greater than 30%, systems are better defined by their variance (a nonequilibrial feature) rather than the mean. Other proposed metrics for defining nonequilibrial systems include average annual rainfall below 400 mm (Coppock 1993), or annual versus perennial vegetation types (Dr. Layne Coppock, personal communication). Ellis and Swift (1988) contrast equilibrium and nonequilibrium systems based on different criteria of observation (see Table 1.1).

Although several cases of both equilibrial and nonequilibrial systems have been documented (Lamprey 1983, Ellis and Swift 1988, Coppock 1993, Scoones 1993a), various permutations of system behavior are possible (Wiens 1984). Coppock (1996), for example, makes the distinction between dynamic versus static equilibrial systems. Static equilibrium is thought to occur in more mesic, predictable climates where intense feedback is chronic and plant-animal interactions are tightly coupled (Coppock 1996). Ideally, animal off-take would be constant and populations could be fixed at some stable carrying capacity. Dynamic equilibrial systems, on the other hand, are characterized by more periodic bouts of intense feedback ("boom and bust" cycles), more characteristic of semiarid climates (Dr. Layne Coppock, personal communication). The population in dynamic equilibrium, however, still oscillates around some long-term population mean, and conservative stocking could still yield a relatively stable output of products (Dr. Layne Coppock, personal communication). Heavier stocking in dynamic equilibrial systems would result in a more variable output due to greater coupling with climatic events. Theoretically, an infinite number of system dynamics are
Table 1.1. Characteristics of equilibrial and nonequilibrial grazing systems (from Ellis and Swift 1988).

<table>
<thead>
<tr>
<th>Abiotic Patterns</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abiotic conditions constant</td>
<td>Stochastic/variable conditions</td>
</tr>
<tr>
<td></td>
<td>Plant growing conditions relatively invariant</td>
<td>Variable plant growing conditions</td>
</tr>
<tr>
<td>Plant-Herbivore Interactions</td>
<td>Tight coupling of interactions</td>
<td>Weak coupling of interactions</td>
</tr>
<tr>
<td></td>
<td>Feedback control</td>
<td>Abiotic control</td>
</tr>
<tr>
<td></td>
<td>Herbivore control of plant biomass</td>
<td>Plant biomass abiotically controlled</td>
</tr>
<tr>
<td>Population Patterns</td>
<td>Density dependence</td>
<td>Density independence</td>
</tr>
<tr>
<td></td>
<td>Populations track carrying capacity</td>
<td>Carrying capacity too dynamic for close population tracking</td>
</tr>
<tr>
<td></td>
<td>Limit cycles</td>
<td>Abiotically driven cycles</td>
</tr>
<tr>
<td>Community/Ecosystem Characteristics</td>
<td>Competitive structuring of communities</td>
<td>Competition not expressed</td>
</tr>
<tr>
<td></td>
<td>Limited spatial extent</td>
<td>Spatially extensive</td>
</tr>
<tr>
<td></td>
<td>Self-controlled systems</td>
<td>Externalities critical to system dynamics</td>
</tr>
</tbody>
</table>

possible, ranging from equilibrial to nonequilibrial (Wiens 1984). The sustainability of these systems, in terms of maintaining a pastoral livelihood for households, however, would depend on the amplitude or variance of the rate of disturbance, as well as changing social and economic contexts, such as human population growth and greater market integration.

Although discussions of equilibrial and nonequilibrial systems have resulted in new models of rangeland dynamics, the variables that define a system are often inconsistent or vague as to whether they are referring to animal dynamics, plant dynamics, or both. Berryman (1989), for example, focuses on animal dynamics without specifying vegetation response. Other discussions of equilibrial models assume plant and animal dynamics are consistently linked (Ellis and Swift 1988, Behnke and Scoones 1993).
One means of clarifying the issue would be to separate plant and animal dynamics, recognizing the possibilities for change in one component and not in the other. Coppock (personal communication) has proposed a matrix (see Figure 1.1) that defines a system based on whether separate density-dependency exists in animals and plants.

Box A in Figure 1.1 describes systems in which nonequilibrial forces dictate both plant and animal dynamics. The Turkana system of Northern Kenya described by Ellis and Swift (1988) would be one example of this type of system where nonequilibrial forces, in this case climate, determine both animal and plant responses.

Box B describes systems in which the vegetation production is independent of animal influences; however, animal population dynamics may be influenced by high stocking rates. This type of system might occur where the vegetation has had a long history of grazing and thus is not highly influenced by further heavy grazing. Livestock populations, however, could reach high enough levels to lower herd productivity. The arid altiplano of the Andean region could potentially fit this model due to the long history of grazing (see next section).

Systems in which heavy grazing strongly impacts the vegetation, but abiotic forces determine animal response, are represented in Box C. Examples of this type of system could be marginal areas with a short grazing history, where introduced grazing imposes a negative impact on vegetation production, but climate or other abiotic force determines livestock populations.

Box D describes a complete equilibrial system in which density-dependent factors determine both animal and plant responses. The Borana system of Southern Ethiopia, described by Coppock (1994), is an example of one such system in which heavy grazing results in vegetation change, in this case change from grassland to shrubland. The livestock
Density-Dependent Feedback for Animals

<table>
<thead>
<tr>
<th>Density-Dependent Feedback of Heavy Grazing on Plants</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Yes</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

Fig. 1.1. Proposed classification of pastoral-rangeland ecosystems based on separate plant and animal dynamics.

population is at a high enough stocking level to induce vegetation change, as well as to impose a negative impact on itself.

The application of this classification scheme to range management and pastoral development includes determining the utility of different management practices for a given system. Optimization models (i.e., calculations of maximum gain/hectare), for example, commonly used in Western range management assume an equilibrium system. The above classification would help determine whether this assumption is valid. For example, estimates of carrying capacity and rangeland trend would only be appropriate for Box D. For Box A, conventional rangeland management would not be appropriate, while in Box B range management may improve livestock production, but may have no effect on vegetation resources.

Application to the High Andes

*Pastoral System Dynamics*

The Bolivian altiplano is a high-elevation plateau surrounded by the western and eastern Cordillera of the Andes. Production on the altiplano is low and often erratic due to climatic fluctuations which result in frequent occurrence of frost and drought. The production
of livestock, alone or complemented with agriculture, has been the basis of human survival in the rural, semiarid and arid regions of the altiplano for over 7,000 years (Browman 1984). The original domesticated livestock species raised by Andean pastoralists were the llama and alpaca (2 of the 4 native camelids found in South America). Following Spanish invasion, European livestock species (i.e., sheep, cattle, and donkeys) were introduced, and in many parts of the altiplano, completely replaced the native camelids.

Traditional management practices employed by Andean pastoralists to deal with environmental uncertainty have involved both "opportunistic" strategies, such as transhumant migration, indicative of nonequilibrial systems, as well as manipulating the environment to create stability, a strategy found in equilibrial systems. For example, archeological evidence has now shown that irrigation to create highly productive wetland areas (bofedales) was a common practice in prehispanic pastoral systems (Erickson 1992). Irrigation of bofedales, through the use of small canals, still continues today (Palacio Rios 1977). Washington-Allen et al. (1998), using satellite imagery, found that the wet meadow (or bofedal) vegetation type in an agro-pastoral community on the altiplano was the most resistant to drought.

Due to the highly erodible soils and sparse vegetation cover, degradation of rangelands on the altiplano is thought to be a major problem (Browman 1974, Ellenberg 1979, Posnansky 1982). Anthropogenic factors, such as poor land management and overgrazing by livestock, have been implicated as the main causes of rangeland degradation (LeBaron et al. 1979, Cardozo 1979, Posnansky 1982, McCorkle 1990). According to Posnansky (1982), the introduction of exotic livestock species (sheep, cattle, donkeys, and pigs) by the Spanish led to greater soil erosion and a decline in forage quality on the altiplano. In order to prevent further degradation, conventional range management recommendations, assuming equilibrium
conditions, have focused on reduction in herd sizes to "appropriate" carrying capacities, improved distribution of animals, rotational grazing schemes, and changes in herd composition (McCorkle 1990). Conservative stocking rates are recommended, which are determined by the number of animals that can be supported in the dry season (Browman 1987a, McCorkle 1990).

Data to support the assumption of grazing-induced degradation on the altiplano are equivocal. Recent studies using MSS-Landsat satellite imagery found no evidence of irreversible vegetation change from 1972 to 1987 in one community on the Bolivian altiplano (Washington-Allen et al. 1998). Additional research using satellite imagery for the community of Turco in the southwestern altiplano of Bolivia also found no evidence of land cover change (Roland Bosseno, personal communication). Genin and Alzárreca (1995) state that there is no conclusive evidence that overgrazing on the altiplano has led to rangeland degradation.

Given the above statements, the relative importance of grazing on rangeland system dynamics for the altiplano is questionable. Looking only at precipitation amounts and variability, one would expect nonequilibrial characteristics to dominate. However, other factors, such as cool temperatures, may mitigate drought impacts by increasing the effectiveness of scant rainfall.

Range-Livestock Development

Range-livestock development programs in the Andes have focused primarily on improving livestock production, primarily among sheep (Browman 1987b). The international demand for wool, for many years, encouraged sheep-oriented production, replacing much of the native camelid populations. Cultural, social, and economic biases against camelid products (especially meat), introduced by the Spanish, and carried on to the present, have also been responsible for the marginalization of the llama and alpaca to the most remote portions of the
altiplano. The introduction of trucks in recent years also displaced llamas as pack animals, further contributing to the decline in camelids (Browman 1987b).

Development interventions have largely focused on technical solutions to improve livestock production. These technical innovations include water development, introduced forage varieties, veterinary services, and introduction of improved European livestock breeds (Browman 1987b). Additional development approaches have included improvements in services to pastoralists (i.e., extension services and marketing) and improvements in organization of pastoralists through the formation of collectives and cooperatives (Browman 1987b). Very little success, however, has resulted from these attempts to improve productivity for pastoralists. Browman (1987b) criticizes these programs for their unquestioned acceptance of mechanization and high technology as the only methods of improvement, while ignoring the sociocultural aspects of development. He also suggests that sheep may not be the most appropriate species for the high Andes, and emphasizes the use of native flora in improving rangelands on the altiplano (Browman 1987b).

Recent worldwide interest in sustainable development and conservation of native and indigenous ecosystems and populations has prompted development agencies working in Bolivia to begin to look at improving the production potential of native domesticated camelids (i.e., the llama and alpaca). Camelids are considered less destructive than sheep to vegetation and soil resources due to their foraging behavior and padded hooves, which reduce trampling effects. Their intake requirements are relatively low compared to European livestock, and they can survive on poor quality forage (Tichit 1991). In 1991, the Asociación Integral de Ganaderos en Camélidos de los Andes Altos (AIGACAA) was awarded a grant from the United Nations to implement Project Alpaca. The goals of the project were to improve the processing,
production, and marketing of alpaca wool through the construction the first indigenous-owned alpaca fiber-processing plant, as well as through technical interventions at the farm level. More details about Project Alpaca and AIGACAA are presented in Chapter 2.

**Research Objectives and Dissertation Structure**

Based on the models of rangeland dynamics and pastoral development described above, the objective of this research was to first determine which conceptual model of system dynamics (equilibrial or nonequilibrial) best approximates the ecological processes and management strategies of the pastoral system in the community of Cosapa. A model of pastoral system dynamics for Cosapa, based on the empirical findings, is then compared to the models assumed by Project Alpaca in terms of the development interventions employed at the farm level. These development innovations will then be evaluated in terms of their implications for system dynamics in the community.

Chapter 2 describes in greater detail the herders' organization (AIGACAA) and Project Alpaca, in terms of the goals, philosophy, and approach to development, as well as the historical and social context within which the project came about. Chapter 3 provides a description of the study site--the community of Cosapa--in terms of the natural and social environment. Pastoralism on the altiplano, and specifically in Cosapa, is described in greater depth in Chapter 4, including details concerning land and livestock management practices and production.

Chapters 5 and 6 discuss testing models of rangeland system dynamics. Chapter 5 presents an analysis of the vegetation dynamics in Cosapa in terms of the impacts of livestock grazing on vegetation production and species composition. It tests the assumptions of
rangeland equilibrium with respect to the vegetation. Chapter 6 is an analysis of livestock population dynamics in Cosapa. Assumptions of rangeland equilibrium with respect to fluctuations in livestock populations are also examined.

Chapter 7 provides an evaluation of the development interventions introduced by Project Alpaca at the farm level. The implications for livestock production are evaluated, and the potential long-term consequences of the project are discussed in terms of the impact on social relations within the community. Chapter 8 provides a summary of findings and presents conclusions that can be drawn from this research.
CHAPTER 2
PROJECT ALPACA AND AIGACAA

Introduction

The purpose of this chapter is to describe in greater detail the local, national, and international context from which the herders' organization (AIGACAA) emerged, as well as the specifics of Project Alpaca, in terms of its development goals. Discussion will include a brief history of the international alpaca wool industry up to the present, and the role of Bolivian herders in this market. The discussion will then turn to the history of AIGACAA, in terms of the organization's philosophy and goals, followed by a description of Project Alpaca.

Discussion

General Overview

In 1991, the United Nations Development Program (UNDP) and the United Nations Capital Development Fund (UNCDF) approved funding for a US$4.6 million grant to the Asociación Integral de Ganaderos en Camélidos de los Andes Altos (Integral Association of Camelid Herders of the High Andes--AIGACAA), an association of Aymara alpaca and llama herders living on the Bolivian altiplano. The grant was to fund "Project Alpaca," a development project intended to "increase camelid raisers' incomes through higher livestock productivity and production" (Project Alpaca Proposal 1991). Project implementation was to be carried out by AIGACAA, working in collaboration with Appropriate Technology International (ATI), a U.S.-based, non-governmental organization.
The goals of Project Alpaca were to improve the production, processing, and marketing of alpaca wool through construction of a modern alpaca fiber-processing plant, and farm-level, technical interventions. The plant would be the first indigenous-owned alpaca wool-processing plant in the world, and the only functioning one in Bolivia. The factory was completed in November 1994, and began production of scoured and combed alpaca wool (called "tops") for local markets and international export. Because of AIGACAA's status as a nonprofit association, an independent corporation, called the Camelid Products Corporation (COPROCA), was created to manage the plant. Forty percent of the stock for COPROCA is owned by AIGACAA, 40% is owned by individual alpaca producers, and 20% is publicly owned (Scholte 1994).

To guarantee a sufficient flow of crude wool to the factory, financial and technical assistance was provided to local camelid producers to increase fiber output. As part of Project Alpaca, assistance was provided in the form of credit (US$1.5 million) for range improvements such as fencing and purchasing improved breeds of alpaca, irrigation projects to expand bofedales (high-elevation wetlands that are crucial grazing lands for alpacas), veterinary care, and direct purchasing of alpaca fiber and skins.

The following section briefly describes the alpaca wool industry to better understand the constraints placed upon AIGACAA, and the attempts by Project Alpaca to overcome some of these constraints.

**International and National Context**

Historically, the international alpaca wool market has been dominated by powerful Peruvian firms monopolizing the export of wool, primarily to British textile mills. Trade relations were established early in the mid-nineteenth century between Peru and Great Britain,
with several British export houses settling in the town of Arequipa, in southern Peru (Orlove 1977). Britain's control over the Peruvian wool export market can be explained by its early involvement in the development of the textile industry combined with the dominant role of the British merchant marine in international shipping and foreign trade in western South America (Orlove 1977). Throughout the nineteenth century, Britain was thus the primary source of foreign credit in Peru, and owned the majority of import-export businesses and shipping lines (Orlove 1977). Arequipa served as the main distribution center for both sheep and alpaca wool, and dominated international trade in southern Peru both during the colonial period and following independence (Orlove 1977). The monopolizing power of the Arequipa wool industry enabled them to fix wool purchase prices (Hale 1981).

Bolivia's lack of involvement in the international alpaca wool market can be attributed to several factors. During the early to mid-nineteenth century, Bolivia lacked operational seaports which precluded any major foreign trade (Hale 1981). Following the War of the Pacific in 1879, Bolivia lost complete access to the sea by Chile, thus rendering the country land-locked (Klein 1992). In addition to its lack of seaports, the more arid climate of Bolivia provided a less ideal habitat for alpaca production compared to Peru. Peru is therefore able to support a much higher number of alpacas than Bolivia. Most of the alpaca wool produced in Bolivia was thus sold or traded to the Peruvians. The Peruvian monopoly on alpaca wool exports still remains one of the major constraints on Bolivian involvement in international export (Dr. William Gschwend, personal communication; Hale 1981).

In the early 1960s, the Bolivian government, in an attempt to break the Peruvian monopoly, organized the Comité Boliviano de Fomento Lanero (COMBOFLA) to begin alpaca wool collection, export, and processing. Britain's decline as the world distribution center for
alpaca wool enabled Bolivia to make contracts directly with other countries (Hale 1981). Collection centers were established by COMBOFLA throughout the Bolivian altiplano and purchased wool at fixed prices. Wool was then sent to La Paz for sorting and cleaning and either exported or sent to an antiquated spinning plant in Pulacayo (Department of Potosi) (Hale 1981). Price fluctuations for alpaca wool, however, tend to be quite high. Orlove (1977:27) explains that for the wool industry in general:

> There is ... relatively rapid movement of the wool clip, and stocks are correspondingly low. Since growers and purchasing firms tend to build up short-term debts that must be repaid, they do not have independent funds that would permit them to retain their clips. The system of auctions also encourages immediate sales. Thus supply is relatively inelastic with respect to demand, and prices fluctuate more sharply than those of most other world commodities. Potential holders of wool futures would therefore run higher risks than holders of other commodities because the danger of gluts is greater.

Alpaca fiber prices are also highly influenced by the supply and demand of other fibers (Project Alpaca Proposal 1991). For example, the abundance of cashmere fiber will tend to diminish alpaca fiber demand and prices. World fashion trends, and decisions made by one large manufacturer, such as Benetton, to include alpaca fiber in one of its articles can potentially increase world demand for alpaca fiber by 50% or more (Project Alpaca Proposal 1991).

This high volatility in the international alpaca wool market precluded COMBOFLA from maintaining a steady stockpile of wool (Hale 1981). This hindered Bolivia from maintaining reliable trade relations with international buyers. As a result of these fluctuations, alpaca wool purchases by COMBOFLA were highly variable (Hale 1981). In addition, producers began receiving a lower proportion of the profits from export (Hale 1981).
In 1978, COMBOFLA was replaced by the *Instituto de Fomento Lanero* (INFOL) (Hale 1981). With backing by the World Bank, INFOL began an integrated development project in Ulla Ulla (Department of La Paz) and began collecting alpaca wool for the proposed construction of a spinning plant (Hale 1981). By 1980, however, international wool prices had crashed. A few years later, INFOL, faced with financial and political problems, stopped purchasing wool. The spinning plant was never constructed, and the US$5 million worth of fiber processing machinery remains in its original crates (Dr. Walter Vilela, personal communication).

Prior to the operation of the AIGACAA/COPROCA fiber processing plant in 1994, Bolivia's alpaca wool processing industry was thus either nonexistent or completely antiquated. The majority of alpaca yarn necessary to supply Bolivia's sweater industry was imported from Peru. In 1994, Bolivia imported 70,000 kg of alpaca yarn from Peru (Scholte 1994). Ironically, much of the crude fiber to produce the yarn may have originated from Bolivia.

**The Producers' Economy**

Discussions of the "traditional" economy of camelid herders living on the Bolivian altiplano have focused primarily on reciprocal exchange or barter (called *trueque*) (Orlove 1981, Hale 1981). These exchange relations have been based on long-established trade between highland herders and agricultural communities in the valleys and lowlands, in which wool and dried meat were traded for agricultural goods (i.e., fruits, vegetables, grains, coca) (Orlove 1981). The terms of trade of this system of reciprocal exchange were generally fixed; however, since the 1950s it has tended to fluctuate according to the monetary value of goods being traded (Hale 1981). Today, the increasing need for cash has resulted in herders selling
their products on the market, which has made them more vulnerable to fluctuations in prices (Hale 1981).

Despite what appears to be recent integration into the market economy, many have argued that Andean herders have been involved in the monetary system for almost a century (Flores Ochoa 1977, Caro 1985). Producers often received cash for their wool, and were subject to fluctuations in supply and demand of the international wool market (Flores Ochoa 1977). The long history of market integration, however, has not radically altered Andean culture or traditional exchange relations (Flores Ochoa 1977). Unlike other "traditional" societies where the market penetration has commonly transformed the relations of production, Caro (1985) has argued that Andean herders have neither been transformed by the market nor have they retreated from active participation in market transactions (Caro 1985). She states that "in many instances, they [herders] have sought out greater participation in the market by diversifying their production and exchange relations" (Caro 1985:ii).

The ability of Andean herders to diversify their markets has been crucial to survival on the altiplano (Caro 1985). Browman (1987a) describes how diversification of productive activities serves as a risk-reducing strategy among Andean pastoralists. Thus, when COMBOFLA was the dominant buyer of wool, and gradually offered lower prices to producers, herders would immediately switch their markets and sell wool contraband to Peru (Hale 1981). This strategy thus limited the degree to which the Bolivian government could exploit the herders (Hale 1981). Today, alpaca herders sell their wool to intermediaries in Peru and Chile, AIGACAA, and markets in La Paz or other cities. Wool is sold in crude form, or sold as hand-spun yarn (called kayto). Local producers also sell hand made scarves, sweaters, gloves, and other knitted and woven textiles. The ability of the herders to diversify
and selectively choose their buyers demonstrates that they are not merely responding to the market, but may actually play a role in affecting market relations (Orlove 1977, Caro 1985).

Orlove (1977) highlights 2 major aspects of wool marketing: centralization and vertical rather than horizontal movements of goods. Wool is commonly passed along a vertical path from producers to various sets of intermediaries to the export houses (Orlove 1977). The role of the intermediaries, or middlemen, has been crucial in the movement of crude wool to the export houses or processing plants. The poor system of transportation and lack of paved highways, as well as inaccessible and highly dispersed production units throughout both Bolivia and Peru, require a large number of middlemen to purchase and transport wool to buyers (Orlove 1977). The level of operation of a middleman will vary from travelling throughout the highlands and purchasing wool directly from producers, to purchasing wool at weekly markets or annual fairs, to those who operate with the largest volume (generally in the biggest towns) and buy wool from the larger traders (Orlove 1977). These intermediaries may be herdsmen themselves, with access to transport (see Chapter 4), or full-time merchants. It was out of the desire to eliminate the middleman, and thus increase profits for producers, that AIGACAA was originally formed.

History of AIGACAA

AIGACAA was founded in 1979 by a group of Aymara camelid herders seeking economic improvements and indigenous self-determination. Through the formation of an association, AIGACAA hoped to "revitalize and reorganize" the traditional ayllu (original, indigenous community) (Hale 1981). Luis Ticona, one of the original founders of AIGACAA and co-director of Project Alpaca, described the objective of the organization as "...to reclaim what is ours, to raise to new heights what is the llama and the alpaca" (Luis Ticona, personal
communication). Ticona (unpublished presentation, 1995), in a speech to the people of Curahuara de Carangas (Department of Oruro), described the historical context from which AIGACAA emerged as an organization:

The llama and alpaca herders once were not only in this area [the high Andes], but in all of the altiplano as well as in the valleys. When the Spanish arrived, bringing with them their sheep and other animals, they took over the best lands which had the best forage. Llama and alpaca herders were marginalized to the most remote areas of the altiplano. Because of this we herders are only in the Cordilleras [Andean Range]…. The llamas are native but the sheep and cows are not, they were brought here from outside…. Fifteen to 20 years ago (1975-80) no one wanted to know about llamas; the llama was considered the animal of the "Indians." They said that we should not eat llama meat because it carried diseases…. But today, since we created this organization of AIGACAA, we lead the way, no longer afraid to hide our faces, we are llama and alpaca herders, conserving our traditional economy and patrimony.

The foundation of AIGACAA, thus, was not only based on improving economic welfare for herders, but also in reinforcing and strengthening the Aymara culture and heritage, and increasing political leverage and power.

The internal structure of AIGACAA is also based on traditional Aymara social organization. Annual meetings are held in which delegates from each participating community come together and elect a president and executive committee for the coming year. Candidates to be elected officials are selected based on ayllu (or community), with representation from different ayllus rotating each year. Prior to and following the annual meetings, delegates meet with their respective communities to discuss issues, disseminate information, and receive input from other members. Hale (1981) states that "AIGACAA attempts to reinforce Aymara social organization by making the ayllu the mediator between individual members and the decision-making body" (p. 102).
The grassroots origins of AIGACAA have made it unique in terms of rural development in Bolivia. Ticona (unpublished presentation, 1995) states:

AIGACAA is not an outside organization telling you what to do or how we will help you, but is an organization of ayllus, dedicated to raising llamas and alpacas. AIGACAA was created in 1979 with the participation of 3 ayllus from the province of Pacajes, the province of Sajama, and some ayllus in Turco. With this small membership, the organization grew year after year to the present membership of over 1000.

This "bottom-up" approach to development, in which the producers themselves take the initiative to organize and identify problems, is unique for Bolivia, where external or government agencies commonly dictate development objectives.

Although the structure and ideology of AIGACAA is based on Aymara heritage and indigenous self-determination, the means by which problems are approached and solutions identified are highly technically oriented (i.e., "Western"), and at times paternalistic (Hale 1981). Hale (1981) suggests that this technical orientation to problem solving is a result of the Western-style training of its members. A scholarship program was offered by AIGACAA in which selected members of herding communities were sent to technical schools to learn veterinary medicine and agricultural extension techniques. When members returned from schooling they were often given a higher status and considered "experts" in their field.

Because of Western-style training, these technicians used models and concepts derived from the U.S. or Europe to identify problems. Short-courses were offered to local herders to teach modern techniques of animal husbandry, sanitation, and pasture improvement. Often these models were inappropriate for the altiplano. Many of the recommendations made by technicians were either unfeasible in terms of the capital investments needed or did not work. Herders' reluctance to adopt new technologies based on their riskiness and capital requirements created divisions between technicians and herders; technicians regarding the herders as
backwards and ignorant, and herders regarding the technicians as paternalistic. This tendency was witnessed by Hale (1981) and was still applicable at the time of this study.

In addition to technical solutions, AIGACAA, in its early days, focused on improving economic conditions for producers by eliminating market intermediaries for alpaca fiber. Fiber was collected and sold directly to the government processing plant. AIGACAA was also involved in selling handicrafts and sweaters made by local herders directly to retailers. All of these efforts focused on the local farm level. Hale (1981) cautions that this local-level emphasis may lead to misdiagnosis of the real constraints and problems. He states, for example, that problems with price exploitation are not primarily due to local intermediaries, but are found at higher levels within the market (Hale 1981).

The local, farm-level emphasis, although, perhaps inappropriate, was "safe" relative to more politically-oriented options. Given the political climate of the country during the 1980s, any attempts at influencing policy were either ignored or severely repressed (Hale 1981). More visible attempts at organization for indigenous empowerment may have been perceived as a threat to the government and quickly dissolved. Another explanation for AIGACAA's initial technical/farm-scale focus is that they simply did not have the leverage to take alternative, political approaches to improving the economic and social welfare of Aymara herders.

Regardless of why AIGACAA took the approach it did, the results of their efforts seemed to bring about limited improvements in the economy of the herders. Many members were unhappy with the lack of any visible economic benefits. The constraints both internal to AIGACAA, such as insufficient capital to implement projects, as well as problems with infrastructure and development within Bolivia itself, and the Peruvian monopoly on the alpaca fiber market, all resulted in little advancement for the herders prior to Project Alpaca.
Project Alpaca

As mentioned earlier, funding for Project Alpaca was approved in 1991 by the UNDP and UNCDF. The project was funded for 5 years. Directorship of Project Alpaca was shared by AIGACAA representative, Luis Ticona, and Dr. William Gschwend from Appropriate Technology International (ATI). A private, nonprofit development assistance corporation, ATI's goals are to

...work with local partners in Africa, Asia, and Latin America to identify, adapt, and disseminate technologies through creation of commercially viable and environmentally sustainable enterprises that improve the productivity, incomes, and quality of life of the rural and urban poor. (Project Alpaca Proposal 1991: 22)

The goal of Project Alpaca was to relieve the constraints of alpaca fiber production and processing, and to create a product that could be competitive in the international marketplace.

Specific objectives of Project Alpaca included: (1) increasing annual alpaca fiber production per animal, and (2) maximizing the "added value of the fiber by processing and marketing it in the form of 'tops'" (Project Alpaca Proposal 1991:25). The first objective was to be achieved through enhanced animal nutrition via pasture improvement, veterinary campaigns, and genetic improvement. The second objective was to be carried out by the construction of the fiber processing plant.

At the onset of the project a marketing study was conducted by a German textiles expert to determine the international demand for alpaca wool (Scholte 1994). The study revealed that alpaca wool in the European market would be in high demand for at least the next few years, and that demand was shifting from white to natural colors (Scholte 1994). Peru had been breeding their alpacas for white wool; however, Bolivia's alpacas were a variety of colors (i.e., browns, black, grays, creams). Next, an Italian textile engineer with 20 years of
experience was brought in as a consultant to design and select the machinery for the fiber processing plant. Premium washing, carding, combing, and pressing equipment, worth US$500,000, was purchased. The initial production capacity of the plant was 120,000 kg of alpaca "tops" per year (Scholte 1994). Production could be doubled with the addition of an second shift. The goal was to achieve an export revenue of approximately US$600,000 (Project Alpaca Proposal 1991).

Coincidental to project implementation was an increase in the price of alpaca fiber between 1993-4. The price of crude fiber increased roughly 266%, from 6 Bs./lb. to 16 Bs./lb. The incomes of many herding families increased dramatically during this period. One herder from Cosapa claimed to have occasionally earned up to US$500 per week. This is a major contrast to the average of US$25 to US$50 per month earned previously. Much of the increase in income was based on the ability of some households to work as intermediaries--travelling at times as far as the Argentinean border to buy wool and sell it to either AIGACAA or Peru (Anonymous Cosapa herder, personal communication). The high influx of capital at the time allowed herders to purchase property in La Paz. Others purchased trucks which allowed them to work as intermediaries and also to charge fares for transport.

Improvements in roads also coincided with project implementation. A new international paved highway connecting La Paz to the seaport of Arica, Chile, was completed in July, 1996. The highway passes through much of the camelid-producing region and is in close proximity to many of the ayllus that were members of AIGACAA. Herders claim that travel to La Paz once took up to a week in the rainy season. With completion of the paved highway, travel to La Paz is now possible in 2 to 3 hours. This dramatic change in access to the city will no doubt strongly impact the alpaca fiber marketing capabilities.
The high price attained for alpaca wool in 1994 was artificial and unsustainable. Gschwend (personal communication) claimed that Michell & Cía., S.A., the largest alpaca wool manufacturer in Peru, attempted to crush AIGACAA by competing for their fiber stock. AIGACAA, however, was able to match Michell's prices and remain competitive during the 1994 price inflation. Gschwend (personal communication) claims that Michell lost over US$10 million during this time. Michell, however, in addition to dominating the alpaca wool industry in Peru, is also owner of Coca-Cola of Peru and was therefore able to absorb the loss (Dr. William Gschwend, personal communication).

The ability of AIGACAA to successfully compete with the Peruvians was encouraging for producers. In the early stages of the project contacts were made with the Italian buyer, Lauro Piano, as well as other European textile firms, to negotiate sales (Scholte 1994). This networking has and will be crucial to AIGACAA's success. The inability to maintain international contracts has been one of the main constraints for Bolivia's alpaca wool industry (Scholte 1994). Gschwend has described the international textile market as a "club," which is "good to its members, but quickly excludes those who try to manipulate the market or who break their word" (Scholte 1994:5). For AIGACAA to be included in the "club" indicates a tremendous increase in its potential leverage and power.

Thus, in contrast to the local farm-level emphasis of AIGACAA's past, Project Alpaca took a multi-layered, multi-disciplinary approach, with the primary goal being economic transformation. In addition to focusing on local constraints, Project Alpaca attempted to change the relationship camelid producers had with both national and international institutions. In the context of political economy, the international wool market is no longer an "exogenous" factor influencing the herders' system. The herders themselves, via AIGACAA, are now
establishing contractual agreements with international buyers. These buyers are now "clients" rather than intangible forces affecting the producers.

The model by which Project Alpaca was based follows a standard methodology employed by ATI. ATI first identifies the "value chain," which consists of "the steps in production, processing and marketing that add value to a particular commodity (Cubberly 1994:A)." This "value-chain" approach is commodity-oriented and builds a model of the structure and function of the system surrounding the commodity (Cubberly 1994). Once the steps are identified in a system, the goal is then to relieve the bottlenecks in the production chain.

For Project Alpaca, the "value chain" consists of local farm-level care and pasturing of animals, collection and processing of fiber, and marketing. Specific details of each stage are outlined below in Figure 2.1.

Membership

Although Project Alpaca has been successful in construction of the factory and initial processing of wool, progress at the community level remains slow. The sudden boom in the price of alpaca was temporary, with prices lowering to about 10 Bs/lb in 1995-6. The capital earned and saved during the boom, however, allowed producers to make investments. Credit offered by AIGACAA also provided additional capital. Any benefits from the technical improvements provided for by credit will require several years before they are visible. AIGACAA admits that repayment of credit is not assumed to come from profits made in the investment. Whether AIGACAA can independently continue their credit program will depend upon the repayment success of the beneficiaries in the next few years.
The value to the herders as stockholders in COPROCA also appears to be limited at the moment. The policy of AIGACAA was that all members of the association would automatically hold 4 shares of the company, at US$25 per share (Serapio Ramos, personal communication). Individual herders could then purchase more stock if they desired. Interest in stock was highly lucrative the first few years, with annual returns on investment of 25%. Purchase of additional stock, however, has remained low (AIGACAA Annual Meeting, unpublished data 1996). With the herders as stockholders, AIGACAA hoped to create a

Stage I - Fiber Production
- Credit in the form of a US$1.5 million loan program to enable investment in fencing, pumps, wells, and genetically improved animals
- Fencing for reserve forage
- External parasite baths
- Breeding program for higher quality stock
- Irrigation canals, wells, and pumps
- Veterinary services

Stage II - Primary Fiber Processing
- Improved shearing techniques
- Fiber classification
- Fiber separation-selection of best quality (at local level)

Stage III - Fiber Collection
- Collection points established over a 50,000 sq. mi. area
- Delivery of fiber to plant via truck

Stage IV - Secondary Processing
- Sophisticated machinery to process fiber
- Machine processing capacity of 14 tons/month at single shift, and possibility of double shift
- Classification of fiber
- Final product in the form of "tops" (inch-thick cord of aligned fiber) wound into bales and sealed for shipment
- Fiber washed with biodegradable surfactant and dried in forced air dryers, producing non-toxic effluent

Stage V - Secondary Products Marketing
- Textile industry experts to complete in-depth marketing studies and marketing strategy
- Studies charted the international demand structure for alpaca tops and export-linked
- Direct linkages to major buyers and users national market for alpaca yarn

Fig 2.1. The "value chain" for alpaca wool (modified from Cubberly 1994).
greater incentive for producers to sell their wool exclusively to AIGACAA. Herders, however, still look to the highest price when selling. This perhaps can be explained by the economic and cultural need to have "cash in hand" or to at least have some tangible indication of their wealth. In 1996, AIGACAA had not yet released information on the amount earned by individual stock holders. Rather than returning the profits earned to producers, AIGACAA is reinvesting the fund to purchase more wool. This lack of visible earnings may explain why herders are reluctant to invest more in COPROCA.

Technical Interventions

Adams (1990) discusses the "nature of ideologies of desertification" as determining how problems are perceived and how policy recommendations are made. "Overgrazing" has traditionally been blamed for causing land degradation and desertification (Sandford 1983). Improvements in range management have thus been recommended to combat and reverse the "adverse" affects of overgrazing. This perspective conforms to the "Classical" paradigm of conservation-environmentalism described by Blaikie and Jeanrenaud (1996) that assumes that humans are inherently destructive to nature. Management recommendations to reduce overgrazing and degradation are based on equilibrial concepts of pastoral system dynamics in which some fixed carrying capacity is estimated for a site, and animal numbers are adjusted to meet the proper carrying capacity (Ellis and Swift 1988, Behnke and Scoones 1993). Fencing, to exclude animals or to set up rotational grazing schemes, has also been recommended, based on the equilibrium model.

Project Alpaca has not been immune to the overgrazing model. For example, the proposal to fund Project Alpaca states:
Resources are scarce and often mismanaged. Pasture and rangelands are overgrazed...[G]iven the ongoing degradation of the natural resources...it has been estimated that within 5 to 8 years the producers of the region...will be unable to support themselves due to the condition of the degraded resources (Project Alpaca Proposal 1991:74-5).

The technical interventions proposed by Project Alpaca to offset the assumed degradation and improve productive capacities include: (1) improved pasture management through the use of fencing and rotational grazing systems; (2) improved pasture production through implementation of small-scale irrigation; (3) improved health of herds through introduction of both preventative and curative health programs; and (4) improved genetics of herds, especially alpaca, through use of systematized culling and introduction of improved bloodlines (Project Alpaca Proposal 1991).

In addition to the technical innovations listed above, several major irrigation projects were implemented in 4 different regions, with costs of each project ranging from US$50,000 to US$75,000. These projects were intended to divert water from existing local rivers to irrigate and expand wetland bofedal areas. These wetland areas serve as important grazing pastures for alpacas (see Chapter 3 for more details). The technical interventions of Project Alpaca, thus, are heavily based on Western models of sedentary, ranch management. The ecological and social impacts of many of these interventions will be evaluated in Chapters 5 and 7.

Conclusion

The domination of the alpaca wool market by Peru, combined with the failures of government-owned wool processing attempts within Bolivia, provides the context for the emergence of Project Alpaca. The Bolivian herders' ability to diversify their market relations has enabled them to be highly integrated in the wool market economy, yet maintain control
over production relations. AIGACAA was organized by camelid herders to strengthen control over these relations, and create lasting improvements in the herders' economy. Project Alpaca provides the vehicle from which the goals of AIGACAA can be achieved. The appropriateness of project goals, its success, and implications will be evaluated in later chapters.
CHAPTER 3

COSAPA: ENVIRONMENT AND SOCIAL SETTING

Introduction

One of the main target communities for Project Alpaca is the cantón, or municipality, of Cosapa, also referred to as the ayllu (traditional, Aymara community) of Sullka Jilanaka. Approximately 90 households currently residing in Cosapa are members of AIGACAA. Because of its high level of membership, the AIGACAA main headquarters is located in Cosapa. Project Alpaca provided funding for a resident veterinarian and 2 extensionists to serve the area. Cosapa was selected as the focal community for this study because of its close affiliation with AIGACAA, and because it served as one of the target communities for Project Alpaca's technical interventions. The purpose of this chapter is to describe the local environment and social setting of Cosapa to provide the context for understanding pastoral system dynamics in the community, as well as the impacts of development interventions.

Environment

Location

The Bolivian altiplano, or high plateau, is a high-elevation tableland surrounded by the western and eastern Andean mountain ranges (referred to as the Cordillera occidental and Cordillera oriental, respectively). The altiplano extends approximately 500 miles south from Lake Titicaca, with an average elevation of 4,000 m.a.s.l. Productivity on the altiplano is often uncertain and highly variable, and is characterized by a low and erratic rainfall regime, frequent droughts, soil salinity, chronic risk of frost, and low soil fertility.
Cosapa is located on the western edge of the south-central altiplano in the Province of Sajama, Department of Oruro, in what has been one of the most isolated regions of Bolivia (see Figure 3.1). The elevation of Cosapa is approximately 3,900 m.a.s.l. Figure 3.2 shows the location of Cosapa within the Province of Sajama, Department of Oruro. The community and its associated hamlets (called estancias) are located in a broad valley just south-east of Mount Sajama (6,542 m.a.s.l.), Bolivia’s highest mountain (see Figure 3.3). Additional mountain ranges surround the valley to the west and east, and form part of the Western Cordillera of the Andes. The community encompasses approximately 60,000 ha of land consisting of mountains, alluvial fans, and valley bottom or pampa.

Cosapa is approximately 260 km southwest of the city of La Paz, and approximately 45 km east of the Chilean border. In 1994, the only form of public transportation from the community was by truck, which made trips once a week to the city of Oruro. Travel time to Oruro ranged from 14 to 24 hours, depending on season and road conditions. A large, open-top truck loaded down with passengers transporting sacks of wool and meat would leave the community at midday and arrive in the Oruro markets in the morning of the following day. Passengers would huddle together in the back of the truck, wrapped in blankets, as the creaking truck bounced along the dusty road to Oruro. By car, however, travel time to Oruro was only about 5 hours. Average travel time to La Paz was 8 to 15 hours by pickup truck or car, also depending on season. Construction of a major paved highway from the town of Patacamaya to the Bolivia-Chile border of Tambo Quemado began in 1994. The highway, which passed just north-west of Cosapa, would provide a direct route from La Paz to the Chilean sea port of Arica. The highway was completed in July 1996, after which travel time from Cosapa to La Paz was reduced to 2 to 3 hours.
Fig. 3.1. Map of Bolivia indicating the location of Cosapa (Province of Sajama, Department of Oruro).
Fig. 3.2. Map of the Department of Oruro, indicating the location of Cosapa within the Province of Sajama.
Fig. 3.3. Photograph of Cosapa, Province of Sajama, Department of Oruro, showing the main town (or pueblo), with Mount Sajama (6,542 m.a.s.l.) in the background.
A portion of Cosapa lies within the boundaries of Sajama National Park. Prior to the existence of the new highway, tourism in the area was primarily by American and European alpine climbers interested in ascending Mt. Sajama. The impact of tourism on the community, however, has been minor. Some of the park policies established thus far include prohibition of hunting wildlife listed as endangered, and removal or cutting of *khenua* (*Polylepis tarapacana* Philippi) for fuel wood, which is the only tree species in the area.

**Climate**

The climate of Cosapa is semiarid. From 1975 to 1996, average annual precipitation was 332 mm with a coefficient of variation of 43% (Figure 3.4) (Servicio Nacional de Meterología e Hidrología--SENAMHI, unpublished data). It is important to note that most long-term precipitation means and variances require a minimum of 30 years of data, and thus extrapolation of these summary statistics for Cosapa should be done with some degree of caution. The pattern of precipitation is unimodal, falling primarily in the summer months between December and February (Figure 3.5). March through November are dry and cold. There is occasionally snowfall in August; however, due to high daytime temperatures, snow remains for only a few days.

Figure 3.6 shows the monthly temperature statistics for Cosapa. The diurnal temperature fluctuation can be very high, with daytime temperatures of 20 °C and nighttime temperatures falling to -10 °C. The minimum extreme temperature in July is -14.4 °C (SENAMHI, unpublished data). Frost occurs 260 days of the year, with an average of 31 days in July and 13 days in February.
Fig. 3.4. Mean annual precipitation (1975-6 to 1995-6) for Cosapa based on a water year (August to July) (SENAMHI, unpublished data 1996). A water year is defined by the beginning and end of a growing season. MAP is mean annual precipitation, and CV is the coefficient of variation, defined as the standard deviation divided by the mean.

Fig. 3.5. Mean monthly precipitation for Cosapa from August to July, based on data obtained from 1975 to 1996 (SENAMHI, unpublished data 1996). A water year is defined by the beginning and end of a growing season.
Fig. 3.6. Mean monthly temperature ranges for Cosapa, based on data collected between 1985 and 1996. Source: SENAMHI (unpublished data).

Soils

According to SENAMHI, most of the soils of the foothills and alluvial fans of Cosapa are derived from Western Cordillera parent material. Soils are thus volcanic in origin, moderately deep to deep, and coarsely textured. Soils found on foothills and alluvial fans are classified as Typic Ustochrepts and Typic Ustorthents (SENAMHI, unpublished data). The dominant soils found in the valley bottom and floodplains are classified as Typic Cryaquepts and Aquic Cryopsammments (SENAMHI, unpublished data).
Hydrologic Resources

Several perennial streams and rivers cut through the valley, the Cosapa River being the major one. Many of the perennial sources of water originate from glacial runoff from Mt. Sajama. Diversion of water from these sources to create irrigated, wetland pastures, or bofedales, has been an ancient practice that is critical for alpaca production (Palacio Rios 1977). Elaborate, earthen canals are constructed and maintained over generations to provide constant irrigation of the bofedales. More aspects regarding bofedales will be reviewed in the following section.

Vegetation

The region encompasses several biomes, including mountain desert and steppe, mountain matorral desert, and subalpine desert and matorral (SENAMHI unpublished data). Several plant communities can be defined for the area. Alzérrea (1988) describes 5 major vegetation types in the arid altiplano: t'olares (shrubland), t'olar- pajonales (shrub-bunchgrass), pajonales (bunchgrass), bofedales (wetland forbs, sedges, and grasses) and gramadales (shortgrass). The t'olares, or shrubland, occurs primarily on upland foothill sites and alluvial fans, with sandy, well-drained soils. Common species include Parastrephia lepidophylla (Wedd.) Cabr., P. quadrangularis (Mey.) Cabr., P. lucida (Meyen) Cabr., Baccharis incarum Weddell, and B. polyccephala Wedd. The pajonal, or bunchgrass community, occurs on the alluvial fans and sandy portions of the valley bottom, and is dominated by Festuca orthophylla Pilger and Calamagrostis breviaristata (Wedd.) Pilger.

The bofedal is a high-elevation, wetland community dominated by low-growing grasses, sedges, and forbs. Also referred to as "cushion peat bogs," the bofedales receive a constant supply of water from glacial runoff, a high water table or irrigation (Estenssoro
Cernadas 1991). They naturally occur around rivers, seeps, and springs where there is a year-round supply of water. They have also been maintained and expanded by human intervention through irrigation (Palacio Rios 1977). T'olar or pajonal sites can be converted to bofedal with irrigation in a period of 3 to 5 years (Serapio Ramos, personal communication). AIGACAA has divided bofedales into 3 classes based on degree of moisture (Serapio Ramos, personal communication). A Class 1 bofedal is the most moist, having permanent inundation and dominated by *Distichia muscoides* Nees & Meyen and *Oxychloe andina* Phil. In Cosapa, this type of bofedal is found only in the mountains. A Class 2 bofedal is less moist, often in slightly saline areas, but still receives enough water to remain green year-round. Class 2 bofedal is dominated by *Werneria pygmaea* Gill., *Plantago tubulosa* Decne, *Juncus stipulatus* Nees & Meyen and *Puccinellia oresigena* Phil. A Class 3 bofedal is the driest, receiving semi-permanent to intermittent moisture. These areas can be dry in the winter, and are dominated by *Calamagrostis curvula* (Wedd.) Pilger, *Distichlis humilis* R.A. Phil, and *Carex* sp L. When this type is dominated by *Distichlis humilis*, it is called a gramadal. The vegetation found in bofedal Classes 1 and 2 provide essential green forage for alpaca, especially during the dry season. Class 3 bofedales are more preferred by llamas, due to the higher fiber content of the forage.

In highly saline areas, dominant species include salt-tolerant cushion plants, such as *Salicornia* spp. L. and *Anthobryum triandrum* Remy, as well as grasses, such as *Calamagrostis breviaristata*. On slopes of surrounding mountains, woodlands of khenua (*Polylepis tarapacana*) can be found at elevations of 4,300 to 5,200 m.a.s.l. (Liberman 1986). Also found in this community type are species of t'ola shrubs (see above), as well as *Adesmia spinosissima* Meyen, *Tetraglochin cristatum* (Britt.) Rothm., *Calamagrostis* spp. Adans.,
Lupinus sp. L., Festuca orthophylla, Pycnophyllum molle Remy, and Azorella compacta.

Finally, khotales are areas with very little vegetation cover except for cushion plants of species Pycnophyllum glomerratum Remy and Junelia minima (Meyen) Mold. Table A.1 in Appendix A provides a complete list of plant species found in Cosapa.

Wildlife

Compared to other parts of the Bolivian altiplano, Cosapa and its surrounding area are rich in native fauna. A large proportion of Bolivia’s threatened and endangered animal species are found in the region. These include the puma or mountain lion (Felis concolor), vicuña (Vicugna vicugna-- a wild camelid), condor (Vultur gryphus), flamingo (Phoenicopterus sp.), suri or emu (Pterocnemia pennata), Andean cat (Felis jacobita), quirquincho (Chaetophractus nationi--a close relative of the armadillo), huallata (Chloephaga melanoptera--a native duck), and the vizcacha (Lagidium viscaccia--a species of chinchillid). More common species include the Andean fox (Pseudalopex culpaeus andinus--the major predator of sheep and young camelids), skunk (Conepatus chinga rex), and an introduced hare (Lepus sp.).

Social Setting

The People

The people of Cosapa are pastoralists belonging to the Aymara indigenous group. Their native language is Aymara, although most community members are now bilingual in Spanish and Aymara. Many of the older women in the community, however, do not speak Spanish. The total human population of Cosapa is 934, with the majority of the population residing in dispersed estancias. Households are generally defined by nuclear families
consisting of a married couple, their children, and occasionally a widowed parent (Orlove 1981). The number of households living in an estancia ranges from 3 to 30 and are often kinship-based. There are approximately 200 estancias within the cantón of Cosapa. There is also a central village, or pueblo, where the primary and secondary schools are located, along with churches and shops. Most households have a house in their estancia and one in town. Production systems are primarily pastoral with livestock species composed mainly of llama, alpaca, and sheep. Some families also keep pigs and chickens. Some estancias have access to more hilly terrain, where occasionally potatoes, barley, and quinoa (*Chenopodium quinoa* Willd.) are cultivated. The high risk of frost and drought, however, generally precludes other forms of agriculture. Many households have stated that within the past 10 years they have not been able to cultivate potatoes due to low rainfall. Households with estancias located closer to the mountainous regions are able to take their male llamas to separate mountain pastures to graze.

**Herd Composition**

Because of the aridity of the central and south-western altiplano, alpaca production is often marginal in these areas, while llama and sheep production is more favored. Without sufficient bofedales, alpaca production is very limited. In Cosapa the average number of alpacas per household is 34, whereas the mean number of llamas is 64 per household, and 43 for sheep, based on a pre-project survey conducted by Project Alpaca (Mamani Consultores, unpublished data 1991). Herd sizes of llamas, alpacas, and sheep per surveyed household are presented in Figure 3.7 (Mamani Consultores, unpublished data 1991).
Fig. 3.7 (a, b, c). Herd sizes of (a) llama, (b) alpaca, and (c) sheep among households from Cosapa surveyed by Project Alpaca in 1991 (Mamani Consultore, unpublished data 1991).
Historical Background

Pastoralism on the altiplano dates back to 7,000 to 9,000 years ago when llamas and alpacas were first domesticated (Browman 1974). Archeological records indicate that the earliest Paleoindians hunted native camelids (llama, alpaca, guanaco, and vicuña) for meat, wool, and fat as far back as 14,000 years ago when these animals first entered the South American continent (Kolata 1993). Following domestication the llama and alpaca soon became the cornerstone of the altiplano economy (Kolata 1993). The Aymara kingdoms, which dominated the central highlands of Bolivia from the end of the 12th century until the arrival of the Spanish in the 16th century, were said to have controlled large herds of llamas and alpacas (Kolata 1993). According to Kolata (1993), these animals were carefully bred, primarily for wool, to produce a variety of woven textile products used for clothing, exchanged for food, or to fulfill social obligations. In addition to their wool value, the domesticated camelids were important sacrificial animals during religious ceremonies. The llama provided an important source of meat and fat and the bones were crafted into tools. Llama dung was an important fuel source. The llama was also an important pack animal, transporting textiles, dried meat, metals, and salt over long distances. Kolata (1993) states that the llama was the only efficient pack animal in the ancient Americas, and by the 16th century llama caravans included up to 2,000 animals.

The organizational structure of the contemporary Aymara society still reflects much of the historical foundations of the Aymara kingdoms. The basic unit of Aymara social organization was the ayllu, which consisted of endogamous kin groupings (Hale 1981). Membership in an ayllu entitled an individual to common rights to land. Each ayllu had a
leader known as a *jilakata*. The jilakatas, in turn, served regional chiefs, or *kurakas*, who held land apart from the ayllus and extracted free labor from their constituent ayllus (Klein 1992).

**Community Organization**

The municipality of Cosapa is divided into 4 administrative zones based on geographical location. The 4 zones in Cosapa are Anta Qollu to the northeast, Laguna Parada to the southeast, Posito Verde to the southwest, and Kara Qollu to the northwest. Households whose estancia falls within one of the zones is considered a member of that zone. Representatives from each zone are alternately selected to fill administrative positions for the entire community. Sports teams within the community are also organized by zone, with members from each zone participating in the annual men's soccer and women's basketball tournaments. Zones are also represented during the festival of Carnival, with each zone having its own band of dancers and musicians.

Community leadership and representation in Cosapa still includes a jilakata, who is considered the indigenous community leader and has specific duties and responsibilities to the community. These duties include hosting various festivals, by providing llamas and alpacas for meat, organizing labor groups to build and maintain public structures, collecting fees and tribute, and resolving local conflicts. In addition to the jilakata, local administrators (i.e., mayor, *corregidor*, and judge) also govern community affairs and serve as local representatives to the state. The jilakata, mayor, and corregidor are positions held for 1 year by adult male community members. These positions are considered obligations and duties of all men who have title to land. Members are elected by the current administration. Jilakatas from 2 of the 4 zones are selected each year, with zone representation alternating every other year. All of
the community leaders, or *autoridades*, work together, and organizational meetings are held weekly.

**Livelihood**

As mentioned above, livelihoods in Cosapa are based on pastoralism of llamas, alpacas, and sheep. Livestock production provides for both subsistence needs, and as a means of engaging in larger exchange relations. Historically, reciprocal exchange and trade relations have been critical to survival on the harsh altiplano environment (Orlove 1981). Since agricultural production is highly limited in this region, trading dried meat, textiles, and salt with lowland agriculturalists and coastal communities for fruits, vegetables, and grains helped maintain a balanced diet for the herders.

Alpacas are primarily raised for their wool, although their meat is often used for home consumption and occasionally for sale. Wool is sold for cash or bartered for food or other goods. Alpaca wool receives the highest price compared to llama or sheep wool. In addition to selling bulk fiber, herders will also sell secondary wool products (i.e., hand-spun yarn, and knitted or woven textiles).

Llamas are primarily raised for meat production. Commercial sales of meat constitute the largest revenue generator for herders in Cosapa (Project Alpaca Proposal 1991). Llamas are generally slaughtered in Cosapa, and their meat transported to La Paz or Oruro for sale. Llama fiber is also sold, albeit at a much lower price than alpaca wool. Unlike alpacas, llama wool consists of a combination of coarse, hair-like fibers mixed with finer wool. Many households will pick out the coarser hairs and sell the wool, claiming that it is alpaca. Llama wool is also used for subsistence needs (i.e., made into rope or woven into blankets).
Sheep are raised for meat, wool, and occasionally for milk for making cheese. The sheep in Cosapa primarily belong to the criollo breed, and produce coarse wool of low economic value. Most households will use their sheep wool to weave blankets, although they may also sell their wool for cash. Sheep meat and cheese are consumed in the home, sold locally, or transported to the cities (i.e., La Paz or Oruro) for sale.

In addition to selling wool and meat from their own animals, many of the pastoralists in Cosapa work as intermediaries—buying wool from producers throughout the altiplano, and reselling it to Peruvian wool manufacturers, at weekly and annual fairs, or to markets in La Paz. Intermediaries of meat sales are also common in Cosapa. These middlemen will purchase live animals, primarily sheep either from households within Cosapa or from the larger region, slaughter the animals, and sell the meat to markets in La Paz or Oruro. Within the community, 2 to 3 people own large trucks that transport wool and meat. Many of the truck owners either work as intermediaries themselves or receive payment from intermediaries to transport their products.

**Wage Employment**

Although livestock production is the primary occupation for the majority of households in Cosapa, many community members are also involved in other types of income-generating activities. Construction of the paved highway through the region (Patacamaya-Tambo Quemado highway) opened up employment opportunities in construction and trucking from 1993 to 1996. During this period monthly cash incomes for many households increased dramatically, as much as 100% (Dr. William Gschwend, personal communication).

Migration to the cities to work as wage laborers is also common, especially among the youth. Teenage girls are often sent to work in the city as maids or in factories. Adult males
also leave the community to work as wage laborers in construction, trucking, agriculture, and factories. Migration to Arica, Chile, to seek employment in agriculture or factories is also common. Many community members also work as herders for Chilean ranchers in the mountains near the border. Often their payment is in alpaca or llama offspring rather than in cash.

Remittances are commonly sent back to Cosapa, and migrations are generally temporary. Compared to other communities on the altiplano, however, the rate of emigration from Cosapa has been relatively low. The rise in wool prices in 1994 allowed many households to accumulate cash and purchase land in La Paz (El Alto) or Oruro, as well as purchase other material items such as motorcycles, cars, trucks, and bicycles. A few households have also purchased televisions and VCRs, and charge entry fees to community members to watch television and videos.

Land Tenure

Grazing lands in Cosapa are under ownership by groups of households that share a common estancia. Each household holds title to land, but may share that title with other households. Within this system of communal ownership, however, each household has a designated area where their animals are allowed to graze. Rights to grazing in the mountains (generally for male llamas) are less rigidly defined. Some sources indicate that because human emigration is relatively low for the area, population growth has resulted in increased pressure on grazing lands (Anonymous herder from Cosapa, personal communication). Trespassing is a common complaint, and some individuals stand guard over their property to insure that neighboring animals do not enter their land.
Land use rights are obtained through inheritance from father to son (Llanque 1995). A woman will generally move to her husband's estancia and thus lose grazing rights in her native estancia (Llanque 1995). In some cases, if there is insufficient land in her husband's estancia or if there is abundant land in her native estancia, she may be allowed to keep animals in both places. In situations where there are only daughters in a family, one of the daughters will inherit the land and her husband will come to her estancia (Llanque 1995). If the family has several sons and parcelization of the land results in too small of a parcel, then the father will give the entire piece of land to his oldest son (Llanque 1995). The other sons would then be required to seek rights to land from other relatives, marry into a family composed of only daughters, or migrate out of the community (Llanque 1995).

Labor

Many households in Cosapa claim that labor requirements among camelid herders are much lower than for other types of livestock. Llamas and alpacas, in general, require less herding than cattle or sheep. In the dry season, pastoralists in Cosapa will generally check their herds once or twice a day—in the morning to take animals to pasture and in the evening to bring animals home. In general, however, camelids require very little herding and will come home on their own.

During the wet season (December through March), however, labor requirements are high (Llanque 1995). This period is referred to the *epoca del ganado* or the livestock period. It is during this period that llamas and alpacas are bred, marked to identify ownership, sheared, and give birth. During the birthing period herders must be vigilant and check on the animals during the early mornings (i.e., 3 to 5 a.m.) to make sure that camelid offspring (called crias) born during the night or at dawn do not freeze to death. For other tasks that require many
individuals (i.e., marking, shearing, slaughtering), a family will request assistance from neighbors or relatives. Payment for labor is often in the form of reciprocal labor exchange where a household will repay assisting households by providing labor in a similar activity (Orlove 1981). In other cases, the household will repay their laborers in the form of food, coca leaves (*Erythroxylon coca*), and drinks (Orlove 1981).

Labor demands are also higher for households who utilize mountain pastures. These mountain pastures are commonly reserved for male llamas and alpacas. Female llamas are also taken to mountain pastures during the dry season. Female llamas often require constant herding in the mountains, while male animals require herding from 1 to 3 times per week. A herder will often stay in a temporary hut in the mountains if it is necessary to remain with the animals for several days and if the distance needed to travel back to the estancia is too far.

Browman (1987) states that following the Bolivian Agrarian Reform in 1953, available labor for herding was substantially reduced. Universal schooling has removed children from the labor pool, although in Cosapa many households will remove one teenage daughter from school in order to herd. The expansion of agriculture in eastern Bolivia, as well as in Chile and Argentina, has opened up opportunities in wage labor for herders with few or no animals (Browman 1987). Job and educational opportunities in the cities have also increased emigration from the rural, highland communities. Thus, labor is becoming an important constraint on livestock production.

**Acquisition of Livestock**

Individuals, both male and female, begin to inherit livestock from both parents often at birth or as young children (Orlove 1981). The first hair-cutting ceremony, when a child is 2 to 5 years of age, has traditionally been a time when parents, relatives, and the *padrino* or
madrina (godfather or godmother) give animals to the child. The custom is currently changing, however, such that children are given cash rather than animals. One problem with giving cash, however, is that rather than investing the money in animals for the child's future, the parents may use it for more immediate needs (i.e., clothing, school supplies).

Parents or godparents may also give animals to their children during the annual marking ceremony (or k'illpa). The animal given to the child is marked with a specific tag during the ceremony, indicating its ownership to the child. Llanque (1995) discusses how this practice initiates the child into pastoral society and the responsibilities of animal management. Although a child may "own" animals within the family herd, if the animal is sacrificed for meat or wool, the benefits are shared among the family (Llanque 1995). Thus, the act of giving an animal to a child not only provides the child with a means to build her/his own herd over time, but also serves to socialize the child to the norms of reciprocity and sharing (Llanque 1995).

Inheritance of livestock also occurs when a couple is married (or united) and forms a new home (Orlove 1981, Llanque 1995). Animals are given to both sons and daughters in a family. Upon marriage a woman will take her livestock to her husband's estancia (Llanque 1995). Parents may also decide at some point to "retire" and divide their animals equally among their children (Llanque 1995).

Additional ways in which individuals acquire livestock apart from gifts or inheritance include purchasing animals from neighbors, or receiving a portion (usually half) of lambs or crias in exchange for herding. According to Browman (1987b), this latter mechanism of exchanging herding for livestock (called wak'i) has become more popular in recent times due to reductions in labor availability. This strategy is a particularly important means by which poorer households can acquire animals. Prior to forced schooling of children and the lack of
wage labor opportunities in the lowlands and cities, labor was abundant and households with large herds would contract a poorer household to herd their animals. The herder would receive only a few of the offspring as payment for herding. Following the 1953 Agrarian Reform, available labor was highly reduced, thus increasing the cost of labor. Payment for herding, today, is commonly half of the offspring born per year (Browman 1987b).
CHAPTER 4
PASTORAL MANAGEMENT AND PRODUCTION

Introduction

This chapter focuses on describing the components of land and livestock management in Cosapa, as well as the current status of herd productivity. The aim is to provide a sufficient context of pastoralism in Cosapa from which pastoral system dynamics and development interventions can be evaluated. The technical aspects of animal husbandry and pasture management will be highlighted, along with livestock production and marketing. Because technical components of Andean pastoralism have evolved within a broader Aymara cultural, social, and economic organization, the rituals and customs associated with a given management practice will also be described.

The long history of Andean pastoralism has resulted in the development of highly specialized forms of land and livestock management practices. Browman (1990) emphasizes the risk-reducing (versus yield-maximizing) strategies of Andean pastoralists. Risk management strategies include (1) specialized pasturing and stocking strategies; (2) diversification of productive activities; (3) movement of animals, and labor migration; and (4) establishment and maintenance of social institutions and networks (Browman 1987). Embedded within these macro-level strategies are specific practices that combine historical knowledge, passed down over generations, and recently adopted contemporary innovations.
Methods

Study Site

The study was conducted within the cantón of Cosapa. Detailed description of the study area is provided in Chapter 3.

Participant Observation

One of the primary means of obtaining information on land and livestock management in Cosapa was through participant observation. Lofland (1971) describes participant observation as "the circumstance of being in or around an on-going social setting for the purpose of making a qualitative analysis of that setting" (p. 93). Patton (1990) discusses the many advantages of using participant observation for field researchers. These advantages include: (1) obtaining a better understanding of the context of a situation; (2) being open, discovery oriented, and inductive; (3) seeing what may normally escape conscious awareness among local residents; and (4) use of personal knowledge and direct experience to aid in understanding and interpreting a situation.

In addition to benefitting the researcher, participant observation provides the opportunity for researchers to "pay back" the people and community for the information they obtain (Van Esterlik 1985). Jorgensen (1989) states that despite the fact that many research projects offer no benefits to the people being studied, there is a moral obligation to compensate research collaborators or subjects in exchange for their cooperation. Kusel (1991) addresses the importance of establishing relationships between researcher and community members that are fair and can contribute to the community.
For example, within the Aymara culture labor is often a constraint, and it is generally expected that all available hands provide assistance when needed. Whether it be building a new school house or slaughtering sheep for market, collaboration and cooperation in activities is the norm among community members. Thus, my participation in household chores or community events was not only highly appreciated but also expected of me as a resident of Cosapa.

To learn more about customary management practices, as well as to provide needed assistance to households, I participated in many of the daily and seasonal activities associated with animal husbandry and livestock management. A journal was kept of each day’s activities. Activities included shearing, slaughtering, breeding, bathing, marking, and herding of animals. I also accompanied the AIGACAA veterinarian and extensionists on visits to different communities and households throughout the region, and assisted with veterinary treatments and tagging of animals.

Key Informant Interviews

Informal interviews were conducted frequently throughout the 2 years of field work in Cosapa. Kusel (1991) defines informal interviewing as any informal questioning outside of pre-planned, one-to-one communication. Key informants are defined as individuals who are knowledgeable about specific aspects of the community (Kusel 1991). The key informants in this study were primarily the staff of AIGACAA who resided in Cosapa. These included the resident veterinarian, Dr. Walter Vilela, as well as the extensionists, Gerardo Apaza and Froilan Chuquimia (who also were Aymara pastoralists from a neighboring community). These informants were able to provide an "outsider's" perspective of Cosapa, combined with the knowledge and heritage of the local system and culture.
Additional key informants included the *porteros* (grounds-keepers) of the AIGACAA compound in Cosapa, along with their families. The porteros were members of Cosapa who were elected by the community to work for 1 year in the compound. Representation was based on the 4 political zones in Cosapa, such that each year the new portero would come from a different zone. The job was highly valued, since it paid a salary and provided steady income for a household for a year. There were 3 different porteros and their families that resided in the compound during my 2 years in Cosapa. They were a valuable source of information for community events, people, cultural norms and traditions, families and kinship ties, land use and tenure, and livestock management practices.

**Household Survey**

In addition to observational methods, a standardized survey was used to obtain more quantitative information on land and livestock management practices, and animal productivity. The survey was originally designed to compare livestock productivity among 3 "zones" in Cosapa (Chapter 6) as well as to determine the impacts of Project Alpaca's development interventions (Chapter 7). Thus, selection of households to be surveyed was based on residence within the 3 zones. Additional households who had fenced grazing exclosures and at least 1 neighbor from the same estancia that did not have an exclosure were also selected for the survey to determine exclosure effects on animal production. Exclosures will be discussed in greater detail in Chapters 5 and 7.

Selection of households to be surveyed from each of the 3 zones was made by first identifying all households that utilize each respective zone's bofedal for livestock grazing. Attempts were made to interview the entire population of households that were identified. Several households were not sampled, however, due to absence or unwillingness to participate.
in the survey. The percentage of nonrespondents was 33% for Zone 1, 38% from Zone 2, and 42% for Zone 3. Ten households were surveyed from Zone 1, 8 households from Zone 2, and 7 households from Zone 3. Seven additional households associated with the exclosure comparison were also added to give a total of 32 sampled households.

The survey was conducted through personal interviews with the female and/or male head-of-household. Commonly, other household members (i.e., children) were also present during interviews and, depending on their age and degree to which they cared for the livestock, would participate. The duration of the interviews ranged from 1 to 2 hours. Interviews were conducted in Spanish; however, questions and replies were often translated into Aymara by a family member for those who were less fluent in Spanish. The survey included questions concerning current herd productivity, land and livestock management practices, availability of grazing lands and seasonal migration patterns for different livestock species and flocks. Appendix B provides a copy of the survey form in both Spanish and English.

The survey design and question formation was based on methods recommended by Fowler (1993). Prior to implementing the survey, field pretests were conducted. The purpose of the pretest was to determine how effectively data collection protocols and survey instruments performed under realistic conditions (Fowler 1993). The first pretest was administered to one of the AIGACAA extensionists in Cosapa. Four additional pretests were administered to households from Cosapa, which were not selected in the survey sample. All pretests were tape-recorded in order to evaluate problems in the question-and-answer process (Fowler 1993). Modifications were then made to the questionnaire based on pretest results.

The final version of the survey was then administered to the 32 households. Interviews were carried out from May to June 1996, prior to my departure in July 1996. I found that this
was the best time to conduct interviews since by then I had spent 2 years in the community and was well-known by most households.

The survey was divided into 6 sections: (1) household demographics, (2) land and livestock management practices, (3) livestock productivity, (4) historical livestock numbers and mortality, (5) temporal and spatial distribution of animals, and (6) household income sources, opinions about changes in land availability and disease frequency, and recommendations to AIGACAA/Project Alpaca. Appendix B provides a sample of the survey form used, along with an English translation. This chapter describes the results obtained from the sections on land and livestock management, and livestock productivity. Since the data were collected on the basis of a census rather than a random sample of a larger population, only summary statistics are presented.

Results and Discussion

The following results and discussion are based primarily on quantitative information obtained from the survey, or qualitative information obtained through participant observation and informal interviews. Thus, all factual information that is not cited by a secondary source was obtained from the survey or my own observations.

Livestock Management

Breeding ("Empadre")

Two main types of camelid breeding management were identified in Cosapa, and are common techniques practiced by camelid herders throughout the altiplano (Llanque 1995). These are known as amarado and jañachu. Amarado, which literally translates to "bound" or "tied-up," is a practice in which rope is tied around the hind legs and back of female llamas or
alpacas, such that they are forced into a sitting position and immobilized. Reproductive males, either belonging to the household or borrowed from a neighbor, are then brought to the corral and allowed to mate with the bound females. Mating is allowed to occur for about 30 minutes, after which the males are removed from the corral, females are untied, and the two sexes are herded to separate grazing areas. Breeding is generally carried out from January through March. Often this procedure will be repeated the following week, or may continue for 2 or 3 weeks. Llanque (1995) states that if a female rejects a male during the second or third round of breeding, this indicates that she has been impregnated.

The second form of breeding is known as jañachu, and involves placing a single reproductive male in the herd of females. Selection of the reproductive male is based on desired genetic qualities (i.e., fleece color and wool quality). Often, a household will practice both amarado and jañachu, where a single male is placed in the herd of females following the amarado breeding sessions.

Since not all households own male llamas or alpacas in Cosapa, borrowing reproductive males from a relative or neighbor is common. In addition to local males, a herd of imported male alpacas was available for households in Cosapa to borrow. These males belonged to the Corporación Regional de Desarrollo de Oruro (Oruro Regional Development Corporation--CORDEOR) and were kept in a 17-hectare exclosure constructed by the corporation. The program began in 1987 and was aimed at improving the genetic quality of the alpacas in Cosapa. The original, CORDEOR alpaca males were imported from Peru, and were considered genetically pure, with desired traits such as white fleece and black eyes. When Project Alpaca began, male alpacas from Ulla Ulla (the northern portion of the Department of La Paz) were also brought to Cosapa to breed with local females.
Incidence of the different breeding techniques varied by livestock species. Among the surveyed households in Cosapa, amarado was most common among llamas, and jañachu dominated for alpacas and sheep (Figure 4.1). A lack of separate grazing pastures for male reproductive alpacas may explain the low proportion of households that use the amarado method for their alpacas. Only in the mountains southwest of Cosapa were there bofedales (wetland grazing pastures) where male alpacas could be kept apart from females year-round.

Castration

The lack of separate grazing pastures for male alpacas may also explain the high proportion of households that castrate their alpacas. Among surveyed households in Cosapa, 80% castrated a portion of their male alpacas, while only 16% of households practiced castration of their llamas. This difference, as mentioned above, can be attributed to the fact

![Bar chart showing the percentage of surveyed households that practiced different animal breeding techniques for llamas, alpacas, and sheep.](image)

**Fig. 4.1.** Percentage of surveyed households that practiced different animal breeding techniques for llamas, alpacas, and sheep (based on a sample size of 32 households).
that male llamas can be taken to separate mountain pastures, while male alpacas require
mountain pastures with bofedales, which are much more rare. For sheep, 73% of households
practiced castration. One of the surveyed households stated that they castrated their male
alpacas that had undesirable characteristics (i.e., brown fleece). These results differ from
those found by Llanque (1995) for the adjacent community of Turco. He states that, in
general, households in Turco do not castrate their livestock except for extreme cases, such as
when a male llama is constantly disrupting the herd (Llanque 1995).

Marking ("K'illpa")

The k'illpa is a traditional marking ceremony for livestock that is carried out by
households during the months of January to March. It often coincides with the festivities of
Carnival, in late February, or on Godfathers' or Godmothers' Day (Día de Compadres and
Comadres) in January and February. The k'illpa is a highly ritualized event in which a
household will bring together its entire herd of llamas and alpacas to a central corral for
blessing and marking. Llanque (1995) describes the k'illpa as a series of technical and religious
acts. Animals are blessed, thanks are given to pachamama (mother earth), and prayers are
sent for continued fertility and reproduction of animals, as well as for rain and good forage.
Sugar, confetti, alcohol, and coca are used to bless the animals. The atmosphere is highly
festive, with much food and drink, dancing and music. Extended family, friends, and
neighbors come to join in the celebration and to help with the marking of the animals.

The literal translation of k'illpa from Aymara is "piece of skin." Identification marks
among camelids are made by cutting a small piece of skin from the ears. The location of the
cuts and the number of cuts distinguishes animals of one household from another. Thus, each
family has a particular pattern of ear marks among their camelids. Yearlings are the primary
recipient of this procedure, since older animals are already marked, and crias are too young to be marked. In addition to the marking, animals are adorned with colorful yarn to distinguish sex, and also so that ownership can be identified from a distance. Within a family, some animals may belong to different sons and daughters, and are thus given a different combination of yarn colors. The yarn is commonly made into pom-pom-like tassels that are pierced through the tips of the animals' ears. Yarn is also tied to the back of the neck on males, and along the back on females.

In general, households in Cosapa with large numbers of livestock will carry out the k'illpa annually. Households with smaller herds may only perform the k'illpa every 2 to 3 years. The k'illpa for sheep generally is carried out on June 24, the Day of San Juan. San Juan is considered the patron saint and protector of sheep (Llanque 1995). The k'illpa for sheep is usually a less elaborate festival compared to that of camelids.

The tradition of the k'illpa thus insures that households keep a relatively close inventory of the number of animals in their herds. This provides useful information for assessing long-term herd dynamics (see Chapter 6).

*Weaning ("Destete")*

Forced weaning among camelids was relatively rare among sampled households, with only 19% of households weaning llamas, and 17% of households weaning their alpacas. The age at which weaning was forced for camelids ranged from 8 months to 1 year, which is the approximate age at which natural weaning occurs. Forced weaning among camelids was thus practiced primarily when young animals failed to quit nursing at the normal weaning age, and especially when nursing continued past 1 year and interfered with the nursing of a
newborn cria. Methods used to force weaning include placing a stick through the nostrils of the yearling, such that it is unable to physically nurse.

Weaning was more common among sheep, with 52% of surveyed households practicing forced weaning. This higher rate of weaning in sheep can be explained by the fact the many households will milk their sheep to make cheese. Weaning the lambs removes competition for milk, making it available for cheese production. The age at which weaning was forced for sheep ranged from 5 to 7 months. Six months is considered the age of natural weaning.

Disease Treatment and Prevention

A combination of both modern veterinary medicine and traditional healing practices was used by households in Cosapa to treat illnesses and diseases among their animals. Common illnesses afflicting camelids include mange (or scabies) caused by the llama itch mite (Sarcoptes scabiei var. auchenidae), diarrhea, distomatosis or liver fluke infestations, bloat, and fever caused by Streptococcus pyogenes (Dr. Walter Vilela, personal communication; Fernández Baca 1975).

Home remedies/medicinal plants. Traditional medicines and home remedies have historically been the primary means of disease treatment among households in Cosapa. Although most households in recent years are using more commercial pharmaceuticals, herbal medicines continue to be used to treat sick animals. The continued use of natural medicines is related to customary habits, the high cost of purchased medicines, and, in some cases, the belief that they may be more effective in treating illnesses than modern medicines.

Local medicinal plants commonly used to treat both animals and people include Lampaya (Lampaya medicinales), Munia (Satureja boliviana), Tara T’ola (Fabiana densa
Remy), and Chachakoma (*Senecio graveolens* Wedd.). Other home remedies include the use of lemon juice to treat diarrhea, and rubbing motor oil on animals to treat mange and ticks. Bazalar and McCorkle (1989) provide a detailed study of local medicinal plants of the high Andes that are used to treat illnesses among livestock.

**Veterinary services.** Veterinary services became available in Cosapa with Project Alpaca, and included treatment of diseases and infections, internal and external parasite control, and vitamin supplementation. The resident veterinarian for Project Alpaca or extensionists would travel to the estancias of households requesting their services. A messenger or household member would commonly come to the AIGACAA compound in Cosapa, to request veterinary care. Households were generally required to pay for any medicines used, but not for the service. The AIGACAA compound also housed a small pharmacy where medicines could be purchased directly by households. The majority of surveyed households used veterinary services to some extent; 75% of households using services 1 to 5 times per year, and 3% of households using them more than 5 times per year. Twenty-two percent of households surveyed never used veterinary services, preferring the use of traditional medicines.

Many households have stated that availability of veterinary medicine has reduced the number of animal deaths from disease. However, others have claimed that with the introduction of modern veterinary medicine, new types of diseases and illnesses have also afflicted their animals. Most households felt that modern medicines were more effective in treating sick animals, but continued to use natural medicines due to the costs associated with modern medicines.
**Dipping baths.** Beginning in the mid-1970s, mandatory dipping of animals for external parasites was implemented in Cosapa. Once a year, generally in the months of March through April, households from the different zones of Cosapa brought their animals to specially constructed cement bathing troughs for dipping. All species of animals were dipped, including pigs and dogs. Mandatory dipping was necessary since noncompliance by one household could lead to the spread of an infestation to other herds grazing in the same area. Many of the residents of Cosapa have noted that the incidence of mange, which would often result in massive animal deaths, has substantially been reduced due to dipping.

**Vitamins.** Included in the veterinary services provided by AIGACAA was vitamin supplementation, either given orally or by injection. Vitamin supplementation was recommended for crias and weak animals as a disease prevention measure and to fortify diets during the dry season. Only 28% of surveyed households gave vitamin supplementation to their livestock. Many of the households who did not give vitamins either had a bad experience with vitamin injections, or were suspicious of the practice because of negative reports from other households. One household claimed that they lost 50 of their alpacas due to an incompetent extensionist who gave vitamin injections to their animals. According to the AIGACAA veterinarian, however, it was a drought period and the animals were already weak and to the point of starvation at the time. Despite the fact that the vitamin supplements were given too late in this particular case, many households now believe that vitamin injections may harm or even kill their animals.

**Supplementation**

The use of forage supplementation was relatively common in Cosapa. Most households gave supplements to augment animal diets when natural forage was highly limited
(i.e., during a drought). Supplements were primarily given to crias/lambs and thin animals (Figure 4.2). Following the initiation of Project Alpaca, the most common supplement was alfalfa hay, which was brought by truck to Cosapa and available for purchase from AIGACAA. Additional supplements included barley, wheat bran, milk (canned or powdered), and native vegetation. The native vegetation was hand-picked and fed to animals, and included *k'ela* (*Lupinus mutabilis*), obtained from the mountains; *kora* (*Geranium sessiliflorum* Cav.); *siki-visuro* (roots from *Distichlis humilis*); and *lima* (*Alopecurus* sp.), an aquatic plant. Figure 4.3 shows the percentage of surveyed households who used different types of supplements. Supplements combined under the category of "other" include liquid from soaked *chuño* (freeze-dried potatoes), corn meal, lemon juice, and quinoa husks.

![Figure 4.2](image-url)

**Fig. 4.2.** Percentage of surveyed households who gave supplements to only crias and lambs, thin animals, mothers, or various combinations of the 3 for llamas, alpacas, and sheep. " Mothers" are defined as lactating females.
Fig. 4.3. Percentage of surveyed households that gave different dietary supplements to their llamas, alpacas, and sheep. The category of "Other" includes liquid from soaked chuño (freeze-dried potatoes), corn meal, lemon juice, and quinoa husks.

Pasture Management

Traditional forms of pasture management in Cosapa include the rotation of animals to different grazing pastures, development and maintenance of extensive canal systems to irrigate bofedales, and the occasional use of fire. Project Alpaca introduced barbed-wire fencing to the area, for the establishment of dry-season forage reserves (Chapter 2).

Grazing Rotations

Although extensive migrations of livestock are not currently observed in Cosapa (i.e., migrations to lowland valleys with llama caravans), local movement of livestock to different grazing areas is common. In general, alpacas, sheep, and female llamas graze year-round in the bofedal and upland areas of the estancia of a given household. The area of grazing land available to households generally ranges from 300 to 1500 ha. Within this overall territory,
however, herders will rotate their animals to different grazing sites. Generally during the wet season, livestock are taken to upland areas (i.e., t'olar, pajonal) one day and the bofedal the next day. By alternating days, less grazing pressure is exerted on both upland or bofedal sites during the growing season. In the dry season, animals spend more time grazing in the bofedales; however, they are often taken to the uplands in the early morning to prevent consumption of frozen forage found in the bofedal during this time of year. Many people claimed that the frozen forage caused diarrhea if consumed by the animals.

If households have access to mountain pastures, then male llamas are commonly kept there year-round. Most of the mountain grazing lands tend to be quite dry; however, in some areas there are extensive bofedales where male alpacas are kept year-round. All households felt that the forage was of much higher quality in the mountains and animals were healthier and hardier when allowed to graze there. Male animals are kept in the mountains because of the high nutritional quality of the forage, and to keep them apart from the females. Unless the males are castrated, they commonly fight and attack other animals if kept together with the females. Males are brought down to the bofedales once every 2 to 3 months in the wet season to drink water and to obtain salt. In the dry season, they enter the bofedal more frequently unless a water source is available in the mountains.

If mountain pastures are close to an estancia, then female llamas will also be taken there to graze, generally between March and November. Some households will take only their female llamas to graze between March and June, to take advantage of the annual herbs that are available during these months, and to preserve the forage in the bofedales for other animals and for the dry season. Others will take their females to the mountains until November. Female llamas, however, usually are brought down to the bofedal at least once a week, and are not
taken as far in to the mountains as the males. Female llamas and alpacas with young crias and sheep generally require more attentive care and are not taken to the mountains. Chapter 6 provides a description of the different grazing rotations found in different zones in Cosapa.

**Bofedales**

As mentioned in Chapter 3, bofedales are low-growing wetland communities that naturally occur around springs or river channels. Through human intervention they are expanded and enhanced over extensive areas and are a key resource for alpaca production, since they provide year-round green forage (Palacio Rios 1977). In Cosapa, the creation and preservation of bofedales is dependent on the maintenance of irrigation canals that divert water from the rivers or mountain springs. Each year, households dig new canals or clean the mud, rocks, and debris from older, larger canals such that specified areas can be flooded and/or watered. Households closely monitor the flow of water to insure that the entire bofedal is receiving adequate moisture. According to the residents of Cosapa, an area that was formerly pajonal can be converted to a bofedal in 3 to 5 years with irrigation. To accelerate the conversion from pajonal/t’olar to bofedal, some households transplant bofedal species (i.e., *Festuca dolicophylla*) into the area, although most species will naturally enter a site with irrigation.

One component of Project Alpaca was to expand the bofedales in Cosapa via the construction of a large irrigation canal (see Chapter 2). A US$50,000 project funded by the *Fondo de Desarrollo Campesino* (Farmer Development Fund) was implemented in Cosapa to divert a portion of the Cosapa River to expand the bofedal in the northwestern portion of the valley. An elaborate cement canal was completed in 1996, although irrigation had not yet
begun when I left the community in July of the same year. Unfortunately, the project was expected to benefit only 15 households out of the 200 that resided in Cosapa.

Fire

In general, the lack of a heavy fuel load and the low oxygen content of the air precludes fire as an important component of the system in Cosapa. Nevertheless, in some of the mountain regions, areas are burned by households for forage improvement. Households claim that the resprouts of burned paja (*Festuca orthophylla*) are highly palatable and nutritious to llamas. Indeed, personal observations of llamas grazing in the mountains revealed they grazed heavily on the regrowth of *Festuca orthophylla* following a burn (Buttolph, unpublished data). In addition, I was told that burning induced the germination of k'ela (*Lupinus mutabilis*), an important forage source and supplement. The timing and frequency of burning is important, however, since frequent burning often encourages homogeneous stands of sikulla (*Stipa ichu*), which is low in nutritional content and palatability. Thus, many households are against burning in the mountains for fear the pastures will be converted to sikulla stands.

Exclosures

One of the main technical interventions introduced by Project Alpaca was the construction of barbed-wire fenced grazing exclosures. The project provided credit and building supplies such that the pastoralists could construct exclosures on their land. The location, size, and use of the exclosures was determined by the individual landowner. The first exclosures that were constructed ranged in size from 1 to 3 hectares. Later, as more households began to build exclosures, the size increased up to 8 hectares. Most households used the exclosures for reserve forage during the dry season, and generally put crias and thin
animals in the exclosures to graze. Some households stated that they no longer needed to give feed supplements to their animals, since they now had their exclosures. The ecological and social consequences of the exclosures will be discussed in greater detail in Chapters 5 and 7.

**Livestock Productivity**

Table 4.1 provides a summary of the livestock productivity variables and responses measured in the survey.

**Natality**

In general, natality rates among camelids raised on the altiplano tend to be quite low compared to European livestock species (Tichit 1991, Fernández Baca 1975). This is attributed to both low fertility and high embryo mortality during the first month of pregnancy (Fernández Baca 1975). Also, the majority of camelids in Cosapa only give birth every other year. Thus the low camelid natality rates among surveyed households in Cosapa are similar to those found in other studies. For example, Tichit (1995a) found the llama natality rate to be 27.4% in 1993 for the adjacent community of Turco. Rodriguez et al. (1988) found fertility rates for llamas and alpacas to be 42.8% and 42.5%, respectively. Natality rates among sheep in Cosapa, however, are relatively low compared to other sources (Tichit 1995a). For example, in Turco, mean sheep natality was 68.9% in 1993 (Tichit 1995a).

**Mortality**

_Cria and lamb mortality_. As shown in Table 4.1 mean mortality among lambs was the highest compared to alpacas, which were intermediate, and llamas, who had the lowest cria mortality rates. Rodriguez et al. (1988) found llama and alpaca cria mortality to be 14.3% and
Table 4.1. Mean livestock productivity measures with their standard deviations based on responses to questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>Llama</th>
<th>Alpaca</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Natality (1995)</td>
<td>34.4 ± 18.1</td>
<td>37.9 ± 16.1</td>
<td>34.4 ± 20.9</td>
</tr>
<tr>
<td>Natality (1996)</td>
<td>17.9 ± 6.9</td>
<td>24.1 ± 13.8</td>
<td>-</td>
</tr>
<tr>
<td>Cria/Lamb Mortality</td>
<td>18.9 ± 17.0</td>
<td>26.1 ± 20.2</td>
<td>32.3 ± 24.2</td>
</tr>
<tr>
<td>Abortion</td>
<td>9.1 ± 11.4</td>
<td>20.6 ± 18.5</td>
<td>-</td>
</tr>
<tr>
<td>Adult Mortality</td>
<td>7.9 ± 6.9</td>
<td>10.0 ± 7.7</td>
<td>5.6 ± 7.8</td>
</tr>
<tr>
<td>Adult Morbidity</td>
<td>15.4 ± 25.9</td>
<td>18.9 ± 20.4</td>
<td>24.7 ± 32.6</td>
</tr>
</tbody>
</table>

1 Number of crias born between November 1994 and April 1995 or lambs born between July and December 1995 divided by the number of reproductive females.
2 Number of crias born between November 1995 and April 1996 divided by the number of reproductive females.
3 Number of crias/lambs that died prior to weaning divided by the total number born in 1995 (November 1994 to April 1995 for crias and July to December 1995 for lambs).
4 Number of camelid aborted fetuses noted by households divided by the number of reproductive females.
5 Number of adult animal deaths (including weaned juveniles) between July 1995 and interview date divided by the total number of adult animals.
6 Number of sick adult animals between July 1995 and interview date divided by the total number of adult animals.

20.6%, respectively. Tichit (1995a) found llama cria mortality to be 10.7% and 11.6% among lambs in Turco.

Figure 4.4 shows the reasons attributed by surveyed households for cria and lamb deaths. Among llama crias, mortality was attributed primarily to lack of forage, while for alpacas mortality was attributed primarily to disease or illness. The most common disease afflicting alpaca crias is enterotoxaemia caused by Clostridium perfringens (welchii), types A and C, which is spread by dirty corrals (Fernández Baca 1975, Tichit 1991). The primary reason for lamb mortality was for other reasons apart from disease or starvation. The category of "other" included deaths due to predation (i.e., foxes, condors, mountain lions), falling into streams or irrigation canals, accidents, getting lost, and carelessness by the herder.
Fig. 4.4. Mean percentage of livestock cria and lamb mortality attributed to illness and disease, lack of forage, or "other," as stated by surveyed households. The category of "other" includes deaths due to predation, falling into streams or irrigation canals, accidents, getting lost, and carelessness by the herder.

Abortions. The number of aborted fetuses noted by households was used to estimate the abortion rate among llamas and alpacas. The abortion rates reported in Table 4.1, however, may underestimate the true rate since not all aborted fetuses are noted by herders. Fernández Baca (1975), for example, claims that only about 50% of embryos survive beyond the first month of gestation. Households in Cosapa have stated that abortions are often a result of exposure of pregnant females to cold temperatures.

Adult mortality. Results from Table 4.1 show that mean adult mortality among livestock species was highest for alpacas and lowest for sheep. Rodriguez et al. (1988) found alpaca mortality to be 12% compared to 4.5% among llamas. Most households in Cosapa admitted that alpacas were the most "delicate" and susceptible to disease, while sheep were considered very hardy.

Figure 4.5 shows the reasons attributed by households for adult livestock mortality from July 1995 to the time of the interview (May and June, 1996). Among llamas, reasons
for death were fairly equally divided among disease and illness, lack of forage, and reasons other than disease or lack of forage ("other"). The majority of alpaca deaths were attributed to disease or illness, followed by lack of forage. Illnesses common to alpaca include infections that cause fever, and endo- and ectoparasites (Fernández Baca 1975). For sheep, both disease and "other" were equally reported as the causes of mortality. The reasons other than disease or lack of forage are the same as those included for cria and lamb mortality.

*Morbidity*

Despite the fact that adult sheep mortality was relatively low, morbidity was high for sheep compared to llamas and alpacas. Although the incidence of illness was high among sheep, households claimed that recovery was also high through the use of medicinal herbs and supplemental feed.

![Graph showing livestock mortality by category](image)

**Fig. 4.5.** Mean percentage of adult livestock mortality attributed to illness and disease, lack of forage, or "other," as stated by surveyed households. The category of "other" includes deaths due to predation, falling into streams or irrigation canals, accidents, getting lost, and carelessness by the herder.
Livestock Marketing and Exchange

Table 4.2 provides a summary of the mean number of livestock sold, consumed, purchased, and received through loan for sampled households in 1995-6. In general, exchange (buying and selling) and consumption of sheep exceeded that for llamas and alpacas.

Sales

Animal sales, in general, occurred during specific times of the year, depending on the species, sex, and age.

Llama. For those households who raised male llamas, 60% of those surveyed sold their animals between September and December, due to the higher market prices received during this period. The remainder of those surveyed either sold them at different times of the year (i.e., April through August) when animal weight was maximized or when cash was needed. The majority of male llamas are sold live to either an intermediary buyer or are taken directly to slaughterhouses in La Paz or Oruro. Males are sold when they reach 3 to 4 years of age. In general, male llamas are raised for commercial meat production, rather than for subsistence.

Sales of female llamas, on the other hand, generally occur when the animals are old and past their reproductive peak (i.e., over 8 years old). Among surveyed households, 82% sold their older female llamas between the months of March through June, when the animals were at their maximum weight. Some households (17%) did not sell their female llamas, but only used them for home consumption when they were old.

Among surveyed households, 77% also sold their yearling llamas primarily to local markets within the area (i.e., other households in Cosapa who raised male llamas). Reasons
Table 4.2. Mean numbers and standard deviations of livestock sold, consumed, bought, and received through loan among surveyed households in Cosapa during 1995-6.

<table>
<thead>
<tr>
<th></th>
<th>Llama</th>
<th>Alpaca</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Sold</td>
<td>8.9 ± 18.4</td>
<td>2.5 ± 4.1</td>
<td>25.6 ± 39.2</td>
</tr>
<tr>
<td>Consumed</td>
<td>5.4 ± 4.2</td>
<td>4.5 ± 4.0</td>
<td>9.5 ± 7.3</td>
</tr>
<tr>
<td>Bought</td>
<td>6.2 ± 16.3</td>
<td>1.8 ± 4.6</td>
<td>11.1 ± 39.6</td>
</tr>
<tr>
<td>Received by Loan</td>
<td>0.3 ± 1.8</td>
<td>2.4 ± 9.6</td>
<td>0.2 ± 0.5</td>
</tr>
</tbody>
</table>

for selling a yearling (or maltón) include the need for cash, the presence of a buyer, and to prevent the juveniles from harassing the females and crias.

In addition to selling animals for meat, many households also sold the wool of their llamas. There are 2 general breeds of llamas that exist in Cosapa: k’ara and thampulli. K’ara llamas are raised for meat production, and have a short wool length. Thampulli are raised more for wool, having a longer wool length, although they may also be used for meat. Thus, households who have thampulli llamas will often sell their wool. As mentioned in the previous chapter, llama wool is considered lower in value than alpaca wool because its combination of coarse, hair-like fibers and fine fibers. At the time of the study, AIGACAA was attempting to buy a dehairing machine such that the finer portion of llama wool could be separated and marketed. Many households, in the mean time, try to pass their llama wool off as alpaca wool by hand picking out the course fibers. The wool is then sold to AIGACAA, regional markets, Peru, or markets in La Paz or Oruro.

Alpaca. Alpacas are sold much less frequently than llamas, and primarily only males are sold. As with male llamas, the most popular time of year to sell male alpacas is between September and December, when prices are high. Other households will sell animals any time...
of the year when there is a need for cash, or will sell from March through June, when animals are at their maximum weight. Male alpacas are sold mainly to intermediaries.

As with female llamas, female alpacas are only sold when they are old (i.e., over 8 years old). Typically they are sold between March and June, when animals are at their heaviest weight. The females are generally slaughtered by the household and taken directly to local markets or the city. If the female alpacas are not sold, they are consumed by the household when old.

Only 37% of surveyed households sold their juvenile alpacas. Juveniles are typically sold to local buyers. Reasons stated for selling their yearling alpacas include a high price offered, lack of forage, and need for cash.

In terms of wool sales, 87% of surveyed households sold their alpaca wool to AIGACAA. Of the 87%, 44% also sold their wool to other buyers. These other buyers include outlets in Peru, La Paz or Oruro, or regional markets (ferias). Many households would sell their high quality wool to AIGACAA and sell the lower quality (which AIGACAA refused to take) elsewhere. Many households would also sell to other markets if they offered a higher price than AIGACAA. In addition, other buyers (i.e., Peru) would accept bags of wool without checking the contents. Since wool was sold by weight, households could get away with including llama wool, wet wool, and wool containing dirt and rocks in their bags. Other households would spin the wool into yarn, to sell locally or in the city.

Sheep. The period during which households sold their male sheep was much longer than for camelids. Among surveyed households, 56% sold their male sheep between the months of July and November because the price was high. Only 20% sold their male sheep between April and June, when animals had the greatest weight. The remainder of the
households either sold their animals when there was a need for cash, or only consumed their male sheep. Most households sold their sheep to an intermediary and/or directly to regional or city markets.

Female sheep, in contrast, were only sold between March and June, when they were at their maximum weight. Often they would only be sold when old. Among sampled households, 26% did not sell their female sheep, which were used only for home consumption. Female sheep were also either sold to an intermediary buyer or taken directly to market.

Sheep wool was used primarily in the home to make woven blankets. Sheep wool was also sold locally to other households, or sold in regional or city markets. The wool was either sold as spun yarn or unprocessed.

Consumption

Home consumption of livestock also varied by species and sex of animal. Consumption of sheep, in terms of total numbers, was highest since they tend to be the most dispensable species, and are also small and easy to prepare. In terms of total weight, however, camelid consumption was equivalent and often even exceeded sheep consumption. Unlike other tropical pastoral systems where lack of refrigeration precludes consumption of larger livestock species, the cold and arid climate of the altiplano allows for a longer period of fresh meat storage. More importantly, the ancient technique of preserving meat in the form of dried charque (or jerky), which remains edible for up to 6 months, allows for the consumption of llama and alpaca meat by a household.
Among surveyed households, purchasing sheep was most common compared to llamas and alpaca, since sheep were cheaper to buy. For younger households who generally had few animals, sheep provided a means to quickly increase their herd size, due to their higher reproductive rate. Once the households established a high-enough sheep population, they could trade or sell their animals to obtain camelids. Sheep were also easier to herd and manage by young children. A widowed woman was also more likely to have more sheep in her herd due to their lower labor requirements (see Chapter 6). Other households who purchased sheep were intermediary buyers, who immediately sold them in the city markets. Many of the households that purchased llamas were purchasing male llamas to raise and later sell for cash.

Obtaining loans to purchase alpacas was made available through credit offered by Project Alpaca.

It is important to note that trade and reciprocal exchange were not measured in the survey, although they may be equally, if not more, important than monetized exchange. A highly developed and institutionalized system of reciprocity or barter (called trueque) has been in place among Andean pastoralists for thousands of years (Browman 1974). Trips to the coast, intermontane valleys, and agricultural portions of the altiplano were commonly made by pastoralists, using caravans of llamas, to barter dried meat, wool, textiles, and salt for grains, tubers, fruits, and vegetables (Orlove 1981). In the past, it was common for exchange rates
between pastoralists and agriculturalists to remain fixed, and long-term barter relations, lasting several generations, to be maintained (Orlove 1981).

It is clear, however, that the degree of market integration has increased in recent years in Cosapa, with cash having greater value, and more material items (i.e., bicycles, motorcycles, trucks, T.V.s) being purchased. The introduction of trucks and improved roads has virtually eliminated the llama caravans. The relative proportion of livestock that are sold and purchased for cash versus barter is not known for Cosapa. AIGACAA, in an attempt to maintain the traditional forms of exchange via trade, offers food (i.e., bulk flour, rice) and supplemental livestock feed (i.e., alfalfa) in exchange for alpaca wool and manure. Credit payments can also be paid in wool instead of cash.
CHAPTER 5
VEGETATION DYNAMICS

Introduction

Up to this point, the focus of the dissertation has been on describing the local context of pastoralism in Cosapa and development efforts by AIGACAA. In this chapter, the focus now shifts to testing models of rangeland system dynamics in terms of the vegetation dynamics at Cosapa. Specifically, assumptions of rangeland equilibrium will be analyzed by studying the impacts of livestock grazing on plant production and plant species composition.

Background

Historically, assumptions about rangeland production and composition following "rest" from grazing have included the belief that the vegetation will return to a more desirable and productive climax state through the process of plant succession (Clements 1916, Stoddart et al. 1975). Management recommendations for improving rangeland ecosystems, based on the successional model, include deferment or rest from grazing using fencing to control livestock movement. One of the main goals of grazing protection via fencing is to improve forage productivity and range condition (Dyksterhuis 1949, Stoddart et al. 1975). Brand and Goetz (1986), for example, describe how protection from grazing in the mixed grass prairie results in greater aboveground herbaceous biomass, greater grass height, and a greater proportion of mid-grasses.

Not all plant communities, however, follow predicted patterns of plant succession following rest from grazing. In semiarid and arid climates, in particular, the rate of recovery and the trajectory of vegetation change following release from grazing is not always continuous.
or predictable (Westoby et al. 1989, Friedel 1991). Several variables, in addition to or apart from grazing, such as climatic regime, evolutionary history of grazing, level of degradation, and invasion of exotics, often play an important role in determining the degree of vegetation change (Milchunas and Lauenroth 1989). For example, several studies have found that the removal of livestock from desert grasslands and shrublands resulted in no change in the vegetation (Smith and Schmutz 1975, Smeins et al. 1976, West et al. 1984). In other cases, changes in vegetation may occur with grazing protection, but only during favorable climatic periods (Alzérreca 1996, Wondzell and Ludwig 1995). Ellis and Swift (1988) and others have proposed that in ecosystems with low and highly erratic rainfall, plant production is more dependent on the amount of precipitation received than the intensity of livestock grazing.

In degraded sites where significant soil loss has occurred or invasion by exotics and/or weedy species has taken place, successional stages that mirror retrogression may never occur and systems may be pushed into new "domains of attraction" (Friedel 1991). Examples of irreversible shifts in vegetation states as a result of exotic invasion include the California annual grassland (Heady 1958) and cheatgrass invasion in the Great Basin (West et al. 1984). The relative stability of a plant community and the sensitivity of different plant species to long-term grazing may also depend on the evolutionary history of grazing (Milchunas and Lauenroth 1993), as well as morphological and/or physiological adaptations of plants to herbivory (McNaughton 1984). Some have claimed that grazing may increase plant productivity in systems where plants and herbivores have coevolved (McNaughton 1979, 1983, McNaughton et al. 1983).

In Cosapa, the rangeland has been said to be in a poor and degraded condition (Alzérreca 1992, unpublished report, Project Alpaca Proposal 1991). To prevent further
rangeland degradation, development recommendations for Cosapa include the use of fencing to control stocking densities and timing of grazing. Areas ranging from 1 to 8 hectares were fenced by producers to exclude livestock during the growing season. Fencing was primarily encouraged in the bofedal areas, which provide the most important forage resource for alpacas. Bofedales are also considered the most productive due to the presence of irrigation. The goal of fencing was to create forage reserves that could be used to feed livestock, particularly weak, pregnant and thin animals, during the dry season. The assumption was that protection from grazing would not only improve livestock productivity, but would also increase plant production and improve species diversity, thus reversing some aspects of rangeland degradation.

Previous studies conducted on the Bolivian altiplano to determine the response of vegetation to grazing protection have been few and the results equivocal. Parker (1974) estimated that 4 times the productive capacity of the altiplano vegetation could be achieved with grazing protection. His results were based on 2 years of grazing protection using 55 caged exclosures in 7 different range sites (Freeman et al. 1980). In one of Parker’s study sites, located in the Province of Pacajes in the west-central altiplano, he found that after 22 months of grazing protection plant composition and yield changed markedly on range sites with adequate moisture (Parker and Alzérreca 1978). The greatest increase in production was found in the wetland (bofedal) site, where production in protected sites was nearly 4-times higher than in unprotected sites, and 2 species of palatable *Poa* spp. increased dramatically (Parker and Alzérreca 1978). On a drier, upland site, however, production increased only 12% after the first year, and decreased in the second year, which was thought to be due to mild drought conditions (Parker and Alzérreca 1978).
Alzérreca (1978) found that after 4 years of rest from grazing, total plant production on an eroded site increased only slightly at the Patacamaya Experiment Station in the central Bolivian altiplano. Species composition, on the other hand, shifted to more palatable forage species on the ungrazed site, thus increasing the estimated carrying capacity for the site and the total amount of available forage (Alzérreca 1978). Braun (1964) studied the impact of 5 years of rest from grazing on plant species composition, cover, and plant height, also at Patacamaya Experiment Station. He found that total plant cover decreased from 36% to 26%, height of the grass *Nasella* sp. increased from 20 to 32 cm, and *Trifolium amabile* H.B.K. increased from 0 to 2% in cover, but no other changes were noted (Braun 1964).

**Research Objectives**

In this chapter the ecological implications of fencing were evaluated in order to better understand the processes that control plant production and plant community dynamics in Cosapa. The development model of Project Alpaca assumed that fencing would be beneficial to livestock production via improvement of the forage resource. This chapter focuses on testing the proposition that livestock grazing negatively impacts the vegetation and that rest from continuous grazing increases plant production and species diversity.

Specific objectives were to determine the effects of recently established grazing exclosures (one to 3 years old) on aboveground net primary production (ANPP) during the main growing season, end-of-season standing crop of aboveground biomass (SC), and plant species composition and diversity for 2 plant communities in Cosapa. Aboveground net primary production (calculated as the amount of biomass production per day (g/m²/day)), was estimated to determine if grazing protection had any impact on the productivity of the rangeland. Measurements of SC (calculated in g/m²) were made to determine the amount of
aboveground biomass preserved in the exclosures for dry season grazing. The two plant communities evaluated were (1) bofedal, a sub-irrigated meadow community; and (2) gramadal, a rainfed, shortgrass community. A third community, pajonal (a rainfed, bunchgrass community) was separately evaluated; however, lack of replication precluded any inferential statistical analysis of this vegetation type.

Expectations about how each plant community would respond to grazing protection were based primarily on the degree to which abiotic variables (i.e., moisture availability, and soil properties) affected each community. Since soil moisture and soil nutrients are less limiting for the bofedal vegetation compared to the rainfed communities, grazing is thought to have a greater role in affecting plant production and composition for this community (Ellis 1992). With release from chronic grazing pressure, the bofedal vegetation community was expected to exhibit higher relative rates of ANPP, a relatively higher standing crop, and relatively greater (and more "favorable") changes in plant species composition compared to other vegetation types found on drier sites. Increased length of time a site has been protected from continuous grazing was also expected to enhance plant productivity and plant species changes, especially for the bofedal community.

Methods

Study Site

The study was conducted in 10 exclosure sites across 6 different estancias (hamlets) in Cosapa (see Chapter 3 for a general description of Cosapa). It is important to note that exclosures were not randomly assigned or selected, but instead were built by local households and were pre-existing when this study began. All existing exclosures in Cosapa were used in
the study. After the study began, several other households constructed exclosures, mostly in estancia Anta Qollu, which was one of the most populated estancias (10 to 15 households) having one of the most productive bofedales. Because exclosures were not all located on the same site, variability among sites existed in terms of inherent potential plant productivity, stocking density, irrigation of bofedales, salinity and other soil properties.

Placement of exclosures was determined by each household, and was based on land tenure agreements and vegetation type. Land in Cosapa is communally owned, in that several households have title to a particular tract of land. Within a given parcel of land, however, specific grazing areas are allotted to each household. Exclosure sites were often constructed in areas where there was the least contention among neighbors over grazing rights. Conflicts over property rights, however, did emerge in some instances as a result of the fencing (see Chapter 7 for more details).

Climatic data were provided by Servicio Nacional de Meteorologia e Hidrologia (SENAMHI) in La Paz and Oruro, based on data recorded from a weather station in Cosapa. The majority of the precipitation for the area falls between December and March. Figure 5.1 depicts monthly precipitation since 1987, when the 17-ha CORDEOR exclosure was first constructed. All years subsequent to the 1988-1989 growing season were less-than-average rainfall years, based on the 20-year average from 1975-76 to 1995-96.

**Plant Communities**

*Satellite Imagery*

A general assessment of the vegetation resources available in Cosapa was made through the use of satellite imagery. One Landsat Thematic Mapper (TM) satellite image of Cosapa from April 1995 was used to create an unsupervised (computer-generated) vegetation
classification. Image processing was carried out using IMAGINE software, and was georeferenced and corrected for atmospheric haze with single image normalization using histogram adjustment. Figure 5.2 shows a Landsat TM color infrared satellite image of Cosapa. The areas in red represent a high degree of infrared reflectance, indicative of green vegetation which is primarily found in the bofedales in Cosapa. Figure 5.3 is an unsupervised classification of the Cosapa image, with 10 vegetation classes and approximate areas for each vegetation type. It is important to note that the vegetation classification was not ground-truthed, and the potential for misclassification exists. Therefore, areas for each vegetation class are considered crude and used only at a very general level of resolution.

Exclosures

Most exclosures were constructed in sites containing a combination of different vegetation types--primarily bofedal and gramadal.

![Graph showing total annual precipitation (mm) from August 1987 to April 1996.](image)

**Fig. 5.1.** Monthly precipitation for Cosapa during which exclosures or paddock were constructed (August 1987 to April 1996). MAP is mean annual precipitation based on data collected from 1975 to 1996.
Fig. 5.2. Landsat Thematic Mapper (TM) color infrared satellite image of Cosapa, Province Sajama, Department Oruro, Bolivia. TM bands 2 (in blue), 3 (in green), and 5 (in red) are shown, indicating green (0.52-0.60 µm), red (0.63-0.69 µm), and near infrared (0.76-0.90 µm) wavelengths of the electromagnetic spectrum, respectively. (Raw image courtesy of ABTEMA/ORSTOM, La Paz, Bolivia.)
Fig. 5.3. Unsupervised classification of the Landsat TM satellite image of Cosapa, with 10 vegetation cover classes and approximate areas for each. (Raw image courtesy of ABTEMA/ORSTOM, La Paz, Bolivia; printout courtesy of Robert Washington-Allen).
As mentioned in previous chapters, the bofedal is a high-elevation, wetland whose vegetation is dominated by low growing grasses, sedges, and forbs. Bofedales receive a constant supply of water from glacial runoff, a high water table or through irrigation and are characterized by acidic soils with a high organic matter content (Estenssoro Cernadas 1991). A description of common bofedal species found in Cosapa can be found in Chapter 3. Class 2 bofedal was the dominant type found on exclosure sites, and included species such as *Werneria pygmaea, Plantago tubulosa, Juncus stipulatus,* and *Puccinellia oresigena.* Figure 5.4 provides a photograph of a Class 2 bofedal in Cosapa. Although in Cosapa all livestock species can be found grazing in the bofedales, it is an especially important forage resource for alpacas, since nutritionally they require a year-round supply of green forage (Tichit 1991). It is estimated, based on satellite imagery, that bofedales comprise approximately 4500 ha or 9% of the total land cover in Cosapa (see Figure 5.3).

The gramadal vegetation type is a shortgrass community dominated by *Distichlis humilis* (Figure 5.5). *Distichlis humilis* (known locally as *ch’iji*) is a small, perennial grass that grows to about 1 to 2 cm in height and can tolerate moderate levels of salinity (Tapia 1971). It can be found alone or in association with other species such as *Calamagrostis curvula* (*p’orkhe*) or *Festuca orthophylla* (*paja*). Although the palatability of the gramadal type is low (Tapia 1971), it is considered a relatively important forage for sheep (Genin et al. 1994). Approximately 2600 ha or 5% of the total land cover of Cosapa is estimated to be gramadal (refer again to Figure 5.3).

The pajonal community is a grassland community dominated by the bunchgrass *Festuca orthophylla* (Figure 5.6). *Festuca orthophylla* is a spiny-leaved, caespitose grass that can grow to over 1 meter in height. The pajonal community generally occurs on sandy soils. The
Fig. 5.4. Photograph of a Class 2 bofedal at Cosapa. This wetland vegetation type is dominated by low-growing forbs, sedges, rushes, and grasses, including *Werneria pygmaea, Plantago tubulosa, Juncus stipulatus,* and *Puccinellia oresigena.* Bofedales are considered "key" or critical forage resources for alpacas.
Fig. 5.5. Photograph of a gramadal, or shortgrass, vegetation type at Cosapa. The dominant plant species in this type is *Distichlis humilis* (known locally as "ch'iji").

Fig. 5.6. Photograph of a pajonal, or bunchgrass, vegetation type at Cosapa. The dominant plant species in this type is *Festuca orthophylla* (known locally as "paja" or "wichu").
forage value of *Festuca orthophylla* is considered low; however, consumption by all livestock species, especially llamas, is high (San Martin and Bryant 1989, Genin et al. 1994, also see Chapter 4). It is estimated that 13,000 ha or 26% of the total land cover in Cosapa consists of pajonal (Figure 5.3).

**Research Design**

Ten grazing exclosures, fenced with barbed-wire and ranging in age from 1 to 3 years old, were used in this study. Exclosures were primarily grazed in the dry season (i.e., between July and August) by llamas and alpacas. Occasionally, sheep would enter the exclosures to graze, but were quickly herded out. Exclosures ranged in size from 1 to 3 hectares, and often contained a mix of vegetation types. All exclosures contained the bofedal vegetation type. Seven out of 10 exclosures also contained the gramadal type. Since only one of the exclosures contained the pajonal type, this community was analyzed separately from the bofedal and gramadal types.

To determine the impacts of grazing protection for a single growing season, and to control for the possibility of animals entering the exclosures, 1x1-m² cages were placed inside and outside of each exclosure. Cages were constructed of 1.5-m wooden posts placed in the ground and sided by chicken wire. The tops of the cages were left open to reduce cage effects on vegetation growth. A string of barbed wire was placed along the top perimeter of the wooden posts to prevent camelids from bending their necks down into the cages. One cage was placed both inside and outside of each exclosure in August 1995. Three additional cages were placed outside of each exclosure in December 1995, to distinguish ANPP on a "grazed" site protected between September and December (generally drier) from ANPP during the wetter period between December and March.
Specific treatment locations within each exclosure site were randomly selected. Four treatments were assigned to each exclosure site, and are described as:

- **Exclosure/Cage (EX/C)** - inside the exclosure, inside the cage;
- **Exclosure/No Cage (EX)** - inside the exclosure, outside the cage;
- **No Exclosure/Cage (C)** - outside the exclosure, inside the cage;
- **No Exclosure/No Cage (grazed) (GR)** - outside the exclosure, outside the cage.

Figure 5.7 provides an example of the experimental unit. These treatments were thus the main explanatory variables used in the study, along with vegetation type. Other potential covariates used were exclosure age, stocking rate, length of time under irrigation (for bofedal only), and soil properties. Response variables were ANPP, SC, and plant species diversity.

In addition to the 10 exclosures constructed by the local herders, 1 9-year-old fenced paddock, constructed by the Corporación Regional de Desarrollo de Oruro (CORDEOR) was also used in this study. This paddock was created to raise improved breeds of alpaca, which could then be bred with local animals (Chapter 4). The paddock is 17 hectares in size and includes bofedal, gramadal, and pajonal vegetation types. In 1994, the paddock was divided into two parts: the lower part consisting primarily of bofedal, gramadal, and some pajonal, and the upper part consisting primarily of pajonal. The females and young were kept in the lower section. Sheep and llamas, belonging to the caretaker of the paddock, were also allowed to graze in the lower paddock. The upper paddock was grazed primarily by male alpacas and was the portion used in this study. The pajonal vegetation from this paddock was analyzed separately from the exclosures.
Fig. 5.7. Diagram of an exclosure site which was the experimental unit for this study. A total of 10 exclosure sites were used in this study, each treated as a block.
Main Effects

Biomass

In September 1995, aboveground biomass samples were collected both inside and outside of each cage and exclosure. The method of harvesting the material was based on procedures described by Hutchinson (1967) for shortgrass prairie. Due to the low-growing nature of bofedal and gramadal communities, conventional clipping by shears was problematic since it was often difficult to cut all aboveground biomass. The method suggested by Hutchinson (1967) involves taking core samples, which include soil and roots, and later clipping off the aboveground plant portion. A standard 10-cm diameter soil auger was found to work efficiently in collecting core samples.

The size and shape of the core were found to be the most efficient for bofedal and gramadal types. Efficiency was evaluated by clipping different plot sizes (0.01 m², 0.02 m², 0.04 m²) and shapes (circular, square, rectangular) by hand and timing the rate at which plots could be clipped (Bonham 1989). Variances in dry weight for each plot were then measured. The average clipping time and biomass variances were then compared among samples to determine minimal sample area (Bonham 1989). The 0.01 m² circle (corresponding to a 11 cm diameter) was found to be the most efficient for hand clipping, with variances being equal for all sizes (Table 5.1).

Biomass samples were collected and promptly brought to the "lab" where the aboveground portions were cut off using curved surgical scissors. Soil matter attached to the clipped vegetation was then washed off by placing the aboveground plant sample in a small cone-shaped container of water. The sample was stirred to create a centrifuge type motion which allowed the heavier soil particles to fall to the bottom and the live plant material to float
Table 5.1. Size and shape comparisons to determine minimal sample area for biomass determination in bofedal and gramadal.

<table>
<thead>
<tr>
<th>Shape</th>
<th>Size (cm)</th>
<th>Area (m2)</th>
<th>Mean Time (min)±SE</th>
<th>Time Efficiency¹</th>
<th>Mean DW² ±SE</th>
<th>Statistical Efficiency³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>r=5.5</td>
<td>0.01</td>
<td>3.4 ± 0.46</td>
<td>1.00</td>
<td>1.93 ± 0.30</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>r=8</td>
<td>0.02</td>
<td>5.6 ± 1.69</td>
<td>0.61</td>
<td>3.00 ± 0.78</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>r=11</td>
<td>0.04</td>
<td>12.8 ± 2.55</td>
<td>0.27</td>
<td>8.03 ± 1.64</td>
<td>0.18</td>
</tr>
<tr>
<td>Square</td>
<td>10x10</td>
<td>0.01</td>
<td>4.0 ± 0.40</td>
<td>0.85</td>
<td>1.53 ± 0.41</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>15x15</td>
<td>0.02</td>
<td>7.6 ± 1.15</td>
<td>0.45</td>
<td>3.57 ± 0.73</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>20x20</td>
<td>0.04</td>
<td>10.4 ± 1.15</td>
<td>0.33</td>
<td>6.93 ± 1.14</td>
<td>0.26</td>
</tr>
<tr>
<td>Rectangle</td>
<td>8x13</td>
<td>0.01</td>
<td>3.4 ± 0.46</td>
<td>1.00</td>
<td>2.09 ± 0.63</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>10x20</td>
<td>0.02</td>
<td>8.6 ± 1.57</td>
<td>0.40</td>
<td>3.68 ± 0.83</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>15x26</td>
<td>0.04</td>
<td>12.6 ± 1.46</td>
<td>0.27</td>
<td>8.11 ± 0.75</td>
<td>0.40</td>
</tr>
</tbody>
</table>

¹Minimum mean time divided by mean time required to clip plot.
²DW is dry weight of clipped biomass sample (26 hr. at 100° C).
³Smallest dry weight standard error divided by dry weight standard error.

on top. The plant samples were then carefully skimmed off of the top and allowed to air dry. Upon being air-dried, samples were placed in envelopes and dried in a drying oven at 100° C for 24 hours. Loss of volatiles at this temperature was not considered significant since biomass samples consisted primarily of forbs and grasses which tend to be low in these secondary compounds. Dried samples were then weighed.

Three subsamples were collected from each treatment (EX/C, EX, C, GR) in September 1995, December 1995, and March 1996. Note that in September only 1 cage inside and 1 outside were present, while in December 3 additional cages outside of the exclosures were constructed, thus increasing the number of subsamples collected.

Mean phytomass was then calculated by subtracting the dry-weight phytomass in March from that collected in December, as well as subtracting dry-weight phytomass in
December from that collected in September. These differences were then divided by the number of days between harvests to give mean phytomass values between December and March, and September and December. Mean phytomass was used as a proxy for aboveground net primary production (ANPP). It is important to note, however, that loss of plant material from decomposition, as well as the possibility of compensatory plant growth from herbivory (McNaughton 1983), was not accounted for in this estimate. End-of-season standing crop (SC) was estimated from the dry-weight phytomass samples collected in March 1996.

For the pajonal type (*Festuca orthophylla*) aboveground biomass was measured only once in April 1996, both inside and outside of the 3-year-old exclosure and the 9-year-old paddock. Biomass was estimated by a double-sampling technique. Because the growth of *Festuca orthophylla* often forms a conical shape, the volume was estimated by measuring the diameter of the long and short axes and height of reference plants (Lyon 1968). These reference plants were then harvested to determine dry weight. A volume-to-weight relationship was then established by plotting sample points to create a regression equation (see Figure C.1 in Appendix C). The predictability of the model was quite high, with an R-square of 0.95. Randomly placed 30-m transects were run both inside and outside of exclosure and paddock in the pajonal vegetation type and the volumes of plants intersecting the transect were then calculated by measuring the plant dimensions.

In addition, the density of *Festuca orthophylla* was also measured by recording the longest parallel and perpendicular lengths of each intersected plant along the tape measure (modified from Lucas and Seber 1977). The diameter of each plant was then estimated by taking the average of the two lengths, and density calculated using the formula:

\[
m = \frac{\sum_{i=1}^{k} (1/D_i)/L}{L}
\]

(Eq. 5.1)
where \( D_i \) is the diameter of the \( i \)th plant, \( k \) is the total number of plants, and \( L \) is the length (30 m) of the transect (Lucas and Seber 1977).

*Plant Species Composition*

Plant species composition was measured for the bofedal and pajonal vegetation types. Since the gramadal was composed exclusively of *Distichlis humilis*, species composition was not measured in this community. The line-point method (Bonham 1989) was used to estimate species crown-cover composition for both vegetation types. In the bofedal, a 0.5x0.5-m grid was used, with points measured every 5 cm for a total of 100 points. For the pajonal, the 30-m transect used to estimate biomass was also used to measure vegetation crown cover, with points measured every 30 cm.

The Shannon-Weiner index (Shannon 1948, Hurtubia 1973) for species diversity (alpha) was calculated from the cover data and compared among treatments for the bofedal vegetation. The index was also calculated separately for the pajonal type. This index was selected because it is the most familiar amongst ecologists and because it has been shown to be normally distributed over repeated sampling (Odum 1971), thus satisfying the assumption of normality for parametric statistical procedures. It is calculated from the formula:

\[
\text{Diversity (H')} = -\sum_{i=1}^{s} p_i \ln p_i
\]

where \( s \) is the number of species, and \( p_i \) is the abundance of the \( i \)th species expressed as a proportion of total cover.

Additional indices based on the Shannon index and Simpson's index were used as indicators of species abundances and evenness. Hill's diversity numbers (\( N_0, N_1, \) and \( N_2 \))
(Hill 1973) were selected as additional measures of diversity, due to their ease in interpretation 
(Ludwig and Reynolds 1988). These indices are defined as:

\[ N_0 = S \]  
\[ N_1 = e^{H'} \]  
\[ N_2 = \frac{1}{\lambda} \]

where \( S \) is the total number of species, \( H' \) is Shannon's index (see Eq. 5.2), and \( \lambda \) is Simpson’s 
index (see Eq. 5.7). \( N_0 \) is an expression of all the species in a sample (without regard to their 
abundances), and will thus include rare species. \( N_1 \) is an index that can be interpreted as the 
number of abundant species in a sample, and will include fewer species. \( N_2 \) (the inverse of 
Simpson’s Index) can be regarded as an estimate of the "effective" number of species or 
number of very abundant species in a sample, and will have the smallest value (Hill 1973).

According to Hill (1973), a diversity number can be interpreted as a figurative measure of the 
number of species present in a sample when examined at a certain resolution of species rarity. 
For example, an in-depth investigation (e.g., using \( N_0 \)) would encounter all species present, 
while a superficial investigation (e.g., using \( N_2 \)) would only encounter the more abundant 
species (Hill 1973).

In addition to species abundance, species evenness was also determined by using the 
modified Hill’s ratio (Alatalo 1981). This index (represented as \( E_5 \) from Ludwig and Reynolds 
1988) is calculated as:

\[ E_5 = \frac{1}{\lambda} - 1 = \frac{N_2 - 1}{e^{H'} - 1} \]

(Eq. 5.6)
where $\lambda$ is Simpson's index, $H'$ is Shannon's index, $N_2$ and $N_1$ are Hill's diversity numbers (Eqs. 5.4 and 5.5). ES is recommended over other evenness indices because it tends to be independent of sample size, and is easily interpreted (Ludwig and Reynolds 1988).

Percent cover of each species was also calculated from the cover data. Data on the palatability of different bofedal species were not available, and thus an assessment of changes in range condition could not be made.

The Morisita index of similarity (Horn 1966) was also calculated to determine the degree of plant species overlap among treatments. The index is calculated by the formula:

\[
C\lambda = \frac{2 \sum_{i=1}^{S} x_i y_i}{(\lambda_x + \lambda_y)XY} \quad \text{(Eq. 5.7)}
\]

where $S$ is the total number of species, $x_i$ and $y_i$ are the number of times species $i$ is represented in populations $\{X_0\}$ and $\{Y_0\}$, respectively, $X$ is the sum of all $x_i$ from $i=1$ to $S$, $Y$ is the sum of all $y_i$ from $i=1$ to $S$, $\lambda$ is Simpson's diversity index (Simpson 1949). $\lambda_x$ and $\lambda_y$ are defined by the following equations:

\[
\lambda_x = \frac{\sum_{x=1}^{S} x_i(x_i-1)/X(X-1)}{(\lambda_x + \lambda_y)X} \quad \text{(Eq. 5.8)}
\]

and

\[
\lambda_y = \frac{\sum_{x=1}^{S} y_i(y_i-1)/Y(Y-1)}{XY} \quad \text{(Eq. 5.9)}
\]

$C\lambda$ ranges from 0 to 1, with 1 indicating samples that are identical in proportional species composition and 0 indicating samples that are completely distinct.
Covariates

Irrigation

To determine the impacts of irrigation levels for the bofedales, interviews were conducted with the owners of the exclosures to determine the months of irrigation. Four common irrigation levels were found (2, 4, 6, and 7 months of irrigation per year). Irrigation for all of the households begins in mid/late-August to early September and continues for 2, 4, 6 or 7 months. This is a logical period to irrigate since it is the beginning of spring, the risk of frost diminishes at this time, and the rains do not arrive until November or December.

Stocking Rates

Stocking rates were also determined through interviews. Landowners mapped the area of land grazed by their livestock on a topographic map and gave the total number per year of each species of livestock grazing on that land. Area of land was estimated based on the area drawn on the topographic map and compared with the areas reported by households during interviews. When there was a discrepancy between the area reported and the area drawn, the drawn area was considered more accurate since topographic maps included landmarks familiar to interviewees. Stocking rates were then calculated by first converting alpaca and llama numbers to Animal Unit Equivalents (AUEs)--in this case, to criollo sheep units (Tichit 1994). Table 5.2 provides the conversions for llamas and alpacas to sheep units. The calculation of AUEs is based on the following formula:

\[
AUE = (W_{cam}^{0.75}/W_{sh}^{0.75}) - (0.30)[W_{cam}^{0.75}/W_{sh}^{0.75}] \]  
(Eq. 5.10)

where \( W \) is the live weight (in kg) for each species, \( W_{cam}^{0.75} \) and \( W_{sh}^{0.75} \) are the metabolic weights for camelids (llama and alpaca) and sheep, respectively, and 0.30 is the proportion of
Table 5.2. Conversion table for llamas and alpacas to criollo sheep unit equivalents (from Tichit 1994).

<table>
<thead>
<tr>
<th>Species</th>
<th>Age</th>
<th>Live Weight (kg)</th>
<th>Metabolic Weight ( (W^{0.75}) )</th>
<th>MW/MW( _{sheep} )</th>
<th>SheepUnit( ^3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>Adult</td>
<td>22</td>
<td>10.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Lamb</td>
<td>13</td>
<td>6.8</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Llama</td>
<td>Adult</td>
<td>87</td>
<td>28.5</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Lamb</td>
<td>41</td>
<td>16.2</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Alpaca</td>
<td>Adult</td>
<td>60</td>
<td>21.6</td>
<td>2.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Lamb</td>
<td>30</td>
<td>12.8</td>
<td>1.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

\( ^1 \text{Metabolic weight is the live weight taken to the 0.75 power.} \)
\( ^2 \text{Metabolic weight divided by the metabolic weight of a sheep.} \)
\( ^3 \text{Calculated by subtracting 30\% of the ratioed weight for camelids.} \)

The ratio of camelid and sheep metabolic weight subtracted to obtain equivalent sheep units (Tichit 1994). The total AUEs were then summed and divided by the total area grazed to give the stocking density. Stocking density was then multiplied by 12 months to give stocking rate (in Sheep Unit Months per hectare) (Heady 1975). Stocking densities ranged from 5.1 to 20.5 AUE/ha. Eight of the 10 exclosures sites had a stocking density of less than 10 (see Table A.2 in Appendix A for calculations).

The large range in stocking rates and densities among different exclosure sites can be explained by variability in the amount of each vegetation type available to a household, which would determine the grazing capacity for that site. For example, one exclosure site might be located in a highly productive bofedal, thus allowing for a higher stocking rate compared to an exclosure site located in a drier area. The number of households living in an estancia also varies, and could also contribute to variability in stocking rates. Finally, calculated stocking rates should be considered rough estimates since animals commonly move on from their designated grazing lands to neighboring areas not included in the estimates of area.
For the 9-year, CORDEOR paddock, data on the number of animals kept inside since initial construction were obtained from the caretaker (Froilan Marca, personal communication). The stocking rate outside of the paddock, during the 1995-96 growing season, was obtained by interviewing a neighboring household. Since information for only the current year was obtained through the interview, it was assumed that stocking rates were relatively similar for previous years. Table A.3 in Appendix A provides the calculation of stocking rates inside and outside of the CORDEOR paddock. Although stocking rates for the lower paddock were found to occasionally exceed that found outside, for the upper paddock (used in the study) stocking rates were consistently lower. Stocking rates for the upper paddock ranged from 11 to 65 AUM/ha, whereas the value outside of the paddock was calculated as 134 AUM/ha.

**Soils**

Soil parameters such as texture, organic carbon, pH, electrical conductivity, and effervescence were measured to determine the importance of edaphic factors on vegetation response. In March 1996, soil samples were also collected from each treatment group among all of the exclosures. Soil samples were collected using an auger to a depth of 15 cm from the ground surface. Soil moisture was calculated by weighing fresh samples, and then subtracting the weight of oven-dried samples. Additional soil samples were air-dried and brought back to Utah State University for analysis of soil pH, electrical conductivity, texture, organic carbon, and effervescence. Soil texture was determined by the texture-by-feel method, which was sufficient for the level of resolution desired (Dr. Janise Boettenger, personal communication).

Soil organic carbon was determined through a combination of the Walkley-Black procedure (Walkley and Black 1934) and the loss-on-ignition (LOI) method (Gavlak et al. 1994, Storer 1984). Approximately 50 soil samples were analyzed using both the Walkley-
Black procedure and LOI to calculate a regression equation (Figure C.2 in Appendix C). Results of the regression equation gave an R-square value of 0.97. Thus, remaining samples were analyzed by LOI and back-calculated to give an estimate of percent organic carbon (Gavlak et al. 1994).

**Statistical Analyses**

All statistical analyses were conducted using SAS-PROC MIXED (SAS Institute, Inc. 1996). A two-way analysis of variance (ANOVA) was used to determine treatment and vegetation type effects on ANPP and SC. A mixed model was used based on a 2 x 4 factorial split-plot design with a blocking factor. The location of each exclosure (referred to as "household") was the experimental unit and was used as the block. The bofedal and gramadal vegetation types were factors within the block. All treatment combinations (EX/C, EX, C, and GR) occurred within each vegetation type. Only those exclosures containing both vegetation types were used in this analysis, giving a sample size of 7. Changes in plant growth and plant community composition were analyzed only for the period between December 1995 and March 1996, which was the main growing period. Preliminary analyses for the period between September 1995 and December 1995, showed very little growth of the vegetation and this period was not included in the final analysis.

Potential covariates were age of each exclosure (1-to 3-years-old), stocking rate, soil organic matter, soil pH, soil moisture (end-of-season), and soil electrical conductivity, and were analyzed separately in the mixed model. Each of the soil properties measured were also separately analyzed as covariates to determine if any interactions existed among soils and plant production and composition. Although separate analyses preclude the ability to determine correlations among covariates, it was necessary due to a lack of degrees of freedom (Susan
Durham, personal communication). To determine if the length of the irrigation period was an important covariate, the model was run only with the bofedal vegetation type using all 10 exclosures. An analysis of covariance (ANCOVA) was used, with irrigation level as the covariate, and "households" as the block or random variable.

In the analysis of ANPP, linear contrasts were used to test differences between the uncaged and caged treatments inside of the exclosures, EX/C and EX, respectively, to ensure that growth was the same between the two. A linear contrast was then made between these treatments (EX/C and EX) and the caged treatment located outside of the exclosure (C). This comparison was intended to test differences in ANPP between sites that were ungrazed for 1 season and the longer-term exclosures.

In the analysis of SC, comparisons using linear contrasts were also made to test differences between uncaged (EX) and caged (EX/C) treatments inside of the exclosures. Additional comparisons were made to test differences between grazed (GR) and protected treatments (EX/C, EX, and C). The caged treatment outside of the exclosures (C) was also compared against the exclosure treatment (EX) to test for seasonal versus long-term effects.

For the analysis of species diversity, a one-way ANOVA, based on a randomized block design was used to determine treatment effects in the bofedal vegetation type. All 10 exclosures were used in the analysis. Separate analyses were run for each diversity index (Shannon Index, N0, N1, N2, and E5). Descriptive statistics were used to compare proportions of species abundances and species similarities among treatments.

For the pajonal vegetation type, descriptive statistics were used to look at differences inside and outside of the 9-year-old paddock and the 3-year-old exclosure. Variables looked at
were SC of *Festuca orthophylla*, density of *Festuca orthophylla*, and species diversity (Shannon Index, N0, N1, N2, and E5).

**Results**

**Soils**

Figure 5.8 shows the results of the soil analyses. In general, the bofedal vegetation type had, on average, higher soil organic carbon, greater soil moisture, a lower pH, and lower electrical conductivity than the gramadal type; however, variances were high for all soil variables except pH. Soil texture was relatively homogeneous among all exclosure sites and vegetation types, ranging from very fine sandy clay loam (60% sand, 20% clay) to loamy, very fine sand (85% sand, 8% clay). When analyzed as covariates in the analysis of variance to determine treatment effects on ANPP and SC for the bofedal and gramadal vegetation types, a significant pH-by-treatment interaction was found for SC ($P = .03$) (Table A.4 in Appendix A). Treatments outside of the exclosures (C and GR) showed a positive correlation between pH and SC, while treatments inside of the exclosures (EX/C and EX) showed a negative correlation (i.e., increasing pH with decreasing SC). The validity of this result, however, is questionable, since scatterplots of each treatment are highly variable and the sample size is relatively low (Susan Durham, personal communication). None of the other soil variables were found to be important covariates in the analyses.

**Plant Productivity**

**Bofedal and Gramadal**

No significant differences were found among treatments or vegetation types for ANPP ($P > 0.05$) (Figure 5.9 and Table A.5 in Appendix A). Comparisons of treatment EX/C versus
Fig. 5.8. Results of soil analyses comparing treatments and vegetation types for (a) percent soil organic carbon, (b) percent soil moisture, (c) soil pH, and (d) soil electrical conductivity.
Fig. 5.9. Comparison of aboveground net primary production among treatments and vegetation types.

EX, and C versus EX and EX/C using linear contrasts were not significant (Table A.5). For SC, there was a trend towards higher biomass for all ungrazed treatments (EX/C, EX, and C) compared to the grazed treatment (GR) for both vegetation types, however these differences were not significant (Figure 5.10 and Table A.6 in Appendix A). Linear contrasts comparing the grazed treatment (GR) to all other treatments, C versus EX, and EX/C versus EX were not significant (Table A.6). Both ANPP and SC values overall were slightly higher for the bofedal vegetation type than the gramadal, but were not significantly different. Exclosure age and stocking density were not important covariates in either analysis and were dropped from the final model.

In the analysis of irrigation as a potential covariate in the bofedal vegetation type, a longer period of irrigation resulted in higher ANPP and SC ($P=0.0359$, and $0.0389$,
respectively), but did not affect treatment responses (see Tables A.7 and A.8 in Appendix A). A linear contrast between the grazed treatment (GR) versus all other nongrazed treatments (EX/C, EX, and C), however, did show a trend towards greater SC for the nongrazed plots (P=0.0966) (Table A.8).

**Pajonal**

Separate descriptive statistics used for the pajonal vegetation community showed a higher peak standing crop inside the exclosures versus outside for the 9-year-old paddock, but not for the 3-year-old exclosure (Figure 5.11). Density of *Festuca orthophylla* was higher outside of the 9-year-old paddock than inside. Conversely, for the 3-year-old exclosure, the density of *Festuca orthophylla* was greater inside than outside of the exclosure (see Figure 5.12).
Fig. 5.11. Comparison of end-of-season standing crop of *Festuca orthophylla* in the 3-year-old exclosure and 9-year-old paddock.

Fig. 5.12. Comparison of density of *Festuca orthophylla* in the 3-year-old exclosure and the 9-year-old paddock.
Plant Species Composition

Bofedal

The Shannon-Weiner Index for species diversity was significantly higher in treatments outside of the exclosures (C and GR) than for the treatments inside of the exclosures (EX/C and EX) for the bofedal vegetation type \((P=0.0002)\) (see Figure 5.13 and Table A.9 in Appendix A). Figure 5.14 shows mean percent cover of plant species for each treatment.

Results show that the relative abundances of 6 dominant species (*Plantago tubulosa*, *Scirpus deserticola*, *Werneria pygmaea*, *Juncus stipulatus*, *Puccinellia oresigena*, and *Hypsela reniformis*) vary among treatments.

Significant treatment effects were found for species abundances (N0, N1, and N2), showing a higher number of total species, abundant, and very abundant species outside of the exclosures (treatments C and GR) versus inside the exclosures (treatments EX/C and EX) \((P=0.0001, 0.0002, \text{ and } 0.0019, \text{ respectively})\) for the bofedal community (see Figure 5.15.

![Fig. 5.13. Comparison of the Shannon-Wiener Index of species diversity for treatments in bofedal.](image-url)
For the pajonal vegetation type, the Shannon Index was higher outside of the 9-year-old paddock, but higher inside of the 3-year-old exclosure (see Figure 5.17). Greater numbers
Fig. 5.15. Comparisons of plant species abundances and evenness among treatments within the bofedal vegetation type. Figure 5.15 (a) is the total number of species (N0), (b) is a figurative estimate of the number of abundant species (Hill's First Diversity Number--N1), (c) is a figurative estimate of the number of very abundant species (Hill's Second Diversity Number--N2), and (d) is species evenness based on the modified Hill's ratio (E5).
Fig. 5.16. Comparison of mean species similarity for all treatment combinations in bofedal using Morisita's Index of Similarity (1 = sites are identical, 0 = sites completely distinct).

Fig. 5.17. Shannon-Wiener Index of species diversity for pajonal inside and outside of the 3-year-old exclosure and the 9-year-old paddock.
of total species (N0), abundant (N1), and very abundant (N2) species were found outside of the 9-year-old paddock but not for the 3-year-old exclosure (Figure 5.18a-c). No differences in species evenness were found in either the 9-year-old paddock or 3-year-old exclosures (Figure 5.18d). Similarity indices between inside and outside the exclosures were 0.64 and 0.90 for the 3-year-old exclosure and 9-year-old paddock, respectively.

**Discussion**

The lack of significant treatment differences in ANPP and SC for the bofedal and gramadal types indicate that up to 3 years of grazing protection between 1993 and 1996 in Cosapa did not significantly improve plant productivity. These results differ from those found by Parker (1974), who found 4-fold increases in plant production with grazing protection. Many other authors have cited Parker's results, stating that overgrazing and poor grazing management are the cause of low production on the Bolivian altiplano (LeBaron et al. 1979, Freeman et al. 1980, Wennergren 1974). Alzérreca (1978), however, tempers the results found by Parker by stating that "the potential for the natural recovery in the altiplano is highly variable due to climatic and environmental conditions and degree of depletion" (p. 71). He states that the sites studied by Parker and Alzérreca (1978) had good potential for recovery and were also located in the north and central altiplano, where environmental conditions are slightly more favorable (i.e., greater precipitation, less frost--Alzérreca 1978). It is also important to note that recovery took place in the bofedal sites, and no major increases were observed in upland sites (Parker and Alzérreca 1978). Furthermore, Alzérreca (1978) states that recovery of the vegetation following rest from grazing is expected to be slow in the southern altiplano, where the climate is more arid.
Fig. 5.18. Comparisons of plant species abundances and evenness inside and outside of the 9-year paddock and 3-year exclosure within the pajonal vegetation type. Figure 5.18 (a) is the total number of species (N0), (b) is a figurative estimate of the number of abundant species (Hill's First Diversity Number--N1), (c) is a figurative estimate of the number of very abundant species (Hill's Second Diversity Number--N2), and (d) is species evenness based on the modified Hill's ratio (E5).
Thus, the lack of strong treatment effects for vegetation production (particularly differences between the grazed and ungrazed treatments) suggests that the short-term effects of rest from grazing are minimal. Several interpretations are possible as to why this may be the case. One possibility is that detectable changes in plant productivity require a longer time scale, as well as a period of favorable precipitation. It is important to note that the 3-year period during which the exclosures were established were less-than-average rainfall years. Several studies conducted in semi-arid and arid rangelands have found that changes in plant community dynamics following rest from grazing occur primarily during wet years (Alzérrreca 1996, Wondzell and Ludwig 1995). In Cosapa, a wetter climatic regime may be necessary to see significant effects of grazing protection, particularly on upland, rainfed sites.

In the analysis of irrigation within the bofedales, there was a simple positive correlation between amount of irrigation versus plant production. Why all households do not irrigate their bofedales for more time may be due to water rights, labor availability, or problems with poor soil drainage and salinization. The fact that there was a trend towards greater standing crop (SC) in the ungrazed treatments (EX/C, EX, and C) compared to the grazed treatment (GR) suggests that in bofedales with a long period of irrigation, productivity may increase with rest from grazing.

Site characteristics may also be important in determining plant productivity. The results from the soil analyses showed a high degree of variability for some soil properties among exclosure sites. Differences, such as in soil organic carbon, pH, and moisture, may be related to differences in the productive potential of the vegetation. It was mentioned earlier that subsequent to the beginning of this study, other households constructed exclosures in the estancia of Anta Qollu. Communication with the owners of these newer exclosures indicated
that they perceived a positive vegetation response with rest from grazing. They noticed higher standing crops inside their exclosures (Maximo Ramirez, personal communication). Why this particular site is more productive than other sites may be due to soil factors, geomorphology, and lower levels of salinity. Anta Qollu is located on the alluvial fan formed from the eastern mountains surrounding the Cosapa valley. It receives freshwater from a spring that irrigates the bofedal. Other areas of Cosapa receive water from the river and are located on the floodplain, where soils are higher in clay content and salinity is greater.

Another approach to interpreting the results of plant productivity (ANPP and SC) is to consider the possibility that the vegetation is highly resistant to herbivory, and thus does not respond in a dramatic way when protected from grazing. The altiplano has a long evolutionary history of grazing. Browman (1974) estimates that alpaca and llama pastoralism in the Andes has existed for at least 7,000 years, with evidence of severe overgrazing in some areas dating back 2,000 years. Milchunas and Lauenroth (1993), in an attempt to assess global trends in vegetation responses to large herbivore grazing, found that differences in ANPP between grazed and ungrazed sites decreased with longer evolutionary grazing histories and lower productivity. If this were the case in Cosapa, then protection from grazing would not result in dramatic vegetation changes. This may help explain why stocking density was not an important covariate in this study.

Physiological and morphological adaptations to frost and drought conditions may also confer resistance of the vegetation to other "stressors" (i.e., grazing). The dominant plant species found within the 3 plant community types studied all exhibit characteristics that allow for tolerance to frost and drought: needle-like leaves (*Festuca orthophylla*), short growth form (*Distichlis humilis*), and rosette, cushion, and creeping form (found in bofedal species). In
addition, many bofedal species store the majority of their biomass in their roots. Estimates have been made of root:shoot ratios of 10:1 for bofedal species in Cosapa (Buttolph unpubl. data). Although data on belowground biomass were not collected in this study, root biomass may be significantly affected by reduced grazing pressure (Milchunas and Lauenroth 1989, Rodríguez et al. 1995).

For the pajonal communities studied, the fact that the biomass of *Festuca orthophylla* was greater with 9 years of protection compared to 3 years suggests that a longer period of rest, and possibly a more favorable precipitation regime, is necessary to increase plant productivity. Although inference cannot be made for the pajonal community due to a lack of replication, results can be interpreted to suggest that over time, reduced grazing pressure may lead to a lower density of large individual bunchgrasses that currently dominate the community.

Changes in species composition at the intra-community level indicate that in the bofedal, up to 3 years of rest from grazing leads to reduced plant species diversity. These results match those of other rangeland systems where moderate levels of grazing were found to increase plant species diversity (West 1993, Quinn and Robinson 1987, Collins and Barber 1985, Coppock et al. 1983, Naveh and Whittaker 1979). Grazing acts as a means of controlling the height and abundance of taller and/or more aggressive species, thereby increasing the competitive ability of other species, especially when resources are less limiting (West 1993, Quinn and Robinson 1987). Milchunas et al. (1988), however, predicted small changes in species composition at low ANPP and a long evolutionary history of grazing—a scenario that characterizes the bofedal and gramadal in Cosapa. Their prediction was based on the idea that in semiarid areas, plant adaptation to drought and grazing are the same, so competition was primarily for belowground resources, and rest from grazing would not impart
a significant competitive advantage on taller or faster-growing species. It is important to note that a reduction in plant species diversity with grazing protection may be beneficial to livestock producers if dominance by more nutritious, palatable species is taking place, as was found by Parker and Alzérreca (1978). Since palatability data were not available for the bofedal species encountered in Cosapa, an evaluation of range trend is not possible.

For the pajonal type, however, it is interesting to note that species diversity was higher with reduced grazing pressure after 3 years, but lower with reduced grazing for the 9-year-old exclosure. Once again, it is difficult to extrapolate from these data; however, one possibility is that an initial response to grazing release is an increase in species in the interspace of the "paja" bunchgrasses. As the bunchgrasses increase in size over time due to lack of grazing, they may eventually outcompete the smaller vegetation growing in the interspace, thus reducing diversity.

**Comparison with Pastoral Ecosystem Models**

Based on the results found in this study, the vegetation dynamics in Cosapa can be compared to pastoral ecosystem models described in Chapter 1 to determine whether conditions reflect more equilibrial or nonequilibrial characteristics. Project Alpaca assumed that fencing would improve forage resources for livestock and reduce rangeland degradation. This reflects an equilibrium model in which negative feedback occurs between plants and herbivores, and grazing negatively impacts plant production and composition (Behnke and Scoones 1993). The results of the present study, however, found that plant production follows a nonequilibrium model. Plant species composition in the bofedales also exhibited more nonequilbrial characteristics since expected Clementsian succession, in which grazing is assumed to have a negative impact on diversity, was not observed.
The unique characteristic about this system is that although precipitation is relatively low and highly variable, plant growth is relatively constant. This may be attributed to physiological and morphological adaptations of the vegetation to frost and drought. Table 5.15 extracts the abiotic and plant-herbivore components of Table 1.1 from Chapter 1, indicating which characteristics apply to Cosapa.

Implications for Rangeland Management in Cosapa

One of the main conclusions that can be made from this study is that rest from grazing does not necessarily improve forage productivity in Cosapa, at least during low precipitation years, and especially on rainfed sites. In order to maximize forage production, fenced exclosures should be constructed on sites with the greatest productive potential. Bofedales have a greater productive potential than gramadal sites, and longer periods of irrigation are recommended. It is important to realize, however, that the climatic regime may also play a substantial role in determining vegetation production. In Cosapa, dramatic increases in aboveground biomass were not encountered for the 3 years of protection that were analyzed. This can be explained by both a period of low precipitation and by site characteristics. The importance of exclosure location is shown in the estancia Anta Qollu, where increases in bofedal production following rest from grazing were witnessed. Thus, pastoralists should take into consideration site characteristics (i.e., soils with low pH, low salinity, and high organic matter) when selecting the exclosure location. Despite the lack of dramatic increases in production and lower species diversity, all households in Cosapa with exclosures felt that livestock mortality decreased, particularly for young animals (crias), when these animals were allowed to graze inside the exclosures during the dry season (see Chapter 7).
Table 5.3. Characteristics of equilibrial and nonequilibrial grazing systems found in Cosapa, Bolivia, in terms of abiotic patterns and plant-herbivore interactions (adapted from Ellis and Swift 1988).

<table>
<thead>
<tr>
<th>Abiotic Patterns</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Abiotic conditions constant</td>
<td>✓Stochastic/variable conditions</td>
<td></td>
</tr>
<tr>
<td>✓Plant growing conditions relatively invariant</td>
<td>• Variable plant growing conditions</td>
<td></td>
</tr>
<tr>
<td>Plant-Herbivore Interactions</td>
<td>• Tight coupling of interactions</td>
<td>✓Weak coupling of interactions</td>
</tr>
<tr>
<td>• Feedback control</td>
<td>✓Abiotic control</td>
<td></td>
</tr>
<tr>
<td>• Herbivore control of plant biomass</td>
<td>✓Plant biomass abiotically controlled</td>
<td></td>
</tr>
</tbody>
</table>

✓ = characteristics that apply to Cosapa, Bolivia.

Households also mentioned that forage from the exclosures also reduced the need for supplemental feeds (i.e., alfalfa) (Chapter 7). Improvements in livestock production may be possible with exclosures simply because equal amounts of biomass produced during the growing season were made available to fewer animals during the dry season. That is, animals may benefit from exclosure due to reductions in stocking rates.
CHAPTER 6
LIVESTOCK POPULATION DYNAMICS

Introduction

The previous chapter focused on the response of vegetation at Cosapa to livestock grazing. In this chapter, the aim is to develop an understanding of the patterns of livestock dynamics in Cosapa and determine what forces are involved in controlling animal populations. Thus, the goal is not only to describe livestock population dynamics for Cosapa, but also to determine to what degree the environment, management, and market forces and subsistence use influence these dynamics.

Background

The factors involved in population control within natural communities have been the subject of study and debate in ecology for over a century (Krebs 1994). The question stems from the basic observation that no population (with the possible exception of humans) continues to increase without limit (Krebs 1994). Both facultative and catastrophic agents were originally identified as potential factors that limit populations (Howard and Fiske 1911). Facultative agents are factors that constrain populations to a greater degree as density increases. Examples of facultative (later termed "density-dependent") agents include predators, parasitoids, disease, and competition. Catastrophic agents (also known as "density-independent" factors) are mainly physical or abiotic, such as climate. The average density of a population, that is, the point of equilibrium between density of a population and its resource base, is said to be controlled only by density-dependent factors (Smith 1935). That is, once a population is stable or at equilibrium, it will be regulated by density-dependent factors.
Many of the theories underlying conventional rangeland management have been based on the premise that livestock populations are at equilibrium and that density-dependent population regulation is responsible for maintaining that equilibrium. These models assume a negative, linear relationship between gain per animal and livestock density (Jones and Sandland 1974). That is, there is the assumption that livestock populations are regulated by stocking densities via competition for forage resources. Animal gain per area, based on this model, is maximized at moderate densities but declines both at high and low densities. A maximum sustained yield of animal products can then be determined by maximizing both gain per area and gain per head (Jones and Sandland 1974). Thus, optimum stocking rates for a given area can be determined based on assumptions of density-dependent livestock interactions. Figure 6.1 shows the relationship graphically between stocking rate and animal gain per area and per head.

Fig. 6.1. Theoretical relationship between stocking rate and animal gain per head and per area, showing the optimum stocking rate or point of maximum sustained yield (from Jones and Sandland 1974:337).
Application of this model to a broad range of pastoral settings, however, has often proven inappropriate and problematic (Sandford 1983). Essentially, the model is based on the premise that density-dependent factors alone are responsible for regulating livestock populations, and that populations hover around some average density. Frequent stochastic perturbations, however, may create a situation in which populations never reach a level where density-dependent factors (i.e., competition) play a significant role (Ellis and Swift 1988, Scoones 1993b). These systems have been referred to as "unsaturated" or at "nonequilibrium" (Wiens 1984). Ellis and Swift (1988) were the first to suggest that for many pastoral ecosystems, livestock populations are regulated by density-independent controls. Based on research conducted in Turkana, Kenya, they proposed that in rangelands where climatic perturbations are frequent, density-dependent feedbacks on populations are weak, and density-independent mechanisms, such as climate, are responsible for limiting livestock populations (Ellis and Swift 1988).

Thus, theoretically, in an equilibrium system livestock population dynamics are driven by density-dependent factors, such as stocking rate, while in a nonequilibrium system density-independent factors (i.e., climate) determine system dynamics. Figure 6.2 (a, b) illustrates the idealized relationships between livestock population dynamics (in this case, mortality), stocking rate, and climate (expressed as precipitation).

**Research Objectives**

The objective of this research was to determine the degree to which different environmental factors influence livestock herd dynamics in Cosapa. Specifically, the relative importance of location, livestock species, stocking density, and climate on livestock population dynamics was assessed. Climate is thought to be an important factor in limiting animal
Fig. 6.2. Idealized relationships between livestock mortality versus stocking density and precipitation for (a) an equilibrial, density-dependent system and (b) a non-equilibrial, density-independent system.
populations since precipitation is often low and highly variable. Bofedales, on the other hand, could be considered "key resources" (Scoones 1993a) that stabilize system variability, since moisture is less of a constraint in this vegetation type (see Chapter 5 for a description of bofedales). For livestock that are more dependent on bofedales, stocking densities may be more important in limiting populations than climate. One hypothesis is that herds that utilize high-quality bofedales (i.e., more mesic and less saline) will exhibit population fluctuations related to stocking densities and less to climate. Mortality rates are predicted to be higher during droughts in areas with low-quality bofedales (i.e., drier, more saline) than in areas with high-quality bofedales. Alpacas, which require more forage from bofedales, are expected to exhibit population fluctuations associated with stocking rate, while mortality among sheep and llamas is expected to be correlated more to climate. If this is the case, then management interventions that attempt to reduce stocking densities (i.e., exclosures) should have a greater impact for alpaca production compared to that of other species.

Methods

Study Sites

To determine the degree to which bofedales act as "key resources" that stabilize livestock populations, 3 "zones" within Cosapa, with differing qualities of bofedales, were selected for this study (see Chapter 3 for a general description of Cosapa). Zones consisted of 1 or more estancias whose households shared a common bofedal. The 3 zones selected were (1) Anta Qollu, (2) T'ola Tilla, and (3) Kota Kuchu. The bofedales for each zone were approximately equal in area but differed in quality (i.e., level of salinity) and degree/duration of greenness. The bofedal in Zone 1 (Anta Qollu) received the longest period of irrigation,
with relatively low salinity, and was considered the highest quality bofedal of the 3 zones. The
bofedal in Zone 2 (T'ola Tilla) was intermediate in terms of irrigation, but was the most saline.
The bofedal in Zone 3 (Kota Kuchu) was the driest, receiving almost no irrigation, but
historically had been irrigated. The bofedal vegetation type was the focal point of this study
since it is utilized by all households within each zone, and is considered a key resource,
particularly for alpaca production. Climatic data, presented in previous chapters (see Chapters
3 and 5), were used to look at the correlation between climate and herd population fluctuations.

Zone Differentiation

Vegetation and Soil Resources

Differences in the bofedales for each zone were quantified through vegetation and soil
measurements. Degree of "greenness" was determined by estimating the proportion of green
versus dry vegetation at different times of the year. Vegetation cover composition and
proportion of greenness were measured using the step-point method (Bonham 1989). Twelve
parallel transects, each separated by 100 paces, were established across each bofedal. One
hundred points were measured per transect, with points separated by 2 paces. Vegetation
measurements were taken in August (1995), November (1995), February (1996), and May
(1996).

Soil samples were also collected in May 1996 from each bofedal per zone. Soil
samples were collected using an auger to a depth of 15 cm from the ground surface. Soils
were analyzed for percent moisture, organic carbon, pH, electrical conductivity, texture, and
effervescence. Methods of analysis are the same as described in Chapter 5.
Satellite Imagery

In addition to the more intensive measurements conducted in the bofedales, a more general assessment was made of the vegetation resources available to households within each zone using satellite imagery. The approximate boundaries of each zone were estimated based on the areas delimited by surveyed households within each zone. Zonal boundaries were then digitized into a Geographic Information System (GIS) layer using ARC/INFO software. This zonal layer was then overlaid onto a land cover map of Cosapa derived from a Landsat Thematic Mapper (TM) satellite image of Cosapa from April 1995 (described in Chapter 5). The cover map was created from an unsupervised classification (i.e., computer generated) of the image using IMAGINE software, with 10 cover classes assigned. Approximate areas of each cover class for each zone were then calculated using ARC/INFO. As mentioned in Chapter 5, it is important to note that the land cover map (or vegetation cover map) was not ground-truthed, thus precluding error estimations in the classification. The image also excluded some of the mountainous portions of Zone 3, thus underestimating the total area for the zone as well as the proportion of mountain cover classes. The approximate areas for each cover class among the 3 zones should therefore be considered crude and used only at a very gross level of resolution.

Household Survey

To determine land and livestock management practices for each zone, a survey (described in Chapter 4) was conducted among households within each zone. All households that utilized a common bofedal for each zone were identified, and attempts made to interview the entire population using a standard questionnaire form (see Appendix B for sample questionnaire). Several households were not sampled, however, due to absence or
unwillingness to participate in the survey (see Chapter 4 for the proportion of nonrespondents). Ten households were surveyed from Zone 1, 8 households from Zone 2, and 7 households from Zone 3. The survey included questions concerning current herd productivity, land and livestock management practices, availability of grazing lands, and seasonal migration patterns for different livestock species and flocks. Surveyed households were also asked to list their top 3 sources of income. Data collected from the survey were used to identify differences among households living in the 3 zones.

**Livestock Population Dynamics**

Historical information on household herd numbers was obtained using the same survey (described above) to determine changes in livestock populations over time. Interviewees were asked to recall from memory the number of sheep, llamas, and alpacas they had each year since 1982-3 (a major drought year). In addition to total livestock numbers per year, households were also asked to provide information on herd mortality, natality, sales, and purchases. Interviewees were also asked to estimate the stocking densities of camelids and sheep for their zone over the same time period. Important community and family events, the names of community leaders for each year, and important climatic events were used as prompts to help interviewees recall livestock numbers for a given year (see survey form in Appendix B).

Percent herd mortality was calculated based on the number of animal deaths reported by each household in relation to their total herd size for each species per year. Households that could not recall mortality rates for any year were eliminated from the analysis.

Stocking densities for each zone were estimated by summing the total number of female llamas, alpacas, and sheep per household from each zone, for each year since 1982-3.
Male llamas were excluded from the calculation since they are generally kept in separate mountain pastures. Llama and alpaca numbers were then converted to criollo sheep unit equivalents (SUEs) in which llama numbers were multiplied by a factor of 2 and alpacas by a factor of 1.5 (Tichit 1994) (see Chapter 5 for conversion equation). SUEs were then totalled for the zone and divided by the estimated grazing area for sampled households to give a stocking density in SUEs per hectare. Since not all households from each zone were included in the survey, stocking density for each zone may be underestimated. The relative fluctuations in stocking density within a zone, however, was compared over time since total grazing areas were constant and animal numbers were provided by the same households over time. Comparison of stocking densities among zones, however, was not possible since absolute stocking densities could not be determined.

**Statistical Analysis**

Although the sampling design for the survey was intended to be a complete census of the population of households from each zone, rather than a random sample, in the following analyses these data will be considered a "sample," in time, in order to make inferences about the relationships among livestock species, zone, livestock numbers and mortality, stocking rate, and precipitation. The following survey data were thus analyzed using inferential statistics. Some have argued that the use of census data to make inference is valid if the population can somehow be considered a sample of all possible time periods, such that the descriptors of the historical data could become estimates of what might be expected at other times (i.e., the future) (Dr. John Whittington, sci.sat.consult newsgroup 1995, Susan Durham, personal communication). This argument, however, is open to theoretical attack, and some degree of caution should thus be taken when interpreting and extrapolating the following results. The
potential for bias in the results also exists because the data were not an \textit{a priori} random sample, and there was no measure of whether nonrespondents differed from those that participated in the survey.

Given the above caveat, the livestock population data were first analyzed using SAS-PROC MIXED (SAS Institute, Inc. 1996). An analysis of variance (ANOVA) of a $3 \times 3 \times 13$ factorial was used in a repeated measures, split-split plot design. The 3 factors used were livestock species (alpaca, female llama, and sheep), zone (1, 2, and 3), and year (1982-3 to 1994-5). As mentioned above, male llamas were excluded from the analysis since they graze separately from other animals in mountain pastures and are considered more of a "cash crop" (i.e., sold at 3-4 years of age for meat) than a longer-term investment. The random variables were households within each zone, species by households within zone, and year by households within zone. Separate analyses were done for mean number of each species per household, and percent mortality of each species per household as the response variables. The standard errors of the differences among least squares means were calculated to allow for \textit{post hoc} mean-separation tests.

To determine the degree to which livestock mortality is related to precipitation versus stocking density, a linear regression of a mixed model was used (SAS-PROC MIXED, SAS Institute, Inc. 1996). A mixed model was required since data points were not completely independent (i.e., stocking densities were the same within a zone for a given year and precipitation was the same among all households for a given year). Percent species mortality per household was the response variable, and precipitation, stocking density, and the interaction between precipitation and stocking rate were the explanatory variables. Separate analyses were conducted for female llamas, alpacas, and sheep. In order to satisfy the
assumption of linearity, percent mortality and precipitation were log-transformed. The
covariates (i.e., stocking density and precipitation) were centered for the regression analysis
(Susan Durham, personal communication).

A separate regression analysis was also conducted using the same mixed model
described above, however, with the 1982-3 drought year eliminated from the analysis. This
was done to determine if removal of extreme, outlier "stress years," such as in 1982-3, might
reveal a different pattern of dynamics in the data (Scoones 1993b).

Results

General Zone Description

The following is a general description of each of the 3 zones to provide an appropriate
context for comparison.

Zone 1

Zone 1, also known as Anta Qollu, is located in the northeastern side of Cosapa valley,
approximately 10 km northeast of the town of Cosapa. Anta Qollu is the largest estancia
within the general area, and consists of approximately 15 households. Anta Qollu has its own
elementary school, church, and general store. The majority of households surveyed from this
zone were residents of Anta Qollu; however, households from other nearby estancias were also
included since they often shared common pasture lands.

The primary, secondary, and tertiary sources of income among sampled households
from Zone 1 are shown in Figure 6.3a. The primary sources of income include sales of
animals for meat, work as an intermediary in wool and/or meat sales, sales of handicrafts (i.e.,
hand woven or knitted wool items--scarves, gloves, hats, shawls), and work outside of the
Fig. 6.3. Primary, secondary, and tertiary sources of income among surveyed households for (a) Zone 1, (b) Zone 2, and (c) Zone 3.
community (i.e., in La Paz and Arica). The two most common secondary income sources were sales of wool and meat. Tertiary income sources also included sales of wool and meat, along with sales of handicrafts and secondary products (i.e., hand-spun yarn [kayto], and sheep cheese).

Grazing lands within Zone 1 are divided into the bofedal (wetland), pajonal (upland bunch-grass land), and t'olar (upland shrubland) vegetation types, located close to the village, and the more distant mountain pastures located to the east (see Chapter 5 for further description of bofedal and pajonal vegetation types). Figure 6.4a provides the relative proportions of each vegetation class/cover type based on the classification of satellite image data. Approximately 70% of the total land area in Zone 1 consists of t'olar (or shrubland) vegetation, 42% of which is mountain t'olar. Only 10% is class 1 or 2 bofedal, and 15% is pajonal. The bofedal in this zone is irrigated via a spring located at the base of the mountains to the east.

Alpacas and sheep generally graze in the bofedal-pajonal types close to home. Generally, animals graze from early to mid-morning in the drier pajonal vegetation type, then enter the bofedal in late morning until mid-afternoon, and then return to the pajonal type from mid-afternoon until evening. Other households will have a rotation, such that sheep and alpacas graze in the uplands one day and then in the bofedal the following day. Both male and female llamas, however, follow a different grazing rotation. Between March and June, female llamas are commonly taken to the mountain areas to graze. The remainder of the year, female llamas graze with the alpaca and sheep in the bofedal-pajonal types close to home. Male llamas spend the majority of time in the mountains, and may only enter the bofedal once every few months for a few days to drink water, or in the breeding season to mate. Since the male llamas are bigger, stronger, and hardier, and have lower nutritional demands than pregnant or
Fig. 6.4. Relative proportions of different vegetation classes/cover types (expressed as percent) for (a) Zone 1, (b) Zone 2, and (c) Zone 3, based on an unsupervised classification of a Landsat Thematic Mapper satellite image of Cosapa. Bofedal (1 & 2) refers the bofedales of class 1 and 2, while Bofedal (3) refers the bofedal class 3 (see Chapter 3 for explanation of bofedal classes).
lactating females, they are able to travel farther and require less herding. Generally, a herder will check on the male llama herd once every 3 to 4 days, or at a minimum of once per week.

**Zone 2**

Zone 2 is located approximately 3 km north of the town of Cosapa, and will be referred to as T’ola Tilla. Unlike Zone 1, Zone 2 consists of a group of small estancias and lacks the infrastructure and centralization of Anta Qollu. Since it is close to the main village of Cosapa, many households have a house both in the estancia and in town. Most households from this zone will live in town during the school year (i.e., April to November) and walk or ride their bicycle or motorcycle to the estancia to herd animals during the day.

Income sources for sampled households in Zone 2 are shown in Figure 6.3b. The most common source of primary income among sampled households is herding animals belonging to other people. Payment for herding is often in the form of livestock, where the herder will receive half of the crias or lambs born in a given year. It is common for individuals to travel as far as Chile (approximately 40 km from Cosapa) to herd animals belonging to wealthy, absentee, Chilean owners. It is important to note that 3 of the 8 households surveyed from Zone 2 were either widowed or single-female headed households. Additional primary income sources include meat sales, work as an intermediary in meat or wool sales, sale of handicrafts, work outside of the community, and work in the community (i.e., shopkeeper, carpenter, restaurant owner). Secondary sources of income are from meat sales, wool sales, as an intermediary, and from handicrafts. Tertiary income sources are primarily through sales of wool, meat, handicrafts and secondary products.

The grazing lands available to households in Zone 2 consist primarily of bofedal and pajonal types close to home, more distant t’olar vegetation, and very distant mountains. Water
diverted from the Cosapa River is used to irrigate the bofedal in this zone. Figure 6.4b shows the relative proportion of each vegetation type/cover class for Zone 2. As in Zone 1, the majority of land area (60%) is composed of t'olar (or shrubland) vegetation; however, only 20% is found in the mountains. Zone 2 also has a larger proportion of class 3 bofedal (12%) compared to Zone 1 (0.4%), as well as class 1 and 2 bofedal (13%) and pajonal (11%).

Alpacas, female llamas, and sheep all generally graze together in the bofedal and pajonal types. The rotation is similar to that found in Zone 1, where animals either graze a half day in each type, or on alternate days. Some households alternate bofedal, pajonal and t'olar types in the wet season (i.e., January to June). Households from Zone 2 have access to mountain pastures to the west and southwest of the valley. Since the distance to the mountains is much farther in Zone 1, only male llamas are kept in the mountain pastures year-round.

**Zone 3**

Zone 3, whose bofedal area is locally called Kota Kuchu, is approximately 8 km south of the town of Cosapa. Like Zone 2, it is composed of a group of small estancias and has no central village. Habitants of Zone 3 also commonly have a house in town and reside there during the school year. Since it is further from town, there will often be some household members who remain in the estancia throughout the year to tend the animals. During a brief period of road construction there was a detour that passed through the area. Some households established restaurants for truckers passing through on the Arica, Chile - Oruro route.

Figure 6.3c provides a summary of the income sources for sampled households in Zone 3. The majority of households surveyed relied on income from outside of the community as their primary source. Meat sales as well as work as an intermediary were also important primary sources of income. Secondary sources of income include sales from meat, wool, and
handicrafts, work as an intermediary, and employment in town. Tertiary sources of income were derived from the sale of wool, meat, secondary products and handicrafts. Some households within this zone are also able to grow quinoa in the mountains, which can provide a substantial income.

The grazing lands available to households in Zone 3 include a relatively dry bofedal and pajonal close to home, as well as t'olar in the foothills, and mountain pastures to the west. Figure 6.4c shows the relative proportion of each vegetation class/cover type for Zone 3. Once again, the largest proportion of land area is covered with t'olar (50%). According to the image data, however, only 10% of the areas is mountain t'olar. This is an underestimate since the image did not include a substantial proportion of the mountain areas in Zone 3. The pajonal was estimated to consist of 32% of the total area, and bofedal class 1 and 2 was 7% and class 3 was 2%. Bofedal class 3 also appears to be underestimated, and much of the area from class 1 and 2 may actually be class 3. Because the image was taken in April, the class 3 bofedal may still have appeared green, thus leading to the misclassification. The bofedal was originally established through irrigation from a small river. According to local sources, within the last 15 years the water stopped flowing into the bofedal. Explanations for this change include prolonged drought, over-consumption and divergence of water by estancias upstream, and changes in the course of the river due to the movement of sand dunes (Matilde Mamani de Marca, personal communication; Buttolph, unpubl.data).

Female alpacas and sheep generally graze year-round in the bofedal, pajonal, and t'olar sites. As with the other sites, the animals will generally graze the upland areas in the morning and mid-afternoon, and the bofedal during midday. The mountains in this area contain highly productive bofedales created from mountain seeps and springs. Male alpacas are taken to these
mountain bofedales and are kept there year-round. Female llamas are also taken to grazing pastures in the mountains during the dry season (i.e., March to November) or will alternate between mountain and bofedal pastures during this time. In the wet season female llamas remain in the bofedal-t'olar areas closer to home. The male llamas, as with the other zones, are kept exclusively in the mountains year-round.

Key Resources

As mentioned in the Methods section, demarcation of the 3 zones was based on a gradient of increased aridity of the bofedales from Zone 1 to 3. The assumption was made that the bofedales serve as key forage resources due to irrigation to maintain year-round greenness. It was assumed that in the dry season, or in drought years, the bofedales maintain animals when other forage resources are not available. The bofedales were assumed to be especially important for alpaca production.

Figure 6.5 (a-c) shows the total percent cover of green vegetation, dry vegetation, bare ground, salt encrustation, rock, water, and manure for each bofedal within the 3 zones. Zone 1 showed the highest proportion of green vegetation relative to all other cover classes, and also showed the greatest amount of green cover in August (the driest month of the year) compared to other zones. Zone 2 also showed a high degree of green cover in November, February, and May, but showed only 22% green cover in August. Zone 2 also had the highest proportion of salt encrustation among the 3 zones, comprising a major portion of the total cover in August. Zone 3 was the driest of all 3 zones and also had the highest proportion of bare ground. These results provide quantitative evidence to confirm the original qualitative assessment that a gradient of high to low moisture exists from Zone 1 to 3.
Fig. 6.5. Comparison of seasonal variation in cover of bofedales in (a) Zone 1, (b) Zone 2, and (c) Zone 3.
Soils

Table 6.1 presents the results of the soil analyses for bofedales within each zone. Both percent soil moisture and organic carbon were found to be lowest for Zone 3 and highest for Zone 2. Soil salinity was highest for Zone 2 and lowest for Zone 1, as indicated through measurements of electrical conductivity. The pH and effervescence were also highest in Zone 2 and lowest in Zone 1, indicating higher concentrations of carbonates in Zone 2. Soil texture among the zones was approximately the same, and ranged from very fine, sandy loams to loamy, very fine sands. Percentage clay was estimated at 8 to 12%, and sand at 70 to 85%, for all 3 zones.

Livestock Population Dynamics

Herd Size

Results of the 3 x 3 x 13 factorial analysis comparing livestock species by zone by year showed significant zone by species by year interactions (P=0.0006) for number of livestock per household as the response variable. Table A.14 in Appendix A provides the results of the analysis of variance. Figure 6.6 (a-c) shows the relative proportions of female llamas, alpacas, and sheep per household for each zone. In general, Zones 1 and 3 appear to have greater proportions of llamas than other livestock species. Sheep appeared to comprise the greatest proportion of livestock in Zone 2. The proportion of alpacas was smallest in Zone 3 and largest in Zone 2. No major changes in these proportions are observed over time, although for Zone 3 there is a slight trend towards greater numbers of llamas and fewer numbers of alpacas in recent years.

Figures 6.7 (a-c) and 6.8 (a-c) show mean numbers of animals per household separated by zone and by species. In general, all species showed a decline in numbers following the
Table 6.1. Soil parameters measured from the bofedales within the 3 zones in Cosapa.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Soil Moisture (%)</th>
<th>Soil pH</th>
<th>Soil Effervescence</th>
<th>Soil Electrical Conductivity (mS/cm)</th>
<th>Organic Carbon (%)</th>
<th>Soil Texture¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.17</td>
<td>7.56</td>
<td>Slight</td>
<td>1.20</td>
<td>6.72</td>
<td>v.f.s.l. - l.v.f.s.</td>
</tr>
<tr>
<td>2</td>
<td>35.58</td>
<td>8.39</td>
<td>Violent</td>
<td>4.75</td>
<td>8.61</td>
<td>v.f.s.l.</td>
</tr>
<tr>
<td>3</td>
<td>6.93</td>
<td>7.92</td>
<td>Moderate</td>
<td>2.32</td>
<td>4.07</td>
<td>v.f.s.l.</td>
</tr>
</tbody>
</table>

¹v.f.s.l. = very fine sandy loam, l.v.f.s. = loamy very fine sand.

1982-3 drought for all zones. Comparing Figures 6.7 and 6.8 indicates that most of the variability is found among species rather than zones. Figures 6.8b and 6.8c show that both the mean numbers and patterns of change over time for alpacas and sheep are similar across all zones. The pattern of change over time among llamas is also similar across all zones, as shown by the 3 relatively parallel lines in Figure 6.8a. The relative number of llamas differs among zones, however, with Zone 2 having significantly less animals compared to Zones 1 and 3 for most years. Both llamas and sheep showed a relatively steady increase in numbers following the 1982-3 drought, except for sheep in Zone 1. Alpaca populations, on the other hand, never achieved predrought numbers, and in Zone 3 showed a relatively steady decline over time.

Herd Mortality

Results of the 3 x 3 x 13 factorial analysis comparing livestock species by zone by year for percent mortality as the response variable showed a significant species-by-year interaction (P=0.0001), but no zone effect. Table A.15 in Appendix A provides the results of the analysis of variance. Figure 6.9 shows the mean percent mortality for female llamas, alpacas,
Fig. 6.6. Mean percentage of female llamas, alpacas, and sheep per household for (a) Zone 1, (b) Zone 2, and (c) Zone 3.
Fig. 6.7. Changes in mean number of livestock per household from 1982-3 to 1994-5 for (a) Zone 1, (b) Zone 2, and (c) Zone 3. Significant differences between pairs of livestock species within a given year occur when the vertical distance is greater than or equal to the standard error of the difference between means (SED).
Fig. 6.8. Changes in mean number of livestock per household from 1982-3 to 1994-5 for (a) female llamas, (b) alpacas, and (c) sheep. Significant differences between pairs of livestock species within a given year occur when the vertical distance is greater than or equal to the standard error of the difference between means (SED).
and sheep over time, pooled across zones. In general, sheep showed the lowest overall mortality across all years, and alpacas the highest. Mortality was highest for all species during the 1982-3 drought year. Pairwise comparisons among species for each year (using Bonferroni-adjusted \( p \) values) showed significant differences among all species in 1982-3, with alpacas having the highest mortality and sheep the lowest. Additional differences were found in 1989-90, with llamas having significantly higher mortality than sheep; and in 1991-2, with alpacas having significantly greater mortality than llamas and sheep.

Figure 6.10 (a-c) plots percent mortality versus precipitation for each livestock species. The graphs suggest that there is a threshold precipitation level at approximately 250 mm below which mortality dramatically increases among all species. The greatest percent mortality,
however, primarily occurred during the 1982-3 drought. Figure 6.11 (a-c) compares percent mortality to stocking density for llamas, alpacas, and sheep per zone. These graphs show no obvious association between mean percent mortality and stocking rate.

Table 6.2 shows the $p$ values from the regression analysis comparing the effects of precipitation and stocking density on livestock mortality for each species. Precipitation was highly significant for all 3 species of livestock, with $p$ values of 0.0001, 0.0377, and 0.0001 for llamas, alpacas, and sheep, respectively. Stocking densities were not significant for any of the species. The interaction between stocking density and precipitation was also not significant for any of the 3 species. Table A.16 in Appendix A provides the results from the mixed model linear regression.

When 1982-3 was considered an "outlier stress year" (Scoones 1993b), and thus removed from the regression analysis, a different set of dynamics was observed. Table 6.3 shows the $p$ values from this modified regression analysis comparing the effects of precipitation and stocking density on livestock mortality for each species. Although significant associations between mean percent livestock mortality and precipitation are found for female llamas and sheep (as was found in the previous analysis), there is a trend towards a significant relationship between alpaca mortality and stocking density ($P=0.0978$), and no significant precipitation association. Table A.17 in Appendix A provides the complete results of the mixed model analyses.

**Discussion**

Based on the statistical analyses presented above, precipitation was found to be the strongest factor explaining livestock mortality. Thus, one possible conclusion could be that
Fig. 6.10. Relationship between mean annual precipitation and livestock mortality for (a) female llamas, (b) alpacas, and (c) sheep.
Fig. 6.11. Relationship between stocking density and livestock mortality for female llamas, alpacas, and sheep in Zones 1, 2, and 3.
Table 6.2. Comparison of the effects of precipitation and stocking density on livestock mortality for each species.

<table>
<thead>
<tr>
<th></th>
<th>Stocking Density (SD)</th>
<th>Precipitation (PPT)</th>
<th>SD x PPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Llama</td>
<td>0.3616</td>
<td>0.0001</td>
<td>0.4618</td>
</tr>
<tr>
<td>Alpaca</td>
<td>0.1403</td>
<td>0.0377</td>
<td>0.5596</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.1926</td>
<td>0.0001</td>
<td>0.3606</td>
</tr>
</tbody>
</table>

component of the system is non-equilibrial (Ellis and Swift 1988). Despite the statistically significant association between precipitation and mortality, however, mean livestock numbers per household appear to be independent of the rather erratic precipitation regime. Only during the 1982-3 drought was there any obvious crash in average herd size. Mean animal numbers per household, in general, remain stable and even increase in subsequent years despite low precipitation years from 1989-90 through 1994-5.

Factors such as reproductive rates may be important in maintaining population stability despite climate-related mortality. Although consistent data on livestock natality over the 13-year period were not available, the notion that high natality is compensating for high mortality during drought years is dubious. Most of the Andean data on birthrates for camelids, as well as population dynamics are driven by climate (a density-independent factor) and the livestock as the natality data presented in Chapter 2, indicate that natality is generally quite low (approximately 30%, Tichit 1995a). The long gestation period of camelids (11 months), along with the fact that female camelids bear offspring every other year, suggests that it is unlikely that a high natality is off-setting mortality during drought years. The low reproductive rates, however, could explain the lack of recovery of alpaca populations following the 1982-3.

Another factor that may influence livestock population stability is marketing (i.e.,
Table 6.3. Comparison of the effects of precipitation and stocking density on livestock mortality for each species with 1982-3 "outlier" year removed.

<table>
<thead>
<tr>
<th>Species</th>
<th>Stocking Density (SD)</th>
<th>Precipitation (PPT)</th>
<th>SD x PPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Llama</td>
<td>0.5331</td>
<td>0.0041</td>
<td>0.5016</td>
</tr>
<tr>
<td>Alpaca</td>
<td>0.0978</td>
<td>0.7712</td>
<td>0.9565</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.5029</td>
<td>0.0180</td>
<td>0.6694</td>
</tr>
</tbody>
</table>

buying and selling) of animals. Since commercial sales of meat (primarily from llama and sheep) is one of the main sources of income among households in Cosapa, animals are constantly sold and often purchased (see Chapter 4). Households also regularly consume their animals. The ability of households to raise livestock for both subsistence and commercial production may prevent animal populations from reaching both high and low extremes in density. Marketing, as well as home-consumption of animals, may also buffer climate-induced mortality by reducing natural death rates and limiting growth rates.

The majority of sold or consumed animals, however, tend to be males or very old females (see Chapter 4). If animal sales were determining total numbers, then one would expect populations to remain relatively stable, and not increase, as was observed for llamas and sheep. Although stable herd sizes were observed for alpacas, these animals are raised primarily for wool and not meat. It is possible that cash obtained from male llama and sheep sales could have allowed households to purchase more female animals.

Finally, it is possible that llamas and sheep are relatively tolerant to fluctuations in rainfall, and only in extreme drought years, such as that observed in 1982-3, are their numbers significantly affected. This would explain the recovery and steady increase in numbers of both female llamas and sheep following their crash in 1983-4. Alpacas, on the other hand, may be
more susceptible to climatic perturbations. For example, there is a slight recovery following the 1982-3 drought which coincided with high rainfall years. Alpaca populations, however, may not have been able to recover fast enough before the next period of low precipitation (i.e., between 1989-90 to 1995-6), which may have precluded any further increase in numbers. It is only in 1993-4 that alpaca numbers begin to slightly increase, which coincides with the period when Project Alpaca began offering credit to producers to purchase alpacas.

In terms of differences between the 3 geographical zones, most of the variability can be explained by differences in the mean number of each species and their relative proportions, rather than differences in the patterns of population dynamics. First, the fact that Zones 1 and 3 had access to grazing sites in the mountains contributed to the ability of households from these areas to have higher llama populations. Tichit (1995b), in a characterization of 6 estancias in the adjacent community of Turco, found that the relative proportions of llamas, alpacas, and sheep within a household herd were highly related to the dominant forage resources available. That is, households with access to both mountain and lowland pajonales tended to have a greater proportion of llamas than other species, while alpacas were dominant in areas with bofedales, and sheep were dominant in foothill t'olar (Tichit 1995b). The low numbers of llamas for Zone 2 can be explained by the lack of nearby mountain pastures. In addition, several households surveyed from Zone 2 were female-headed, single mothers. The time and labor constraints for single women could preclude their ability to take llamas to the mountains. This might also explain the dominance of sheep in Zone 2, since it is easier for women to tend sheep rather than larger alpacas and llamas.

The decline in the sheep population for Zone 1 can be explained not by biological factors, but by a local campaign to eliminate sheep from the area (Maximo Ramirez, personal
communication). This campaign was based on the belief that sheep consume as much or even more forage than camelids and are more damaging to the range due to their tendency to scratch the ground with their hooves. Thus, elimination of sheep would allow for an increase in camelid numbers.

The "higher quality" bofedales of Zones 1 and 2 did not have the expected "buffering" capacities of reducing mortality during the 1982-3 drought. Instead, mortality was independent of any zonal variation, and was dependent primarily on species of livestock. Alpacas, in general, appear to be the most vulnerable of the 3 species, showing the highest mortality in most drought years. Although mortality was strongly related to climate for all 3 livestock species, the trend towards significant stocking density effects for alpacas when the 1982-3 drought year was removed from the analysis suggests that density-dependent factors may have a greater impact on alpacas than the other species. This combination of both density-dependent and density-independent factors on animal populations was also observed by Scoones (1993b) for cattle in southern Zimbabwe. He concluded that high mortality resulting from episodic "stress years" dramatically reduced livestock populations below their "equilibrium" level; however, as populations increased towards an "equilibrium" or "carrying capacity" level, density-dependent factors became important in regulating populations, albeit weakly compared to "stress year" levels (Scoones 1993b).

Thus, within a given pastoral system, the factors responsible for limiting or regulating population size may vary depending on the species observed. Most studies of livestock population dynamics focus only on a single species (i.e., cattle--Scoones 1993b, Tapson 1993, Abel 1993, Coppock 1994). Generalizations about system behavior are often made based on the dynamics of a single, dominant species (Coppock 1994) or without discriminating among
co-dominant species (Ellis and Swift 1988). Understanding the dynamics of each species within mixed herds provides important information for determining appropriate range management strategies. For example, a combination of equilibrium and non-equilibrium-based strategies may function well for alpacas, but not for llamas and sheep.

Comparison with Pastoral Ecosystem Models

The results presented above show that livestock mortality in Cosapa is strongly influenced by precipitation, and suggests that density-independent factors are driving system dynamics. The rate of occurrence and severity of drought, however, do not appear high enough to completely eliminate other potential factors from influencing livestock population dynamics. Livestock populations over the 13-year period were relatively stable, and a trend toward stocking rate-related mortality among alpacas was observed. Thus, both equilibrial and nonequilibrial factors may be influencing livestock dynamics. By reviewing the table by Ellis and Swift (1988) presented in Chapter 1 (Table 1.1) for population patterns, Cosapa appears to exhibit both density-dependence and density-independence (see Table 6.4). Livestock populations also seem to track a certain carrying capacity, rather than being highly dynamic (Table 6.4).

It is important to note that the dichotomy between density-dependent and density-independent factors has been under considerable debate since the concepts were first introduced (Smith 1935, Andrewartha and Birch 1954). Smith (1935) recognized that climate may act as a density-dependent factor under some circumstances. For example, in the case of a protective refuge, only a limited number of refuges may exist in a given area and climate-induced mortality would be determined by the number of individuals with no access to a refuge.
Table 6.4. Characteristics of equilibrial and nonequilibrial grazing systems found in Cosapa, Bolivia in terms of livestock population patterns (adapted from Ellis and Swift 1988).

<table>
<thead>
<tr>
<th>Population Patterns</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓Density dependence</td>
<td>✓Populations track carrying capacity • Limit cycles</td>
<td>✓Density independence • Carrying capacity too dynamic for close population tracking • Abiotically driven cycles</td>
</tr>
</tbody>
</table>

= characteristics that apply to Cosapa, Bolivia.

Climate would thus be density-dependent in this case. One possibility for Cosapa then, based on this idea, might be that bofedales serve as a type of "refuge" during periods of drought, but since they only have a limited carrying capacity, those animals that cannot effectively use the "refuge" are killed by drought.

Ellis and Swift (1988) also discuss the connection between livestock density and the degree of nutritional stress experienced during drought periods. They admit that any time there is variability in forage quality, density-dependent interactions can potentially exist via competition for the best available forage (Ellis and Swift 1988). Their main argument for density-independent livestock mortality is based on the occurrence of multi-year droughts, in which forage depletion by termites, microbes, wind, etc., is so severe that livestock mortality becomes a matter of the duration of the drought rather than the number of animals enduring the drought (Ellis and Swift 1988). In Cosapa, severe, multi-year droughts were not observed during the 13-year period of study. Thus, mortality during droughts may well be related to resource competition for limited, high quality forage, illustrating, once again, the potential for climate to have density-dependent effects. This may especially be the case for alpacas.
Management Implications

In terms of livestock population dynamics, Project Alpaca assumed that animals tracked a carrying capacity for the system, and intensification practices, such as fencing and bofedal expansion, would improve livestock production by increasing carrying capacities and reducing stocking rates within exclosures. The goal was thus to maximize, as well as stabilize, livestock populations (particularly that of alpacas).

If livestock population dynamics in Cosapa were completely nonequilibrial, then technical interventions based on density-dependent optimization strategies (i.e., exclosures) would be expected to provide little benefit or improvement to livestock productivity. Many of the households with exclosures, however, claim that exclosures have reduced animal mortality. Results presented in Chapter 7 also show that cria mortality is lower for households with exclosures than those without. Thus, it appears that reduced stocking densities within exclosures provide some benefit to livestock. The approach taken by Project Alpaca to improve and stabilize animal populations may therefore be appropriate in terms of the livestock component of the system.
CHAPTER 7
EVALUATION OF DEVELOPMENT INTERVENTIONS

Introduction

The bulk of this dissertation thus far has focused on testing models of pastoral ecosystem function and dynamics to better understand the context and constraints of the system in Cosapa. The value of testing these models is to determine how appropriate development interventions might be for the system, as well as to be able to explain both the successes and failures of development programs. This chapter turns to the more explicit evaluation and analysis of Project Alpaca’s development program at the "farm" level. Although an analysis of the marketing and organizational components of Project Alpaca is critical to a comprehensive evaluation of the overall project, this chapter will restrict its evaluation to the farm-level interventions introduced by the project.

Pastoral Development

The goals of pastoral development in the past have been most commonly defined by governments, project planners, and donor agencies. Rarely has a development project been organized by pastoralists themselves, nor have the goals of pastoralists been consulted or incorporated into a development plan. Livestock development projects commonly seek to improve animal production and introduce new and "improved" technologies and management practices to achieve higher productivity (Browman 1984). Additional development goals have included integrating pastoral populations into market economies, increasing government revenues from the livestock sector, and reducing assumed rangeland degradation (Dr. Brien Norton, personal communication).
It is not surprising then, that pastoral development projects have been notorious for their high rate of failure. Attempts to integrate pastoralists into the market economy have commonly either failed or led to greater social stratification, dissolution of traditional exchange relations, and the breakdown of traditional social institutions and communities. For many livestock development projects the means of achieving "development" have involved introducing radical changes in the ecology, economy, and administration of traditional pastoral systems (Baker 1975). Development schemes have commonly been imposed upon pastoralists rather than involving the pastoralists in project planning, implementation, and decision-making.

Much of the failure of livestock development projects thus can be attributed to a lack of understanding of the pastoral system, incompatibility in development goals among planners/government administrators and pastoral peoples, and social, institutional, and technical deficiencies in project and program design (Behnke and Scoones 1993). The universal application of Western range management, with all of its accompanying technical interventions, has also proved inappropriate for most pastoral systems (Sandford 1983). Emphasis of development on maximizing production, especially meat production, has often been incompatible with the risk-reduction strategies of many pastoral societies (Browman 1987b). The benefits of livestock for purposes other than meat production and commercial sale (i.e., savings account, animal traction, manure, wool, milk, portage) is often overlooked in development programs. Misconceptions about rangeland degradation and the notion that overgrazing causes degradation are also common assumptions among development planners (see Chapter 5).

Browman (1984, 1987b) describes 4 standard development programs that have been attempted in the Andes as: (1) improvements in the carrying capacity of arid rangelands via
improving water supplies and forage production; (2) improvements in livestock productivity through disease control, selective breeding, and introductions of "improved" breeds; (3) improvements in services to pastoralists (i.e., extension services and marketing); and (4) attempts to improve efficiency among pastoralists through government cooperatives and collectives. He criticizes these programs in their focus on externally derived technology and mechanization while lacking attention to the sociocultural sphere (Browman 1987b).

The purpose of this chapter is to evaluate the impacts of farm-level interventions introduced by Project Alpaca on livestock productivity, local management, and community and social relations. The specific goals of each intervention, as defined by Project Alpaca, will be outlined, and the technical innovations assessed in light of past development efforts, and within the context of Cosapa. Discussion will also include questions about what appropriate development goals may be and the means of achieving those goals.

AIGACAA Technical Interventions

Unlike most development projects, Project Alpaca is unique in that project planning and implementation was carried out for the most part by AIGACAA, that is, the local herders themselves. At the institutional and organizational levels, Project Alpaca has benefitted from a high degree of participation among its members. The annual meetings of AIGACAA and COPROCA in El Alto were well attended and well represented by all participating ayllus (or communities). The fact that traditionally the Aymara communities have been well organized has contributed to the highly democratic and organized institutional structure of AIGACAA. Thus, from an organizational standpoint, the project has been highly successful.

The farm-level interventions of the project, however, have involved highly Western, technically oriented solutions. These technical innovations introduced by Project Alpaca at the
farm level include: (1) introducing barbed-wire fencing materials to construct grazing exclosures for dry-season forage reserves; (2) large-scale construction of irrigation canals to expand bofedales; (3) importing improved genetic stock of alpacas; (4) veterinary services; and (5) providing supplemental feed in the form of imported alfalfa hay. Many of the technical innovations were financed through credit available from the project. Credit was provided to eligible households to purchase alpacas, veterinary supplies and medicine, supplies to construct barbed-wire exclosures, and for small-scale water improvements (i.e., pumps, irrigation canals). Credit was given to groups of households, rather than individuals, such that repayment was guaranteed by the group.

Methods

Both qualitative and quantitative methods were used to evaluate the impacts of Project Alpaca. Qualitative methods included personal observations, informal interviews with key informants, participant observation, project documents and reports, and attendance at local community meetings and regional AIGACAA meetings. Both qualitative and quantitative information was also obtained through household surveys.

Household Survey

The survey used to describe management practices in Cosapa and livestock population changes among the 3 zones (described in Chapters 4 and 6, respectively) was also used to evaluate the impacts of development interventions. Comparisons were made between households that did and did not use the different technical innovations introduced by Project Alpaca. Chapter 4 provides a description of survey methods.
Since controlled experiments were not employed, both for logistical reasons and time constraints, on the variables measured, the survey was considered to be the next most feasible option to determine the effectiveness of development interventions. Controlled experimentation most likely would have found positive benefits to all of the interventions if tested in isolation. What may be more relevant, however, is how these interventions impact livestock productivity within the context of the whole production system in Cosapa, including the real environmental, social, and economic constraints. The perceived benefits of the interventions by the pastoralists are also important in evaluating the Project’s success. The survey, thus, is both useful in that the potential utility of the development interventions are evaluated within the broader context of the pastoral system (with all of its complex interactions), and documents the benefits perceived by the pastoralists.

Evaluation of project interventions was made by comparing productivity of llamas, alpacas, and sheep among households who used the interventions to those who did not. The variables used to measure livestock productivity were the number of crias born in 1995 and 1996, the number of lambs born in 1995, the number of crias and lambs that died prior to weaning between July 1995 and May-June 1996, the number of adult animal deaths in 1995-6, livestock morbidity in 1995-6, and the number of noted abortions in 1995-6 among llamas and alpacas. All responses were converted to a proportion of total reproductive females or total animals for each species.

Comparisons were also made of alpaca herd numbers and colors in 1991 and 1996. Seven different wool colors were identified: white, black, gray, brown, "api" (brownish-gray), "light fawn" or "vicuña" (tan), and spotted/mixed. Surveyed households were asked to provide the number of animals of each color in 1991 and in 1996, in order to determine if households
were beginning to specialize in a particular color following initiation of the project. To determine the degree to which households began to specialize in a few dominant wool colors, the Shannon-Weiner index of diversity (Shannon 1948, Hurtubia 1973) was calculated for each household’s alpaca herd (see Chapter 5, eq. 5.2). Diversity was expected to decrease with increasing specialization.

In addition, interviewees were asked to provide information on their exclosures and any problems encountered with the use of exclosures. Households were also asked to state their opinion about changes in land availability and disease rates since the 1960s, as well as suggestions about how AIGACAA and Project Alpaca could be improved. Appendix B provides a sample questionnaire.

**Statistical Analyses**

As mentioned in Chapter 6, despite the fact that the sampling design for the survey was intended to be a census of the population households from 3 zones, as well as additional households that did and did not have access to exclosures, for the purposes of evaluating the impacts of development interventions, surveyed households were considered a "sample" of the entire population of Cosapa. Once again, the use of inferential statistics in this case is open to considerable debate (Susan Durham, personal communication). Thus, results from the following statistical analyses should be interpreted with a degree of caution and an understanding of the potential for bias in error estimations.

To determine if changes in alpaca herd color diversity had occurred among surveyed households between 1991 and 1996, a paired t-test was used to compare Shannon-Weiner diversity indices. The analysis was conducted in SAS-PROC T-TEST (SAS Institute Inc. 1996).
Because the goal of the interventions was to increase livestock (primarily alpaca) productivity, statistical tests were conducted to compare animal productivity between households that did and did not use the interventions. Multivariate analyses of survey data were conducted using logistic regression in SAS-PROC LOGISTIC to determine the impacts of different technical interventions on livestock productivity (SAS Institute Inc. 1996). Specifically, the explanatory variables of interest were use versus no use of exclosures, alfalfa supplementation, veterinary services, treatment of internal parasites, and vitamin supplementation. Response variables used were productivity of llamas, alpacas, and sheep. These include natality rates in 1995 and 1996, cria and lamb mortality rates (1995), adult animal mortality rates (1995), abortion rates (1995), and livestock morbidity rates (1995). Each response variable was represented as a binary outcome or proportion (i.e., number died in herd/total in herd), and was analyzed separately.

Initial analyses using logistic regression revealed statistically significant Pearson $\chi^2$ and deviance values, suggesting poor model fit due to overdispersion of the data (SAS Institute Inc. 1996). Overdispersion can lead to underestimation of standard errors, and cause the Wald tests to be too sensitive (SAS Institute Inc. 1996). To adjust for overdispersion, the Williams' model was used in SAS-PROC LOGISTIC as a scale option. The Williams' model estimates a scale parameter $\phi$ by equating the Pearson $\chi^2$ value for the full model to its approximate expected value, and creating a set of weights based on that estimation (SAS Institute Inc. 1996). The weights are then used to fit subsequent models with fewer terms than the full model (SAS Institute Inc. 1996). The criterion for judging the significance of a variable was based on the $\chi^2$-statistic where $P < 0.10$. The odds ratio ($\exp(\beta)$) was used to predict the odds
that an event will occur given the explanatory variable of interest (Hosmer and Lemeshow 1989).

Results and Discussion

Moris (1988), in a discussion of the failure of pastoral development projects in Africa, lists common technical interventions introduced to pastoral systems and the problems associated with each. Standard interventions described by Moris include water development, breed improvement, veterinary campaigns, and forage reserves—all of which were implemented by Project Alpaca. In the following section each of these improvements will be discussed in terms of the general goals and problems encountered in the past, and will then be analyzed in the context of pastoralism in Cosapa.

Water Development

Water development projects commonly consist of drilling wells to establish permanent watering points for livestock. The basis for this practice is to create a more even distribution of grazing across the landscape, such that areas that were formerly too distant from water can be efficiently utilized and opened up to grazing (Stoddart et al. 1975, Holechek et al. 1989). Water developments are the easiest form of pastoral development, and are often the only planned activity actually carried out (Sandford 1983). Sandford (1983) states, however, that water developments not only change the physical environment, but also the social relations surrounding access, use, and control of both old and new water supplies. Some of the problems associated with water development projects include buildup of artificially high numbers of livestock around watering points, which leads to overgrazing and site erosion;
conversion of grazing lands to croplands; high water loss and siltation; and the inability to maintain and repair pumps (Moris 1988).

Project Alpaca's development package included funding for the establishment of watering points, and pumps. Outside funding from the European Community-financed Fondo de Desarrollo Campesino also provided for construction of large-scale irrigation canals to expand bofedales. There are currently 4 projects underway in 4 different communities, each costing on average of US$50,000. The irrigation project in Cosapa is diverting water from the Cosapa River, through the construction of cement canals, to expand the area of bofedal in the northwestern part of the community.

The problems associated with water development for dryland Africa appear to be less relevant for camelid production on the altiplano. First, soil erosion due to trampling and uprooting of plants is less of a problem in camelids than in European livestock (i.e., cattle or sheep). Llamas and alpacas have soft, padded hooves, which are considered less damaging to the vegetation and soil surface. They also tend to snip off plant parts rather than pulling plants out of the ground. Because the risk of frost precludes crop production on the exposed valley bottoms in Cosapa, there is no threat that lands will be converted to agriculture with water developments.

Water diversion and canal development for the expansion of bofedales conform to pre-existing social and institutional structures surrounding bofedal establishment and maintenance (Palacio Rios 1977). The only potential source of conflict with the bofedal expansion project is that only 15 families are expected to benefit directly from the US$50,000 project, and there is the risk that some households downstream, who already experience more arid conditions, might receive even less water due to the diversion. These benefits to only a small proportion
of the community have the potential to create greater disparities of wealth within the community and increase conflict. The success of the irrigation project might also be short-lived if the river channel alters its course over time. Because of failed negotiations with a community located upstream of Cosapa, construction of the diversion canal, which was originally planned for a steeper topographic grade, was forced to occur in the shallow flood plains. The current location of the diversion poses the risk that over time the river will alter its course and migrate away from the canal (Dr. Humberto Alzérreca, personal communication). Thus, although bofedal expansion conforms well to the local ecology and traditional management practices, better planning and negotiations could have increased the number of beneficiaries, as well as guaranteed the long-term viability of the project (Dr. Humberto Alzérreca, personal communication).

**Breed Improvement**

The introduction of improved genetic varieties and breeds of livestock has been another common intervention in pastoral development projects. The objectives of introducing improved genetic varieties or breeds of livestock are to provide a rapid increase in animal productivity (Moris 1988). "Improved" breeds of livestock generally produce more meat, fat, milk or fiber per animal; however, they also tend to have much higher nutritional, energy, and water requirements, are more susceptible to disease, and usually are not able to tolerate environmental and/or nutritional stress as well as unimproved breeds. Thus, under the harsh conditions of dry-land systems, improved breeds of livestock often perform poorly or do not survive (Moris 1988).

Past development efforts in the Andean region have focused on either upgrading the existing European livestock breeds (i.e., sheep), or importing and replacing local breeds with
improved foreign breeds (Browman 1984). Browman (1984) states that under the Peruvian Agrarian Reform, over 100,000 Corriedale sheep were imported from New Zealand to replace the highland criollo breed. The project failed, however, because many animals succumbed to climatic stress, and those that survived were no more productive than the criollo breed (Browman 1984). Although many Andean pastoralists and agropastoralists currently raise populations of Corriedale sheep, as well as hybrids of Corriedale/criollo breeds, supplementation with alfalfa and barley is necessary to meet the higher nutritional requirements of these animals (Villanueva 1995). Browman (1984) suggests that rather than focusing attention and technology on improving the productivity of European livestock species (i.e., sheep and cattle), development efforts should focus on improving the already superior adaptations of the native camelids (llama and alpaca).

One of the major achievements of Project Alpaca was its emphasis on improving alpaca productivity. Not only is the alpaca highly adapted to the harsh environmental conditions of the altiplano, but it also has a long history of cultural and economic significance among Andean pastoralists. In terms of breed improvement, Project Alpaca focused on fine-tuning the existing genetic varieties of alpaca within Cosapa, as well as introducing breeds from outside the community. Genetic improvement in alpacas was based primarily on wool color (white brought the highest price), although wool growth rate and fiber quality were also desired traits. Unlike many of the Peruvian herds, which are primarily white in color, in Cosapa and other communities in the south-central altiplano of Bolivia, the fleece color of alpacas ranges from various shades of brown, black, and grey, in addition to white. Many animals in Cosapa are also spotted or a combination of different colors. White has traditionally been favored by industry because it can be more easily dyed; and higher prices are obtained for wool that is
pure white or black. In terms of processing it is also important that different colored fibers are not mixed. This poses problems for animals who have a combination of different colored wool.

Thus, in an attempt to refine the wool quality at the farm level, Project Alpaca established a campaign to improve the genetic pool of alpacas (Project Alpaca Proposal 1991). Households that received credit from the project, either to purchase new animals or for improvements (i.e., fenced exclosures), were expected to select 1 or 2 colors among their animals in which to specialize (Dr. Walter Vilela, personal communication). Generally, the predominant colors found within the herd were selected for specialization. Careful breeding among the selected colored animals was expected. Households were expected to trade, sell, or cull their animals of other colors. The goal was to eliminate from the breeding pool animals with spots or undesirable colors, and to create a more reliable and predictable breeding pool. Breeding had been fairly unpredictable—a black alpaca would commonly give birth to a white offspring. Thus, the color of an offspring was considered more a matter of luck than something that could be controlled. By specializing in 1 or 2 colors, each household could narrow the genetic variation in their herds and produce more animals with predictable colors.

The project also provided credit such that producers could purchase pure-colored alpacas brought from Ulla Ulla (the major alpaca producing area in northern La Paz department) or Peru. Other households purchased animals locally with desirable genetic traits. The project also had a breeding stock of white alpaca males, which could be borrowed by households during the breeding season to mate with their females.

It is important to mention that most households in Cosapa felt that white alpacas were weaker and more susceptible to disease than alpacas of other colors. Because white reflects rather than absorbs sunlight, households claimed that they were more susceptible to cold
weather. Many of the white alpacas in the area had blue eyes, an undesirable trait. The occasional snowfall in August can be blinding for blue-eyed alpacas, while black-eyed animals are better-able to tolerate the bright reflectance of snow. Thus, many households were wary of maintaining a pure white herd of animals. Overall, however, the genetic improvements introduced by the project were desired by the community, were not extreme alterations of the preexisting system, and were more of a refinement of the current stock rather than a radical change.

Results of the analysis comparing changes in alpaca herd color diversity found a significantly higher Shannon-Weiner diversity index in 1996 compared to 1991 ($P=0.007$), indicating a trend towards diversification of colors rather than specialization. Table 7.1 summarizes the results of the analysis.

Thus, specialization by households in only a few alpaca colors was not found to be occurring in 1996. This indicates that either (1) no selective breeding, culling, or trading of animals is taking place; (2) households desire a diversity of herd colors; or (3) a longer time period is required to observe visible changes in genetic improvements and selection, and color specialization. According to the resident veterinarian in Cosapa, this last possibility may be important since the long gestation period and low birthing rates of alpacas result in very slow changes in genetic improvement (Dr. Walter Vilela, personal communication).

**Veterinary Services**

Disease control measures have been one of the oldest and most popular interventions employed in livestock development projects (Moris 1988). They have regularly had high acceptance among pastoralists, and often lead to dramatic increases in livestock numbers (Goldschmidt 1981). The major criticism surrounding veterinary campaigns is that they lead to
Table 7.1. Results of the paired t-test comparing herd color diversity (expressed as the Shannon-Weiner index) per household between 1991 and 1996.

<table>
<thead>
<tr>
<th></th>
<th>1991</th>
<th>1996</th>
<th>Difference</th>
<th>T</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SE</td>
<td>1.33±0.07</td>
<td>1.53±0.03</td>
<td>0.19±0.06</td>
<td>2.7819</td>
<td>29</td>
<td>0.0094</td>
</tr>
</tbody>
</table>

livestock population explosions that result in overgrazing (Goldschmidt 1981). Others have argued that veterinary campaigns are often only treating a symptom of a larger systemic problem (Baker 1975). For example, policies that encourage fire suppression may lead to brush encroachment, creating habitat for ticks and other disease vectors (Baker 1975). Rather than taking preventative measures (i.e., burning of brush), many development efforts attempt to treat the secondary symptom using capital-intensive technologies (i.e., dipping baths and veterinary campaigns). These programs tend to create greater dependency by pastoralists on external inputs.

As mentioned in the introduction, Project Alpaca’s veterinary campaign in Cosapa involved a resident veterinarian, who served the community and the greater region. Two extensionists also resided in Cosapa and were trained in basic veterinary care. The AIGACAA compound in Cosapa also housed a small pharmacy which supplied veterinary medicines, as well as a small laboratory to run diagnostic tests for parasites and other infections. Veterinary services generally involved treatment of diseases and parasites, and vitamin supplementation. The veterinarian or extensionist would commonly go to a household’s estancia to treat the animals. A household member or messenger would usually come to the AIGACAA compound requesting the service. Households were expected to pay a fee for the medicines, but were not required to pay for the service. Individuals could also come to the AIGACAA headquarters and purchase medicines from the pharmacy.
Dipping baths had already been established in many estancias in Cosapa prior to Project Alpaca, although the project did provide funding for the construction of new dipping stations in areas where they were lacking. Mandatory dipping was required of all households at least once a year for treatment of external parasites (i.e., ticks, mange or scabies). Dipping was done primarily between February through March when warmer temperatures helped to insure that animals would not freeze following the baths. Occasionally a second dipping was done in September or October. All animals were dipped, including pigs and dogs.

Results of the survey indicate that 17 out of 29 households (or 59%) felt that livestock morbidity was higher now than in the past (the past being defined as the 1960's and earlier), with more different types of diseases afflicting animals. Other households (38%) felt that morbidity was higher in the past, primarily due to mange infestations. One household felt that no change had occurred in terms of morbidity; however, mortality, particularly from mange epidemics, was lower now than in the past due to the animal dipping campaign.

The results of the logistic regression for all explanatory variables (i.e., interventions) and response variables (i.e., productivity measures) are presented in Table 7.2. The odds ratio can be interpreted as the magnitude to which a given intervention increases or decreased the odds of the response variable. An odds ratio greater than 1 indicates a positive contribution of the intervention. For example, an odds ratio of 1.74 for an intervention indicates that the odds of a response is 1.74 times (or 74%) higher than without the intervention. Estimated correlation matrices from each analysis are presented in Table A.18 in Appendix A.

No statistically significant associations were found between veterinary use and livestock productivity in 1995-6. Treatment for internal parasites (also referred to as "dosification") was also not a significant variable in any of the analyses. Explanations for the apparent "neutral"
Table 7.2. Results of the logistic regression analyses showing the significant explanatory variables for each response variable. The William's model was used in all analyses to correct for overdispersion of data.

<table>
<thead>
<tr>
<th>Response and Explanatory Variables</th>
<th>Wald</th>
<th>df</th>
<th>p</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpaca natality ('96)(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin supplementation(^2)</td>
<td>4.33</td>
<td>1</td>
<td>0.0374</td>
<td>1.74</td>
</tr>
<tr>
<td>Alpaca cria mortality(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exclosure use(^2)</td>
<td>9.95</td>
<td>1</td>
<td>0.0016</td>
<td>0.26</td>
</tr>
<tr>
<td>Alpaca morbidity(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa supplementation(^2)</td>
<td>3.36</td>
<td>1</td>
<td>0.0668</td>
<td>0.29</td>
</tr>
<tr>
<td>Vitamin supplementation(^2)</td>
<td>6.06</td>
<td>1</td>
<td>0.0138</td>
<td>4.27</td>
</tr>
<tr>
<td>Llama natality ('96)(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin supplementation(^2)</td>
<td>5.89</td>
<td>1</td>
<td>0.0152</td>
<td>1.50</td>
</tr>
<tr>
<td>Llama natality ('95)(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa supplementation(^2)</td>
<td>5.68</td>
<td>1</td>
<td>0.0172</td>
<td>0.50</td>
</tr>
<tr>
<td>Llama abortion rate(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin supplementation(^2)</td>
<td>3.44</td>
<td>1</td>
<td>0.0638</td>
<td>2.22</td>
</tr>
<tr>
<td>Exclosure use(^2)</td>
<td>5.46</td>
<td>1</td>
<td>0.0195</td>
<td>2.78</td>
</tr>
<tr>
<td>Llama morbidity(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin supplementation(^2)</td>
<td>4.94</td>
<td>1</td>
<td>0.0263</td>
<td>3.48</td>
</tr>
<tr>
<td>Exclosure use(^2)</td>
<td>3.06</td>
<td>1</td>
<td>0.0802</td>
<td>2.73</td>
</tr>
<tr>
<td>Sheep natality ('95)(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exclosure use(^2)</td>
<td>4.95</td>
<td>1</td>
<td>0.0261</td>
<td>2.05</td>
</tr>
<tr>
<td>Lamb mortality(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa supplementation(^2)</td>
<td>3.19</td>
<td>1</td>
<td>0.0740</td>
<td>0.44</td>
</tr>
<tr>
<td>Sheep mortality(^1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa supplementation(^2)</td>
<td>2.79</td>
<td>1</td>
<td>0.0951</td>
<td>11.43</td>
</tr>
</tbody>
</table>

\(^1\)Response variable.
\(^2\)Significant explanatory variables included in model.
impacts of veterinary services and dosification include the possibility that disease outbreaks were low in 1995-6, and only in extreme stress periods or during disease epidemics do these interventions substantially improve production.

Vitamin supplementation was a significant component for some production measures, but its contribution varied from positive to negative. Vitamin supplementation had significant positive benefits on both alpaca and llama natality in 1996, improving the odds by 74% and 50%, respectively. The use of vitamins, however, was also found to be associated with greater alpaca and llama morbidity, and higher rates of abortions in llamas. These apparent negative impacts of vitamin use can be explained by the fact that households will often resort to vitamin supplementation only after their animals are weak, thin, and sick. Thus, it seems that apart from the perceived benefits of dipping baths in reducing livestock morbidity from mange, the use of additional veterinary services were not very important in overall herd productivity during 1995-6.

**Supplementation**

Supplementation of animal diets with hand-picked native forage or purchased feeds was quite common among households in Cosapa prior to Project Alpaca (see Chapter 4). Supplemental feeds were commonly given to crias and lambs, particularly orphaned animals, and undernourished adult livestock. Most households gave their adult animals supplemental feed only in drought years. With the implementation of Project Alpaca, truckloads of baled alfalfa hay were brought into the community and made available for purchase by households. The intention of the alfalfa supplementation was to increase alpaca productivity and maintain animals through the dry season or during drought. Most households fed their livestock 0.25 to 1 kg of alfalfa per day per animal during the dry season (July to September).
Results of the logistic regression found that alfalfa supplementation reduced the odds of alpaca morbidity in 1995-6 ($P=0.0668$), as well as reduced the odds of lamb mortality ($P=0.0740$; Table 7.2). Alfalfa supplementation, however, was also found to be negatively associated with natality among llamas in 1995 ($P=0.0172$), and positively associated with sheep mortality in 1995-6 ($P=0.0951$). Once again, explanations for these negative impacts include the possibility that alfalfa was given to animals when they were already weak, sick, and/or thin, and that significant values indicate only correlations rather than causality.

**Forage Reserves**

The practice of establishing forage reserves for drought or dry-season grazing has been a common practice among pastoralists worldwide (Niamir 1991). Movement of herds or seasonal transhumance have been the most common ways in which dry-season forage reserves are established (Niamir 1991). For example, many pastoral groups will take their animals to desert or upland sites in the wet season in order to preserve the more mesic, bottomland sites for dry-season grazing (Jacobs 1980, Caro 1985). These transhumant practices not only preserve forage for dry-season grazing, but also reduce disease outbreaks by keeping animals out of the wetter, swampy areas during the wet season, as well as keep animals out of croplands during the growing season (Niamir 1991, Caro 1985).

The replacement of transhumant migration with more sedentary forms of livestock production has increased grazing pressure on rangeland resources as well as reduced the possibilities for deferment of grazing on dry-season pastures. Whether the sedentarization of pastoral groups is imposed from external sources (i.e., governments or development projects), or is a result of population growth and/or land scarcity, the implications commonly include reductions in the carrying capacity of the land (Western 1982).
Barbed-wire fenced, grazing exclosures have been introduced worldwide to establish dry-season forage reserves. One common problem with fencing is that it is often imposed as a substitute for transhumant migration, therefore leading to sedentarization. Another major problem is that fencing tends to encourage individuation of land holdings (Moris 1988). In pastoral societies that have a long history of communal land tenure relations, the "privatization" or parcelization of land often increases vulnerability for households without access to those holdings who must rely on marginal pastures, or lack political power within the community (Moris 1988).

Fencing also reduces labor requirements for herding. Although this may be preferred in societies where labor is scarce or expensive, many pastoral societies rely on exchange relations of labor to maintain community cohesion and persistence of poorer households. Various forms of herding contracts exist such as quasi-adoptions, kin cooperation, stock associates, and patron-client relationships (Sikana and Kerven 1991). Contracts in which herding labor is exchanged for livestock offspring is a common practice in many pastoral societies, and provides a means by which younger and/or poorer households can increase their own herds (Sikana and Kerven 1991, Browman 1987b). Sandford (1983) points out that these types of herding contracts provide an important mechanism for increasing equity within a community by creating a more equal distribution of livestock between households.

The goals of Project Alpaca's fencing program are stated as follows:

Fencing is required so as to allow pregnant and lactating alpacas (dams) to receive improved nutrition during the critical period of their productive cycle which usually falls between the dry seasons. The areas to be fenced will be comprised of the irrigated pastures and bofedals which have been allocated to alpaca production. In an effort to maximize the use of these areas by the alpaca herds all other species will be kept out. This increased management will considerably reduce overgrazing, minimize pasture recuperation time and contribute very substantially to improve meat and fiber quality....It is estimated
that approximately 45% of the total bofedal area will be fenced. (Project Alpaca Proposal 1991:29)

Essentially, the project assumed that households would only allow alpacas to graze in the exclosures, and that both alpaca and plant productivity would increase as a result of the fencing.

*Impacts of Exclosures on Plant Productivity*

The assumptions of pasture recuperation and improvements in plant productivity with grazing exclosures were not found to occur in Cosapa, at least not within the first 3 years of protection. Chapter 5 provides more details on the impacts of exclosures on vegetation dynamics.

*Impacts of Exclosures on Livestock Productivity*

Results of the logistic regression indicate that households with access to exclosures had significantly lower odds of alpaca cria mortality ($P=0.0016$; Table 7.2). Qualitative information obtained from interviews with households who have access to exclosures supports the quantitative results in terms of the benefits of the exclosures on alpaca production. Many households have stated that cria mortality has been reduced by allowing them to feed inside the exclosures.

Although sheep were not intended to benefit from the exclosures, results of the analysis also found exclosures to benefit lambing rates in 1995 (Table 7.2). One explanation for this is that sheep occasionally are able to enter the exclosures without the knowledge of the owner. In contrast to the positive benefits of exclosures on sheep and alpaca production, for llamas the odds of having an aborted fetus were positively associated with households that had exclosures ($P=0.0195$). Morbidity among llamas was also positively associated with exclosure use.
If households were only allowing alpacas into the exclosures to graze during the dry season (apart from the accidental entry of a vagrant sheep), then it might make sense that llama performance would decline due to their exclusion from these reserves. In actuality, however, results of the survey and personal visits to the exclosures during the dry season found that, in general, both alpacas and llama were allowed to grazed in the exclosures. Rather than focusing on the pregnant and lactating females, however, most households placed the crias and thin animals inside the exclosures to graze. The benefits of exclosures on reducing alpaca cria mortality and improving sheep natality explain their immediate attraction for households.

**Impacts of Exclosures on Social Relations and Vulnerability**

Despite the benefits of grazing exclosures on livestock productivity, many potential negative implications exist in term of land-tenure relations, vulnerability, and equity within the community. As mentioned above, fencing programs have commonly led to privatization of land ownership, which, in turn, often results in increased vulnerability and marginalization for poorer households.

Existing pressures on land availability have contributed to the desire among households in Cosapa to build fenced exclosures. Results of the survey indicated that 75% of sampled households felt that there was more land per household available in the past compared to the current situation. This was explained by the fact that the population of the community was smaller in the past. The remaining 25% of households felt there was no change in the amount of land per household. The land tenure system in Cosapa is based on group ownership of specified tracts of land. Although several households may share title to common grazing lands, agreements are made in which each household is allotted a specific portion of the communal
area to graze their animals. Thus, one family will generally graze their animals in one area, and another family in an adjacent area. Overlap does occur, however, due to lack of herding or deliberate grazing on neighboring lands.

Conflicts over land-use rights have increased as the population of Cosapa grows, and tension among neighbors is often high. I once witnessed a woman screaming and chasing the neighbor's children whose livestock were trespassing on her land. Herding has become, in a large part, keeping the neighbors' animals off the land, rather than tending to one's own herd.

Reductions in labor availability in Cosapa may be contributing to reduced mobility of livestock and greater pressures on the land. Although herding is a minimal task when the animals graze near the estancia, additional labor is required for taking animals to the mountain pastures. Many households in Cosapa with tenure rights to mountain pastures are not able to utilize those rights due to restrictions on labor. Browman (1987b) states that following the Bolivian Agrarian Reform in 1953, universal schooling removed children from the labor pool. The opening up of large agricultural areas in the eastern portion of the country also attracted many herders from the highlands to work as wage laborers (Browman 1987b). Increased opportunities in the cities for jobs and education have also resulted in emigration from the community and reductions in the herding labor.

Thus, the construction of private grazing exclosures is highly appealing to many community members in Cosapa due to reductions in both labor and land availability. At first, only households with relatively small herds were given credit to purchase fencing materials. The argument was that the larger herd owners were accruing greater benefits from the communally owned land, and that the exclosures would allow them to build up their own herds. These initial exclosures were relatively small in size, (i.e., ranging from 1 to 3 hectares), and
were placed on relatively noncontroversial sites where there was little communal overlap of grazing rights. The locations of these exclosures were generally on the margins of large bofedales, rather than in the central portions where communal grazing use was more common.

As time went on, however, others began constructing larger exclosures, ranging up to 8 hectares in size. Many of the newer exclosures were built by large herd owners, and were placed in the center of the communal bofedales. Conflicts between neighbors has thus increased. Some households who do not have exclosures, as a means of protest, place their sheep inside their neighbor’s exclosure to graze, or create holes such that animals can freely pass in and out. In one estancia (Anta Qollu) up to 50% of the bofedal is fenced off. Thus, rather than reducing pre-existing tensions over land use and access, the exclosures seem to be exacerbating the problem.

Not all households in Cosapa, however, are constructing exclosures. Results of the survey found that many households chose not to put up exclosures because their land was under communal ownership and use. Why some estancias maintain the social norms and conventions regarding common property rights and others do not is unclear. Closer kinship networks and ties, as well as more available land may explain why many households choose not to construct exclosures.

The social implications of the exclosures, thus, include the potential for increased vulnerability for households who do not have access to exclosures, greater social stratification due to differential access to grazing lands, and marginalization and exclusion of households from the system. Flexibility and opportunism for producers also become more limited with fencing. Caro (1992) discusses the benefits of communal land tenure on the altiplano, in that it allows herders to redistribute pasture resources among households according to relative
changes in their herd sizes and labor pools. Under communal ownership the welfare and decision-making of individual households are inextricably linked (Runge 1981). The social institutions established over generations to insure the continued viability of households and livelihoods based on pastoralism are thus under greater threat of dissolution as land becomes individualized with fencing.

Recommendations by Households

When asked how AIGACAA could improve its program, surveyed households responded by requesting more services, markets for livestock products, credit, and education/training. Table 7.3 provides the percentage of responses for each recommendation. Specific services requested include bringing in improved genetic varieties of both llamas and alpacas to breed with local animals, more irrigation projects to expand bofedales and provide livestock watering holes, and increasing the availability and quantity of veterinary medicines. In terms of livestock marketing, requests were made for improving and establishing markets for meat (camelid and sheep) and handicrafts (i.e., hand-knitted sweaters, hats, gloves, woven shawls, blankets, scarves), and offering higher alpaca wool prices. Many households also requested more short-courses and training sessions in animal health and sanitation. Finally, households requested more credit for purchasing animals, constructing exclosures, and funding irrigation projects. One herder who was interviewed articulated the need for greater amounts of credit. He said that US$2,000 of credit, which was the average amount loaned to producers, is not enough to dedicate oneself completely to raising livestock, and felt that at least US$5,000 was necessary.

The recommendations made by households for project improvement are essentially an expansion of the technical and marketing interventions Project Alpaca initiated. This could be
Table 7.3. Recommendations made by surveyed households and the percentage of households that made each recommendation as to how AIGACAA can improve its program at the farm level.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Percent of Households¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic Improvement of Camelids</td>
<td>42.3</td>
</tr>
<tr>
<td>Credit</td>
<td>30.8</td>
</tr>
<tr>
<td>Water Developments/Irrigation Projects</td>
<td>23.1</td>
</tr>
<tr>
<td>Veterinary Medicines</td>
<td>19.2</td>
</tr>
<tr>
<td>Marketing of meat or wool</td>
<td>15.4</td>
</tr>
<tr>
<td>Courses in Animal Health</td>
<td>11.5</td>
</tr>
<tr>
<td>Range Improvements</td>
<td>11.5</td>
</tr>
<tr>
<td>Marketing of Handicrafts</td>
<td>7.7</td>
</tr>
</tbody>
</table>

¹n=26

an artifact of the technical orientation of the survey, or the technical bias of the project. It also reflects the herders' desire for tangible, visible improvements. Establishing markets for woven textiles and knitted handicrafts was especially important among the women who were surveyed, since knitting represents an important activity for women and can be done while herding.

The recommendations made by surveyed households, however, should not necessarily be equated to the overall goals or objectives of the herders of Cosapa. For example, a herder may request fencing materials but her overall objectives may include maintenance of pastoralism as a source of livelihood, which may be threatened by fencing. Thus, immediate benefits may often conflict with long-term goals. Sandford (1983) discusses the difficulties associated with finding out the objectives of pastoralists based on direct questioning. He recommends instead attitudinal surveys or observation of their behavior, culture, and institutions that bind the society together (Sandford 1983). He also points out that a society's objectives may be quite dynamic and change rapidly over time (Sandford 1983). Thus,
although direct questioning of pastoralists to determine development goals is important, observations and understanding of pastoralists' culture and institutions may help determine more relevant and appropriate development.

Conclusions

The models assumed by Project Alpaca match those of conventional livestock development efforts in that standard technical innovations are assumed to release pastoralists from the constraints of low productivity. The universally applied package of technical innovations includes water development, genetic improvement, veterinary campaigns, and fencing/privatization of rangelands. What is unique about Project Alpaca is that many of these interventions have been appropriate for the given ecological and sociocultural environment. For example, rather than introducing entirely new species, genetic improvements of native alpacas have been employed. Expansion of bofedales also mirrors traditional land use practices of water diversion and canal management.

One problem with the "tech-fix" approach, however, is that changes are imposed on the system without consideration of associated social relations and institutions that may be disrupted as a consequence. This approach assumes that society will take care of itself, so long as profits increase for herders. The problem is that incomes and benefits may accrue to a certain portion of the population, but may increase vulnerability and poverty for another portion. For example, the introduction of fenced exclosures threatens to privatize communal grazing lands in Cosapa. Common property resources provide a complex system of norms and conventions for regulating individual rights to grazing lands (Runge 1992). Disruption of these social relations through individualized ownership opens up opportunities for exploitation and
marginalization. For example, households without access to exclosures could become marginalized and forced to leave the system during a drought period. Individuals who construct larger exclosures may eventually gain greater power and authority within the community by virtue of his or her land holding. Although this may naturally occur since available land size varies within the community, the exclosures may exacerbate the problem and create new conflicts. As more and more households build exclosures, especially in the bofedales, flexibility, mobility, and opportunism are reduced.

Thus, it is important to recognize the limitations and potential pitfalls of the technical innovations found in any development program. Development projects must take into consideration the impacts of an intervention on the existing social institutions that regulate access to land and labor and promote community cohesion and equity. Some benefits to livestock productivity were observed from Project Alpaca; however, these short-term benefits may be short-lived if the long-term consequences of the project are not as well considered.
CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Pastoralism in Cosapa has been characterized by a continuous tension between maintaining a historically and culturally defined system of production and transforming the structure to meet changing contexts and constraints. The interventions of Project Alpaca provide a unique opportunity to better understand system dynamics in Cosapa by manipulating some of the environmental constraints on livestock production. They also provide an opportunity to evaluate "development from within," in which indigenous Aymara herders are intimately involved in planning, organizing, and implementing the development process, while at the same time promoting Western, technically-oriented, farm-level interventions.

The equilibrium models of rangeland dynamics that have dominated the approach to range-livestock development were found to match the system dynamics observed in Cosapa in some aspects, but not others. In this study, rather than assuming that plant and animal components of a system follow similar dynamics (as has been done in the past), each was evaluated separately. In terms of vegetation dynamics, the development model of Project Alpaca assumed that exclosures would be beneficial to livestock production via improvement of the forage resource. This was essentially an "equilibrium" model in which biotic interactions between livestock and plants were assumed to be strong, and grazing thus expected to negatively impact plant production and composition. What was found instead, however, was a more complex picture of vegetation dynamics in which little to no change in plant production was observed for up to 3 years of protection on bofedales and gramadales. A decline in plant species diversity was also found with grazing protection in the bofedales. Plant community production dynamics could thus be broadly classified as nonequilibrium. Fencing would
therefore not be justified to "improve" plant production, at least within the time frame observed in this study. Greater species diversity with grazing suggests that herbivory is an integral component of the system and vegetation dynamics do not follow standard Clementsian successional models (i.e., equilibrium models). One distinction between vegetation dynamics in Cosapa compared to other semiarid systems (i.e., sub-Saharan Africa) is that plant growth in Cosapa is relatively constant despite variable rainfall, while in other nonequilibrial systems production tends to vary with rainfall. Thus, although vegetation production in Cosapa appears to be highly resistant to grazing, it is also highly tolerant to climatic fluctuations. This may be explained by plant evolutionary adaptations to frost and drought, expressed morphologically in prostrate growth form and spiny leaves.

Regarding livestock dynamics, Project Alpaca assumed that animal populations tracked a stable carrying capacity for the system, and improvements in livestock production could be attained through interventions that reduced stocking densities (i.e., exclosures) or increased carrying capacity (i.e., bofedal expansion). What was found over a 13-year period was a relatively stable livestock population periodically affected by severe drought. Significant, negative correlations between precipitation and livestock mortality could initially be interpreted to suggest that the system was nonequilibrial. The frequency and intensity of drought, however, did not appear high enough to completely eliminate density-dependent interactions. That is, stocking rate, although not statistically significant, may still be an important factor affecting livestock populations. Thus, a combination of both equilibrial and nonequilibrial interactions appears to be influencing livestock dynamics.

In referring to the table from Ellis and Swift (1988) presented in the introduction (Chapter 1, Table 1.1), different system criteria in Cosapa can be identified in terms of
whether they express equilibrial or nonequilibrial characteristics (see Table 8.1). For those criteria that were investigated, namely, abiotic patterns, plant-herbivore interactions, and population patterns, this study found that the system in Cosapa exhibited both equilibrial and nonequilibrial characteristics. These results stress the importance of deeper investigations into system components rather than assuming extremes of system equilibria or nonequilibria. Both equilibrium and non-equilibrium models are theoretical extremes or idealizations, and most real world systems will contain components of both.

In referring back to the proposed classification of pastoral ecosystems in Chapter 1 (Figure 1.1), Cosapa could be placed between Boxes A and B, since there appears to be little density-dependent feedback of heavy grazing on plants, but both density-dependent and density-independent feedback for animals (see Figure 8.1).

Management Recommendations

Management recommendations, based on the ecological characteristics of Cosapa, would thus be based on both equilibrial and nonequilibrial characteristics. Exclosures, as a means of improving plant productivity over a short time period, are not highly effective, and assumptions concerning livestock-induced degradation are questionable. It may be possible that, compared to the distant past, rangelands on the Bolivian altiplano are degraded (Browman 1974, Ellenberg 1979, Posnansky 1982). The findings from this research, however, suggest that the current vegetation in Cosapa is relatively stable, and is not undergoing degradation as a result of overgrazing by llamas, alpacas, and sheep. Furthermore, grazing by livestock may actually play an important role in enhancing plant species diversity in bofedales.

The programs introduced by Project Alpaca that attempted to reduce the impacts of both drought and density-dependent feedbacks on livestock (i.e., alfalfa supplementation,
Table 8.1. Characteristics of equilibrial and nonequilibrial grazing systems found in Cosapa, Bolivia (adapted from Ellis and Swift 1988).

<table>
<thead>
<tr>
<th>Abiotic Patterns</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abiotic conditions constant</td>
<td>✓Plant growing conditions relatively invariant</td>
<td>✓Stochastic/variable conditions</td>
</tr>
<tr>
<td>✓Plant growing conditions relatively invariant</td>
<td></td>
<td>• Variable plant growing conditions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant-Herbivore Interactions</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tight coupling of interactions</td>
<td>✓Feedback control</td>
<td>✓Weak coupling of interactions</td>
</tr>
<tr>
<td>• Feedback control</td>
<td>✓Herbivore control of plant biomass</td>
<td>✓Abiotic control</td>
</tr>
<tr>
<td>✓Herbivore control of plant biomass</td>
<td></td>
<td>✓Plant biomass abiotically controlled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Population Patterns</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓Density dependence</td>
<td>✓Populations track carrying capacity</td>
<td>✓Density independence</td>
</tr>
<tr>
<td>✓Populations track carrying capacity</td>
<td>• Limit cycles</td>
<td>• Carrying capacity too dynamic for close population tracking</td>
</tr>
<tr>
<td>• Limit cycles</td>
<td></td>
<td>• Abiotically driven cycles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Community/Ecosystem Characteristics</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Competitive structuring of communities</td>
<td>✓Limited spatial extent</td>
<td>✓Competition not expressed</td>
</tr>
<tr>
<td>✓Limited spatial extent</td>
<td>• Self-controlled systems</td>
<td>• Spatially extensive</td>
</tr>
<tr>
<td>• Self-controlled systems</td>
<td></td>
<td>• Externalities critical to system dynamics</td>
</tr>
</tbody>
</table>

✓ = characteristics that apply to Cosapa, Bolivia.

Veterinary services, and exclosures) may indeed be effective in improving animal productivity, given both the density-dependent and density-independent nature of livestock dynamics. The problem is that other important components of development, apart from maximizing production, need to be considered. These relate to the sociocultural components of pastoralism in Cosapa that allow for flexibility and opportunistic management in the face of exogenous perturbations. Often in development planning the social institutions that regulate use and access to resources are overlooked and are inadvertently destroyed through introduction of technical interventions. For example, the privatization of communal rangelands, particularly in the bofedales, may be useful for improving livestock production for individual households with
access to exclosures, but may be disastrous for the community as a whole in terms of equity, social stratification, and buffers for poorer households. Such restrictions in land use may allow certain households to incur greater benefits from the land and reduce labor needs, while those who are excluded may face increased vulnerability and marginalization.

Thus, not only is knowledge of the environmental context important in devising development programs, but knowledge of the social relations that maintain pastoralism as a way of life is also. By referring back to Table 8.1 by Ellis and Swift (1988), it is possible to create an additional category that characterizes the socioeconomic component of pastoral ecosystems. For example, nonequilibrial systems may be characterized by strong social and economic networks that buffer the impacts of system variability. Strategies that involve risk reduction, opportunism, and flexibility are critical components in nonequilibrial systems. In equilibrial systems, on the other hand, the social component may be characterized more by intensification practices and privatized resources. Table 8.2 provides an example of an additional socioeconomic component to Ellis and Swift’s (1988) table. Once again, it is important to realize these socioeconomic components are theoretical extremes, and real systems will generally reflect a combination of both equilibrial and nonequilibrial characteristics.
Table 8.2. An additional (socioeconomic) category that could be added to Ellis and Swift's (1988) table (Table 8.1).

<table>
<thead>
<tr>
<th>Socioeconomic Component</th>
<th>Equilibrium</th>
<th>Nonequilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Strong social and economic networks not critical</td>
<td>• Strong social and economic networks critical</td>
</tr>
<tr>
<td></td>
<td>• Privatized resources</td>
<td>• Common-property resources</td>
</tr>
<tr>
<td></td>
<td>• Sedentary herds</td>
<td>• Mobile herds</td>
</tr>
<tr>
<td></td>
<td>• Intensification</td>
<td>• Extensification</td>
</tr>
</tbody>
</table>

Project Alpaca officially ended in July 1996. Transfer of the factory, vehicles, and other materials was made to AIGACAA. The real test of project success is now underway, both in terms of the sustainability of COPROCA and the pastoral livelihood of its members.

The grassroots origins of AIGACAA and its current integration into the international alpaca wool industry provide an interesting view on development models. Inherent in AIGACAA's structure is the contradiction between Western, technically oriented, top-down approaches and indigenous empowerment and cultural preservation. With Project Alpaca, development efforts shifted in scale to include the political economy of international market forces. The need for stronger connections between AIGACAA's larger goals at political and economic leverage, and meeting the immediate needs of the local herders, is crucial.

Recommendations, based on the results of this research, include shifting development efforts away from intensification interventions that limit movement and flexibility, and instead promoting long-term, community well-being, and social equity.

One way to achieve this is to place greater emphasis on the marketing aspects of alpaca wool production. The greatest constraint to maintaining a steady supply of fiber for COPROCA does not appear to be from low production at the farm-level, but in the ability of AIGACAA to purchase wool at competitive prices. Producers will sell to buyers for the
highest price—whether it be AIGACAA, intermediaries, or Peruvian wool processors. Thus, rather than intensifying production at the farm level (which may disrupt traditional social relations), AIGACAA should concentrate its efforts at maintaining a comparative advantage on purchases of alpaca fiber. This includes accumulating a sufficient capital reserve to withstand fluctuations in the international demand for alpaca wool.

**Suggestions for Future Research**

This dissertation establishes a baseline of information about system dynamics in one Andean community and the development efforts of camelid herders. Many new questions, however, have emerged as a result of this research. Suggestions for future areas of investigation include:

1. Revisiting exclosures to determine longer-term impacts of grazing protection on plant community dynamics;
2. Investigating the consequences of exclosures on land tenure relations, social stratification, and marginalization of households;
3. Tracking households who have left the community to understand the "push" and "pull" factors that lead to emigration, and to determine whether emigrants maintain links with the community, face greater vulnerability, or are better-off having left;
4. Investigating the social, economic, and environmental impacts of the new highway in Cosapa;
5. Comparing camelid pastoral system dynamics on the Chilean side of the altiplano (where more Westernized ranching exists) to that of Bolivia to determine if system dynamics are the same and how constraints may differ;
(6) Evaluating the marketing constraints of AIGACAA in terms of the alpaca wool industry; and

(7) Studying income diversification among households in Cosapa, and the marketing potential of handicrafts made from camelid wool.
LITERATURE CITED


McCorkle, C. M. (ed.). 1990. Improving Andean sheep and alpaca production: Recommendations from a decade of research in Peru. SR-CRSP. Univ. of Missouri, Columbia, Mo.


Appendix A

Tables
Table A.1. Nomenclature (Aymara and scientific), location, and life form of plant species found in Cosapa, Bolivia. (Field collection identified by Ing. Emilia García, Instituto de Ecología, UMSA, La Paz, Bolivia).

<table>
<thead>
<tr>
<th>Aymara Name</th>
<th>Scientific Name</th>
<th>Family</th>
<th>Location</th>
<th>Life Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranthus sp.</td>
<td>Amaranthus sp.</td>
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<td>F</td>
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<tr>
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<tr>
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<td>Azorella diapensioides A. Gray</td>
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<td>S</td>
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<td>Scientific Name</td>
<td>Family</td>
<td>Location</td>
<td>Life Form</td>
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<td>SE</td>
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<td>G</td>
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<td>G</td>
</tr>
<tr>
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<td>Festuca orthophylla</td>
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<td>P</td>
<td>G</td>
</tr>
<tr>
<td></td>
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<td>F</td>
<td>G</td>
</tr>
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<td>Scientific Name</td>
<td>Family</td>
<td>Location 1</td>
<td>Life Form 2</td>
</tr>
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<td>-----------------------------------------</td>
<td>-----------------------------------------------------------</td>
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<td>------------</td>
<td>-------------</td>
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<td>G</td>
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<td>G</td>
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<tr>
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<td>T</td>
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<tr>
<td>Kaylla</td>
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<td>T, M</td>
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<td><em>Junelce minima</em></td>
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<tr>
<td></td>
<td><em>Woodsia monteviendis</em> (Sprengel) Hieron.</td>
<td>Woodsiaceae</td>
<td>M</td>
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</table>

1F=foothills/uplands, M=mountains, P=pajonal, B=bofedal, T=t'olar, G=gramadal, and S= saline areas.
2F=forb, CS=cushion shrub, S=shrub, SE=sedge, G=graminoid, T=tree, R=rush.
Table A.2. Determination of stocking densities outside of each exclosure site.

<table>
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<tr>
<th>CODE</th>
<th>Area (ha)</th>
<th>Sheep</th>
<th>Llama</th>
<th>AUE5</th>
<th>Alpaca</th>
<th>AUE</th>
<th>Total AUE</th>
<th>SD (AUE/ha)</th>
<th>SD (Seasonal)</th>
<th>SR (AUM/ha)</th>
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<tr>
<td>2</td>
<td>350</td>
<td>1000</td>
<td>400 (+250 Feb-Ju)</td>
<td>800 (+500 Feb-Ju)</td>
<td>300</td>
<td>450</td>
<td>2,250 (+500 Feb-Ju)</td>
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</tr>
<tr>
<td>3</td>
<td>100</td>
<td>400</td>
<td>200 (+200 Oct-Jar)</td>
<td>400 (+400 Oct-Jar)</td>
<td>100</td>
<td>150</td>
<td>950 (+400 Oct-Jar)</td>
<td>9.5</td>
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<td>600</td>
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<td>120</td>
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<td>170</td>
<td>340</td>
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<td>195</td>
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<tr>
<td>9</td>
<td>200</td>
<td>250</td>
<td>200 (+200 July)</td>
<td>400 (+400 July)</td>
<td>250</td>
<td>375</td>
<td>1,025 (+400 July)</td>
<td>5.1</td>
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<td>300</td>
<td>700</td>
<td>1,400</td>
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<td>750</td>
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<td>98</td>
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<td>750</td>
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<td>20.5</td>
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<td>500</td>
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<td>28</td>
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<td>250</td>
<td>200 (+200 July)</td>
<td>400 (+400 July)</td>
<td>250</td>
<td>375</td>
<td>1,025 (+400 July)</td>
<td>5.1</td>
<td>7.1</td>
<td>63.50</td>
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<td>800</td>
<td>500</td>
<td>750</td>
<td>1,750</td>
<td>17.5</td>
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<td>210</td>
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1 Code numbers from interviewed households with exclosures
2 Area of land estimated from sketch on topographic map.
3 Total number of animals (pooled across households) stocked in the area (based on survey data).
4 Total number of animals stocked in the area, with seasonal changes noted.
5 AUE (Criollo sheep—Animal Unit Equivalents) calculated as criollo sheep unit equivalents from Tichit (1994).
6 Stocking Density
7 Seasonal Stocking Density
8 AUM (Criollo Sheep—Animal Unit Month) calculated by multiplying the stocking density by 12, or by adding seasonal stocking density for number of months indicated.

<table>
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<th>Year</th>
<th>Paddock</th>
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<th>LLAMAS</th>
<th>SHEEP</th>
<th>AUE</th>
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<td></td>
<td>Males</td>
<td>Females</td>
<td>Juveniles</td>
<td>Crias</td>
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<td>17</td>
<td>60</td>
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<tr>
<td>93</td>
<td>17</td>
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<tr>
<td>94</td>
<td>Upper</td>
<td>8.5</td>
<td>15</td>
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<tr>
<td>95</td>
<td>Lower</td>
<td>8.5</td>
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<tr>
<td>96</td>
<td>Upper</td>
<td>8.5</td>
<td>26</td>
<td>62</td>
<td>16</td>
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<tr>
<td>96</td>
<td>Lower</td>
<td>8.5</td>
<td>2</td>
<td>62</td>
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Outside Estimate:

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<th>Crias</th>
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<th>Females</th>
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<td>87</td>
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<td>22</td>
<td>60</td>
<td>90</td>
<td>200</td>
<td>400</td>
<td>100</td>
<td>590</td>
<td>27</td>
<td>134</td>
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</table>

1 In 1994 the exclosure was divided into two paddocks, upper and lower.
The "upper" is located on the northern half and contains mostly "Pajonal" (Festuca orthophylla) and "Porkhe" (Calamagrostis curvula).
The "lower" is located on the southern half and contains "bofedal", "gramadal" (Distichlis humilis) and "Porkhe".
2 AUE (Criollo sheep-Animal Unit Equivalent) calculated as criollo sheep unit equivalent from Tichit (1994).
3 AUM (Criollo Sheep-Animal Unit Month) calculated by multiplying stocking density by 12, except for 1994-6, where values were multiplied by 9 due to supplemental feed given for...
Table A.4. Results of the 2 x 4 factorial, split-plot, mixed model obtained from SAS-Proc Mixed using soil pH as a covariate and end-of-season standing crop (SC) as the response variable. Grazing treatment (EX/C, EX, C, and GR) and vegetation type were the factors.

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<td>5.17</td>
<td>0.0050</td>
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<tr>
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<td>4.96</td>
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CONTRAST Statement Results

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<tr>
<td>Residual</td>
<td>9377.5</td>
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\(^1\)Numerator degrees of freedom.
\(^2\)Denominator degrees of freedom.
\(^3\)Vegetation community (bofedal and gramadal).
\(^4\)Treatment (EX/C, EX, C, GR).
\(^5\)Experimental unit (exclosure site).
Table A.5. Results of the 2 x 4 factorial split-plot ANOVA obtained from SAS-Proc Mixed with aboveground net primary production (ANPP) as the response variable. Grazing treatment (EX/C, EX, C, and GR) and vegetation type (bofedal and gramadal) were the factors.

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<td>TRMT⁴</td>
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<td>36</td>
<td>0.73</td>
<td>0.5407</td>
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<tr>
<td>VEGTYPE x TRMT</td>
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<td>36</td>
<td>0.60</td>
<td>0.6182</td>
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CONTRAST Statement Results

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<tr>
<td>EX/C vs. EX</td>
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<td>0.46</td>
<td>0.5034</td>
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<tr>
<td>CAGE vs. EX/C and EX</td>
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<td>36</td>
<td>0.93</td>
<td>0.3420</td>
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<td>HH x VEGTYPE</td>
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<td>Residual</td>
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</table>

¹Numerator degrees of freedom.
²Denominator degrees of freedom.
³Vegetation community (bofedal and gramadal).
⁴Treatment (EX/C, EX, C, GR).
⁵Experimental unit (exclosure site).
Table A.6. Results of the 2 x 4 factorial split-plot ANOVA obtained from SAS-Proc Mixed with end-of-season standing crop (SC) as the response variable. Grazing treatment (EX/C, EX, C, and GR) and vegetation type (bofedal and gramadal) were the factors.

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<tr>
<td>VEGTYPE x TRMT</td>
<td>3</td>
<td>36</td>
<td>0.60</td>
<td>0.5387</td>
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</tbody>
</table>

CONTRAST Statement Results

| GR vs. all others     | 1          | 36         | 1.73  | 0.1962|
| EX/C vs. EX          | 1          | 36         | 0.46  | 0.5563|
| CAGE vs. EX/C and EX | 1          | 36         | 0.93  | 0.7371|

<table>
<thead>
<tr>
<th>Covariance Parameter</th>
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<tr>
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<td>HH x VEGTYPE</td>
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<tr>
<td>Residual</td>
<td>12,350.8</td>
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\(^1\)Numerator degrees of freedom.  
\(^2\)Denominator degrees of freedom.  
\(^3\)Vegetation community (bofedal and gramadal).  
\(^4\)Treatment (EX/C, EX, C, GR).  
\(^5\)Experimental unit (exclosure site).
Table A.7. Results of the 1-way analysis of covariance obtained from SAS-Proc Mixed with number of months of bofedal irrigation as the covariate and ANPP as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

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<td>ndf(^1)</td>
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<td>TRMT(^3)</td>
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<tr>
<td>IRRIGATION</td>
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CONTRAST Statement Results

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<td>CAGE vs. EX/C and EX</td>
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<td>27</td>
<td>1.38</td>
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<thead>
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<td>Residual</td>
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\(^1\)Numerator degrees of freedom.
\(^2\)Denominator degrees of freedom.
\(^3\)Treatment (EX/C, EX, C, GR).
\(^4\)Experimental unit (exclosure site).
Table A.8. Results of the 1-way analysis of covariance obtained from SAS-Proc Mixed with number of months of bofedal irrigation as the covariate and SC as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

<table>
<thead>
<tr>
<th>Source</th>
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<td>TRMT(^3)</td>
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CONTRAST Statement Results

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<tbody>
<tr>
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<td>Residual</td>
<td>0.013</td>
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\(^1\)Numerator degrees of freedom.
\(^2\)Denominator degrees of freedom.
\(^3\)Treatment (EX/C, EX, C, GR).
\(^4\)Experimental unit (exclosure site).
Table A.9. Results of the randomized block ANOVA obtained from SAS-Proc Mixed with species diversity (Shannon-Weiner Index) as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

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CONTRAST Statement Results

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<td>Residual</td>
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\(^1\) Numerator degrees of freedom.
\(^2\) Denominator degrees of freedom.
\(^3\) Treatment (EX/C, EX, C, GR).
\(^4\) Experimental unit (exclosure site).
Table A.10. Results of the randomized block ANOVA obtained from SAS-Proc Mixed with Hill’s Diversity Number (N0) as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

<table>
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CONTRAST Statement Results

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\(^1\)Numerator degrees of freedom.
\(^2\)Denominator degrees of freedom.
\(^3\)Treatment (EX/C, EX, C, GR).
\(^4\)Experimental unit (exclosure site).
Table A.11. Results of the randomized block ANOVA obtained from SAS-Proc Mixed with Hill's First Diversity Number (N1) as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

<table>
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CONTRAST Statement Results

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<tr>
<td>EX/C vs. EX</td>
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<td>0.9320</td>
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<tr>
<td>CAGE vs. EX/C and EX</td>
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<td>16.36</td>
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\(^1\)Numerator degrees of freedom.
\(^2\)Denominator degrees of freedom.
\(^3\)Treatment (EX/C, EX, C, GR).
\(^4\)Experimental unit (exclosure site).
Table A.12. Results of the randomized block ANOVA obtained from SAS-Proc Mixed with Hill's Second Diversity Number (N2) as the response variable. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

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<td>HOUSEHOLD⁴ (HH)</td>
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¹Numerator degrees of freedom.
²Denominator degrees of freedom.
³Treatment (EX/C, EX, C, GR).
⁴Experimental unit (exclosure site).
Table A.13. Results of the randomized block ANOVA obtained from SAS-Proc Mixed with species evenness (E5) as the response variable. E5 is the modified Hill’s ratio of species evenness. Grazing treatment (EX/C, EX, C, and GR) was the main factor. Analysis was restricted to only the bofedal vegetation type.

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<th>P</th>
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CONTRAST Statement Results

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<th>P</th>
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</thead>
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<td>0.02</td>
<td>0.8863</td>
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<tr>
<td>EX/C vs. EX</td>
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<td>1.21</td>
<td>0.2802</td>
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<tr>
<td>CAGE vs. EX/C and EX</td>
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<td>27</td>
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<td>0.9357</td>
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<thead>
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<th>Covariance Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOUSEHOLD⁴ (HH)</td>
<td>0.000</td>
</tr>
<tr>
<td>Residual</td>
<td>0.013</td>
</tr>
</tbody>
</table>

¹Numerator degrees of freedom.
²Denominator degrees of freedom.
³Treatment (EX/C, EX, C, GR).
⁴Experimental unit (exclosure site).
Table A.14. Results of the 3 x 3 x 13 factorial, repeated measures, split-split plot analysis comparing livestock species by zone by year, with mean animal numbers per household as the response variable.

<table>
<thead>
<tr>
<th>Source</th>
<th>Test of Fixed Effects</th>
<th>Covariance Parameter Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ndf</td>
<td>ddf</td>
</tr>
<tr>
<td>Zone</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Species</td>
<td>2</td>
<td>37</td>
</tr>
<tr>
<td>Zone x Species</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>Year</td>
<td>12</td>
<td>249</td>
</tr>
<tr>
<td>Zone x Year</td>
<td>24</td>
<td>249</td>
</tr>
<tr>
<td>Species x Year</td>
<td>24</td>
<td>416</td>
</tr>
<tr>
<td>Zone x Species x Year</td>
<td>48</td>
<td>416</td>
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</table>

- Test of Fixed Effects
- Covariance Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household (Zone)</td>
<td>795.08</td>
</tr>
<tr>
<td>Household x Species (Zone)</td>
<td>581.38</td>
</tr>
<tr>
<td>Household x Year (Zone)</td>
<td>44.20</td>
</tr>
<tr>
<td>Residual</td>
<td>317.59</td>
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</table>
Table A.15. Results of the 3 x 3 x 13 factorial, repeated measures, split-split plot analysis comparing livestock species by zone by year, with percent livestock mortality per household as the response variable.

<table>
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<th>P</th>
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</thead>
<tbody>
<tr>
<td>Zone</td>
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<td>0.4651</td>
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<tr>
<td>Species</td>
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<td>15.11</td>
<td>0.0001</td>
</tr>
<tr>
<td>Zone x Species</td>
<td>4</td>
<td>37</td>
<td>0.16</td>
<td>0.9563</td>
</tr>
<tr>
<td>Year</td>
<td>12</td>
<td>249</td>
<td>28.45</td>
<td>0.0001</td>
</tr>
<tr>
<td>Zone x Year</td>
<td>24</td>
<td>249</td>
<td>0.99</td>
<td>0.4763</td>
</tr>
<tr>
<td>Species x Year</td>
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<td>416</td>
<td>3.23</td>
<td>0.0001</td>
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<tr>
<td>Zone x Species x Year</td>
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<td>416</td>
<td>0.77</td>
<td>0.8684</td>
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Covariance Parameter Estimates

<table>
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</thead>
<tbody>
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<td>Household (Zone)</td>
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<tr>
<td>Household x Species (Zone)</td>
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<tr>
<td>Household x Year (Zone)</td>
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<tr>
<td>Residual</td>
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</table>
Table A.16. Results of the mixed model regression analysis comparing the effects of precipitation and stocking density on livestock mortality among zones for each species of livestock.

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<th>t</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.530</td>
<td>0.601</td>
<td>1</td>
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<tr>
<td>SD</td>
<td>1.643</td>
<td>1.763</td>
<td>1</td>
<td>22</td>
<td>0.93</td>
<td>0.3616</td>
</tr>
<tr>
<td>log PPT</td>
<td>-2.693</td>
<td>0.495</td>
<td>1</td>
<td>22</td>
<td>-5.44</td>
<td>0.0001</td>
</tr>
<tr>
<td>log PPT*SD</td>
<td>0.845</td>
<td>1.130</td>
<td>1</td>
<td>22</td>
<td>0.75</td>
<td>0.4618</td>
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Covariance Parameter Estimates

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</thead>
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<tr>
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<td>0.068</td>
</tr>
<tr>
<td>Residual</td>
<td>1.660</td>
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</table>

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<tbody>
<tr>
<td>Intercept</td>
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<td>0.480</td>
<td>1</td>
<td>2</td>
<td>0.47</td>
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<tr>
<td>SD</td>
<td>1.888</td>
<td>1.234</td>
<td>1</td>
<td>22</td>
<td>1.53</td>
<td>0.1403</td>
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<tr>
<td>log PPT</td>
<td>-1.538</td>
<td>0.695</td>
<td>1</td>
<td>22</td>
<td>-2.21</td>
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<tr>
<td>log PPT*SD</td>
<td>0.891</td>
<td>1.505</td>
<td>1</td>
<td>22</td>
<td>0.59</td>
<td>0.5596</td>
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Covariance Parameter Estimates

<table>
<thead>
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<tr>
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<td>Residual</td>
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### Table A.16. Continued.

#### Sheep

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<td>22</td>
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<td>0.0001</td>
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#### Tests of Fixed Effects

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<tbody>
<tr>
<td>Zone</td>
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<tr>
<td>log PPT*Year</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Residual</td>
<td>2.406</td>
<td></td>
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Table A.17. Results of the mixed model regression analysis (with data from 1982-3 removed) comparing of the effects of precipitation and stocking density on livestock mortality among zones for each species of livestock.

<table>
<thead>
<tr>
<th>Source</th>
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<th>ddf</th>
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<th>P</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2</td>
<td>-1.23</td>
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</tr>
<tr>
<td>SD</td>
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<td>2.348</td>
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<td>20</td>
<td>0.63</td>
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</tr>
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<td>1</td>
<td>20</td>
<td>-3.24</td>
<td>0.0041</td>
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<tr>
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<td>1.942</td>
<td>1</td>
<td>20</td>
<td>0.68</td>
<td>0.5016</td>
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Covariance Parameter Estimates

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<tr>
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<th>Estimate</th>
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<tr>
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<td>log PPT*Year</td>
<td>0.073</td>
</tr>
<tr>
<td>Residual</td>
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</table>

<table>
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<th>ddf</th>
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<th>P</th>
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<td>20</td>
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<td>0.7712</td>
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<td>20</td>
<td>0.06</td>
<td>0.9565</td>
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Covariance Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
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<tr>
<td>log PPT*Year</td>
<td>0.124</td>
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<tr>
<td>Residual</td>
<td>3.264</td>
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Table A.17. Continued.

<table>
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<tr>
<th>Source</th>
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<th>ndf</th>
<th>ddf</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.230</td>
<td>0.579</td>
<td>1</td>
<td>2</td>
<td>-3.85</td>
<td>0.0613</td>
</tr>
<tr>
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<td>1</td>
<td>20</td>
<td>-0.68</td>
<td>0.5029</td>
</tr>
<tr>
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<td>0.650</td>
<td>1</td>
<td>20</td>
<td>-2.58</td>
<td>0.0180</td>
</tr>
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<td>2.171</td>
<td>1</td>
<td>20</td>
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Sheep Tests of Fixed Effects

<table>
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</thead>
<tbody>
<tr>
<td>Zone</td>
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<tr>
<td>Residual</td>
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</table>
Table A.18 (a-p). Correlation matrices derived from logistic regression analyses comparing development interventions to livestock productivity. Correlation matrices are based on full models in which all 5 explanatory variables are included, regardless of statistical significance.

(a) Alpaca Natality (1996)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intercept</th>
<th>Veterinary</th>
<th>Dosification</th>
<th>Alfalfa</th>
<th>Vitamin</th>
<th>Exclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>-0.28</td>
<td>-0.76</td>
<td>0.27</td>
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</tr>
<tr>
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<td>-0.70</td>
<td>1.00</td>
<td>-0.04</td>
<td>-0.00</td>
</tr>
<tr>
<td>Dosification</td>
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<td>-0.70</td>
<td>1.00</td>
<td></td>
<td></td>
<td>-0.14</td>
</tr>
<tr>
<td>Alfalfa</td>
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<td>-0.06</td>
<td>0.22</td>
<td>1.00</td>
<td></td>
<td>-0.04</td>
</tr>
<tr>
<td>Vitamin</td>
<td>0.27</td>
<td>-0.04</td>
<td>-0.22</td>
<td>-0.32</td>
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<td>-0.10</td>
</tr>
<tr>
<td>Exclosure</td>
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<td>-0.00</td>
<td>-0.14</td>
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(b) Alpaca Natality (1995)

<table>
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<th>Dosification</th>
<th>Alfalfa</th>
<th>Vitamin</th>
<th>Exclosure</th>
</tr>
</thead>
<tbody>
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<td>-0.74</td>
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<td>-0.70</td>
<td>1.00</td>
<td>-0.17</td>
<td>-0.06</td>
</tr>
<tr>
<td>Dosification</td>
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<td>-0.70</td>
<td>1.00</td>
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<td>-0.10</td>
</tr>
<tr>
<td>Alfalfa</td>
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<td>-0.10</td>
<td>0.24</td>
<td>1.00</td>
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<td>-0.05</td>
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<tr>
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<td>-0.05</td>
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### Table A.18. Continued.

#### (c) Alpaca Cria Mortality

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<th>Dosification&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Alfalfa&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Vitamin&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Exclosure&lt;sup&gt;5&lt;/sup&gt;</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veterinary</td>
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<td>1.00</td>
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<td></td>
<td></td>
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<td>-0.69</td>
<td>1.00</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>-0.18</td>
<td>-0.26</td>
<td>1.00</td>
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</tr>
<tr>
<td>Exclosure</td>
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<td>-0.06</td>
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#### (d) Alpaca Abortion

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<th>Dosification&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Alfalfa&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Vitamin&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Exclosure&lt;sup&gt;5&lt;/sup&gt;</th>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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#### (e) Alpaca Adult Mortality

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#### (h) Llama Natality (1995)

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(j) Llama Abortion

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(k) Llama Adult Mortality

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(o) Sheep (Adult) Mortality

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(p) Sheep Morbidity

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1Veterinary services.
2Treatment for internal parasites.
3Alfalfa supplementation.
4Vitamin supplementation.
5Exclosure use.
Appendix B

Survey Forms
Survey form used to determine management practices and productivity of livestock in Cosapa, Bolivia (Original spanish version).

CODIGO: __________

ENTREVISTA

Estoy interesada aprender un poco más sobre el manejo y producción de ganado en la zona de Cosapa. Lo que quisiera hacer con este encuesta es identificar los factores más importantes que limitan la producción de ganado. También, con este estudio quisiera evaluar el "Proyecto Alpaca" de AIGACAA, para ver cuáles son los partes del programa más importantes en el mejoramiento de la producción de alpaca. Esta información servirá a AIGACAA para que pueda mejorar el programa del campo.

Entonces, en esta encuesta le(s) quisiera hacer algunas preguntas sobre el manejo de su ganado y tierra, la productividad de sus animales, y la disponibilidad de mano de obra.

Antes de empezar, quisiera decir que todas estas informaciones son confidenciales, entonces nadie aparte de mí nunca va a saber los nombres de las personas que están participando en esta encuesta. Cada formulario tiene un número para identificación y no va a tener su nombre. Es muy importante que todas las respuestas sean dadas con la mayor exactitud posible. Si algunas preguntas no son muy claras o si tiene(n) preguntas en cualquier momento durante la entrevista, pregúntenme, no más.

Bueno, empezamos.
Cuestionario

Fecha:__________________________  CODIGO:__________________

I. Primero, quisiera obtener algunos datos demográficos sobre la familia.

100. En qué estancia viven Uds?:______________________________

101. Cuántos hijos y hijas tienen Uds. que viven en su hogar?___________

102. Que edad tienen estos hijos y hijas:

______________________________

103. Cuántos hijos y hijas tienen Uds. que viven fuera de su hogar?______

104. Cuántas otras personas aparte de Uds. y tus hijos viven en su hogar?______

[AL JEFE MASCULINO]

105. Hasta qué grado de educación ha cumplido Ud.?_________

[A LA JEFE FEMENINO]

106. Hasta qué grado de educación ha cumplido Ud.?_________

II. Ahora, quisiera saber un poco del calendario de producción y los estrategias del manejo que tengan.

Primero, quisiera preguntarles sobre el EMPADRE de tus LLAMAS.

200. Uds. practican empadre:
   a) amarado (las hembras están amaradas y varios machos pisan)
   b) janachu (1 reproductor dentro de la tropa de hembras)
   c) alternado (tienen diferentes grupos de machos reproductores que meten a la tropa de hembras en diferentes periodos)
   d) libre (cualquier macho pisa las hembras)
   e) otro

201. *Si practican empadre amarado, de dónde obtienen los machos?
   a) Su propia tropa de machos
   b) Prestado del vecino
   c) AIGACAA o CORDEOR
   d) Otro: ___________________________
Ahora, quisiera preguntarles sobre el EMPADRE de tus ALPACAS.

202. Uds. practican empadre:
   a) amarado (las hembras estan amaradas y varios machos pisan)
   b) janachu (1 reproductor dentro de la tropa de hembras)
   c) alternado (tienen diferentes grupos de machos reproductores que meten a la tropa de hembras en diferentes periodos)
   d) libre (cualquier macho pisa las hembras)
   e) otro

203. *Si practican empadre amarado, de donde obtienen los machos?
   a) Su propia tropa de machos
   b) Prestado del vecino
   c) AIGACAA o CORDEOR
   d) Otro: ____________________

Ahora, quisiera preguntarles sobre el EMPADRE de tus OVEJAS.

204. Uds. practican empadre:
   a) amarado (las hembras estan amaradas y varios machos pisan)
   b) janachu (1 reproductor dentro de la tropa de hembras)
   c) alternado (tienen diferentes grupos de machos reproductores que meten a la tropa de hembras en diferentes periodos)
   d) libre (cualquier macho pisa las hembras)
   e) otro

205. *Si practican empadre amarado, de donde obtienen los machos?
   a) Su propia tropa de machos
   b) Prestado del vecino
   c) AIGACAA o CORDEOR
   d) Otro: ____________________

Ahora, voy a preguntarles sobre la DESTETE de tus LLAMAS.

206. Las crias de tus llamas estan destetadas:
   a) naturalmente
   b) forzado

207. *Si esta forzado, hacen destetar las crias despues de cuantos meses de edad: ____________

208. *Si hacen destete forzado, Uds. dan suplementacion a las crias despues de destetar? (S/N) ______
209. *Que tipos de suplemenaciones dan Uds. a las crias destetadas?

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</table>

Ahora, voy a preguntarles sobre la DESTETE de tus ALPACAS.

210. Las crias de tus alpacas estan destetadas:
   a) naturalmente
   b) forzado

211. *Si esta forzado, hacen destetar las crias despues de cuantos meses de edad: ____________

212. *Si hacen destete forzado, Uds. dan suplementacion a las crias despues de destetar? (S/N)_____

213. *Que tipos de suplemenaciones dan Uds. a las crias destetadas?

<table>
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<th>Tipo</th>
<th>Cantidad/día</th>
<th>Cuanto tiempo</th>
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<td>213.3a</td>
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<td>213.3c</td>
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</tbody>
</table>

Ahora, voy a preguntarles sobre la DESTETE de tus OVEJAS.

214. Las crias de tus ovejas estan destetadas:
   a) naturalmente
   b) forzado

215. *Si esta forzado, hacen destetar las crias despues de cuantos meses de edad: ____________

216. *Si hacen destete forzado, Uds. dan suplementacion a las crias despues de destetar? (S/N)_____

217. *Que tipos de suplemenaciones dan Uds. a las crias destetadas?

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<td>217.3a</td>
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Ahora, quisiera preguntarles sobre el uso de los SERVICIOS DEL VETERINARIO

218. Cuantas veces por año Uds. usan los servicios del veterinario para curar tus animales enfermos?
   a) Nunca
   b) 1-5
   c) 5-10
   d) 10-20
   e) > 20

219. *Desde que año han utilizado los servicios del vet.?:

220. *Antes, como han curado los animales enfermos?
   a) con medicinas caseras/naturales
   b) con medicinas compradas que hemos puesto al animal
   c) otro:

221. **Si no utilizan los servicios del veterinario, como curan los animales enfermos:
   a) compran medicinas y les dan Uds.
   b) usan medicinas caseras/naturales
   c) otro:

BANOS ANTISARNICOS
222. Los usan Uds. baños antisarnicas (S/N):

223. Desde cuantos años atrás:

224. Con cual especies de ganado?
   a) todos
   b) otro:

225. Con que frecuencia:
   a) cada año
   b) otro:

DOSIFICACION
226. Uds. dosifican tus animales contra parasitos internos? (S/N)

227. En que año empezaron dosificar tus animales:

228. A cual tipo de ganado dosifican: (MARCA TODOS QUE APLICAN)
   a) llamas
   b) alpacas
   c) ovejas
   d) perros
   e) otro
229. En qué mes(es) dosifican tus animales? __________

CASTRACION

230. Cuántos de tus llamas machos están castrados?: __________

231. Cuántos de tus alpacas machos están castrados?: __________

232. Cuántos de tus ovejas machos están castrados?: __________

233. Uds. dan SUPLEMENTACION a tus LLAMAS? (S/N) ______

234. Normalmente Uds. dan suplementos a:
   a) las llamas crias
   b) las llama madres
   c) las llamas flacas

235. *Qué tipos de suplementaciones dan Uds. a tus llamas?
   Tipo   Cantidad/día   Que meses
   235.1a             235.1b             235.1c
   235.2a             235.2b             235.2c
   235.3a             235.3b             235.3c

236. Dan Uds. suplementos:
   a) cada año
   b) solamente los años de sequía

237. Desde qué año empezaron Uds. dar suplementos a tus llamas: __________

238. Uds. dan SUPLEMENTACION a tus ALPACAS? (S/N) ______

239. Normalmente Uds. dan suplementos a:
   a) las alpacas crias
   b) las alpacas madres
   c) las alpacas flacas

240. *Qué tipos de suplementaciones dan Uds. a tus alpacas?
   Tipo   Cantidad/día   Que meses
   240.1a             240.1b             240.1c
   240.2a             240.2b             240.2c
   240.3a             240.3b             240.3c

241. Dan Uds. suplementos:
   a) cada año
   b) solamente los años de sequía
242. Desde que año empezaron Uds. dar suplementos a tus alpacas: __________

243. Uds. dan SUPLEMENTACION a tus OVEJAS? (S/N) ______

244. Normalmente Uds. dan suplementos a:
   a) las ovejas crias
   b) las ovejas madres
   c) las ovejas flacas

245. *Que tipos de suplemenaciones dan Uds. a tus ovejas
   Tipo                  Cantidad/día          Que meses
   245.1a                245.1b               245.1c
   245.2a                245.2b               245.2c
   245.3a                245.3b               245.3c

246. Dan Uds. suplementos:
   a) cada año
   b) solamente los años de sequía

247. Desde que año empezaron Uds. dar suplementos a tus ovejas: __________

Ahora, voy a preguntarles sobre el uso de vitaminas.

248. Uds. dan vitaminas a tus llamas? ______

249. En que meses dan vitaminas a tus llamas? ________________________

250. Dan vitaminas a tus llamas:
   a) cada año
   b) solo en los años de sequía

251. Desde que año han empezado dar vitaminas a tus llamas? ______

252. Uds. dan vitaminas a tus alpacas? ______

253. En que meses dan vitaminas a tus alpacas? ________________________

254. Dan vitaminas a tus alpacas:
   a) cada año
   b) solo en los años de sequía

255. Desde que año han empezado dar vitaminas a tus alpacas? ______

256. Uds. dan vitaminas a tus ovejas? ______
257. En qué meses dan vitaminas a tus ovejas?

258. Dan vitaminas a tus ovejas:
   a) cada año
   b) solo en los años de sequía

259. Desde qué año han empezado dar vitaminas a tus ovejas?

Ahora, voy a preguntarles sobre terreno alambreado.

260. Uds. tiene terreno ALAMBREADO? (S/N)

261. Cuántas hectáreas de terreno alambreado tienen?

262. Cuántas hectáreas dentro de tu alambreado están con riego?

263. En meses están regado?

264. Por qué lo han hecho tu cerco?
   a) para que no pasan los animales de los vecinos
   b) para preservar los pastos como reserva
   c) para marcar su propio terreno
   d) para mejorar la condición de los animales sanos
   e) para engordar los animales flacos
   f) para destetar las crias
   g) para que no tienen que pastorear
   e) otro:

265. Que especie de ganado meten a tu alambreado? (MARCA TODOS QUE APLICAN)
   a) llamas
   b) alpacas
   c) ovejas
   d) otro:

266. Normalmente meten: (MARCA TODOS QUE APLICAN)
   a) madres
   b) crias
   c) maltones
   d) machos
   e) otro

267. En qué meses meten los animales?

268. Normalmente, cuántos animales meten?

269. Tienen problemas con los vecinos sobre el derecho del uso de este terreno?
270. Que tipo de problemas? ____________________________

271. Si Uds. tuvieran la oportunidad alambrear todo su terreno, lo harían?____

272. Porque: ____________________________

273. *Si no tienen un cerco, tienen vecinos que tienen? ______

274. Hay problemas con el cerco del vecinos en términos del uso de la tierra?____

275. Que tipo de problemas: ____________________________

276. Si Uds. tuvieran la oportunidad alambrear todo o parte de su terreno, lo harían?____

277. Porque: ____________________________

Ahora, les voy a preguntar sobre la venta de tus animales.

278. En que meses VENDEN tus LLAMAS MACHOS: __________

279. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

280. En que meses VENDEN tus LLAMAS MALTONES: __________

281. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

282. En que meses VENDEN sus LLAMAS HEMBRAS: __________

283. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

284. Porque venden en estos meses [INDICA PARA MACHO, MALTON O HEMBRA]:
   a) buen precio
   b) falta de pastos
   c) estan en el punto de morir
   d) los animales estan gordos
   e) necesidad de plata
   f) otro: ____________________________
285. A quien lo venden tus llamas?
   a) comerciante/intermediario
   b) directo al mercado en la ciudad/feria
   c) mercados locales
   d) otro:__________________________

286. A quien lo venden la lana de tus llamas?
   a) AIGACAA
   b) directo a la ciudad/feria/Perú
   c) al comerciante/intermediario
   d) otro:__________________________

287. En que meses VENDEN sus ALPACAS MACHOS: ______

288. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

289. En que meses VENDEN sus ALPACAS MALTONES: ______

290. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

291. En que meses VENDEN sus ALPACAS HEMBRAS:__________

292. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

293. Porque venden en estos meses [INDICA PARA MACHO, MALTON O HEMBRA]:
   a) buen precio
   b) falta de pastos
   c) estan en el punto de morir
   d) los animales estan gordos
   e) necesidad de plata
   f) otro:__________________________

294. A quien lo venden tus alpacas?
   a) comerciante/intermediario
   b) directo al mercado en la ciudad/feria
   c) mercados locales
   d) otro:__________________________

295. A quien lo venden la lana de tus alpacas?
   a) AIGACAA
   b) directo a la ciudad/feria/Peru
   c) al comerciante/intermediario
   d) otro:__________________________

296. En que meses VENDEN sus OVEJAS MACHOS: ______
297. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

298. En que meses VENDEN sus OVEJAS HEMBRAS: ____________

299. Los venden a) VIVOS (parados) o b) FAENADOS (muertos)

300. Porque venden en estes meses [INDICA PARA MACHO O HEMBRA]:
   a) buen precio
   b) falta de pastos
   c) estan en el punto de morir
   d) los animales estan gordos
   e) necesidad de plata
   f) otro: ___________________________________________________________________

301. A quien lo venden tus ovejas?
   a) comerciante/intermediario
   b) directo al mercado en la ciudad/feria
   c) mercados locales
   d) otro: _________________

302. Venden Uds. la lana de tus ovejas? __________

303. A quien lo venden la lana de tus ovejas?
   a) AIGACAA
   b) directo a la ciudad/feria
   c) al comerciante/intermediario
   d) otro: ___________________________________________________________________

Ahora, voy a preguntarles sobre el RIEGO de tus bofedales.

304. En que meses regan los bofedales: _________________

305. Cuantas hectareas estan regadas: ____________

306. En las ultimas 10 años la cantidad de tu terreno que esta regado a) ha aumentado; b) ha disminuido; c) no ha cambiado

307. *Si hay cambio, cuantos hectares han sido afectados: __________
III. Ahora, quisiera preguntarles sobre la productividad de su ganado.

ALPACAS

400. Cuantas alpaca crias han nacido desde Nov.'95 hasta ahora? 

401. Cuantas alpacas crias han nacido en el afio pasado (Nov. 94 - Abril 95)?

402. De estos animales que nacieron en el afio pasado, cuantas han muerto antes de destete?

403. Cuantas han muerto por:
   a) enfermedad: 
   b) falta de leche: 
   c) falta de pastos: 
   d) zorro o otro animal: 
   e) frio: 
   f) se ha caido en el agua (poso): 
   g) comiendo plantas toxicas: 
   h) otro: 

404. Cuantos abortos han notado entre julio de 1995 y ahora?

405. De tus alpacas hembras, cuantas dan crias:
   a) cada afio: 
   b) cada dos afios: 

406. Cuantas alpacas adultas se han muerto entre julio 95 y ahora?

407. Cuantas han muerto por:
   a) enfermedad: 
   b) falta de pastos: 
   c) zorro o otro animal: 
   d) frio: 
   e) se ha caido en en agua (poso): 
   f) comiendo plantas toxicas: 
   g) otro: 

408. Cuantas alpacas adultas han tenido algun enfermedad entre julio '95 y ahora?

Entre julio '95 y ahora cuantas alpacas les han:

409. vendido 
410. regalado 
411. carneado
Entre julio '95 y ahora, cuantas alpacas les han:
412. comprado: 
413. recibido de préstamo: 
414. recibido de regalo: 

Cuántas de tus alpacas son de los siguientes colores:
415.1. Blanco: 
415.2 Negro: 
415.3 Plomo: 
415.4 Cafe: 
415.5 Api: 
415.6 LF/Vicuna: 
415.7 Manchado (wallata): 

En 1991 (5 años atrás) cuántos alpacas tenía de:
416.1. Blanco: 
416.2 Negro: 
416.3 Plomo: 
416.4 Cafe: 
416.5 Api: 
416.6 LF/Vicuna: 
416.7 Manchado (wallata): 

LLAMAS
417. Cuantas llamas crias han nacido desde Nov. 1995 hasta ahora?
418. Cuantas llamas crias han nacido en el año pasado (Nov. 94 - Abril 95)?
419. De estos animales que nacieron en el año pasado, cuantas han muerto antes de destete?
420. Cuantas se han muerto por:
   a) enfermedad: 
   b) falta de leche: 
   c) falta de pastos: 
   d) zorro o otro animal: 
   e) frío: 
   f) se ha caído en el agua (poso): 
   g) comiendo plantas toxicas: 
   h) otro: 
421. Cuantos abortos han notado entre julio '95 y ahora?
422. De tus llamas hembras, cuantas dan crias:
   a) cada año: 
   b) cada dos años: 
423. Cuantas llamas adultas se han muerto entre julio '95 y ahora?

424. Cuantas se han muerto por:
   a) enfermedad: 
   b) falta de pastos: 
   c) zorro o otro animal: 
   d) frio: 
   e) se ha caido en en agua (poso):  
   f) comiendo plantas toxicas:  
   g) otro: 

425. Cuantas llamas adultas han tenido algun enfermedad entre julio '95 y ahora?

Entre julio '95 y ahora cuantas llamas les han:
   426. vendido 
   427. regalado 
   428. carneado 

Entre julio '95 y ahora, cuantas llamas les han:
   429. comprado:  
   430. recibido de prestamo: 
   431. recibido de regalo: 

OVEJAS

432. Cuantas ovejas crias han nacido en el año pasado (julio - dec '95)?

433. De estos animales que nacieron en el año pasado, cuantas han muerto antes de destete?

434. Cuantas han muerto por:
   a) enfermedad:  
   b) falta de leche:  
   c) falta de pastos:  
   d) zorro o otro animal:  
   e) frio:  
   f) se ha caido en el agua (poso):  
   g) comiendo plantas toxicas:  
   h) otro: 

435. De tus ovejas hembras, cuantas dan crias:
   a) cada año:  
   b) dos veces por año: 

436. Cuantas ovejas adultos han muerto entre jul. '95 y ahora?
437. Cuantas se han muerto por:
   a) enfermedad: ______
   b) falta de pastos: ______
   c) zorro o otro animal: ______
   d) frio: ______
   e) se ha caído en en agua (poso): ______
   f) comiendo plantas toxicas: ______
   g) otro: ______________________

438. Cuantas ovejas adultas han tenido algun enfermedad entre julio '95 y ahora? ____________

Entre julio '95 y ahora cuantas ovejas les han:
   439. vendido _______________
   440. regalado ________________
   441. carneado ________________

Entre julio '95 y ahora, cuantas ovejas les han:
   442. comprado: _______________
   443. recibido de prestamo: _______
   444. recibido de regalo: ________

445. Cuantos otros tipos de ganado tienen Uds.?
   a) chanchos _________________
   b) burros _________________
   c) gallos/gallinas __________
   d) otro: ___________________

IV. Ahora, quisiera saber un poco sobre la historia de la productividad del ganado, según el año.
Esta informacion es para entender cual es la presion de pastoreo en los diferentes lugares, y si esta presion cambia en años de sequia y años con mucha lluvia.

En que año Uds. se han juntado? ______
Cuantas alpacas tenian en este año? ______
Cuantas llamas? _______________________
Cuantas ovejas? _______________________

En que año ha nacido tu primer hijo? ______
Cuantas alpacas tenian en este año? ______
Cuantas llamas? _______________________
Cuantas ovejas? _______________________

(CONTINUE TO FILL OUT LIST)
CUADRO 1. Datos de largo plazo de los rebaños.

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## FECHAS CLAVES EN COSAPA

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V. Ahora, quisiera saber un poco sobre la disponibilidad de los pastos y los lugares donde pastorean sus animales. Tengo aquí un mapa de esta zona.

Me puede dibujar donde pastorean las ALPACAS HEMBREAS en la EPOCA SECA. (DIBUJA EL AREA, INDICA CON LA LETRA "A"). Si hay mas que un rebaño, me puede indicar donde pastorean todo los rebaños.

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**QUE MESES**

Ha. Bofedal
Ha. Pajonal
Ha. T"olar
Ha. Mountain

**# ANIMALES**

Comparte?

**# Personas**

Total Alpaca
Total Llama
Total Sheep

**Rotacion***

Que tipos de pastos en cada lugar

# Dias cambian rotacion

Otro lugar si hay sequia?

Pastor(a)

Cada # dias?

---

*Si hay sistema de rotacion, dibuja todos los lugares donde pastorean los animales. 1 = epoca seca, 2 = epoca humeda, 3 = maliones (1 año de edad).
Me puede dibujar donde pastorean las LLAMAS HEMBRAS en la EPOCA SECA. (DIBUYA EL AREA, INDICA CON LA LETRA "G"). Si hay mas que un rebaño, me puede indicar donde pastorean todo los rebaños.

<table>
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<tr>
<th>LUGAR</th>
<th>&quot;G&quot;</th>
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*Si hay sistema de rotacion, dibuja todos los lugares donde pastorean los animales. 1 = epoca seca, 2 = epoca humeda, 3 = maltones (1 año de edad).
Me puede dibujar donde pastorean las OVEJAS en la EPOCA SECA. (DIBUJA EL AREA, INDICA CON LA LETRA "M"). Si hay más que un rebaño, me puede indicar donde pastorean todo los rebaños.

1700-1717 1800-1817 1900-1917 2000-2017

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<tr>
<th>LUGAR</th>
<th>&quot;M&quot; (♀ Oveja (seca))</th>
<th>&quot;N&quot; (♀ Oveja (humeda))</th>
<th>&quot;O&quot; (♂ Oveja (seca))</th>
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*Si hay sistema de rotacion, dibuja todos los lugares donde pastorean los animales. 1 = epoca seca, 2 = epoca humeda.
VI. Ahora, quisiera preguntarles sobre la ganadería en la época de tus padres (o abuelos).

1. 30 años anteriormente, como en 1960s, tus padres (o abuelos) tenían en comparación a lo que Uds. tienen hoy día:
   a) más terreno
   b) menos terreno
   c) no ha cambiado

2. En esta época (1960s), en comparación de hoy, las enfermedades en el ganado habían:
   a) más frecuente
   b) menos frecuente
   c) no ha cambiado

3. En esta época (1960s), en comparación de hoy, durante una sequía el número de animales que murieron habían:
   a) más
   b) menos
   c) no ha cambiado

4. Ahora, quisiera preguntarles, en cual de las siguientes actividades se ganan más dinero:
   (CUAL ES EL SEGUNDO, TERCERO)
   # IMP
   a) venta de carne de tu propia tropa
   b) venta de lana de tu propia tropa
   c) trabajo de intermediario de la venta de carne o lana
   d) venta de productos artesanales
   e) venta de productos secundarios (kayo, queso)
   f) trabajo de pastor(a)
   g) trabajo en la comunidad (tienda/pension/albanil)
   h) trabajo fuera de la comunidad (Arica, La Paz, Oruro)

La última pregunta:
5. Que puede hacer AIGACAA para mejorar su programa del campo?

CONCLUSION

Estas son todas las preguntas que tengo. Quiero agradecerles mucho por su asistencia con este questionario. Si tienen algunos comentarios o otras preguntas yo trato de contestarlos. Otra vez, muchísimas gracias por su tiempo.
Survey form used to determine management practices and productivity of livestock in Cosapa, Bolivia (English version).

This survey was conducted in the community of Cosapa, Province of Sajama, Department of Oruro, Bolivia by Lita Buttolph in May and June of 1996. Both anonymity and confidentiality were promised to all participants. A code is given in place of a name for each household interviewed. All interviews were conducted in Spanish. The following is an English version of the original questionnaire that was written in Spanish.
I. First, I would like to get some information about some household demographics.

100. What estancia (location) do you live in? : __________

101. How many children do you have that currently live at home? __________

102. How old are each one of these children?:

________________________

103. How many other children do you have that do not live at home? ______

104. How many other people live in your house? _____

[TO MALE HEAD OF HOUSEHOLD]
105. Up to what level of education have you completed? ______

[TO FEMALE HEAD OF HOUSEHOLD]
106. Up to what level of education have you completed? ______

II. Now I would like to learn more about your production calendar and livestock management practices.

First, I would like to ask you about your LLAMA breeding strategies.

200. Normally, do you practice breeding in which:
   a) the females are tied up
   b) 1 bull is placed in the herd of females
   c) alternating groups of males are placed in the herd of females
   d) males and females are allowed to breed freely (open)
   e) other: ____________________________

201. *If you practice breeding in which the females are tied, where do the bulls come from?
   a) Your own herd of bulls
   b) Borrowed from a neighbor
   c) AIGACAA or CORDEOR
   d) Other: ____________________________
Now, I want to ask you about your ALPACA breeding practices.

202. Normally, do you practice breeding in which:
   a) the females are tied up
   b) 1 bull is placed in the herd of females
   c) alternating groups of males are placed in the herd of females
   d) males and females are allowed to breed freely (open)
   e) other: ______________________

203. *If you practice breeding in which the females are tied, where do the bulls come from?
   a) Your own herd of bulls
   b) Borrowed from a neighbor
   c) AIGACAA or CORDEOR
   d) Other: ______________________

Now, I want to ask you about your SHEEP breeding practices.

204. Normally, do you practice breeding in which:
   a) the females are tied up
   b) 1 bull is placed in the herd of females
   c) alternating groups of males are placed in the herd of females
   d) males and females are allowed to breed freely (open)
   e) other: ______________________

205. *If you practice breeding in which the females are tied, where do the bulls come from?
   a) Your own herd of bulls
   b) Borrowed from a neighbor
   c) AIGACAA or CORDEOR
   d) Other: ______________________

Now, I am going to ask you about weaning your LLAMAS.

206. Are your lambs normally weaned:
   a) naturally
   b) forced

207. *If they are forced, at what age are they weaned? _______

208. *If they are forced, do you give supplements to the weaned lambs? (Y/N) ______
209. *What type of supplements do you give to the weaned lambs?

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Now, I am going to ask you about weaning your ALPACAS.

210. Are your lambs normally weaned:
   a) naturally
   b) forced

211. *If they are forced, at what age are they weaned? ________

212. *If they are forced, do you give supplements to the weaned lambs? (Y/N) ______

213. *What type of supplements do you give to the weaned lambs?

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Now, I am going to ask you about weaning your SHEEP.

214. Are your lambs normally weaned:
   a) naturally
   b) forced

215. *If they are forced, at what age are they weaned? ________

216. *If they are forced, do you give supplements to the weaned lambs? (Y/N) ______

217. *What type of supplements do you give to the weaned lambs?

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Now, I would like to ask you about your use of VETERINARY SERVICES.
218. How many times a year do you use the services of a veterinarian to cure your sick animals?
   a) Never
   b) 1-5
   c) 5-10
   d) 10-20
   e) >20

219. *What year did you begin using the services of a vet?: 

220. *How did you cure sick animals before you started using veterinary services?
   a) with natural medicines/home remedies
   b) with purchased medicines
   c) other:

221. **If you do not use veterinary services, how do you cure your sick animals?
   a) purchase medicines
   b) use natural medicines/home remedies
   c) other:

EXTERNAL PARASITE DIPPING BATHS

222. Do you use dipping baths (Y/N): 

223. For how many years have you used the baths: 

224. What animal species do you bathe?
   a) all
   b) other:

225. How often do you bathe the animals:
   a) every year
   b) other:

INTERNAL PARASITE CONTROL

226. Do you control for internal parasites (Y/N): 

227. In what year did you begin to control: 

228. Which animal species do you give anti-parasite injections: (MARK ALL THAT APPLY)
   a) llamas
   b) alpacas
   c) sheep
   d) dogs
   e) other
229. In which months do you give the injections? 

CASTRATION

230. How many of your male llamas are castrated? 

231. How many of your male alpacas are castrated? 

232. How many of your male sheep are castrated? 

233. Do you give FEED SUPPLEMENTS to your LLAMAS? (Y/N) 

234. Normally do you give the supplements to: 
   a) the lambs 
   b) the mothers 
   c) all thin animals 

235. *What types of supplements do you give: 

   Type 
   235.1a 
   235.2a 
   235.3a 

   Amount/day 
   235.1b 
   235.2b 
   235.3b 

   What months 
   235.1c 
   235.2c 
   235.3c 

236. Do you give supplements: 
   a) every year 
   b) only in drought years 

237. When did you begin giving supplements to your llamas: 

238. Do you give FEED SUPPLEMENTS to your ALPACAS? (Y/N) 

239. Normally do you give the supplements to: 
   a) the lambs 
   b) the mothers 
   c) all thin animals 

240. *What types of supplements do you give: 

   Type 
   240.1a 
   240.2a 
   240.3a 

   Amount/day 
   240.1b 
   240.2b 
   240.3b 

   What months 
   240.1c 
   240.2c 
   240.3c 

241. Do you give supplements: 
   a) every year 
   b) only in drought years
242. When did you begin giving supplements to your alpacas: ______

243. Do you give FEED SUPPLEMENTS to your SHEEP? (Y/N) ______

244. Normally do you give the supplements to:
   a) the lambs
   b) the mothers
   c) all thin animals

245. *What types of supplements do you give:

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<th>Type</th>
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<tr>
<td>245.3a</td>
<td>245.3b</td>
<td>245.3c</td>
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246. Do you give supplements:
   a) every year
   b) only in drought years

247. When did you begin giving supplements to your sheep: ______

Now I am going to ask you about the use of vitamins for your animals.

248. Do you give vitamin supplements to your llamas? ______

249. In which months do you give vitamins to your llamas? ______

250. Do you give them vitamins:
   a) every year
   b) only in drought years

251. What year did you begin to give vitamins to your llamas? ______

252. Do you give vitamin supplements to your alpacas? ______

253. In which months do you give vitamins to your alpacas? ______

254. Do you give them vitamins:
   a) every year
   b) only in drought years

255. What year did you begin to give vitamins to your alpacas? ______

256. Do you give vitamin supplements to your sheep? ______

257. In which months do you give vitamins to your sheep? ______
258. Do you give them vitamins:
   a) every year
   b) only in drought years

259. What year did you begin to give vitamins to your sheep? __________

Now, I am going to ask you about any fenced parcels of land you may have.

260. Do you have fenced parcels of land? (Y/N) ______

261. How many hectares are fenced? __________

262. How many hectares within your exclosure are irrigated? __________

263. In which months do you irrigate? __________

264. Why did you put up your fenced area (exclosure)?
   a) to keep out neighboring animals
   b) to create reserve forage
   c) to delimit property lines
   d) to improve animal condition
   e) to fatten skinny animals
   f) to wean lambs
   g) so that I don’t have to herd
   e) other: ____________________________

265. What species of livestock do you put in the exclosure? (MARK ALL THAT APPLY)
   a) llamas
   b) alpacas
   c) sheep
   d) other: __________

266. Normally in your exclosure, do you put: (MARK ALL THAT APPLY)
   a) mothers
   b) lambs
   c) juveniles
   d) males
   e) other

267. In which months do you put the animals in the exclosure? ______

268. Normally, how many animals are put in? _______________________

269. Do you have problems with your neighbors about the use of this land that you fenced? ______
270. What types of problems? ________________________________

271. If you have the opportunity to fence all of your land, would you do it? _____

272. Why: ________________________________________________

273. *If you do not have an exclosure, do you have neighbors that do? ____________

274. Do you have any problems with the neighbors exclosure, in terms of land use rights? _____

275. What types of problems: ________________________________

276. If you had the opportunity to fence all or part of your land, would you do it? _____

277. Why: ________________________________________________

Now I am going to ask you about the sale of your animals.

278. In which months do you sell your MALE LLAMAS: ____________

279. Do you sell them a) live or b) slaughtered

280. In which months do you sell your JUVENILE LLAMAS: ____________

281. Do you sell them a) live or b) slaughtered

282. In which months do you sell your FEMALE LLAMAS: ____________

283. Do you sell them a) live or b) slaughtered

284. Why do sell them in these months [INDICATE FOR MALE, JUVENILE, AND FEMALE]:
   a) price is good
   b) lack of forage
   c) they are about to die
   d) the animals are fat
   e) need for cash
   f) other: ________________________________________________
285. To whom do you sell your llamas?
   a) buyer/intermediary
   b) directly to the market in the city
   c) local markets
   d) other: ___________________

286. To whom do you sell your llama wool?
   a) AIGACAA
   b) in the city/feria/Peru
   c) to a buyer/intermediary
   d) other: ___________________

287. In which months do you sell your MALE ALPACAS: ____________

288. Do you sell them a) live or b) slaughtered

289. In which months do you sell your JUVENILE ALPACAS: ____________

290. Do you sell them a) live or b) slaughtered

291. In which months do you sell your FEMALE ALPACAS: ____________

292. Do you sell them a) live or b) slaughtered

293. Why do sell them in these months [INDICATE FOR MALE, JUVENILE, AND FEMALE]:
   a) price is good
   b) lack of forage
   c) they are about to die
   d) the animals are fat
   e) need for cash
   f) other: ___________________

294. To whom do you sell your alpacas?
   a) buyer/intermediary
   b) directly to the market in the city
   c) local markets
   d) other: ___________________

295. To whom do you sell your alpaca wool?
   a) AIGACAA
   b) in the city/feria/Peru
   c) to a buyer/intermediary
   d) other: ___________________
296. In which months do you sell your MALE SHEEP: 

297. Do you sell them a) live or b) slaughtered

298. In which months do you sell your FEMALE SHEEP: 

299. Do you sell them a) live or b) slaughtered

300. Why do sell them in these months [INDICATE FOR MALE, JUVENILE, AND FEMALE]:
   a) price is good
   b) lack of forage
   c) they are about to die
   d) the animals are fat
   e) need for cash
   f) other: __________________________

301. To whom do you sell your sheep?
   a) buyer/intermediary
   b) directly to the market in the city
   c) local markets
   d) other: __________________________

302. Do you sell your sheep wool? (Y/N) _____

303. To whom do you sell your sheep wool?
   a) AIGACAA
   b) in the city/feria/Peru
   c) to a buyer/intermediary
   d) other: __________________________

Now, I am going to ask you about the IRRIGATION of your bofedales.

304. In which months do you irrigate your bofedales: 

305. How many hectares are irrigated: 

306. In the last 10 years, has the amount of land under irrigation a) increased; b) decreased; c) has not changed

307. *If there has been a change, how many hectares have been affected: ____
III. Now, I would like to ask you about the productivity of your animals.

ALPACAS

400. From your herd, how many alpaca lambs were born between Nov. '95 and now? ________

401. How many alpaca lambs were born the year before (Nov. 94 - April -95)? ____________

402. Of those animals that were born last year, how many died prior to weaning? ________

403. How many died due to:
   a) illness: ________
   b) lack of milk: ________
   c) lack of forage: ________
   d) predation by fox or other animal: ________
   e) cold: ________
   f) falling in water: ________
   g) eating toxic plants: ________
   h) other: __________________

404. How many abortions/miscarriages in your alpacas did you note between July 1995 and the present? ________

405. Of all of your female alpacas, how many bear young:
   a) every year: ____________
   b) every other year: ____________

406. How many adult alpacas died between July 1995 and the present? ________

407. How many died due to:
   a) illness: ________
   b) lack of forage: ________
   c) predation by fox or other animal: ________
   d) cold: ________
   e) falling in water: ________
   f) eating toxic plants: ________
   g) other: __________________

408. How many adult alpacas had some illness between July 1995 and the present? ____________

Between July 1995 and the present, how many alpacas have you:

409. sold ________

410. given away as a gift ____________

411. slaughtered for consumption ____________
Between July 1995 and the present, how many alpacas did you:

412. purchase: __________
413. receive by loan: ________
414. receive as a gift: __________

How many of the your alpacas are of the following colors:

415.1. White: __________
415.2 Black: __________
415.3 Gray: __________
415.4 Brown: __________
415.5 Api (mixture of brown and gray): __________
415.6 LF(light fawn)/Vicuna: __________
415.7 Spotted: __________

In 1991 (5 years ago), how many alpacas did you have of the following colors:

416.1. White: __________
416.2 Black: __________
416.3 Grey: __________
416.4 Brown: __________
416.5 Api (mixture of brown and gray): __________
416.6 LF(light fawn)/Vicuna: __________
416.7 Spotted: __________

LLAMAS

417. From your herd, how many llama lambs were born between Nov. '95 and now? __________

418. How many llama lambs were born the year before (Nov. 94 - April - 95)? __________

419. Of those animals that were born last year, how many died prior to weaning? __________

420. How many died due to:
   a) illness: __________
   b) lack of milk: __________
   c) lack of forage: __________
   d) predation by fox or other animal: __________
   e) cold: __________
   f) falling in water: __________
   g) eating toxic plants: __________
   h) other: __________

421. How many abortions/miscarriages in your llamas did you note between July 1995 and the present? __________

422. Of all of your female llamas, how many bear young:
   a) every year: __________
   b) every other year: __________
423. How many adult llamas died between July 1995 and the present? _____

424. How many died due to:
   a) illness: _____
   b) lack of forage: _____
   c) predation by fox or other animal: _____
   d) cold: _____
   e) falling in water: _____
   f) eating toxic plants: _____
   g) other: _______________________

425. How many adult llamas had some illness between July 1995 and the present? __________

Between July 1995 and the present, how many llamas have you:
426. sold __________
427. given away as a gift __________
428. slaughtered for consumption __________

Between July 1995 and the present, how many llamas did you:
429. purchase: __________
430. receive by loan: __________
431. receive as a gift: __________

SHEEP
432. How many sheep lambs were born last year (July - Dec 1995)? _________

433. Of those animals that were born last year, how many died prior to weaning? _________

434. How many died due to:
   a) illness: _______
   b) lack of milk: _______
   c) lack of forage: _______
   d) predation by fox or other animal: _______
   e) cold: _______
   f) falling in water: _______
   g) eating toxic plants: _______
   h) other: _______________________

435. Of all of your female sheep, how many bear young:
   a) every year: ________
   b) twice a year: ________

436. How many adult sheep died between July 1995 and the present? _______
437. How many died due to:
   a) illness:
   b) lack of forage:
   c) predation by fox or other animal:
   d) cold:
   e) falling in water:
   f) eating toxic plants:
   g) other:

438. How many adult sheep had some illness between July 1995 and the present?

Between July 1995 and the present, how many sheep have you:
   439. sold
   440. given away as a gift
   441. slaughtered for consumption

Between July 1995 and the present, how many sheep did you:
   442. purchase:
   443. receive by loan:
   444. receive as a gift:

445. How many other types of livestock do you have?
   a) pigs
   b) donkeys
   c) chickens
   d) other:

IV. Now, I would like to know a little more about the history of your livestock.
(REFER TO CHART 1)

In what year did you (the heads of household) get married?
How many alpacas did you have in that year?
How many llamas?
How many sheep?

In what year was your first child born?
How many alpacas did you have in that year?
How many llamas?
How many sheep?

(CONTINUE TO FILL OUT LIST. USE CHART SHOWING KEY EVENTS PER YEAR IN COSAPA TO ASSIST WITH RECALL)
CHART 1. Long-term herd structure.

<table>
<thead>
<tr>
<th>Year</th>
<th># Alpacas</th>
<th># Llamas</th>
<th># Sheep</th>
<th>Stocking Rate</th>
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<tbody>
<tr>
<td></td>
<td>#</td>
<td># Died</td>
<td>#</td>
<td>Camelids</td>
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<tr>
<td>Married</td>
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<td>Sheep</td>
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<td>Corregidor</td>
<td>Jilakatas</td>
<td>Weather</td>
<td>Other Events</td>
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<td>-------------------------------------------------------</td>
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<tr>
<td>1982</td>
<td>Quintin Ramirez</td>
<td></td>
<td></td>
<td>John Wilson Proj. Concern</td>
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<td>1983</td>
<td>Daniel Marca</td>
<td>Porfirio Chambi, Mario Ramirez</td>
<td>Major drought</td>
<td>Construction of kindergarden</td>
</tr>
<tr>
<td>1984</td>
<td>Gumercindo Marin</td>
<td>Felix Mamani, Vicente Huajlla</td>
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<td></td>
</tr>
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<td>Teodoro Huajlla</td>
<td>Ramon Chambi, Primitivo Aguilar</td>
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<td>Juan Chambi Mamani</td>
<td>Teofilo Marca, Gregorio Marca</td>
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<td>1987</td>
<td>Mario Marca</td>
<td>Juan de Dios Marca, Victor Bedoya</td>
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<td>Felix Marca, Antonio Aguilar</td>
<td>High rainfall</td>
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<td>Francisco Javier Marca</td>
<td>Roman Aguilar, Hilarion Marca</td>
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<td>Benito Bedoya, Leandro Bedoya</td>
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<td>Protest march to Oruro against tax increase</td>
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<td>1991</td>
<td>Ramon Chambi</td>
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<td></td>
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<td>Segundino Mamani</td>
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<td></td>
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<td>Martin Ramirez</td>
<td>Vicente Huajlla, Pablo Armado Aguilar</td>
<td>High snowfall in August</td>
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<td>1994</td>
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<tr>
<td>1995</td>
<td>Eleutario Huajlla</td>
<td>Teodoro Huajlla, Junas Chambi</td>
<td></td>
<td>First high school graduation</td>
</tr>
</tbody>
</table>
V. Now, I would like to know more about the forage availability for your livestock and location of your grazing pastures. I have here a map of this area.

Please sketch the location of where your FEMALE ALPACAS graze in the DRY SEASON. (DRAW AREA ON TOPO MAP, AND INDICATE WITH LETTER "A") If there is more than 1 herd, please indicate the grazing pastures for all herds. [AFTER FILLING OUT COLUMN "A" CONTINUE UNTIL "F"]

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<thead>
<tr>
<th>LOCATION</th>
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<td>MONTHS</td>
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<td>Ha. Bofedal</td>
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<td>Ha. Pajonal</td>
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<td>Ha. T'olar</td>
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<td>Ha. Mountain</td>
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<td># ANIMALS</td>
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<td>Share?</td>
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<td># Persons</td>
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<td>Rotation*</td>
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<td>Veg types/rotation site</td>
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<td># Days/Rotation</td>
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<td>Other site if drought?</td>
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<td>HERDER</td>
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<td>Herd each ?# days?</td>
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</table>

*If the have a rotation system, draw the different pastures. 1 = dry season, 2 = wet season, 3 = juvenile (1 year old).
Please sketch the location of where your FEMALE LLAMAS graze in the DRY SEASON. (DRAW THE AREA ON TOPO MAP, AND INDICATE WITH THE LETTER "G"). If there is more than 1 herd, please indicate the grazing pastures for all herds. [AFTER FILLING OUT COLUMN "G" CONTINUE UNTIL "L"]

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*If the have a rotation system, draw the different pastures: 1 = dry season, 2 = wet season, 3 = juvenile (1 year old).
Please sketch the location of where your FEMALE SHEEP graze in the DRY SEASON. (DRAW THE AREA ON TOPO MAP, AND INDICATE WITH THE LETTER "M"). If there is more than 1 herd, please indicate the grazing pastures for all herds. [AFTER FILLING OUT COLUMN "M" CONTINUE UNTIL "P"]

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</table>

*If the have a rotation system, draw the different pastures. 1 = dry season, 2 = wet season.
VI. Now, I would like to ask you about what times were like when your parents (or grandparents) were young.

1. 30 years ago, like in the 1960's, did your parents have, relative to today:
   a) more land
   b) less land
   c) no change

2. In this same period (1960s), in comparison to today, were illness in livestock:
   a) more common
   b) less common
   c) no change

3. In this period (1960s), in comparison to today, were the number of animals that died in droughts:
   a) more
   b) less
   c) no change

4. Which of the following activities currently earns the most money for you. [THEN LIST THE SECOND MOST IMPORTANT, THE THIRD]

   # IMP
   _____ a) sale of meat from your own herd
   _____ b) sale of wool from your own herd
   _____ c) working as a buyer/intermediary for meat or wool
   _____ d) sale of handicrafts (i.e., scarves, gloves)
   _____ e) sale of spun wool, cheese
   _____ f) working as a herder for others
   _____ g) work in the village (store/restaurant/carpentry)
   _____ h) work outside of the village (Arica, La Paz, Oruro)

The final question:
5. What can AIGACAA do to improve their program at the farm level?

CONCLUSION

Those are all of the questions that I have. I would like to thank you very much for your assistance with this survey. I am happy to accept any additional comments or answer any questions you may have. Once again, thank you very much for your time.
Appendix C

Figures
Fig. C.1. Relationship between crown volume and dry weight of *Festuca orthophylla*, showing high model predictability. A conical shape was used to estimate volume based on Lyon (1968).
Fig. C.2. Scatterplot of percent soil organic carbon showing the relationship between the loss-on-ignition (LOI) method and Walkley-Black.
CURRICULUM VITAE

Lita Polly Buttolph  
(June 1998)

Education


Experience

January 1993 to Present: Graduate Student Researcher
Conducted research on pastoral systems ecology in a traditional Aymara herding community on the Bolivian altiplano. Determined the impacts of a United Nations development project on pastoral system dynamics. Research included 2 years of field work in Cosapa, Bolivia, collecting ecological data (i.e., measurements of vegetation biomass and species composition, and soils), and data on livestock herd productivity and management via interviews. Collaborated with an indigenous herders' association, and evaluated the impacts of an alpaca wool development project on the local ecology and sustainable development for the community.

August 1992 to December 1992: Research Assistant
Studied poverty and community well-being in 3 logging towns in the north-western Sierra Nevada mountains in California. Duties included locating laid-off mill and woods workers, and conducting interviews with the spouses of laid-off workers to determine the impact of recent lay-offs in the timber industry on family and community well-being.

January 1991 to July 1992: Graduate Student Researcher
Developed a resource management plan for Mount Diablo State Park, in California, using an ArcInfo Geographic Information System. Duties included creating a GIS database of park natural and cultural resources using PC ArcInfo and dBASE programs; digitizing maps; updating the database on rare, threatened and endangered species through field identification and mapping; reviewing the literature on the ecology, management, and restoration of native plant and animal communities; and establishing monitoring transects and collected baseline data to monitor the impacts of park management practices on vegetation, riparian systems, and rare, threatened and endangered species.
January 1991 to July 1992: Graduate Student Researcher
Studied the effects of cattle grazing on ground squirrel populations at Del Valle Regional Park in California. Duties included establishing study plots and cattle exclosures; monitoring ground squirrel activity by evaluating burrow use levels; locating and mapping squirrel colonies and burrows; and measuring vegetation biomass, utilization, structure, and composition within plots and transects.

May 1991 to August 1992: Graduate Student Researcher
Assisted in the development of a survey of California hardwood rangeland use and management by private landowners. Worked on the construction of the questionnaire, and on locating landowner names and addresses. The questionnaire focused on grazing practices and land use trends.

September 1989 to August 1990: Instructional Assistant and Tutor
Assisted a visually impaired professor in Introductory and General Chemistry courses at Laney Community College in Oakland, California. Work consisted of helping students in the laboratory, grading exams, lab reports and quizzes, reviewing and dictating text material for the preparation of lectures, and demonstrating laboratory techniques to the class. Tutored students in Math, Biology, Chemistry, English and English-as-a-Second-Language at Laney College.

June 1989 to August 1989: Field Research Assistant
Assisted in field and laboratory observations of grasshopper feeding behavior at the Audubon Research Ranch in southern Arizona. Conducted feeding experiments, choice tests, dissections, and field observations of individual grasshoppers to determine feeding preferences, growth rates, fecundity, and the role of learning in host-plant selection. Also measured vegetation and insect densities.

September 1988 to May 1989: Laboratory Assistant
Assisted in experiments concerning the food preferences and aversions of several species of caterpillar and grasshopper. Duties included performing choice tests and growth tests; maintaining plant and insect colonies; and data entry and analyses.

September 1987 to February 1990: Laboratory Assistant
Assisted with experiments to determine the digestibility of C3 and C4 grasses in caterpillars. Duties included field collection of insects; weighing samples; insect dissection; data entry and organization; planting and maintaining plants; assisting in micro-Kjeldahl and Ninhydrin chemical analyses to determine nitrogen and amino acid concentrations.

June 1987 to August 1987: Field Research Assistant
Assisted in behavioral studies of Blue and Red-tailed monkeys in the Kakamega Forest, Kenya. Conducted daily field observations of colonies, collecting data on group home ranges, territorial behavior and mating behavior.
Scholarships and Awards

High Honors in Biological Sciences, May, 1989, from the University of California, Berkeley, California.

Graduate Opportunities Fellowship for Minority Students, August, 1990, to May, 1991, from the University of California, Berkeley, California.

Ford Foundation Scholarship to attend the Southwest Institute for Research on Women (SIROW) Summer Institute, June 1997, Tucson, Arizona. Theme: "Global Processes, Local Lives: Comparative Approaches to Women's and Area Studies."

Recent Publications and Presentations


Foreign Languages

Spanish (fluent)
Japanese (intermediate fluency in speaking and comprehension, basic writing)
Aymara (basic)