The interactions between environmental, agro-ecological and socio-political factors in determining vicuña distribution and appropriate management systems

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Introduction

Spanning Perú, Bolivia, Chile and Argentina, the Andean highlands, known locally as *puna* or *altiplano*, extend to some 250,000 km². This area was once the focus for the vast pre-Colombian empire of the Incas. In the altiplano, normally defined (Gade 1996) as land over 3,500 m.a.s.l., the rarefied air, long dry season, irregular precipitation, low temperatures with frequent frosts, rugged topography, and poor soils create severe limitations for agriculture, and as a consequence, economic development has been hindered (Browman 1983; Sumar 1988). Nowadays, the indigenous Quechua- and Aymara-speaking communities, descendants of the Inca, base their subsistence economies on pastoralism, with mixed flocks of llama, alpaca, sheep and goats (Kuznar 1996).

The principle wild herbivore of the altiplano is the vicuña, *Vicugna vicugna* (Wheeler 1995). The vicuña and the guanaco, which is found generally at lower elevations are the two extant wild species of South American camelid. Both are highly valued for their fine quality fibre. The vicuña is found at elevations in excess of 3700m in a range which extends from 9º30'S around Ankash in Perú to 29º30' in the III region (Atacama) of Chile (Novoa and Wheeler 1984). The vicuña is classified as "lower risk: conservation dependent" in the 1996 Red List of Threatened Animals (IUCN 1996).

Table 1 Recent population estimates for the two wild and two domesticated species of camelids in Perú, Bolivia, Chile and Argentina (after N. Reneaudeau d'Arc, unpublished thesis).

Species	Argentina*	Bolivia**	Chile***	Peru****	Total
Guanaco	578,700	300	50,000	4,800	633,800
Vicuña	23,000	39,000	19,848	142,000	223,848
Llama	135,000	1,600,000	79,363	1,119,777	2,934,140
Alpaca	400	300,000	45,282	2,675,695	3,021,377

* (Torres 1992) ** Censo de la vicuña 1996, Censo agropecuario, 1995 (# llamas y alpacas), *** (Franklin *et. al*. 1997; Galaz 1998), **** CONACS (1996) (guanaco), CONACS (1997) (vicuñas)

There is widespread belief that sustainable use of vicuña for its fleece through proper management has great potential to contribute both to the long-term conservation of the species and to the economic development of Andean communities sharing the same land (IUCN 1996; Sumar 1988; Torres 1992). This principle is formalised in the

1978 Vicuña Convention, though it was not until 1996 that capture and shearing on a legal commercial basis began. Exploitation of the vicuña is now practised to a greater or lesser extent in all four altiplano countries, though the results in terms of development have been mixed (Lichtenstein *et. al.* 2002). Management practices vary between (and within) the countries, apparently as a result of cultural, political and land tenure differences (Galaz 1998; Lichtenstein *et. al.* 2002).

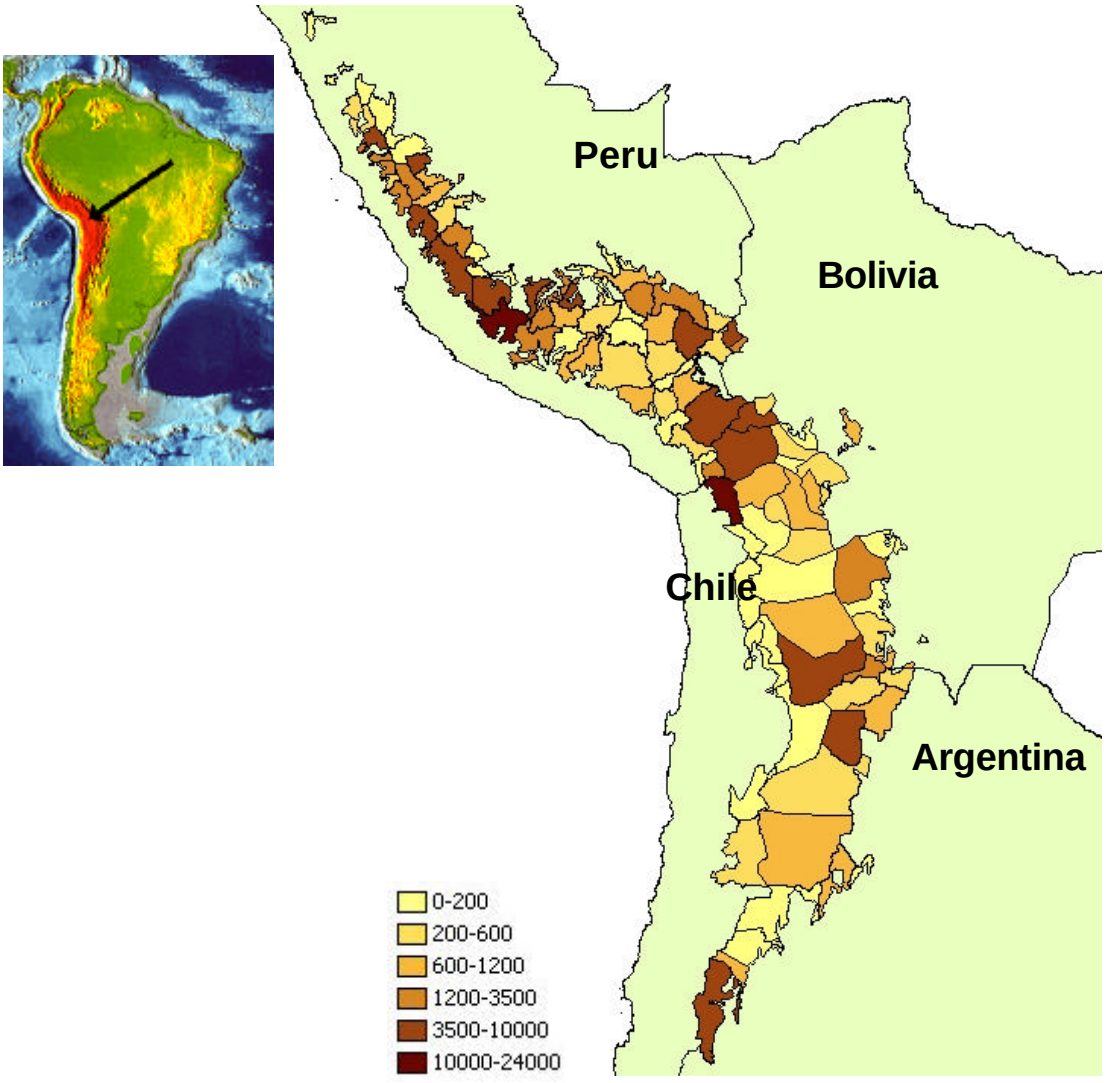

Figure 1 Distribution and population (per administrative region) of the vicuña in the altiplano (contour marked at 3500m).

The sustainable harvest of high quality fibre following live capture and release of a wild mammal is perhaps a unique case in wildlife management. (Wheeler and Hoces 1997) Non-lethal harvesting obviously has many potential advantages over hunting for skins from the point of view of vicuña conservation. The impacts however of capture, shearing and release are not well known, especially over the longer term

(Bonacic *et. al.* 2002). Exposure to sub-zero night-time temperatures may cause significant mortality to animals devoid of the protection of an insulating fleece (Eltringham 1981).

The long-term commercial utilisation of the vicuña requires that systems be developed that are economically viable, while maintaining adequate monitoring of individual animal welfare and population ecology. As many of the indigenous communities involved give religious and cultural importance to the vicuña, there is an extra sociological dimension to the dynamics of vicuña ecology (Bernhardson 1986) . The future of vicuña conservation is inextricably linked to future economic and social change in the altiplano. Vicuña may increase in numbers and colonise new areas only if left to do so by local communities. Tolerance, or the lack of it - the trade-off between culturally reinforced positive attitudes towards vicuña and practical concern for their direct impact on forage availability for livestock - may be a highly significant factor influencing vicuña distribution(Cueto *et. al.* 1985).

This paper examines the interplay between the ecology of the vicuña, and its relationship with human activities in the altiplano, with a view to evaluating the influence of sustainable wildlife use on long-term conservation objectives..

Historical background

Early use of vicuña

The vicuña has a long history of association with man. Early inhabitants of South America began the process of domestication some 6000 years BP in the Lake Titicaca basin of Perú and Bolivia (Novoa and Wheeler 1984). A millennium of selective breeding created the alpaca, an animal which, before the 15th century Spanish conquest was differentiated, as modern day sheep, into a large number of distinct and specialised breeds (Kadwell *et. al.* 2001; Wheeler 1984), mostly used for a combination of draft power, wool and meat. By Incan times, management of the wild vicuña was ritualised and followed strict rules, which ensured not only that the fibre was available for the exclusive use of the Incan royal family, but also maintained a pattern of sustainable utilisation of the wildlife resource (Flores-Ochoa 1994). Hunting of vicuña was prohibited. The harvesting of fibre was a communal activity in organised “chakus”, with each population being captured once in every three to four

years. By modern standards, these chakus were immense affairs – early reports describe 20-30 thousand people taking part in each chaku, with a catch of 30-40 thousand head (Flores-Ochoa 1994). All types of animals were shorn, and some of the males were killed for meat for the participants in the chaku. Cloth made from the fibre was highly prized. Garments are reported to have been worn once only by the emperor, thereafter being given away as favours and for burned offerings to the gods (Wheeler 1995).

The Spanish conquest

This apparently sustainable system of vicuña use broke down completely with the Spanish conquest. It has been estimated that the pre-Colombian vicuña population was in the region of 1.5-2 million head (Flores Ochoa 1977). Though Inca belief systems persisted in communities of indigenous pastoralists, the introduced Spanish culture along with the firearms that they brought, had a profound effect on vicuna abundance. With increasing pressure from hunting, numbers began to fall. Concern about overexploitation was recorded even in the 16th century by Spanish chronicler Pedro Cieza de León, who noted a dramatic decline in the populations of both vicuña and guanaco in Perú following colonisation in 1532 (Flores-Ochoa 1994). Hunting was apparently carried out with the objective of securing both meat and fibre. The first conservation legislation was issued by decree in 1777 by the Imperial Court, when it was ruled that it was illegal to kill a vicuña and that it was necessary to have a suitable person, appointed by a magistrate present at captures. During the colonial period, en export trade for vicuña skins and fibre developed to supply a newly established fine textile manufacturing industry in Spain. Figures are available from Spanish colonial archives in Buenos Aires that suggest that in the late 18th century, these exports reflect the hunting of up to 50,000 individual vicuña per year from the then Viceroyalty of La Plata and Alto Peru (now Argentina and Bolivia) (Yaccobaccio *et. al.* 2003). Trade continued until the independence wars began in 1810 (Figure 2).

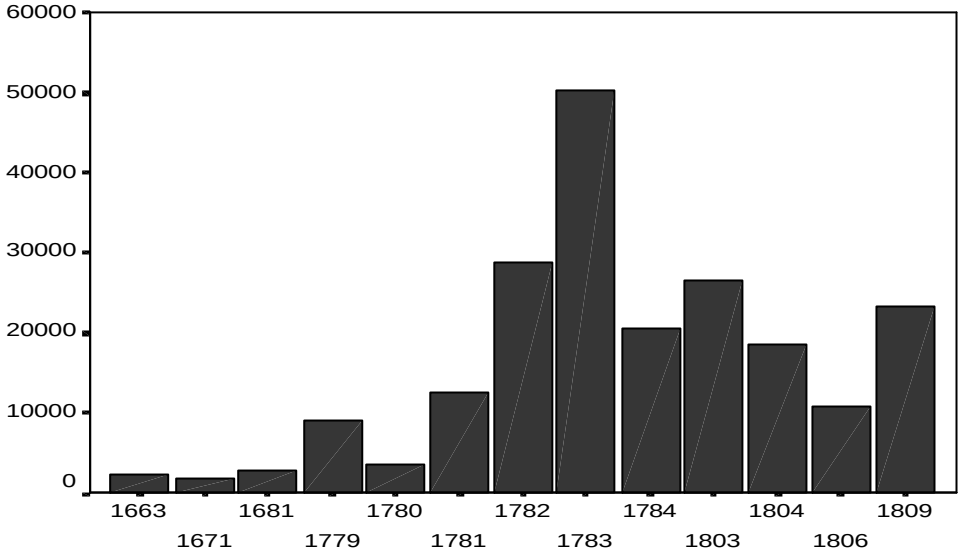

Figure 2 Estimated number of vicuñas killed to supply Spanish colonial export trade in fibre to Spain (After Yaccobaccio, 2003).

In the newly formed Republic of Peru in 1825, Simon Bólivar introduced measures to prevent hunting of vicuña. Acting against this was the establishment of new trading links, principally for alpaca fibres, to export markets by British-owned companies based in Arequipa (Orlove 1977).

Impact of international trade in the 20th century

Laws to protect the vicuña continued to be introduced in Peru. A Supreme Decree in 1920 prohibited trade in vicuña products, and another in 1926 forbade the export of vicuña fibre from Perú. These measures had a limited impact on hunting activities, but in 1933, controls were relaxed again to allow state involvement in licensed vicuña fibre exports. At this time, commercial demand in vicuña skins increased, such that as a result numbers began to crash dramatically. In the period 1937-1965, imports of vicuña fibre to the UK, the principal market, averaged 1270 kg per year (Figure 3, J.Sugden, pers. comm.).. This implies the hunting of some 5500 – 6500 individuals. Over the same period, the vicuña population appears to have fallen from 400,000 in the 1950s to about 10,000 individuals in 1967 (Wheeler and Hoces 1997). The population estimates at this time are likely not to be particularly accurate, but it seems clear that the surge in pressure on vicuña stocks caused a rapid decline, and exposed the species to a very real risk of extinction. Fibre continued to be traded openly (approx. 350kg/yr) until 1970, when international restrictions on trade

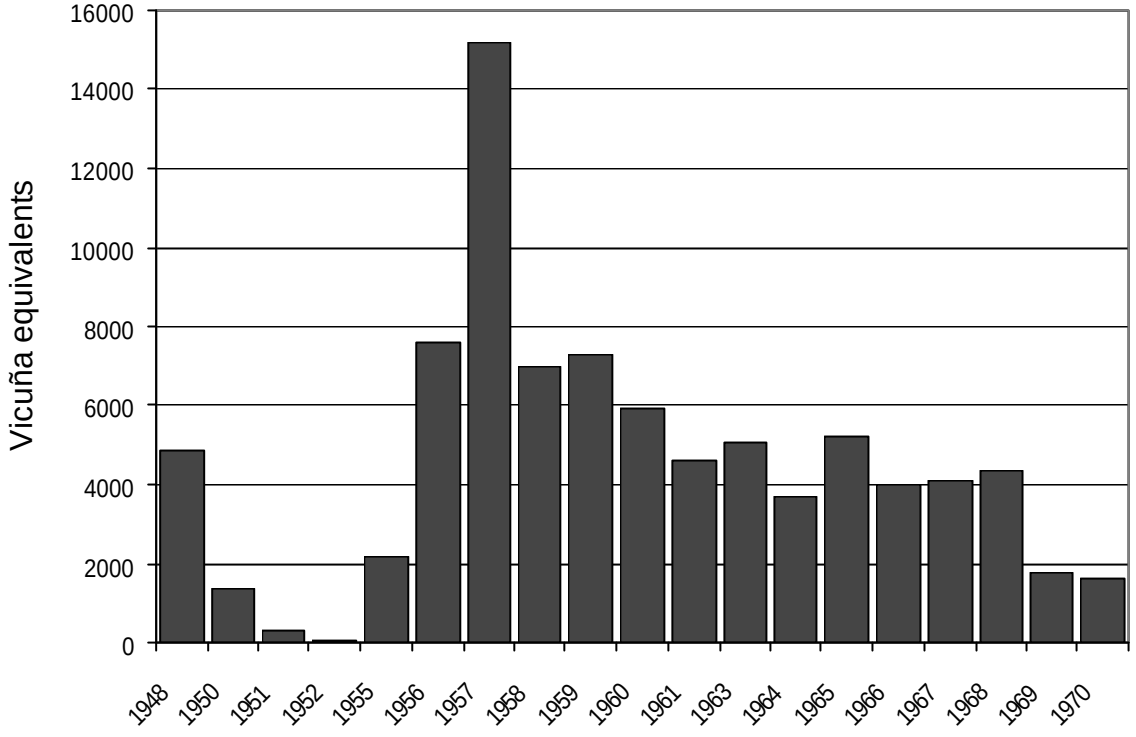

Figure 3 Imports of fibre (in vicuña equivalents) to one UK company during the period 1948 – 1970. (J.Sugden pers.com.)

were enforced, and conservation measures were agreed multilaterally by the signatories of the first Vicuña Convention.

From exploitation to conservation

The course of events took a somewhat different course in each of the four main countries in which vicuña are found. All populations of vicuña were listed in CITES Appendix I in 1975. The gradual recovery from the brink of extinction since this time illustrates the positive results of international co-operation complementing actions at the national and local level. Several Vicuña populations in Chile and Peru were transferred to Appendix II in 1987, and Peru's remaining population and additional Chilean sub-populations transferred to this Appendix in 1995. Exports of fibre were resumed in 1995 under CITES license in specific populations. Since that time, sub-populations in Argentina, Bolivia and Chile have been transferred to Appendix II, generating economic benefits from the sale of fibre sheared from live animals.

Table 2 shows the extent of the recovery of vicuña populations since regular censuses were introduced. Despite these gains, vicuña populations still remain under threat in many parts

of their range. In the absence of economic incentives for managing wild Vicuña populations, competition with domestic livestock represents one of the most serious threats to vicuña populations. Growing interest in the establishment of 'semi-captive' operations by three of the four vicuña range States also represents a potential threat to the creation of incentives for rural communities to manage wild populations through the live-shearing of animals, a practice first developed by the Incas. Establishment of 'semi-captive' operations creates its own suite of problems by limiting potential revenues to private land-owners and thereby reducing the value of maintaining viable habitat for wild vicuña populations.

Table 2. Development of the population of vicuñas between 1969 and 2001 in the five countries in which it is found(Canedi and Virgili 2000; CONACS 1997; D.G.B. 1997).

	1969	**1981**	**1997**	**2001**
Peru	10,000	61,900	102,800	118,700
Bolivia	3,000	4,500	33,800	56,400
Argentina	1,000	8,200	22,100	33,500
Chile	500	8,000	19,800	16,900
Ecuador	0	0	1,600	2,000
Total	**14,500**	**82,600**	**180,100**	**227,500**

There is some controversy over the direction that developments in vicuña management are taking. The debate over who should be benefit from vicuña exploitation, and the forms by which this is best achieved have been aired in CITES. There are fears that gradual domestication of vicuña will virtually eliminate the urgently required economic incentives that would allow for cohabitation of vicuña with domestic livestock (Vila 2002). Coupled with weak enforcement capacity, this could result in increased illegal hunting, a phenomenon that is already occurring (Barbarán 2002). Unless strictly controlled, 'semi-captive' operations could also be used to launder fibre from illegally killed animals should such operations not prove profitable. In short, 'semi-captive' operations in the absence of an effective national management plan could be more detrimental than beneficial to the recovery and conservation of wild vicuña populations

Peru

Conservation activities for vicuña were first developed in Pampa Galeras in Perú. In 1972, the reserve received support from the German Federal Government to conduct research, build infrastructure and establish a security system through armed guards patrolling the 6,500 hectare core management zone. The programme proved highly successful. Removal of hunting pressure resulted in initial recruitment rates of 21% per year (Eltringham 1981). However, by the mid 1970's a negative population growth of 11.3% was detected, possibly caused by prolonged droughts and overgrazing (Brack 1980). Interpreting this fall as a sign of overpopulation, a cull was carried out in 1977 (120 head) and 1978 (400 head). This management response was controversial at the time, and the debate widened out to include not only the Peruvian authorities, but also international conservation agencies – IUCN and the World Wildlife Fund (Otte 1981). The issue brought into stark focus the differences between conservationists on the one hand and wildlife managers on the other. The vicuña had become a high profile cause for wildlife protection agencies, who could not accept culling as an appropriate management tool.

In 1980, the National Plan for the Rational Utilization of the Vicuña was introduced in response to the culling controversy. It was recognised that local communities should see some return for their investment in wildlife protection (Brack *et. al.* 1981), and that their involvement in conservation would help to reduce the level of poaching.

The project established a new set of principles for future management of the species by:

- Local community participation
- Technology transfer to the Andean campesino for effective management of the vicuña
- Generation and organisation of legal markets for vicuña wool (based on live shearing of vicuña)
- Implementation of housing, health and education programs in the campesino communities involved in the project.

Revenue generated by the legal commercialisation of the vicuña wool would, it was hoped, generate additional productive activities for the well-being of the population.

These principles have underpinned subsequent policy development for vicuña sustainable use throughout the altiplano. In 1991, the law was changed to shift the emphasis of vicuña management from protection to sustainable use (*Ley de promocion de las inversiones en el sector agrario, Decreto Legislativo No. 653*), by transferring the custody of the vicuña to local communities as well as transferring technology and methods for the rational use of vicuña wool as a means of local socio-economic development. At this time, international trade was still heavily restricted under CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna). The trade ban for cloth made from Peruvian fibre was lifted in 1995.

In the same year, the government of Perú approved a law granting communities the right to manage the land used by the vicuña, and penalizing illegal game practices (Cueto *et. al.* 1985). Local communities began by exporting 2,000 kg of vicuña fibre (produced between 1987 and 1993). The following year, 3,000 kg (produced from 1994 to 1995) were exported. In 1998 the total export was 2,500 kg.

The commercial harvest of vicuña was pushed harder in Perú than in the other three countries because of strong political pressure from local communities to be allowed access to a potentially valuable resource.

Bolivia

In Bolivia, which has the second largest population of vicuña in the region, the approach has been more cautious. There has been a strong emphasis on conservation since the establishment of national parks in 1969. Unlike in Peru, however, a legislative framework for vicuña sustainable use was not introduced until 1997 (*Reglamento para la Conservación y Manejo de la Vicuña* - D.S. 24.529). Vicuña retain their national heritage status – they belong to the state - and as such may not be kept in enclosures. Rights of use are, however, passed to local altiplano communities who have official approval to undertake vicuña management (Rendon-Burgos 2000) .

Three pilot centres were established: Ulla Ulla, Mauri Desaguadero and Sud Lipez, and a programme of capacity building was initiated by the Ministry of Biodiversity and Sustainable Development (DGB) to establish a system of wild capture for the benefit of indigenous communities. The objective of the Bolivian project was clearly stated as being these communities in decision-making, though unlike in Peru, the government has sought to maintain the conservation of the vicuña as the ultimate objective of management.

The differences in approach taken in the different countries have resulted to a large extent from a combination of land rights and demography. The main characteristics of each country are summarised in Table 3.

Table 3. Level of protection of vicuña and property right regimes (after N. Reneaudeau d'Arc, pers. comm.).

Country	Vicuña	Land	Management regime
ARGENTINA	International: Appendix I & II *res nullius* (without any owner)	Private	Resource: captivity Users: landowners
BOLIVIA	International: Appendix I & II State: ownership Communities: Custodianship & exclusive use rights	Communal	Resource: wild Users: communities
CHILE	International: Appendix I & II State: ownership	Private	Resource: captivity & wild Users: landowners
PERU	International: Appendix II State: ownership Communities:	Communal	Resource: captivity & wild Users: communities

Chile

In Chile, a conservation programme was initiated in 1970, at which time the national population was estimated at 500 individuals (Cattan and Glade 1989). Protected areas were established in Region I (Lauca, Tarapaca). The main priority was to stop poaching and illegal traffic of fibre and to apply the recently agreed Vicuña Convention (Miller 1980; Torres 1992). With the installation of park guards, annual census counts began to rise as the population recovered with the easing of hunting pressure (Rodriguez 1987). By the 1980s, the pressure was beginning to build for sustainable use to be authorised. Several studies were carried out to evaluate fibre quality and ways to distribute benefits of fibre sales (Fernandez and Luxmoore 1995)

and a strategy for the sustainable use of the vicuña was developed (CONAF 1991). It was expected that in the early 1990s, the vicuña should be in use by local communities (Torres 1992). However, the sustainable use by indigenous communities has to date never been realised principally because of problems with agreeing a framework for distribution of benefits.

With the successful population recovery in Chile, the reality on the ground is that conservation has to move forward into a sustainable use phase (Bonacic *et. al.* 2002). However, the debate as to the form which such sustainable use should take is becoming increasingly polarised. A pilot programme for breeding vicuña in enclosures was established at Ancara, near the Peruvian border, in 1999, and, following relaxation of the CITES regulations in 2002, it is expected that this model will be expanded to other areas of the I Region of Chile (Galaz and Gonzalez 2003).

Argentina

Argentina has a population of around 23,000 vicuñas (Torres 1992). Vicuña distribution in Argentina includes portions of the north-western provinces of Jujuy, through Salta, Catamarca, La Rioja to San Juan in the south. The lack of a national census and the scarcity of surveys make it impossible to have reliable data on total vicuña numbers. However most of the researchers in the country agree that some populations have increased in recent years while others maintained their size (SSN 2002). Populations from areas that suffered local extinction in the past are slowly increasing. The distribution of the species is patchy. The attitudes of the local population and the frequency of patrols by wildlife guards appear to be important influences on this, with local abundance of vicuña being associated with communities which have a positive attitude to their presence (Vila, 2002, pers. comm.)

Commercial management of wild vicuñas is currently permitted by CITES in Jujuy, however, to date there are no records of this having taken place. Vicuña utilisation in Argentina takes place on farms. The system is promoted by the agricultural extension organisation, the National Institute of Agriculture and Cattle Technology (INTA) Abrapampa, Jujuy. This station "donates" groups of 12, 24 or 36 vicuñas from their captive herd to individual producers. Young vicuñas plus 10% of their offspring

produced under captive conditions have to be returned to INTA station as a compensation for the initial vicuña "donation".

Argentine vicuña production created some controversy at the 2002 COP-12 CITES meeting in Chile. The US Fish and Wildlife Service had proposed not to allow Argentine fibre to be imported to the US. Their objection was based in their concerns about the relation between the enclosures and the conservation of the wild populations and the genetic fitness associated with the small number of animals in the enclosures. Trade from all producer countries was in the end authorised, on the basis that it would be practically impossible to differentiate traded fibre from different provenance. However, the issue underlines the sensitivity of a major market for the fibre to ethical questions related to animal welfare and conservation.

Vicuña conservation and management in a global context

The international conservation efforts brought back the species from the brink of extinction. As a consequence of its success, the vicuña conservation programme became one of the most symbolic projects in Latin America. The vicuña programme demonstrated that Governments, International Agencies and local communities could work together to stop species population decline.

As an example of live harvesting of wildlife products, the vicuña is probably unique. As an example of the farming of wildlife for the harvesting of commercially valuable products, the vicuña joins a number of other notable examples worldwide. Farm systems have been established within the last century for the production of other wildlife products, such as bear bile and musk. These predominantly Chinese production units have attracted international criticism on animal welfare grounds. The combination of luxury products and animal welfare abuse can be disastrous for product image. Both bear and deer farms have been the subject of hard-hitting animal rights campaigns (Homes 1999; Shrestha 1998). Sustainable use of wildlife is likewise under the spotlight of international concern for both animal welfare and environmental impact (Roe *et. al.* 2002). The nature of fibre as a consumer product ensures that its provenance is far more obvious to buyers than, for example, bile or musk. Consumers are already sensitised to environmental concerns about quality

textiles following extensive publicity about shahtoosh fibre, the fine undercoat of the Tibetan antelope or *chiru* (Traffic 1999). The campaign to increase public awareness of the plight of the chiru has had a significant impact on demand, at least in the US, and should alert vicuña producers to the need to produce fibre within internationally recognised standards of "sustainability".

On the other hand, it is also obvious that harvesting systems must be at the same time profitable and practical. With problems being encountered with achieving expected levels of wealth creation, the initial aims of sustainable use defined during the 1970s are now being reconsidered. There is still no consensus whether the vicuña should be managed communally as a wild animal or be privatised to be farmed by local communities, or indeed other farmers outwith the altiplano. This issue is currently hotly debated in Chile (Galaz 1998). A series of wild capture-release trials were conducted during the last ten years. In 2000, a trial programme of enclosures within the altiplano was initiated, with the idea was that these two systems should be complementary to each other, each being appropriate for different land tenure situations.

In Perú, which embarked on an ambitious programme of enclosure building in the late 1990s, opinion amongst the *campesinos* appears to be swinging away from fencing towards wild management, as cases of psoroptic mange begin to increase in frequency (J. Wheeler, 2002, pers. comm.). Clearly there is a case for improving international collaboration in systems development.

Wildlife sustainable use

This thesis examines the interface between people and wildlife ecology. Such *socioecology* is likely to become increasingly important in the future as humans and wildlife compete for space in an ever more crowded world (Ashish *et. al.* 2000). The issues raised in microcosm in the simplified socio-ecosystem of the altiplano have wide global resonance. In South America, the integration of farmer aspirations with positive environmental management has become a serious issue in another major biome - the Gran Chaco. This region of more than 1.3 million km² extends over parts of Argentina, Bolivia, Paraguay and, marginally, Brazil. The original landscape of the region was mostly a park land with patches of hardwoods intermingled with

grasslands. Increasing human encroachment, largely by poor campesinos, with associated overgrazing, excessive timber harvesting, charcoal production and over-exploitation of wildlife, is transforming the region into a dense and unproductive shrub land and is contributing to increasing rural poverty (Bucher and Huszar 1999). A management system for the sustainable use of the Chaco has been developed based on a multiple-species ranching system that includes beef, timber, charcoal and wildlife production. An evaluation of the management system found that it is capable of protecting and enhancing the resource base, while providing higher economic returns in a sustainable manner. However, high initial costs, as well as a divergence between the "best" interests of campesinos and society, threaten to jeopardize the feasibility of the managed system.

As in the Chaco, wildlife conservation in the Venezuelan llanos has traditionally concentrated on the establishment of national parks and reserves. However, it is recognised there that conservation needs to be practiced on a wider scale if more than a small proportion of the area's natural habitats and wildlife are to be preserved (Hoogesteijn and Chapman 1997). It has been suggested that managing large livestock ranches in the seasonally flooded llanos to encourage more wildlife could provide significant additional income as well as play a major role in wildlife conservation. In this area there is significant potential additional income for ranch owners through regulated capybara (*Hydrochaeris hydrochaeris*) and caiman (*Caiman crocodiles*) exploitation. The economic benefits of capybara and caiman harvests can be realized only by protecting wildlife habitat.

In South America, the sustainable use of wildlife is increasingly seen as the way forward for tackling the dual problems of decreasing biodiversity and rural poverty, particularly outside the National Park system.

In some African countries the intense pressure to improve rural livelihoods has led to moves to open up protected areas and even national parks for low-intensity use by the local population. It is argued that there has been too much land set aside for wildlife in the past (Prins 1992) This conflict in land-use has been noted by conservation authorities, and proposals have been formulated to give way to such pressure. Moreover, it has been suggested that there can be a harmonious coexistence between

wildlife and livestock, so that opening-up of protected areas would not necessarily be to the detriment of wildlife. Indigenous populations were able to coexist with wildlife and their habitats in the past, so why not again in the future? It has even been suggested that 'conservation is an alien concept in Third World countries' (Prins 1992).

The conservation debate in Africa reflects the dynamics of the competition between two polarized land-using philosophies. First, there are conservationists managing wildlife and the habitat of the wildlife in “parkland”. Secondly, there are agro-pastoralists living in the vicinity of the wildlife habitat, whose land use is referred to as “rangelands”. The parkland is used for tourism production and hunting, while the rangelands are used for agropastoral production. Both agents would find it beneficial to expand their land use, so there is a land use conflict (Schulz and Skonhoft 1996). The park manager has economic incentives to conserve the wildlife. The management policy, however, does not take into account the damage caused to the production of the agropastoralists by the wildlife roaming freely in and out of the park (Skonhoft 1995).

The polarised debate that continued throughout the 20th century - the preservation of "wilderness" versus the wise use of "natural resources." Has in many parts of the world moved on to a more inclusive, holistic philosophy of conservation that emphasizes a harmony between human economic activities and ecosystem health (Leopold). Conservation via wilderness preservation is increasingly less viable, especially on a global scale, than conservation via sustainable development (Callicott 1991).

In the altiplano, the conflict between land use within and outwith the national parks is less acute than in Africa. The extreme constraints on primary productivity in the altiplano place severe limits both to pastoralism and to biodiversity. The pressure of population is relatively low in the altiplano, particularly in areas designated as National Parks, and the number of species in competition with herders is also low (3 species of wild ungulate) in comparison with both tropical South America and sub-Saharan Africa. The altiplano is thus an ideal simplified case study in wildlife sustainable use.

A context for research

There are three basic alternatives for vicuña management that are being considered in the altiplano. Large-scale ranching (Perú, Chile), sustainable use of wild animals (Bolivia, Chile) and farming (under contract)of semi-domesticated vicuñas (Argentina). Each of these systems has its advocates, and it is by no means clear yet which will predominate in any of the countries in the future.

Whatever the system, sustainable use of vicuña is still seen to have great potential to contribute to economic development throughout the altiplano (Wheeler and Hoces 1997). However, in spite of considerable public and private investment, examples of significant returns being generated for indigenous communities are few (Lichtenstein *et. al.* 2002). It is clear that if the hopes and aspirations of these communities are not fulfilled, there is a danger that the attraction of illegal hunting will outweigh the perceived advantages of sustainable use. If wide public support for vicuña conservation is lost, then the effectiveness of the conservation strategy will be compromised, and the cost involved of enforcing protection legislation will escalate.

Vicuña conservation in the 1970s succeeded by prohibiting commercial use, and enforcing the legislation by establishment of national parks and deployment of patrols of guards. This intervention broke the link between international market demand for the product and unsustainable exploitation, and created a breathing space for the recovery of populations, and the expansion of range. This resurgence of vicuña was not uniform throughout the altiplano, and was probably mediated in each area by a combination of different factors including primary productivity, competition with livestock and tolerance (or lack of it) on the part of altiplano communities to the recolonisation of their territory by the vicuña.

The move to introduce sustainable use proceeded at different rates in different parts of the altiplano and took different forms reflecting the dynamic in each area of the interplay between conservation and development interests (and the interaction of these with land tenure).

Given the relative simplicity of the altiplano ecosystem, it ought to be possible to test some assumptions about the driving forces behind population regulation in vicuña, and the interactions between wild herbivores, livestock and people. Such a study will place vicuna ecology firmly within its abiotic, biotic and social contexts.

A spatial analysis of vicuña ecology and their interaction with campesino activities

The near extinction of vicuña in the 2 year period prior to 1970 can be thought of as having left large areas of suitable habitat either free of vicuña or with vicuña at population densities well below carrying capacity. To a certain extent, reduced vicuña grazing pressure was probably replaced by increased livestock grazing in the same period, so total resource utilisation may not, at least on the flush meadows (*bofedales*), have changed much compared to pre-crash levels.

The population crash appears to have been relatively even throughout the altiplano, such that the condition of low vicuña population density with high availability of habitat applied across all the countries contemporaneously. Nineteen seventy was a vicuña Year Zero.

During the years following the introduction of protection measures, the vicuña began to expand in range and population density to fill the available habitat. This process was probably centred around the reserves at first, as these offered more protection from illegal hunting. It was also assisted, in Perú at least by restocking programmes. In time, the vicuña has expanded its range far wider than the national park systems (Bonacic *et. al.* 2002; Rabinovics 1985; Svendsen 1987) The expansion has not been even, however, and has apparently been more successful in some regions than others.

During a period of rapid expansion it is possible to look at the pattern of distribution formed by these uneven colonisation rates in different areas. By comparing colonisation with available habitat, and with patterns of habitation and livestock distribution, it ought to be possible to discern which of these three factors plays more of a role in determining distribution, at least on a broad scale. With this information we can identify areas in which different factors predominate. Taking the hypothesis that vicuña will colonise, in the absence of other factors, habitat of equal productivity

at an equal rate, we can identify areas in which vicuña density is correlated negatively with livestock density. Similarly we can identify regions which have either elevated or depressed densities of vicuña apparently independent of livestock density.

This information will form the empirical basis for a survey of campesino households to establish the general feeling about vicuña in the area – how the farmers rate the impact of vicuña on livestock. Do they see vicuña as a real or potential resource, or an important part of their heritage, for example.

This approach will allow us to build up a picture of the variation in the level of tolerance to the (re-)colonisation by vicuña on the part of the campesinos, with a real possibility to link this to observed variation in the success of that colonisation. With luck, the interviews may shed some light as to the most likely mechanism(s) by which resistance to colonisation was effected – for example, by competition with livestock, scaring off or hunting, or maybe natural factors, such as predation.

There are a number of key questions that ought to be well understood by policymakers. All have a strong spatial component as the answers appear to vary depending on location within the altiplano region:

1. What is the actual and potential extent of the resource?
2. What is the impact that people and their livestock have on vicuña conservation now? Is this different from the past, and how is it likely to change in the future?
2. Can sustainable use deliver benefits for vicuña conservation? Does the permission to harvest vicuña wool influence communities' attitudes to the vicuña?

It is proposed that these questions form the core of research in this thesis. They lie at the heart of the sustainable use v. conservation debate. The spatial analysis of this data will inform not only government agencies developing sustainable use in the altiplano, but also the wider scientific community interested in the dynamics of rural development and wildlife use.

Structure of the thesis

The investigation of the socio-ecological interactions of vicuña and campesino communities is carried out in 3 phases, which, it is proposed, will form three chapters of the thesis:

A. **The potential for harvesting of textile fibres from wild vicuña in the Andes.**

What is the current range of vicuña? What is the extent of available habitat, and what are the criteria for defining it? What is the potential for expansion of vicuña range and population? What would therefore be the likely level of annual fibre production per management unit? How does this compare with current livestock production?

B. **The dynamics of coexistence of pastoralists and wildlife in the high Andes.**

What are the driving forces limiting the rate of vicuña colonisation? What impact do people and their livestock have on vicuña conservation now? Is this different from the past, and how is it likely to change in the future? Are the limits to vicuña distribution ecological or social? To what extent do communities restrict expansion or population density of vicuña? What are the trade-offs that need to be made by rural activities?

C. **The contribution of sustainable use to wildlife conservation in the Andean altiplano**

Can sustainable use deliver benefits for vicuña conservation? Does the freedom to practice sustainable use translate into positive wildlife management actions? What solutions have different regions/communities adopted/considered for vicuña management and why? If conservation effectiveness depends on the goodwill and cooperation of the indigenous communities, what are the main factors which create or maintain this support? Does the permission to harvest vicuña wool influence communities' attitudes to the vicuña? Is attitude to vicuña culturally "ingrained" or is it utilitarian, changing in response to the costs and benefits of coexistence? To what extent are benefits from sustainable use real or imagined?

Distribution of the vicuña in the altiplano

Vicuñas have long been known to inhabit the tropical and subtropical high ranges of the Andes, above approximately 3500m a.s.l. (Koford 1957). Within this potential range, extending for some 3000 km, the vicuña was severely restricted by hunting over a period of about 350 years such that in the 1960s it was in obvious danger of extinction if action was not taken.

Grimwood (1969) described the distribution of the vicuña in Peru as almost extinct north of 13.30°S (Lima) in his report to the New York Zoological Society. He concluded that the few remaining northerly populations were doomed, and "would not persist more than a few years". Based on confirmed sightings of under 2500 vicuñas, Grimwood estimated the population to be between 5,000 and 10,000 animals. At the time, by far the largest concentration of vicuñas in the altiplano was in Lucanas province, Ayacucho, where the Pampa Galeras National Reserve for Vicuñas was established in 1967. The population of the reserve at this time was in the region of 400 to 600 animals. Figure 4 shows the numbers recorded by Grimwood per administrative region of Peru.

The most reason for the depressed numbers and confined distribution is generally agreed to be the pressure from hunting. Trade in vicuña fibre was still legal in 1969 in Bolivia, and exports to Europe persisted until about 1970. Records of population status of the vicuña in the other countries in its range are limited. Census records were kept in Ulla Ulla in Bolivia since 1965, indicating a population of about 500. In Chile, records begin with the first systematic survey that was carried out in Parinacota province in 1975. This suggested in the region of 500 animals.

Since the introduction of protection measures, the pressure from illegal hunting has reduced sufficiently to allow the recovery of numbers and the dispersal of these animals to formerly vicuña-free areas (CONACS 1997; CONACS 2000; CONACS 2002; CONACS 2003; CONAF 2003; D.G.B. 1997).

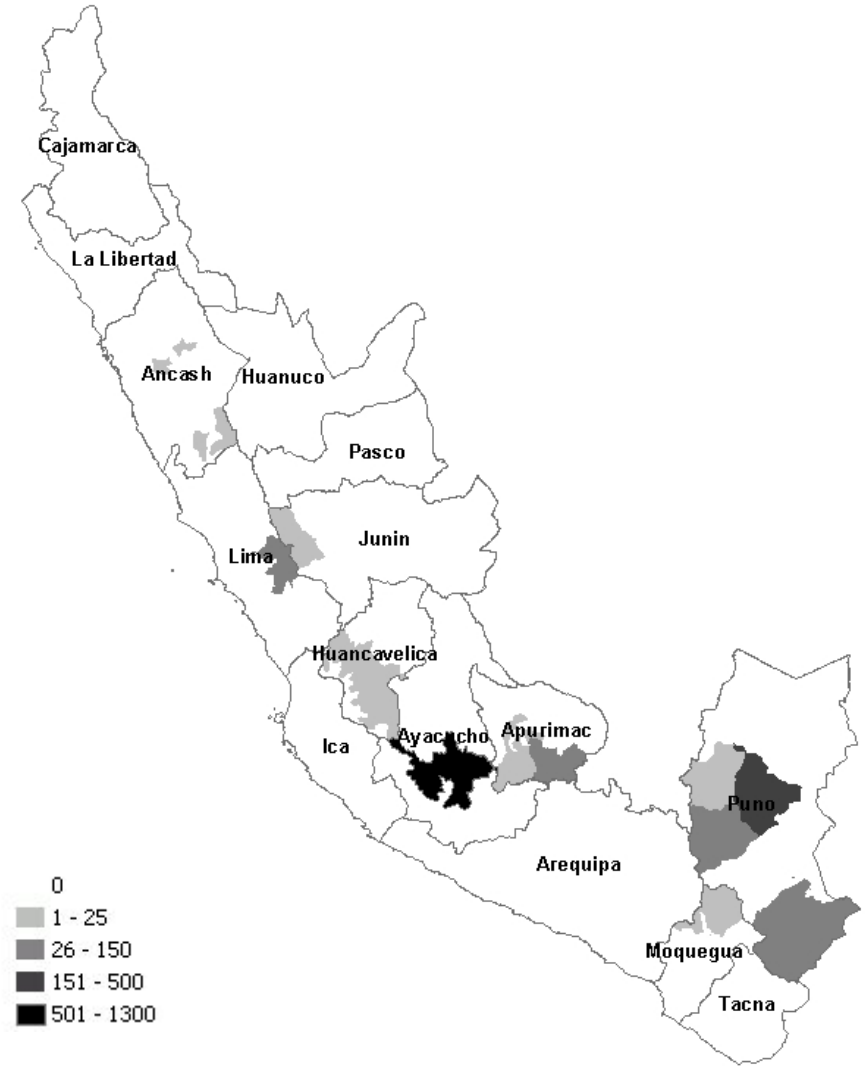

Figure 4. Map showing approximate distribution of vicuña in 1968. Numbers indicated are known numbers observed in each province. Estimated true population at between 2 and 4 times that number (total 5,000 to 10,000)(After (Grimwood 1969)).

The evolution of the Peruvian national population illustrates well this comeback. Figure 5 shows combined data from partial censuses and the three national censuses by INRENA and CONACS. This data is accompanied by area estimates, suggesting that the population density throughout this time series remained relatively constant at around 1.9 per km² (S.D. 0.47). The implication is that growth during this period is explained more by expansion of range than by increasing population density.

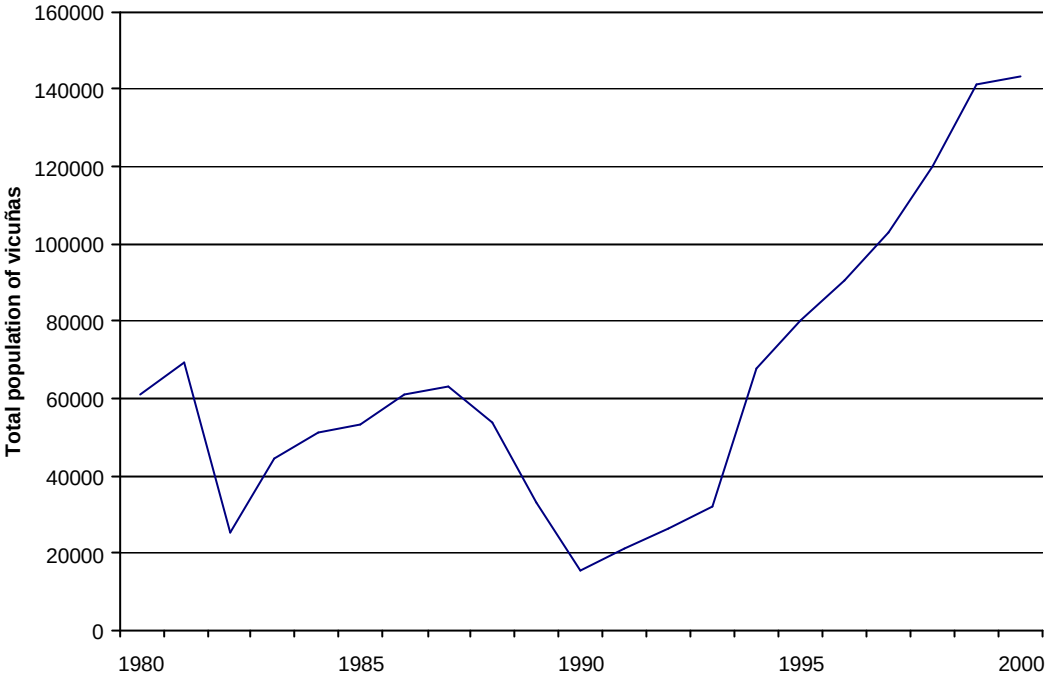

Figure 5 Evolution of the vicuña population in Peru during the period 1980-2000. (INRENA, CONACS)

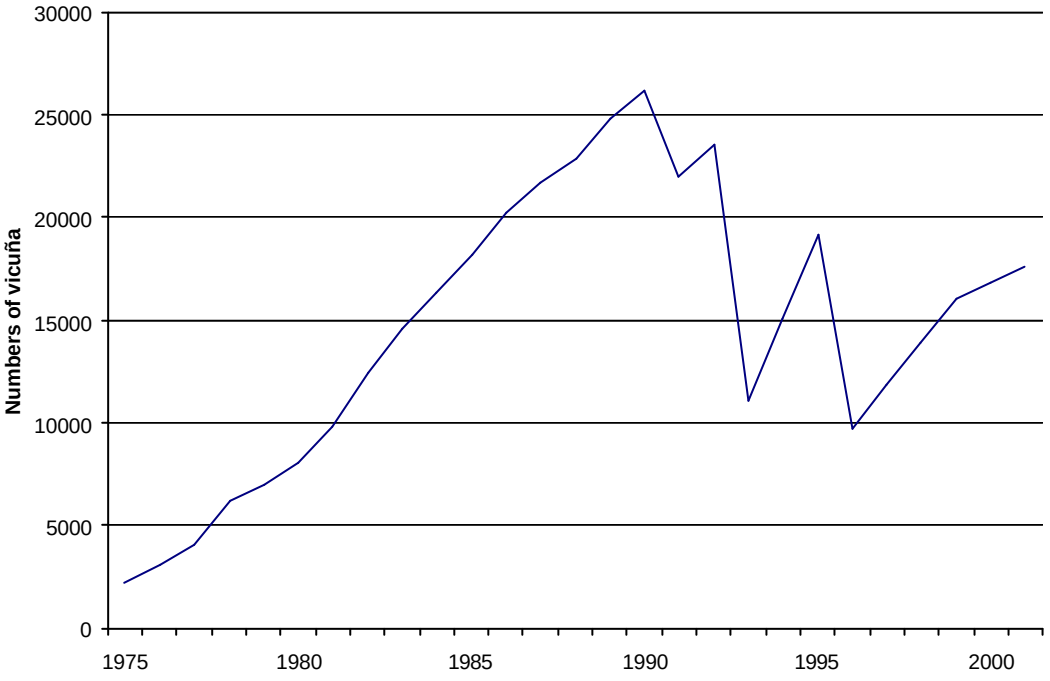

Figure 6. Evolution of the vicuña population in Tarapacá (I Region), Chile during the period 1975-2001. This represents the entire population of V. Vicugna mensalis, and 95% of total vicuñas in the country.

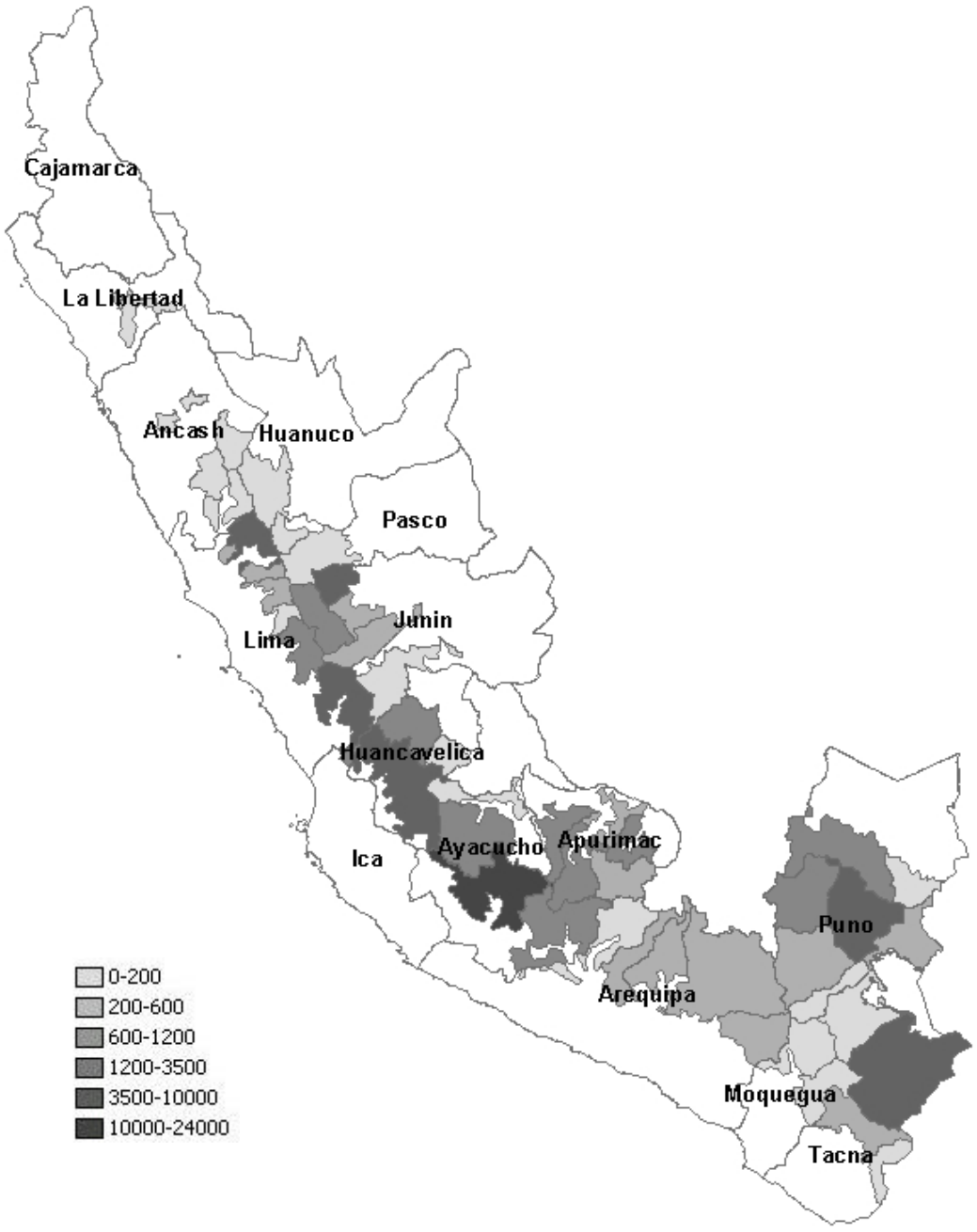

Figure 7. Census results 2000. Total population. 118678 head. Distribution shows administrative region clipped by 3500 m contour to reflect more closely actual distribution. Population illustrated per province. Labels indicate departments.

In Chile, the Parinacota population increased over the same period (Figure 6). After a 15 year period of rapid growth the population stabilised, demonstrating a classic density dependent response (Bonacic *et. al.* 2002). This population represents some 95% of the Chilean vicuñas.

Figure 7 shows the distribution of vicuña per administrative region of Peru in 2000. The species can be seen to be present in all departments that have land over 3500 m.

Taken together, the published census data allows relatively detailed view of the overall distribution of the vicuña in the altiplano. Figure 8 shows population figures taken between 1994 and 1997 in the different countries. The censuses suggest three main focal areas for vicuña populations: Lucanas in Peru, Parinacota in Chile, and San Guillermo in San Juan province in Argentina.

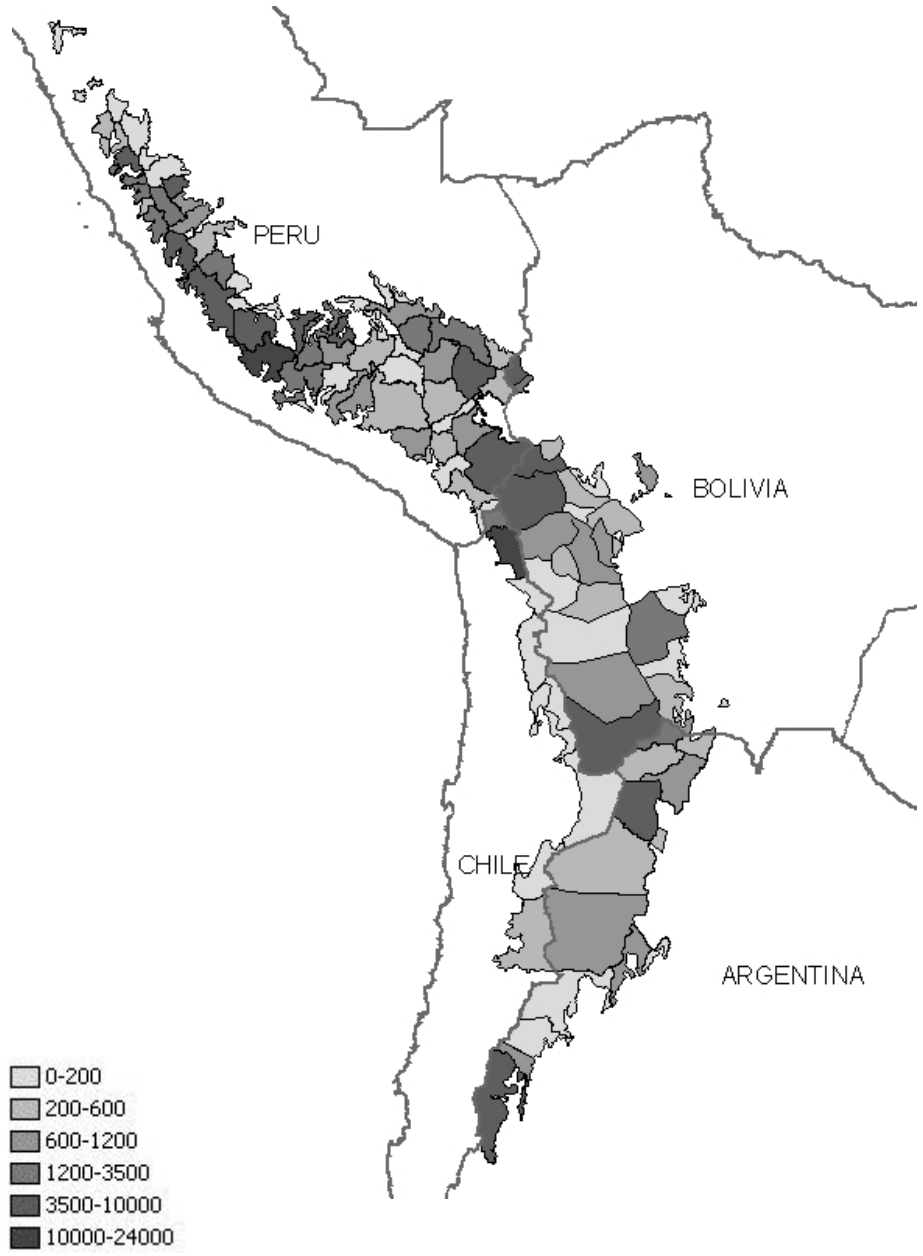

Figure 8. Population census records for vicuña throughout the altiplano – mid 1990s. Administrative boundaries are shown cut by 3500m contour. Total population, 178,615 head.

The use of administrative boundaries to map census results tends to obscure the fact that populations of vicuñas, and to an even greater extent the censuses, are patchy in their occurrence. Using administrative boundaries is a convenient and simple tool to display the data. It is to be hoped that more specific maps will become available during the course of the fieldwork to allow more spatially specific information to be included, such as the locations and extent of each census area. This higher spatial resolution is important for the analysis of habitat use, and the projection of hypothetical future populations.

Methods

This thesis sets out to establish an empirical basis for the evaluation of the contribution that sustainable use of vicuña makes to the continued conservation of that species. The project comprises three main actions:

- Establish a database of vicuña distribution and population throughout its range, and the ecological basis for observed changes in distribution and population.

- Evaluate the degree to which human activities have influenced that distribution, and the possible mechanisms for such influence

- Assess the impact of sustainable use on those activities

These three areas are addressed separately, but their results will mesh together as an integrated multidisciplinary approach.

Population data

The *Convenio para la Conservación y Manejo de la Vicuña* established the need for all the signatory parties – the governments of Chile, Peru, Argentina, Bolivia, and later Equador – to keep records of their populations of vicuñas. The extent to which this has been achieved varies from country to country, but compared with other

wildlife species the combined effort has provided a substantial amount of data on vicuña population, and distribution since about 1975.

Peru

Three national censuses are available – 1994, 1997 and 2000 (CONACS 1997; CONACS 2000; INRENA 1994) . The 1994 census reports numbers of vicuña at the level of 14 departments covering an area of 6.5m ha. The original census sheets are available for this data, but contain limited geographical information that would help to improve the resolution of the data set. The 1997 and 2000 censuses report vicuña numbers down to the level of community, and thus offer a higher level of resolution (Figure 9). Though there appears to be much overlap, there are many communities that appear in either one census or another. A map showing the community boundaries that can be linked to the published data has yet to be located either in digital or paper form. Few of the census forms report the area of the census survey. On a wide scale, therefore, any analysis that involves density is likely to be extremely unreliable. Summaries made by CONACS that do include densities my have been achieved using expert knowledge, rather than field reports.

At a more detailed level, 1:25,000 maps showing the census areas in a number of locations were obtained from CONACS as photocopies. Although in theory these can be linked to the original census forms, the majority of the (in excess of 6,000) forms carry no unique identifier, which may complicate the mapping of this data. Records have been kept by the park authorities at Pampa Galeras (Figure 10), the province with the highest concentration of vicuñas, since 1970 on an annual basis till present in the nucleus zone, and on 5 other nearby sites on a less regular basis. Paper maps at 1:25,000 were obtained from CONACS and digitized at the Universidad Católica de Chile. Only outline census data has been obtained to date, but the detailed dataset should be available when a visit is made in April 2004.

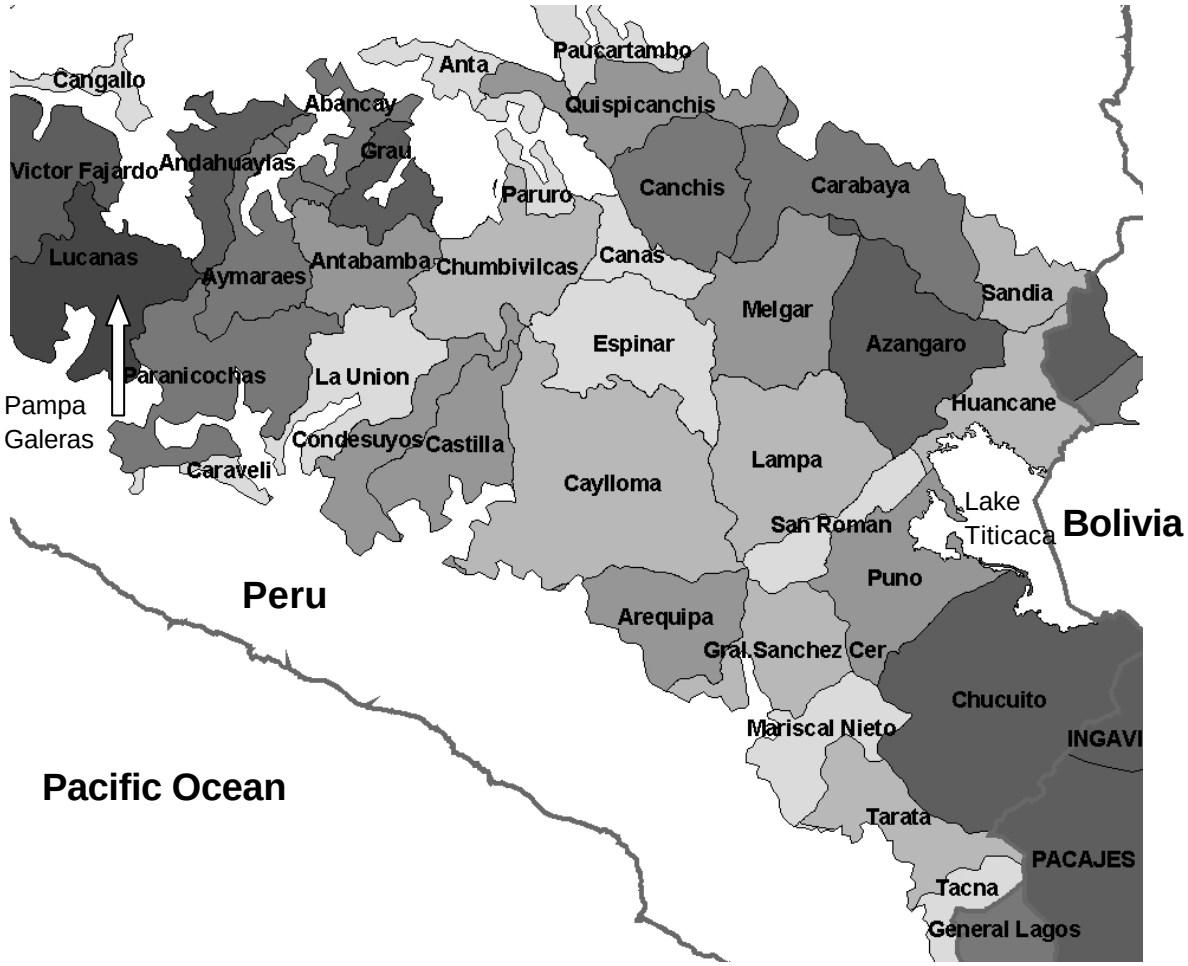

Figure 9 Detail of Southern Peru showing simple data from 1997 census. The administrative level shown is the Province, with boundary cut by 3500m contour to more accurately reflect vicuña distribution.

The census records themselves offer a breakdown of the most obvious social classifications. Males with family groups, females in family groups, cria (< 1 yr), number of bachelor groups, number of vicuña seen in bachelor groups, and solitary (males). This is similar to the structure of the censuses carried out in Bolivia and in Chile. The location of the census is given as sectors within communities, though maps are not available to give precise outlines of census areas. Censuses are presented as total counts, though there is little evidence to justify this. The absence of any detail of sampling methodology makes it impossible to evaluate the degree of error in these censuses. The best that can be concluded is that within each of the administrative zones censused there are at least that number of vicuñas. The national figures can thus be treated as minimum numbers of vicuña present. The relative proportions of

different social categories ought to reflect well the real proportion, at least, as no one category is favoured by the counting system.

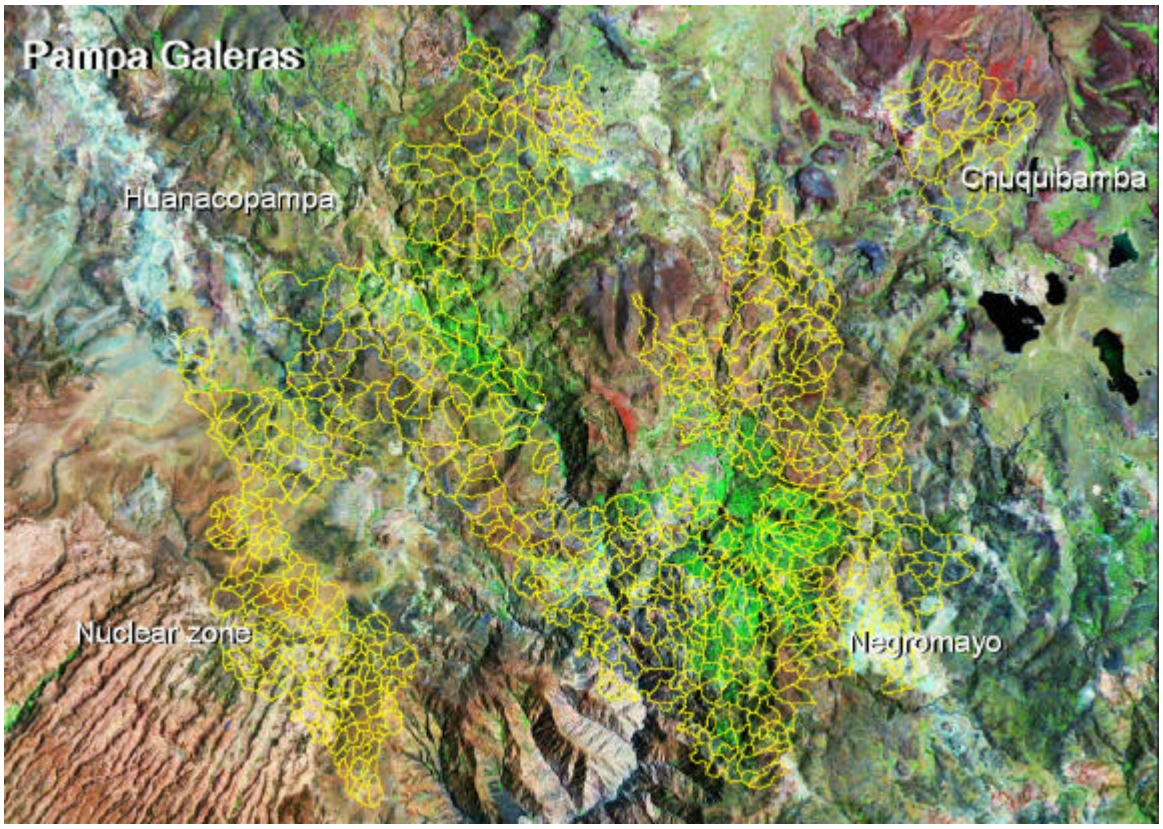

Figure 10 Census areas in Reserva Nacional Pampa Galeras are divided into tour management zones.

Chile

Ninety-five percent of the vicuñas in Chile are concentrated in the I Region (Tarapacá), in the *Comunas* of General Lagos and Parinacota (Figure 11). There are three protected areas: Parque Nacional Lauca, Reserva Nacional Las Vicuñas, and Monumento Natural Salar de Surire. Three vicuña management zones overlap the area, Caquena, Lauca and Las Vicuñas, with the greater part of the Caquena management zone lying outside the protected area (Figure 12). The management zones cover an area of some 5752.5 km². Maps of the layout of the Chilean management zones are given in greater detail in Appendix 1.

Data are available on an annual basis from 1975 to 1993, and then more irregularly to present. The dataset is available with the permission of CONAF, who collected it. Some doubts are expressed locally about the accuracy of some of the years pre-1993, when measures were introduced to cross-check the work of the *guardaparques* in their counting of vicuñas. On the other hand the Chilean dataset is the best available long term record of population data that exists. There are stable census zones, with regular sampling periods.

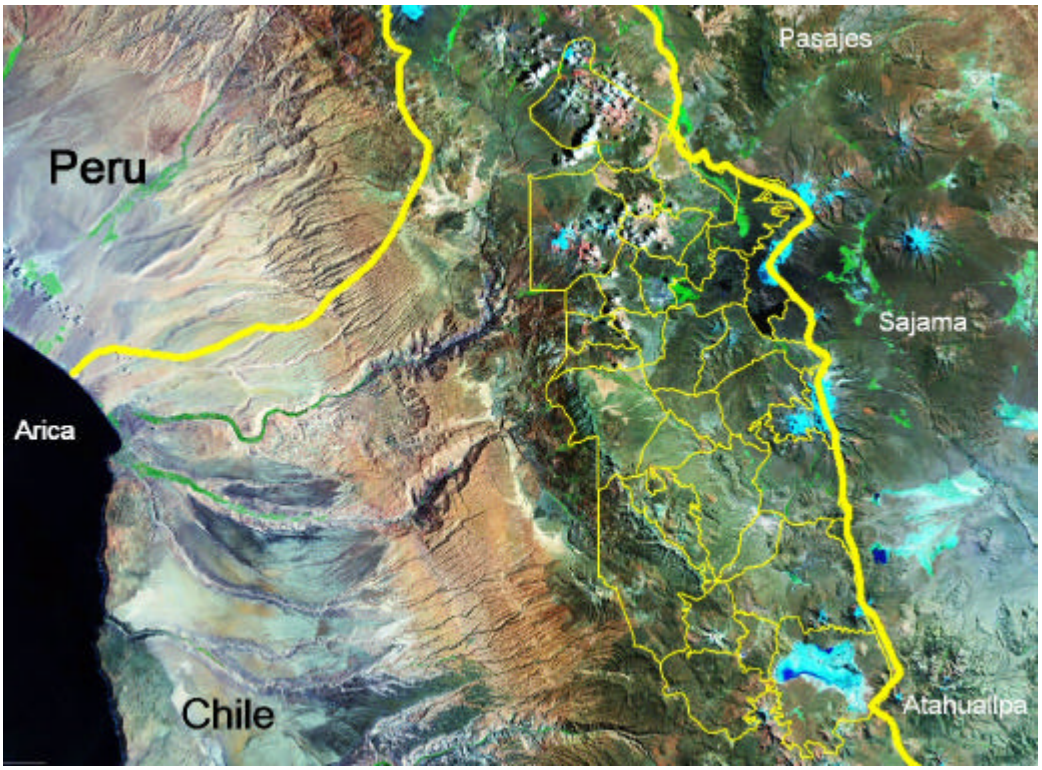

Figure 11. Landsat TM image of northern Chile showing location of the census areas for vicuña. Altiplano vegetation appears olive green, Light blue areas are either salt lake or snow.

Figure 12. Detail of vicuña management zones, (left, shaded) and protected areas (right, outlined) in the I Region of Chile

Bolivia

There is one official national census published in Bolivia (D.G.B. 1997). However, records have been kept in the individual vicuña management areas since around 1975 (and in Ulla Ulla, also known as Apolobamba, since1965). Vicuñas are subject to management in three main areas. Ulla Ulla, straddling the provincial border between Franz Tamayo and Saavedra, to the north of Lago Titicaca, Mauri Desaguadero, also in the Region of La Paz, to the south of Lago Titicaca, and Lipez-Chichas on the border with Argentina to the South (Figure 13). The latter area has the southern subspecies of vicuñas (*Vicugna vicugna vicugna*), as in Argentina, while the other areas have the northern subspecies (*Vicugna vicugna mensalis*), as in Peru.

Within the region of La Paz, the 26 protection areas are mapped, and these maps will become available, as will the time series data for Mauri Desaguadero and Ulla Ulla. It is anticipated that the detailed data will be sourced during a field visit in April 2004.

Figure 13 . Administrative regions (*provincias*) of Bolivia showing density of vicuñas (vicuña/km²) per area censused in 1997.

Argentina

Argentina has had no national census to date. The evaluation of vicuña numbers has been done on an ad hoc basis using numbers produced irregularly by the 4 federal provinces involved – Jujuy, Salta, Catamarca, and San Juan. The detail of these censuses is not published, but may become available if a site visit is made. A number of published censuses have been undertaken (Anon. 1993; Argentina 1988; Canedi and Virgili 2000; Muspratt *et. al.* 1996), that taken together at least give an indication

of the approximate distribution of vicuñas (Figure 14). Maps are also potentially available of the protected areas where vicuña are found.

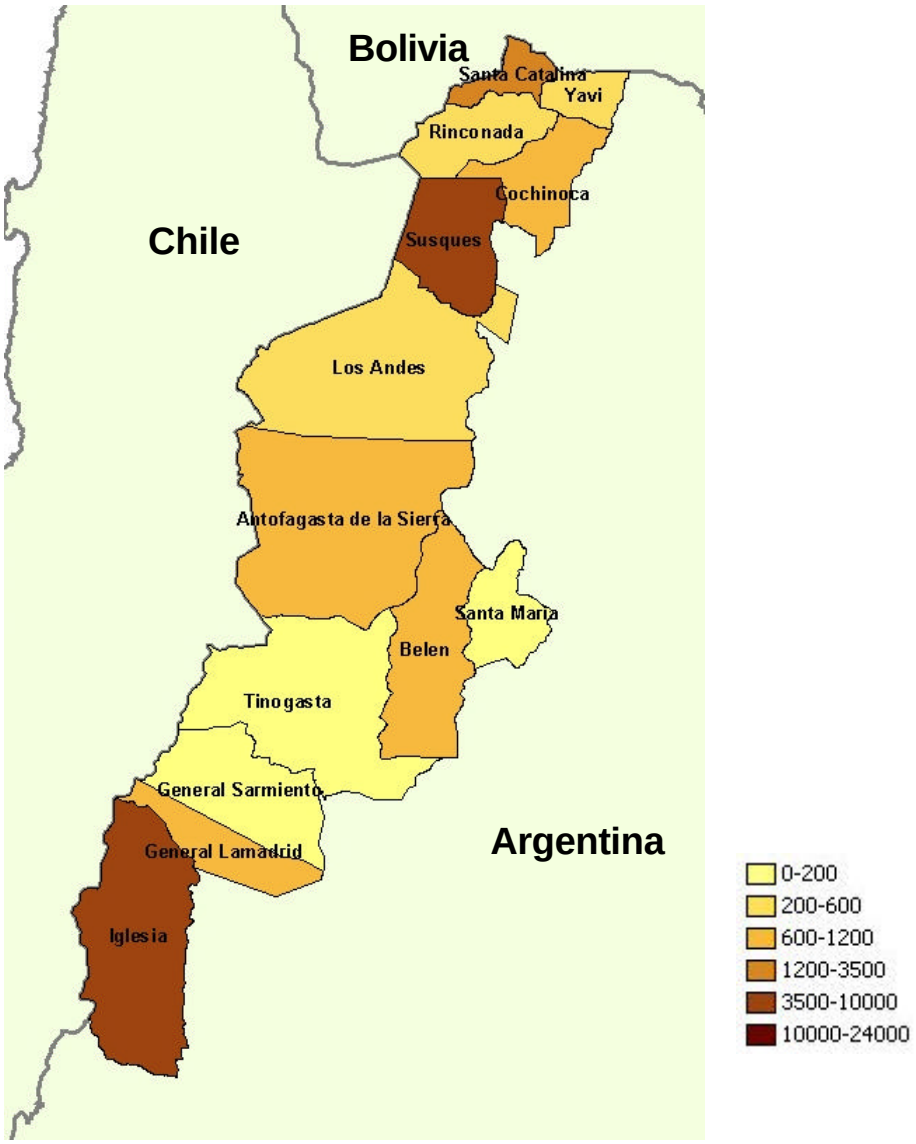

Figure 14. Administrative regions of Argentina showing combined census results taken between 1994 and 1997.

Detailed local level census data is being generated from ongoing scientific work in Cieneguillas, in Santa Catalina, and in Antofagasta de la Sierra (Catamarca - Reserva Nacional Laguna Blanca).

Spatial ecology of the vicuña

In order to evaluate the impact that past and ongoing human activities have had on the distribution and population of the vicuña, it is important to have a firm understanding of the species´ basic ecology. The important elements of this ecological knowledge are:

- The intrinsic rates of vicuna population growth
- The relative importance of density dependent and independent factors in transforming this potential growth into observed changes in numbers.
- The rates of dispersal and the dynamics of distribution change
- The level of interaction between vicuña and domestic livestock

The vicuña is territorial. Dominant males will defend a harem of between 2 and 8 females and a grazing area marked generally by scent in communal dung piles (Franklin 1974). In spite of diurnal movements to overnight areas, the territories are thought to be stable and persistent, usually securing access to grazing resources for the family group (Vila 2002). In the period pre-parturition – Nov-Dec – there is a tendency for greater territorial instability, as young males and females are ejected from the family groups. The fate of young females at this stage is not well documented, largely because the sexes are difficult to distinguish from observations at a distance. It is probable that a proportion of those animals recorded as bachelor males, are in fact female, and that young females running with these groups are the main agents of migration and colonisation of new areas. This theory however, remains conjecture.

Colonisation of unpopulated areas by vicuna does, however, without doubt take place, and in an animal so markedly territorial, the diffusion of animals following spatial variations in food availability for example is probably confined to brief periods of the year, such as the pre-parturition time, as young are ejected from the family groups. Though this is also the main time when censuses are carried out, juvenile females outside the family units are not distinguished. In the absence of a clear idea as to the mechanisms of diffusion of vicuñas in space, it is still, however, possible to build up a

quantitative picture of the dynamics of population growth and movement from annual census data.

The density dependant nature of regulating factors, such as food availability was demonstrated by Bonacic et al. (Bonacic *et. al.* 2002). This study cited lowered fertility of females in larger family groups as the principle density dependent factor. The identification of density dependence was based on the plot of growth rate against population size (Figure 15).

Though undoubtedly the observation of density dependence in the behaviour of the vicuña population as it regained its former level is correct, the mechanisms by which such density dependence is achieved are not so clear, and demand closer investigation.

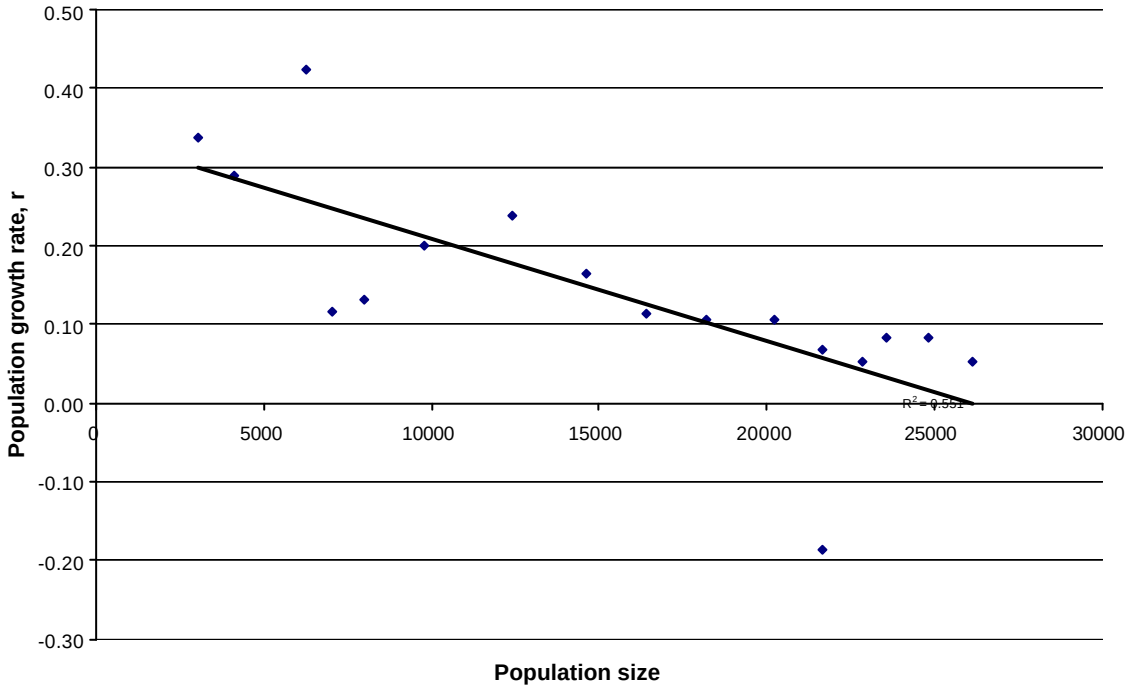

Figure 15. Population growth rate declines with increasing population. The classic test for density dependence. (after (Bonacic *et. al.* 2002)).

The analysis published by Bonacic et al. was based on total counts for the whole study area. Some 100 km in length, and covering an area of 5752.5 km², the study area has uneven topography and vegetation growth, and it is clear that the vicuña are far from homogeneously distributed within it. Nor is the distribution of forage availability

static from year to year or season to season. Given the patchy distribution of vicuña, density dependent mortality factors are unlikely to be impacting evenly across the study area. Neither will such factors act to the same degree in the same place from year to year. The detail of density dependence and its mechanism of action is central to an understanding of the vicuña's ability to take advantage of ecological opportunities as they present themselves, and to expand in range when conditions are favourable.

It is particularly important that the investigation of the population dynamics of the vicuña is made in the context of the anthropogenic environment in which the vicuñas are found. In particular, the presence of livestock, though known not to have a complete niche overlap with the vicuñas, will nevertheless have an impact on the availability of forage for vicuñas on the areas of most productive land. The extent of the competition with livestock is not limited to direct competition for resources, and, possibly, space. Perceptions of competition on the part of the campesinos appear to be a major stimulus for actions to limit the numbers of vicuña on their land. In the context of the Chilean altiplano, the extent of poaching is relatively low (CONAF, Pers. Comm..). However, recent experience in Argentina has demonstrated that illegal hunting remains a serious threat (Barbarán 2002)

This study attempts to demonstrate some of the key characteristics of vicuña (*V.v. mensalis*) ecology in Chile in a form that may later be compared and contrasted with other field sites in Peru and Bolivia. This knowledge will later form an empirical basis for establishing the extent of deviations from expected levels of population. It will also be used to establish the potential limits of wild vicuñas as a resource base for mountain communities.

Population dynamics of the vicuña in Parinacota (Chile)

Censuses were carried out on a near annual basis during the period 1975-2001 on 32 sites in the altiplano of Arica in northern Chile. The census areas remained unchanged from year to year, and the counts distinguished between males with families, females, young (<1 year), bachelor males, family groups and bachelor groups, and single males. During the mid 1990s, there was a period during which censuses were carried

out incompletely, and irregularly. The period until 1992 is uninterrupted, and is also the period on which other published work is based. The following analysis will therefore use this time limit, with a view to extending the analysis at a later stage to include the 1999 – 2001 censuses.

At the time of census in December-January, most cria are approaching one year old, and have survived their first winter – probably the period in their lives of highest mortality. Natality is not recorded.

Vicuñas in the second year of their lives are classified in the census as "adult". Most probably, the females do not reach sexual maturity until age three. Thus, the first adult cohort is non-reproductive. The reproductive life of a female vicuña will last until she is between 7-10 years old (B. Vila, Pers. Comm.) This means that each adult vicuña will live for about 4-7 breeding cycles.

The data collected during the period 1975- 1993 record a period of rapid expansion of the population, and its subsequent stabilisation – see Figure 16.

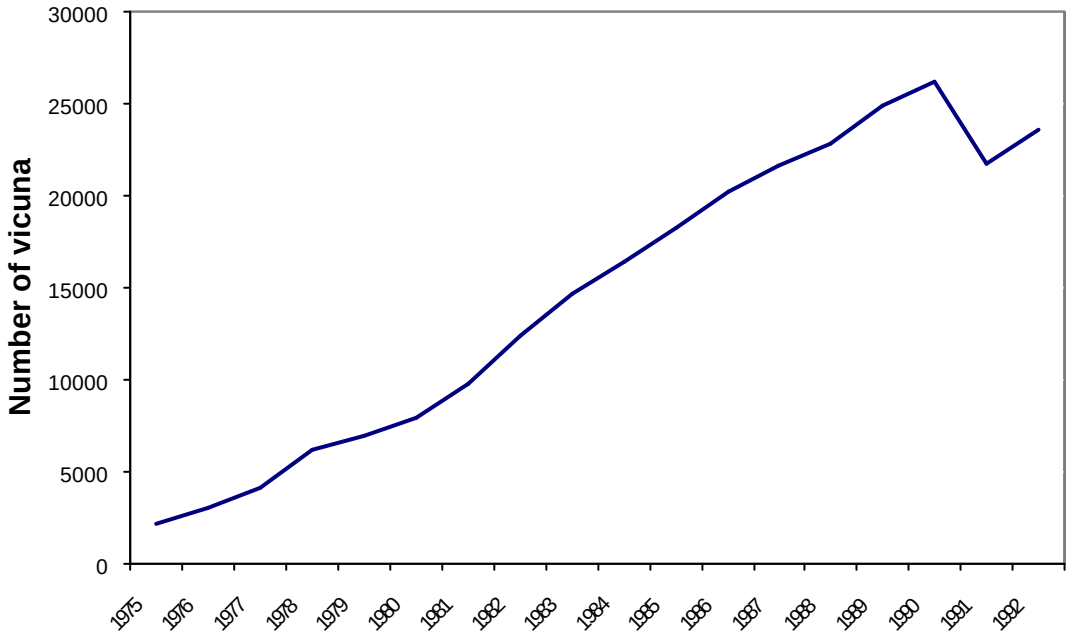

Figure 16. Evolution of population of vicuña in Parinacota province during the period 1975-93.

It appears that this expansion occurred as a direct result of the relaxation of hunting pressure that accompanied the establishment of Lauca National Park in 1975. The population appears to grow linearly during the period 1975-90 by 1696 individuals per year (r^2=0.9928). In itself, this deviation from the logistic growth curve suggests increasing pressure from some density dependent factor(s) that is progressively limiting population growth as time advances. Further evidence for density dependence is seen in subsequent years, where a more stable fluctuating population level is reached (Figure 17). Bonacic et al (2002) estimated the carrying capacity at between 22-26,000 animals.

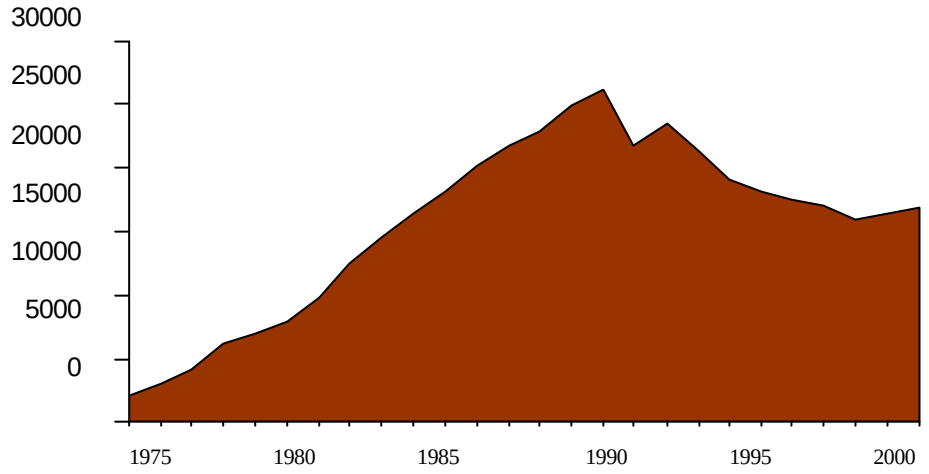

Figure 17. Population change in the Parinacota population, 1975-2001 (data smoothed to compensate for missing records).

The intrinsic rate of population growth describes the potential of a species to expand in population in the absence of factors that would restrict this growth. In most situations, this is rarely found in nature, but the concept is useful for projecting forward possible future population size at some point in the future. Commonly the annotation for per capita rate of growth (discrete) is ?, and it is derived from:

$$N_{t+1} = ?N_t$$

Where N_{t+1} is the predicted population resulting from population N in year t that grows at rate ?. The equation to give N at any time period in the future is:

$$N_T = N_0 ?^T$$

The growth rates of the individual census units averaged 1.18 per year (n=280) during the period 1976-1992, with a range between 0 and 3.8. As growth rate is a geometric, not linear function, there is an apparently progressive density dependent function acting on this population.

However, re examining the information on growth rates on a per census unit basis, we find that the relationship identified by Bonacic (Figure 15) between growth rate and population breaks down (Figure 18).

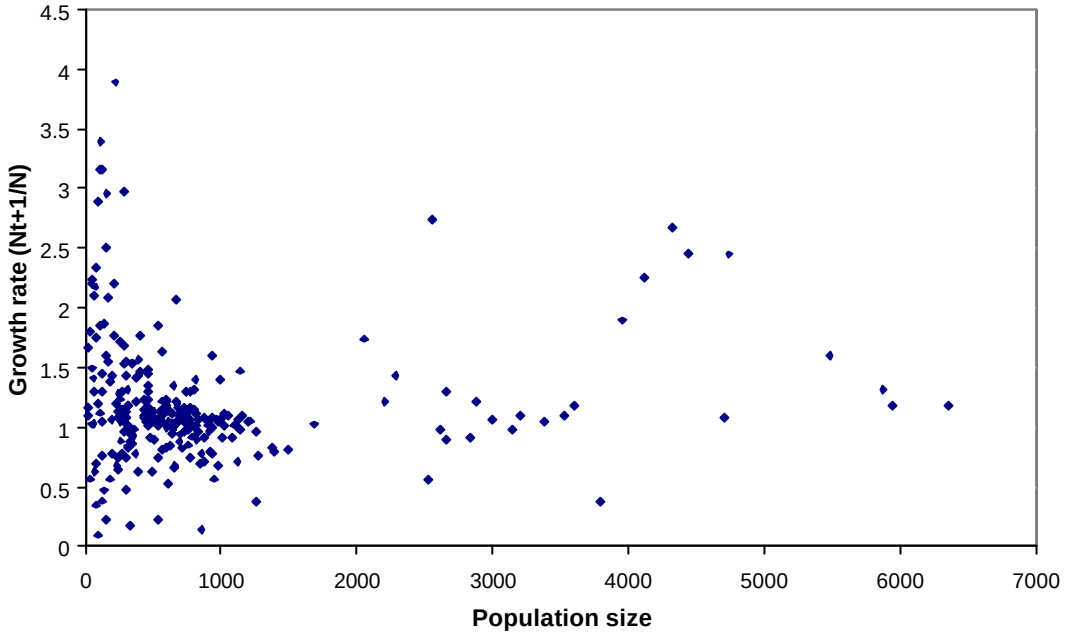

Figure 18. Relationship between population growth rate and population size on a per unit per year basis showing no obvious relationship.

This analysis suggests that there is some other factor acting locally that obscures the general view of density dependency.

In order to identify the variables that contribute to the greatest extent to the variation in population recorded, the observed census counts were compared to the model:

$$f_{t+1,i} = a_i cria_t + b_i f_t - f\ density - relative\ density$$

Where the number of females in year t+1 equals the number of females (f_t) surviving (b) from year t, plus the cria surviving (a) from year t less a function related to female density less a function relative to the relative density.,

This relative density term describes the difference in mean population density between the vicuñas in a census unit and those in the neighbouring units. This is simply calculated as the density in an area less the mean density of the neighbouring units, and is positive when the unit has consistently higher population density than its neighbours. The mean of this value for all the years of the study gives a measure of the degree to which an area consistently supports a higher density of vicuñas than its neighbours. Also, by inference, this is a measure of the tendency for vicuñas to emigrate from or immigrate to each of the units. The distribution of these areas, which may or may not represent sources and sinks, is shown in Figure 18.

The analysis (see appendices for details) indicates that the observed variation in the population of females is to the greatest extent explained by the number of females in the previous year. This result is to be expected, but at least confirms the observation that the species is generally sedentary.

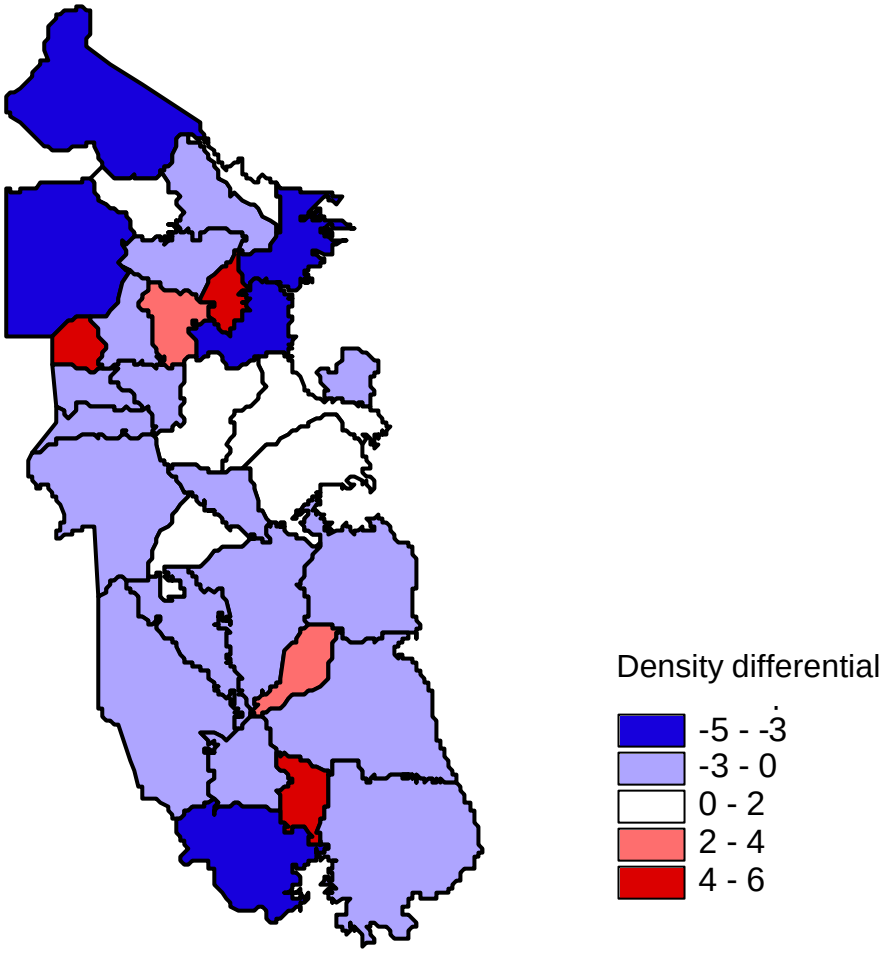

Figure 19 Map of Parinacota showing census units with consistently higher population density (red) or consistently lower population density (blue) than the mean of their neighbours,.

Yearly variation in cria abundance explained a significant part of the observed variance. This effect appears not to be related to rainfall patterns (r=0.00004). However, the cria abundance does not appear to vary with density (Figure 20)

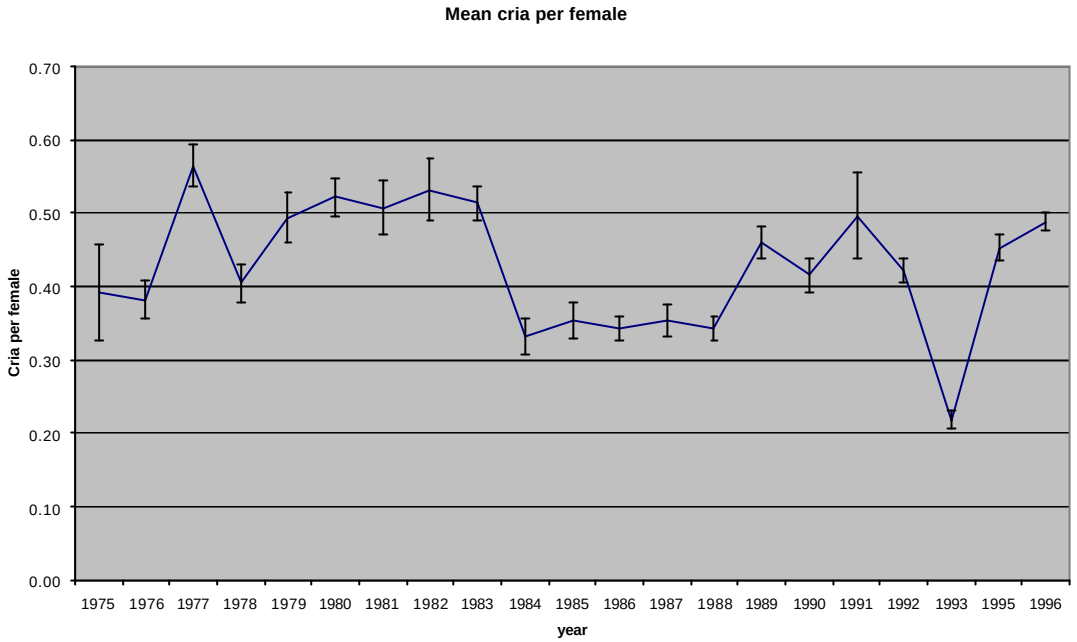

Figure 20. Annual variation in reproductive rate in Parinacota.

Density, as the total number of vicuñas per unit habitat (land less than 5000m a.s.l.) did not explain observed variation in female abundance. However, the derived term, Relative Density, explained only slightly less than cria abundance.

This observation provides evidence that the movement of animals, probably outward from source areas to sinks, has a strong influence on determining vicuña abundance. If this is the case, then the movement to sinks implys the colonisation of less favourable habitat by marginal vicuña families. As population increases, so new males establishing territories are forced to use less favourable (or smaller) territories. Restriction of access to resources will make marginal family groups more vulnerable to adverse weather than established groups on more productive sites.

In this context it is interesting to note that though there is a low correlation between reproductive rate and rainfall, the peak and crash of the vicuña population followed a period of four years of below average rainfall (Figure 21). It is possible that the progressive depletion of groundwater during this period had a cumulative effect on bofedal productivity.

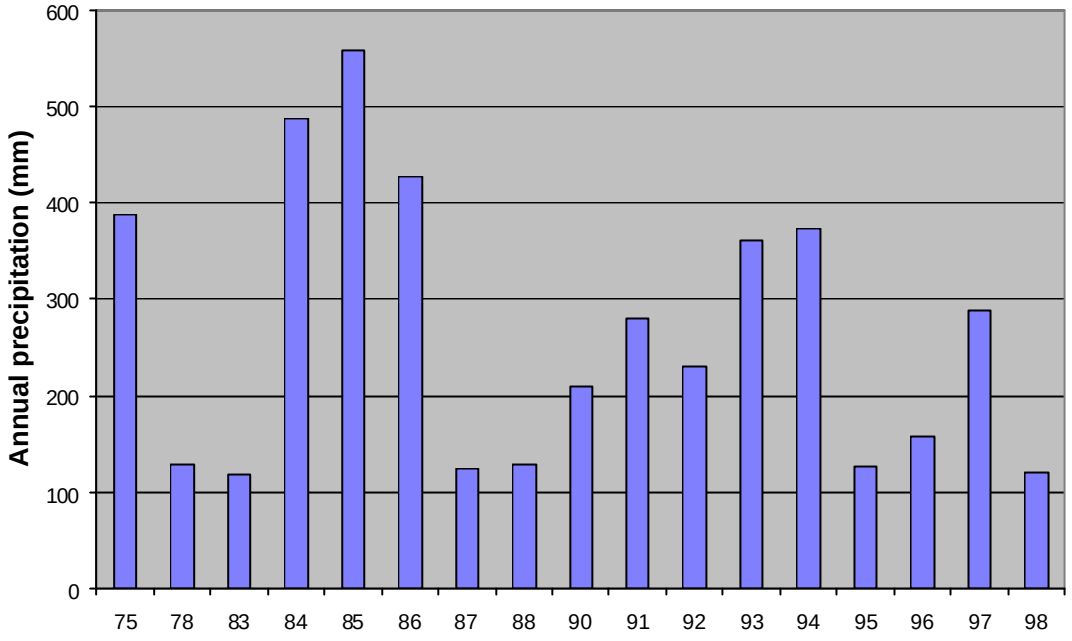

Figure 21. Rainfall data (mm/year) from Parinacota.

Discussion

The data series collected at Parinacota demonstrates how successful the vicuña has been at recovering its numbers following the control of illegal hunting activity. Offtake by hunters had maintained the population at well below carrying capacity.

During the resurgence in numbers, it can be seen that some census units consistently hold a higher population than others. Such units, in particular Japane, Portezuelo Chapiquina, Las Cuevas, Ancocho-lloane, and to the south, Caracota tend to have a high proportion of bofedal, and appear to support a higher concentration of domestic livestock. In 1975, these areas acted as reserves for vicuñas, possibly because the higher concentration of human activity offered some protection to poaching, but also because the habitat characteristics of the place are especially suited to the species. That these refuge areas have remained the more important areas for vicuña since the relaxation of hunting suggests that the latter scenario is probably correct.

Thus the refuges became sources for recolonising the whole area. The duration of the period of growth, from the start of records until the maximum (the limit to growth?) was 15 years. Curiously, the variation in reproductive rate shows little variation about an average of 0.55 cria/female (s.d.=0.034), though the observed degree of variation

appears to follow a cyclic pattern (Figure 22). This analysis may indicate which of the years, or succession of years were more adverse for the vicuña. Adverse years are expected to amplify the difference between the best and worst performing units.

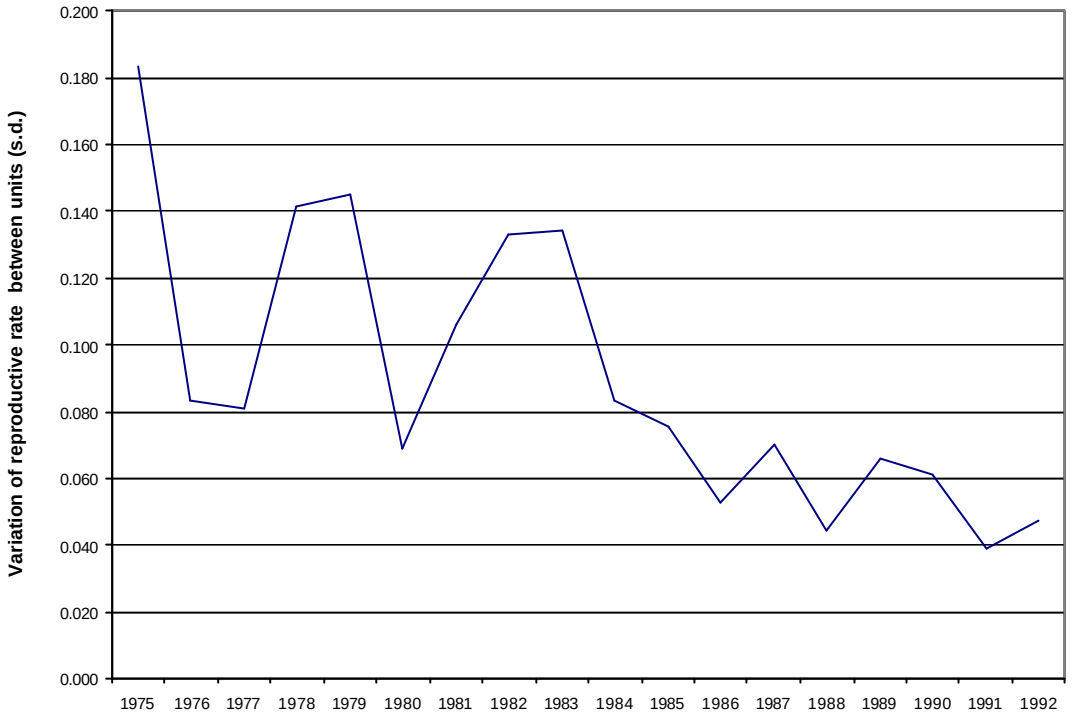

Figure 22. Cyclic pattern in annual variance of reproductive rate across the 32 census units.

The observation of density dependence in the overall figures does not, however, appear to have been brought about by changes in net fecundity (cria surviving to first census). If not cria, then what is driving density dependent regulation?

The two most probable options are adult female mortality and emigration.

The change in population not accounted for by the observed cria in the previous year is the net effect of mortality, emigration and immigration. If positive, this implies net immigration. If negative, then the implication is that mortality and emigration outweigh immigration. For the Parinacota population, following an initial period of immigration, a progressive increase in mortality/emigration was recorded (Figure 23).

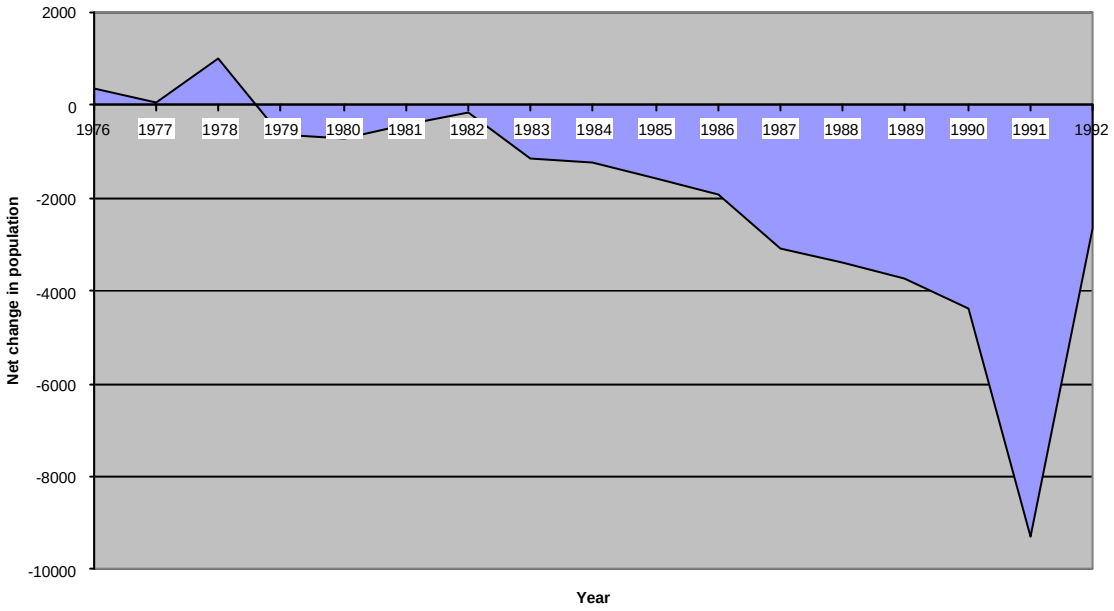

Figure 23. Changes in observed total population not explained by cria abundance in previous year.

These losses represent some 20% of the observed population in each year, and as such are highly density dependent. In itself, however, the analysis does not distinguish between the 2 sources of losses. However, given the nature of the location, with limited potential for emigration on most of the boundaries, the likelihood is that adult mortality makes up the largest share.

This will need to be further explored.

Conclusions.

First indications from the Chilean census data indicate that though territorial, and widely considered to be sedentary, the vicuna is nevertheless able to expand effectively in range, as numbers increase. It is known that most adult vicuna over the age of 2 have approximately one cria per year. The records from Parinacota indicate a reproductive rate of 0.55. Allowing for about 15% of "adult" females being pre-reproductive, this suggests a juvenile mortality of some 30% per year. Correlating this with the observed changes in female population, this mortality does not appear to be density dependent. Density dependent population regulation appears more likely to act on adult female survival, and on emigration.

The development of knowledge on vicuña ecology will be augmented by incorporation of data from Peru and Bolivia. The study sites are:

Peru

Reserva Nacional Pampa Galeras-Bárbara D´Achille, Ayacucho.

This reserve, located in the Ayacucho region between 3,800 and 5,000 meters above sea level, has a surface area of 6,500 hectares. The plateau spans an area of 75 thousand hectares, encompassing the community of Lucanas. Population density of vicuñas in the Nuclear Zone is in the region of 30 vicuña per km², the highest in the altiplano. The community of Lucanas is actively involved in vicuña management and has the longest history of deriving benefits from the capture and shearing.

Bolivia

Reserva Nacional de Fauna Ulla-Ulla, La Paz

Extending to some 200,000 ha, Ulla Ulla has a population of 8500 vicuñas (PDLP, 2003). The park was designated as a UNESCO Biosphere Reserve in 1977. A programme of sustainable use was begun, based on wild captures, but to date the local population have not seen any benefits from sale of fibre. Monitoring of populations began in 1965, and has continued irregularly since that time.

These data will extend the possibility to establish patterns of spatial behaviour and population dynamics for the vicuna. This will be the first time that it will be possible to show quantitatively the relationship between fecundity, mortality, and propensity to move to more suitable habitat. This work provides a sound basis for the evaluation of the impact that human activities have on those ecological processes.

To understand the dynamics of the interaction between human activities a further four study sites will be included in the analysis.

Peru

Reserva Nacional Salinas y Aguada Blanca, Arequipa

The park crossed the provincial borders of Arequipa, Caylloma and General Sánchez Cerro. The area extends to 366,936 hectares and was established in 1979. The height range is from 4500m to 6 075 m (Volcan Chachani). Within the park the sector Pampa Cañahuas and Tocra have significant populations of vicuñas. These are currently being monitored as the subject of a sustainable management programme. There are also a number of fenced vicuñas that are already managed by local communities

Bolivia

Vicuña Management Area Mauri Desaguadero, La Paz

The management area extends to 4,550 km² to the south of Lake Titicaca, and holds a population of 13,389 vicuñas (PDLP, 2003).

Argentina

Cieneguillas Vicuña Panagement Pilot Project, Jujuy

A private vicuña management initiative under licence to the regional government. Cieneguillas has a total population of 960 vicuñas, which share grazings with sheep and llamas. This is an active community just starting wild management of vicuñas.

Laguna Blanca Reserve, Catamarca

The province of Catamarca received its license from CITES to sustainably manage vicuñas in 2002. There are high expectations on the part of the campesinos, but no rewards yet. The level of illegal hunting is relatively high, based on recent

interceptions of traded skins (Barbarán 2002). The population of the reserve is in the region of 3000 vicuñas (Muspratt *et. al.* 1996).

These sites are chosen to include populations of vicuña in different situations, based on the following criteria:

	Practising vicuña management	Planning to practice vicuña management	Not able to sell fibre
Wild capture	Pampa Galeras	Cieneguillas	Ulla ulla, Mauri
Both systems	Parinacota	Laguna Blanca	*
Enclosures	Aguada Blanca	*	*

The population trends at each of these sites will be evaluated and used to compare growth rates and, where possible, mortality factors.

To a large extent the main point of interaction that campesinos have with the vicuña is through perceived competition with domestic livestock. It is the total effective stocking rate that defines the resource availability to both the vicuñas and stock. The relationship between grazing resources allocated to livestock and those used by wild vicuñas can be evaluated given knowledge of the relative numbers of each and their diet selection habits. An index based on this relationship will be used to rank study sites in terms of the amount to which they are directly affected by the presence of vicuñas.

The other important mechanism by which the human population may interact with the vicuña is directly by hunting. Being illegal throughout the altiplano, hunting is difficult to evaluate systematically. However, a broad assessment of habitat suitability can be made, based on remote sensing data. Leading on from this a generalised map of potential vicuña distribution and population will be constructed for the whole of the altiplano. By comparing this with the observed census data, an evaluation will be made of the areas which already have a high saturation of vicuñas, and those which

have for some reason a less than average density of vicuñas given their habitat potential.

A series of field interviews will complement the ecological studies. The aim of these interviews is to assess the personal experience of campesinos to sustainable use, and their attitude towards vicuña. To date, 12 interviews have been carried out in Cieneguillas, Parinacota and La Paz (Mauri Desaguadero).

Timescale

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Field												
Office												

Gant chart showing division of time between field work and writing up.

The April/ May fieldwork will take place in Peru and Bolivia with the dual purpose of securing the available census data and maps, as well as visiting field sites to interview stakeholders.

In November and December, the field work will be in Argentina, and probably Chile, to record community responses to capture events.

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Appendix 1. Statistical log - Genstat

```
Response variate: FEMT_1
     Fitted terms: FEM_T + RELDENS + CRIA_T.YEAR


*** Summary of analysis ***

              d.f.         s.s.         m.s.      v.r.  F pr.
Regression      19     53069352.     2793124.    483.54  <.001
Residual       525      3032641.        5776.
Total          544     56101993.      103129.

Percentage variance accounted for 87.3
Standard error of observations is estimated to be 76.0
* MESSAGE: The following units have large standardized residuals:
         Unit     Response    Residual
           93        613.0       -3.41
          226        721.0        3.26
          256        443.0        4.89
          257         55.0       -3.83
          308        611.0        3.15
          310        634.0        4.04
          394        681.0        5.51
          455        574.0        4.09
          602        232.0       -3.56
          656        473.0        4.94
          657        314.0       -3.66
* MESSAGE: The error variance does not appear to be constant:
           intermediate responses are more variable than small or
large
responses
* MESSAGE: The following units have high leverage:
         Unit     Response    Leverage
           85        101.0       0.135
           88        228.0       0.242
           92        677.0       0.170
           93        613.0       0.230
          127         78.0       0.229
          164        386.0       0.146
          171        224.0       0.166
          191        236.0       0.147
          192        198.0       0.173
          196        396.0       0.174
          197        415.0       0.119
          227        568.0       0.142
          257         55.0       0.273
          311        810.0       0.114
          395        527.0       0.118
          613        156.0       0.125
          652        365.0       0.263
          653        303.0       0.598
          654        227.0       0.344
          657        314.0       0.419
          658        372.0       0.127
          661        883.0       0.285
          662        934.0       0.256
```

663	1064.0	0.305
664	1083.0	0.320
665	1158.0	0.241
666	1211.0	0.216
667	648.0	0.249
668	874.0	0.110

*** Estimates of parameters ***

	estimate	s.e.	t(525)	t pr.
FEM_T	0.7987	0.0759	10.53	<.001
RELDENS	-4.06	1.03	-3.96	<.001
CRIA_T.YEAR 1975	2.083	0.870	2.39	0.017
CRIA_T.YEAR 1976	0.689	0.475	1.45	0.147
CRIA_T.YEAR 1977	0.805	0.295	2.73	0.007
CRIA_T.YEAR 1978	0.107	0.318	0.34	0.737
CRIA_T.YEAR 1979	-0.035	0.271	-0.13	0.897
CRIA_T.YEAR 1980	0.513	0.216	2.37	0.018
CRIA_T.YEAR 1981	0.783	0.207	3.78	<.001
CRIA_T.YEAR 1982	0.854	0.184	4.65	<.001
CRIA_T.YEAR 1983	0.782	0.181	4.32	<.001
CRIA_T.YEAR 1984	0.927	0.241	3.85	<.001
CRIA_T.YEAR 1985	0.899	0.236	3.82	<.001
CRIA_T.YEAR 1986	0.815	0.234	3.47	<.001
CRIA_T.YEAR 1987	0.660	0.226	2.92	0.004
CRIA_T.YEAR 1988	0.487	0.228	2.14	0.033
CRIA_T.YEAR 1989	0.487	0.169	2.87	0.004
CRIA_T.YEAR 1990	-0.305	0.183	-1.67	0.095
CRIA_T.YEAR 1991	0.629	0.175	3.59	<.001
CRIA_T.YEAR 1992	0	*	*	*
CRIA_T.YEAR 1993	0	*	*	*
CRIA_T.YEAR 1995	0	*	*	*
CRIA_T.YEAR 1996	0	*	*	*

*** Accumulated analysis of variance ***

Change	d.f.	s.s.	m.s.	v.r.	F pr.
- Constant	-1	-31448263.	31448263.	5444.21	<.001
+ FEM_T	1	51593325.	51593325.	8931.65	<.001
+ RELDENS	1	99354.	99354.	17.20	<.001
+ CRIA_T.YEAR	17	1376673.	80981.	14.02	<.001
Residual	525	3032641.	5776.		
Total	543	24653730.	45403.		

```
Response variate: FEMT_1
     Fitted terms: CRIA_T + FEM_T + RELDENS + CRIA_T.UNIT +
FEM_T.UNIT +
                   CRIA_T.YEAR + FEM_T.YEAR


*** Summary of analysis ***

              d.f.         s.s.         m.s.      v.r.  F pr.
Regression      97    53696083.      553568.    102.85  <.001
Residual       447     2405910.        5382.
Total          544    56101993.      103129.

Percentage variance accounted for 88.1
Standard error of observations is estimated to be 73.4
* MESSAGE: The following units have large standardized residuals:
         Unit     Response    Residual
           30        235.0       -3.49
           87        391.0        3.57
           93        613.0       -3.40
          114        312.0       -3.13
          227        568.0       -3.48
          256        443.0        5.10
          307        384.0       -3.95
          310        634.0        3.59
          394        681.0        5.91
          657        314.0       -3.26
          668        874.0        3.13
* MESSAGE: The error variance does not appear to be constant:
           intermediate responses are more variable than small or
large
responses
* MESSAGE: The following units have high leverage:
         Unit     Response    Leverage
           93        613.0        0.59
          164        386.0        0.96
          191        236.0        0.61
          247         69.0        0.77
          248        132.0        0.59
          280        325.0        0.64
          350         19.0        0.60
          416        312.0        0.66
          521        253.0        0.55
          539        414.0        0.71
          653        303.0        0.70
          656        473.0        0.57
          657        314.0        0.73
          663       1064.0        0.74
          664       1083.0        0.70
          665       1158.0        0.65


*** Estimates of parameters ***

                             estimate         s.e.    t(447)  t pr.
C
RIA_T                           2.65         1.17      2.26  0.024
FEM_T                         -0.263        0.556     -0.47  0.636
RELDENS                       -14.43         2.39     -6.02  <.001
CRIA_T.UNIT 1                  -2.60         3.33     -0.78  0.435
CRIA_T.UNIT 2                 -0.572        0.974     -0.59  0.557
```

CRIA_T.UNIT 3	-0.02	1.02	-0.02	0.986
CRIA_T.UNIT 4	-0.20	1.64	-0.12	0.906
CRIA_T.UNIT 5	-0.572	0.841	-0.68	0.497
CRIA_T.UNIT 6	-0.495	0.934	-0.53	0.596
CRIA_T.UNIT 7	-0.33	1.50	-0.22	0.826
CRIA_T.UNIT 8	-0.81	1.02	-0.79	0.428
CRIA_T.UNIT 9	-0.149	0.924	-0.16	0.872
CRIA_T.UNIT 10	-0.279	0.857	-0.33	0.745
CRIA_T.UNIT 11	-0.404	0.846	-0.48	0.634
CRIA_T.UNIT 12	1.17	6.86	0.17	0.865
CRIA_T.UNIT 13	-1.82	1.23	-1.48	0.140
CRIA_T.UNIT 14	-0.05	1.04	-0.04	0.964
CRIA_T.UNIT 15	0.034	0.880	0.04	0.969
CRIA_T.UNIT 16	-0.57	1.16	-0.50	0.619
CRIA_T.UNIT 17	-4.5	11.0	-0.41	0.683
CRIA_T.UNIT 18	-0.13	1.41	-0.09	0.925
CRIA_T.UNIT 19	0.086	0.947	0.09	0.928
CRIA_T.UNIT 20	0.60	1.95	0.31	0.759
CRIA_T.UNIT 21	0.15	1.16	0.13	0.900
CRIA_T.UNIT 22	1.71	1.43	1.20	0.231
CRIA_T.UNIT 23	2.62	3.65	0.72	0.473
CRIA_T.UNIT 24	0.48	4.81	0.10	0.920
CRIA_T.UNIT 25	2.22	3.06	0.73	0.468
CRIA_T.UNIT 26	2.04	1.82	1.12	0.263
CRIA_T.UNIT 27	-1.12	1.24	-0.90	0.368
CRIA_T.UNIT 28	-0.754	0.949	-0.79	0.427
CRIA_T.UNIT 29	2.57	1.42	1.81	0.072
CRIA_T.UNIT 30	0.21	1.04	0.20	0.844
CRIA_T.UNIT 31	0.01	4.20	0.00	0.998
CRIA_T.UNIT 32	0	*	*	*
FEM_T.UNIT 1	0.86	1.31	0.65	0.515
FEM_T.UNIT 2	0.413	0.451	0.92	0.360
FEM_T.UNIT 3	0.103	0.447	0.23	0.817
FEM_T.UNIT 4	0.454	0.651	0.70	0.486
FEM_T.UNIT 5	0.147	0.382	0.38	0.701
FEM_T.UNIT 6	0.235	0.418	0.56	0.574
FEM_T.UNIT 7	0.046	0.566	0.08	0.935
FEM_T.UNIT 8	0.691	0.438	1.58	0.116
FEM_T.UNIT 9	0.459	0.419	1.09	0.274
FEM_T.UNIT 10	0.201	0.402	0.50	0.618
FEM_T.UNIT 11	0.418	0.393	1.06	0.289
FEM_T.UNIT 12	-2.18	3.08	-0.71	0.480
FEM_T.UNIT 13	0.741	0.505	1.47	0.143
FEM_T.UNIT 14	0.109	0.448	0.24	0.808
FEM_T.UNIT 15	0.197	0.406	0.49	0.627
FEM_T.UNIT 16	0.371	0.494	0.75	0.453
FEM_T.UNIT 17	0.57	3.81	0.15	0.881
FEM_T.UNIT 18	0.125	0.559	0.22	0.823
FEM_T.UNIT 19	-0.022	0.426	-0.05	0.959
FEM_T.UNIT 20	-0.061	0.825	-0.07	0.941
FEM_T.UNIT 21	0.093	0.494	0.19	0.850
FEM_T.UNIT 22	-0.540	0.628	-0.86	0.390
FEM_T.UNIT 23	-0.84	1.34	-0.62	0.533
FEM_T.UNIT 24	-0.57	1.83	-0.31	0.756
FEM_T.UNIT 25	-0.85	1.30	-0.65	0.513
FEM_T.UNIT 26	-0.710	0.767	-0.93	0.355
FEM_T.UNIT 27	0.739	0.544	1.36	0.175
FEM_T.UNIT 28	0.364	0.429	0.85	0.397
FEM_T.UNIT 29	-1.039	0.611	-1.70	0.090
FEM_T.UNIT 30	0.197	0.459	0.43	0.669
FEM_T.UNIT 31	-0.26	1.78	-0.15	0.883

FEM_T.UNIT 32	0	*	*	*
CRIA_T.YEAR 1975	-4.78	4.78	-1.00	0.317
CRIA_T.YEAR 1976	2.71	4.64	0.58	0.559
CRIA_T.YEAR 1977	0.73	3.20	0.23	0.819
CRIA_T.YEAR 1978	1.13	2.58	0.44	0.662
CRIA_T.YEAR 1979	2.57	1.64	1.56	0.118
CRIA_T.YEAR 1980	-6.15	2.32	-2.65	0.008
CRIA_T.YEAR 1981	-2.81	1.58	-1.78	0.076
CRIA_T.YEAR 1982	-1.36	1.84	-0.74	0.461
CRIA_T.YEAR 1983	-1.66	1.46	-1.13	0.257
CRIA_T.YEAR 1984	-1.79	1.01	-1.77	0.077
CRIA_T.YEAR 1985	-1.38	1.09	-1.26	0.209
CRIA_T.YEAR 1986	-1.35	1.13	-1.19	0.234
CRIA_T.YEAR 1987	-1.83	1.10	-1.66	0.097
CRIA_T.YEAR 1988	-0.18	1.29	-0.14	0.890
CRIA_T.YEAR 1989	-3.11	1.12	-2.77	0.006
CRIA_T.YEAR 1990	-2.17	1.24	-1.75	0.081
CRIA_T.YEAR 1991	0	*	*	*
CRIA_T.YEAR 1992	0	*	*	*
CRIA_T.YEAR 1993	0	*	*	*
CRIA_T.YEAR 1995	0	*	*	*
CRIA_T.YEAR 1996	0	*	*	*
FEM_T.YEAR 1975	2.70	1.79	1.51	0.131
FEM_T.YEAR 1976	-0.72	1.80	-0.40	0.688
FEM_T.YEAR 1977	-0.37	1.75	-0.21	0.832
FEM_T.YEAR 1978	-0.44	1.05	-0.42	0.675
FEM_T.YEAR 1979	-1.312	0.755	-1.74	0.083
FEM_T.YEAR 1980	3.32	1.27	2.61	0.009
FEM_T.YEAR 1981	1.520	0.812	1.87	0.062
FEM_T.YEAR 1982	0.784	0.965	0.81	0.417
FEM_T.YEAR 1983	0.923	0.717	1.29	0.199
FEM_T.YEAR 1984	0.976	0.452	2.16	0.032
FEM_T.YEAR 1985	0.824	0.478	1.73	0.085
FEM_T.YEAR 1986	0.792	0.488	1.62	0.106
FEM_T.YEAR 1987	0.897	0.482	1.86	0.063
FEM_T.YEAR 1988	0.256	0.534	0.48	0.632
FEM_T.YEAR 1989	1.430	0.535	2.67	0.008
FEM_T.YEAR 1990	0.622	0.570	1.09	0.276
FEM_T.YEAR 1991	0	*	*	*
FEM_T.YEAR 1992	0	*	*	*
FEM_T.YEAR 1993	0	*	*	*
FEM_T.YEAR 1995	0	*	*	*
FEM_T.YEAR 1996	0	*	*	*

*** Accumulated analysis of variance ***

Change	d.f.	s.s.	m.s.	v.r.	F pr.
- Constant	-1	-31448263.	31448263.	5842.85	<.001
+ CRIA_T	1	49813114.	49813114.	9254.90	<.001
+ FEM_T	1	1804069.	1804069.	335.18	<.001
+ RELDENS	1	99497.	99497.	18.49	<.001
+ CRIA_T.UNIT	31	254132.	8198.	1.52	0.038
+ FEM_T.UNIT	31	191299.	6171.	1.15	0.272

+ CRIA_T.YEAR	16	1338437.	83652.	15.54 <.001
+ FEM_T.YEAR	16	195534.	12221.	2.27 0.003
Residual	447	2405910.	5382.	
Total	543	24653730.	45403.	

Appendix II. Prodression of population density in Parinacota – 1975-2001