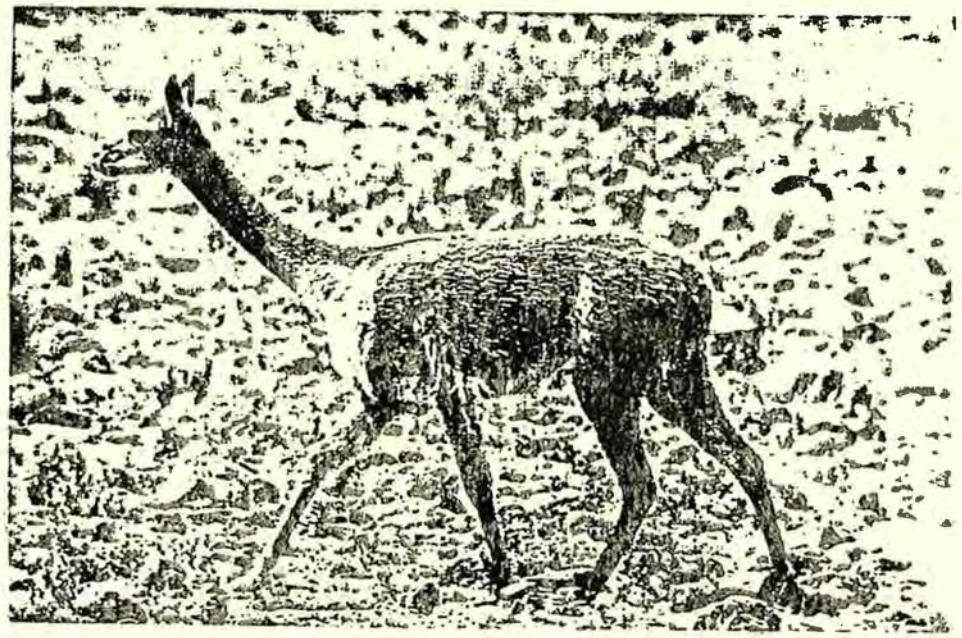
# EVALUATION OF GROUND AND AERIAL CENSUS WORK ON VICUNA IN PAMPA GALERAS, PERU

RESULTS OF A WWF/IUCN EVALUATION MISSION
17 SEPTEMBER - 7 OCTOBER 1980

UNDERTAKEN WITH THE FINANCIAL ASSISTANCE OF
THE GERMAN AGENCY FOR TECHNICAL COOPERATION (GTZ)





WWF WORLD WILDLIFE FUND
INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES

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Results of a WWF/IUCN Evaluation Mission
17 September - 7 October 1980

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the German Agency for Technical Cooperation (GTZ)



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December 1980

# P R E F A C E

This report has been prepared by Dr. Michael Norton-Griffiths and Mr. Hernán Torres Santibañez at the request of IUCN and WWF and with the financial support of the German Agency for Technical Cooperation (GTZ), in response to an invitation from the Government of Peru to observe the General Census of vicuña in Pampa Galeras in 1980. The draft of the text has been reviewed by a number of leading experts in the field and many of their suggestions have been incorporated in this final version.

IUCN and WWF have submitted the report to the Government of Peru indicating their general endorsement of its findings and their broad support for its recommendations. Their position has also been recorded in a policy statement on vicuña, which has been annexed to the report.

IUCN and WWF wish to record their appreciation to the Government of Peru for the opportunity to examine conditions in Pampa Galeras at first hand, and to thank all those concerned for the cooperation extended to their consultants.

IUCN/WWF
Gland, Switzerland
February 1981

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# SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

## CONCLUSIONS

1. With Respect to the General Census of Vicuna, 1980 (Sections 4 & 5)

1.1 The General Census is being carried out in an eminently sensible manner by people who know what they are doing, who are aware of the problems involved and who are highly motivated.

1.2 There is no evidence of gross bias in the method used. The General Census certainly yields a conservative estimate of numbers, but it is unlikely that the understimate is more than 10%.

1.3 The series of double counts indicate that the General Census gives repeatable and reliable results.

1.4 There is no evidence whatsoever of gross misrepresentations or falsifications in the published results.

1.5 A second aerial survey is neither warranted nor cost effective.

2. With Respect to the Pre - 1980 Census Data (Section 6)

2.1 Immigration is unlikely to have been a major factor in the observed increase in vicuna numbers.

2.2 It is not possible to estimate the influence of any increase in census efficiency.

2.3 The observed rates of increase in the Sector Central Galeras are compatible with the observed rates of recruitment.

2.4 The observed rates of increase in the Sectors Huanaco Pampa and Condor Cocha are similar to those observed elsewhere (Chile, Bolivia).

2.5 Small biases in the field classification of age and sex classes may explain the apparant discrepancy between the observed rates of increase in these two Sectors and the observed rates of recruitment.

3. With Respect to Range Condition and Trend in the Reserve National Pampa Galeras (Section 8)

3.1 The data suggested that the vicuna population increased rapidly under conditions of abundant resources and consequentially low rates of mortality. As resources became more limited, through population increase and through environmental fluctuations, mortality rates increased and recruitment rates decreased. Population change declined to zero, and then fell.

3.2 Neither the data on Net Primary Productivity (NPP) nor the data on basal cover support the hypothesis of a substantially degraded or overgrazed rangeland. Instead, they suggest a clear cut, almost classical, picture of a population expanding up to, and stabilising at, its ecological carrying capacity.

4. With Respect to the Management and Utilisation of Vicuna (Section 9)

4.1 The theoretical carrying capacity of the present Management Area is some 205,000 vicunas. At the present rates of increase, this carrying capacity will be reached by 1986/87.

4.2 The theoretical maximum sustained yield (MSY) of vicuna from the present Management Area is 19,000 animals per year from a population of 102,000 animals.

4.3 In Sectors Huanaco Pampa and Condor Cocha, the present population sizes are still below the one half of carrying capacity from which the MSY can be harvested. Stocks should be allowed to increase further before any harvesting is planned.

4.4 In Sector Central Galeras, the population is above the one half of carrying capacity from which the Maximum Sustainable Yield (MSY) can be harvested. An initial reduction crop of 3,800 animals would reduce the population to a level
from which an MSY of 3,400 animals could be harvested annually.

4.5 These calculations are, however, only first approximations, and they MUST be reviewed in the light of the full 1980 census results.

## RECOMMENDATIONS

We recommend as a matter of the utmost urgency and priority:

1. A special investigation into the magnitude of counting bias in the General Census.

2. A special investigation into the magnitude of any bias in the field classification of age and sex classes.

3. A programme to study the dynamics of the production and offtake of food by vicuna, and the extent and nature of competition between vicuna and domestic stock.

4. A programme to study, in detail, the population dynamics of vicuna and the response of the population to harvesting.

With respect to the implementation of a harvesting programme, we recommend:

5. Pressures to commence commercial harvesting should be resisted and no attempts should be made at the present time to harvest at rates even approaching those of the theoretical MSY. We recommend this because:

   a) the data do not suggest that the range is substantially overgrazed or degraded;

   b) there is as yet not structured management model on which to base the design, implementation, monitoring and refinement of harvesting strategies;

   c) there remain certain inadequacies in the data on population dynamics, range production and offtake, and competition between vicuna and domestic stock which must be rectified before a harvesting strategy can be designed.

6. A programme of culling should be designed with the overriding priority of obtaining scientific data about the vicuna population. The objectives of the programme must be to:

   a) obtain data on population dynamics, growth and nutrition;

   b) arrive at more exact estimates of K, $r_m$ and MSY by careful monitoring of the response of the population to the culling;

c) check any biases inherent in the field assessment of age and sex classes;

d) obtain data for calculating the optimum sex ratio for sex selective harvesting.

7. These objectives will be met by harvesting 1,000 animals each year for three years from the Sector Central Galeras.

8. This culling programme should be integrated very closely with studies of range production and offtake, and competition between vicuna and domestic stock.

9. These studies on population dynamics, monitoring, production and offtake and competition should be designed, directed and integrated from Pampa Galeras itself.

10. Serious consideration should be given to appointing a Senior Scientist of considerable experience to the Pampa Galeras sub-project to direct these studies.

## SECTION 1

## INTRODUCTION

### 1.1 Terms of Reference

Following a request from the Ministry of Agriculture and Food, Direccion General Forestal y de Fauna, Lima, Peru, the International Union for Conservation of Nature and Natural Resources (IUCN) and the World Wildlife Fund (WWF) agreed to send a mission to observe the 1980 General Census of Vicuna with the financial assistance of the German Agency for Technical Cooperation (GTZ). The mission was requested in view of an apparant discrepancy between the estimates of vicuna obtained from the ground counts carried out by the Special Project for the Rational Utilisation of Vicuna in Peru and from an aerial survey carried out by PRODENA in April 1980.

WWF/IUCN selected Dr. M. Norton-Griffiths and Mr. H. Torres Santibañez for the Mission. Dr. Norton-Griffiths was selected for his experience in census methodologies and Mr. Torres was selected for his extensive knowledge of vicuna.

The Terms of Reference for the mission were as follows:

"The Mission will observe the annual ground count of vicuna in the Pampa Galeras region in Peru, in order to:

a) evaluate whether the methodology adopted is likely to lead to a reliable assessment of the vicuna population;

b) evaluate the present state of knowledge on range conditions, animal stress and other relevant aspects of the vicuna programme;

c) assess the need for, and feasibility of, carrying out a reliable aerial count and if so prepare a working plan and establish preliminary contact for this purpose;

d) present a final report to WWF/IUCN on the mission, including a detailed report on its findings and eventual recommendations for future action (eg, translocation)".

### 1.2 Itinerary and Work Plan in Peru

| 1980 | | LIMA |
|---|---|---|
| 15th September | : | H. Torres Santibañez arrives in Lima. |
| 16th September | : | Meeting between H. Torres and Ing. Luis Cueto, Director General, Direccion General Forestal y de Fauna. |

| | | |
|---|---|---|
| 17th September | : | Meeting between H. Torres and Ing. Carlos Ponce del Prado of the Agrarian University La Molina. |
| 18th September | : | M. Norton-Griffiths arrives in Lima. |
| 19th September | : | Meeting between the Consultants and Ing. Marco Romero, Deputy Director, Direccion General Forestal y de Fauna |
| | : | Departure for Nazca. |

NAZCA

| | | |
|---|---|---|
| | : | Meeting with the Consultants and Dr. Kai Otte. |
| 20th September | : | Departure for Pampa Galeras. |

PAMPA GALERAS

| | | |
|---|---|---|
| 21st September | : | Meeting with Ing. Fernando Rojas, Sub-Project Head for Pampa Galeras. |
| | : | Compilation of census data. |
| 22nd September | : | Observation of capture of vicuna for translocation. |
| | : | Compilation of census data. |
| 23rd September | : | Meeting with Ing. Fernando Rojas to discuss the organisation and administration of the sub-project. |
| | : | Compilation of census data. |
| 24th September | : | By vehicle to Huanacopampa Guard Post. |
| | : | Meeting with Sr. Saturnino Torres, one of the most experienced Guards involved in the ground census. |
| 25th September | : | By vehicle to Pampa Galeras, via Andamarca and Puquio, thus passing through Sectors Huanaco Pampa and Condor Cocha. |
| 26th September | : | Compilation of census data. |
| | : | Meeting with Dr. Antonio Brack, Executive Director of the Project for the Rational Utilisation of Vicuna. |
| 27th September | : | Compilation of census data. |
| 28th September | : | By vehicle to Jassu Grande Guard Post. Field exercise with the census team recounting Sites already censussed. |
| | : | Brief meeting with Dr. Rudolf Hofmann. |

| | | |
|---|---|---|
| 29th September | : | Seminar class on Census Methodologies with the heads of the census teams, namely Biol. Domingo Hoces, Ing. Walter Herrera and Ing. Hector Galvan. Ing. Fernando Rojas attended as well. |
| 30th September | : | Observation of moving vicuna from holding pens into lorries for translocation. |
| | : | Compilation of census data. |
| 1st October | : | Compilation of census data. |
| | : | Visits to rangeland exclosure plots. |
| 2nd October | : | Departure for Nazca. |

NAZCA

| | | |
|---|---|---|
| 3rd October | : | Flight over Pampa Galeras and Huanaco Pampa to test aerial counting procedures. |
| | : | Meeting with Dr. R. Hofmann. |
| 4th October | : | Departure to Lima. |

LIMA

| | | |
|---|---|---|
| | : | Meeting with Dr. Marc Dourojeanni, Agrarian University of la Molina. |
| 5th October | : | Day off. |
| 6th October | : | Meeting with Ing. Romero, Deputy Director, Direccion General Forestal y de Fauna. |
| | : | Meeting with Dr. A. Brack and Dr. M. Dourojeanni at the Headquarters of the Special Project for the Rational Utilisation of Vicuna. |
| | : | Meeting with Sr. Felipe Benavides and Ing. Mauricio Romana, representatives of PRODENA. |
| 7th October | : | M. Norton-Griffiths returns to Geneva.<br>H. Torres Santibañez returns to Santiago. |

## 1.3 Acknowledgements

Our work would not have been possible without the cooperation of all persons involved with the Special Project for the Rational Utilisation of Vicuna in Peru. In Lima, Nazca and especially Pampa Galeras, we were warmly received and no efforts were spared in helping us with our work and in making information available to us.

We wish to express our personal gratitude, and that of the WWF and IUCN, to the following:

Direccion General Forestal y de Fauna
Ing. Luis Cueto, General Director
Ing. Marco Romero, Deputy Director

Special Project for the Rational Utilisation of Vicuna in Peru
Dr. Antonio Brack, Executive Director
Ing. Fernando Rojas, Sub-Project Head for Pampa Galeras
Biol. Domingo Hoces
Ing. Hector Galvan
Sr. Saturnino Torres
Sr. Julio Marca.

German Agency for Technical Cooperation (GTZ), Federal Republic of Germany
Dr. Rudolph Hofmann
Dr. Kai Otte

Agrarian University of La Molina
Dr. Marc Dourojeanni
Ing. Carlos Ponce del Prado

PRODENA
Sr. Felipe Benavides
Ing. Mauricio Romana

We also wish to thank Mrs. K. Otte and Mrs. R. Hofmann for the many excellent meals they provided for us at Pampa Galeras, and Mr. and Mrs. Volkmar Becker for their hospitality in Lima.

We wish also to mention Ing. Paul Schutz who kept us excellent company throughout our trip and who made himself extremely useful to us at all stages of our work.

Finally, we wish to thank our colleagues to whom a draft of this report was sent for review. Their helpful and constructive comments have helped us in preparing this final text.

## SECTION 2

## SPECIAL PROJECT FOR THE RATIONAL UTILISATION OF THE WILD VICUNA IN PERU

### 2.1 Objectives

According to the official documents of the Department of Agriculture and Food, Lima, the primary objective of the Special Project for the Rational Utilisation of the Wild Vicuna in Peru is to repopulate some 16,000,000 hectares of the Upper Andean zone with vicunas and thus increase the revenues of the farming communities of these marginal lands through the utilisation of vicuna. Furthermore, it is intended to increase the foreign exchange earnings of the country by the international marketing of vicuna products of high commercial value.

The specific objectives of the Project include:

- repopulation of some 16,000,000 hectares in 16 Departments with 3,000,000 vicunas;
- implementation of basic studies into the management, control and utilisation of vicuna;
- expansion of the revenues of the marginal Upper Andean rangelands through the management of this ecologically suitable species;
- compensation to the farming communities of the Puna for tolerating vicuna on their land;
- production of meat, skins and wool from vicuna as a contribution towards the problems of food suply, and for the export of high quality merchandise;
- involvement of other Andean species (such as the Andean Deer, Guanaco and Viscacha) in a programme of integrated resource management;
- development of a Regional Centre for the management of vicuna throughout the Upper Andes;
- development of tourism in the Andes through wildlife management;
- development of a policy for wildlife management throughout Peru.

### 2.2 Short History

Beginning in 1964, the Department of Agriculture and Food has implemented a conservation programme for vicuna throughout Peru, with the long term objective of commercial exploitation of vicuna on belhaf of the people of the Upper Andean region. This programme has been supported by many international organisations including the Food and Agriculture Organisation (FAO) of the United Nations, the World Wildlife Fund, the Government of Belgium, the Government of the Federal Republic of Germany, the Zoological Society of Frankfurt and the New York Zoological Society.

After fifteen years of conservation efforts, there has been a remarkable recovery of the species in the wild. In accordance with the stated objectives of the Project, it is now intended to implement programmes of commercial utilisation. A range of basic studies have been completed and an adequate infrastructure has been built up.

The centre of operations is the National Reserve of Pampa Galeras located in the Province of Lucanas, Department of Ayacucho, where vicuna numbers have increased from around 1000 animals in 1964 to present level of over 43,000[1/] animals. Although the National Reserve itself is only 6500 hectares in extent, from it is controlled a Management Area covering some 500,000 hectares.

## 2.3 Central Administration

The central administration of the Special Project for the Rational Utilisation of Vicuna has its headquarters in Lima. The Executive Director coordinates all the programmes of the sub-projects and provides a central administration for supporting their activities. The central administration also coordinates Project activities with the Department of Agriculture and Food and with international organisations.

There are three main units in the central administration:

a) technical office
   - coordinates activities related to the conservation and utilisation of vicuna and the realisation of the Project's medium and long-term goals.

b) administration office
   - provides centralised, administrative support for all Project activities.

c) marketing office
   - coordinates all activities in the promotion and marketing of vicuna products.

In the field, the Project's activities are centred on sub-projects throughout the vicuna habitat in the Puna zone of the Andes. Sub-projects are presently located at Pampa Galeras, Cuzco, Puno, Arequipa and Huancayo; in 1982 an additional sub-project will be located at Huaraz.

Each sub-project is under the general administration and direction of the Project headquarters, but is responsible for implementing in its local areas programmes of conservation, repopulation and exploitation.

## 2.4 The Sub-Project Pampa Galeras

The headquarters of the sub-project are situated at Pampa Galeras in the Province of Lucanas, and its activities are concentrated in the three Departments of Ayacucho, Huancavelica and Apurimac.

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1/ 1979 figures. Since this report was finalised, the results of the 1980 survey have become available - see Annex 2.

The sub-project has a well developed administration and infrastructure and it acts as the main centre in Peru for all field activities related to vicuna. There is an administrative unit, a control (utilisation) division, a conservation division and a support division for the farming communities.

The sub-project has received considerable technical and financial support from the GTZ, both in terms of equipment and personnel. At Pampa Galeras there are now administrative buildings, laboratories, garages and workshops, museum and library, hostel for visitors, houses for technical and junior staff, slaughter house and freezing plant, holding pens, stables, school, cafes and a Forestry Police Station. In the field are thirteen Guard Posts of a simple but robust design. Equipment includes transport (lorries and cross-country vehicles), a freezer truck, tools, laboratory and darkroom equipment, binoculars, rifles and radio communications.

Two zones are distinguished within the area managed by the sub-project, the Nuclear Zone and the Influence Zone. The Nuclear Zone comprises the National Reserve Pampa Galeras and the two Divisions of Jassu and Ayhuamarca, covering some 96,000 hectares of vicuna habitat. It is referred to as the Nuclear Zone because conservation activities started there and consequently it now contains the highest densities of vicuna.

The Influence Zone comprises the two Sectors of Huanaco Pampa and Condor Cocha, made up by the Divisions Pedregal, Osconta, Huanacopampa, Challhuamayo, Sahuacocha, Condorcocha, Pallca and Soras. This zone covers some 437,000 hectares of vicuna habitat and will be expanded over the next few years.

Translocation of vicuna from Pampa Galeras started on an experimental basis in 1979 when a total of 67 animals were captured. A further 736 animals were captured and translocated in 1980, the majority going to Huancavelica.

Experimental shooting started in 1977, a total of 210 and 400 animals being shot in 1977 and 1978 respectively. This was increased to 1352 in 1979 and to 2100 in 1980. A total of 34.4 metric tonnes of meat were produced and marketed, the hides and wool being stored at Pampa Galeras pending international agreements as to their disposal. Samples of hides and wool have been sent overseas for appraisal and a number of products have been made on an experimental basis to assess market potential.

A range of scientific and technical studies have been completed at Pampa Galeras, both by the personnel of the GTZ and by cooperative research programmes with universities.

# SECTION 3

# CURRENT CENSUS METHODS

## 3.1 The Management Area of Pampa Galeras

The Management Area of the sub-project at Pampa Galeras covers some 500,000 hectares of Puna centred around Puquio (Figure 1). Lying between 4000 and 4600 meters, the natural vegetation consists of treeless, alpine short grasslands. The gently rolling landscape is characterised by broad open valleys dissected by occasional steep scarps and rocky ridges.

The area is heavily used by domestic stock (llama, alpaca, cattle, sheep, horses, pigs) the majority of which move seasonally onto the Puna from the peasant communities in the nearby valleys.

Vicunas are widespread throughout the Management Area and are present year round. Family groups maintain a rigid system of defended feeding and sleeping territories, while male groups move more widely (Franklin 1974).

The Management Area (Table 1) is divided into three Sectors. Central Galeras and Huanaco Pampa lie between Nazca and Puquio, while Condor Cocha lies east of Puquio. Each sector is in turn divided into Divisions, a Division being an area patrolled from a permanently-manned guard post.

## 3.2 The Need for Census Information

The successful conservation and exploitation of vicuna in Pampa Galeras will depend upon accurate and reliable information on the numbers, population dynamics and distribution of the animals throughout the Management Area. These data are all obtained from census work and together they probably form the single most important source of biological information for the sub-project.

Estimates of the total numbers of vicuna are of obvious importance. They are needed to assess the stock of animals and particularly for detecting changes in population size resulting from environmental fluctuations and from management activities such as conservation (anti-poaching and predator control), capture/translocation and culling.

A thorough understanding of the population dynamics of the vicuna will acquire increasing importance as the sub-project moves from its current conservation oriented phase into a phase of more active exploitation. An analysis of the vicuna's population dynamics is an essential prerequisite for calculating the potential yields under different management programmes while continuing studies will be important to monitor in detail the response of the populations to such management.

Finally, data on the distribution of vicuna are important for assessing habitat selection, competition between vicuna and domestic stock, and the numbers of vicuna on the various communal grazing lands. Furthermore, variations in the patterns and rates of mortality and recruitment in different habitats will be of vital importance in the design of management programmes.

These three kinds of information - numbers, population dynamics and distribution - have two important roles to play in the management of vicuna. First, they will lead to a thorough understanding of the ecology of the animals around which management programmes can be designed. Second, they provide the information feedback by which the success and impact of the management programmes may be assessed.

Therefore, these census data must have a high degree of accuracy and reliability. By accuracy, we mean that the census data must be unbiased and that the estimated numbers must be as close as possible to the "true" numbers. By reliability, we mean that the statistical error of the census information must be small enough so that changes may be detected.

Accordingly, we have concentrated our efforts towards assessing the accuracy and the reliability of the census data.

## 3.3 The Census Programme in Pampa Galeras

The sub-project carries out two main census activities, the General Census and the Special Censuses. The General Census is held once a year in September/October with the objective of counting all the vicuna in the Management Area. The census is carried out on foot, and typically lasts between 30 and 40 days. The Special Censuses are held in January, February, March, April, June, August, October and December each year. They are less extensive than the General Census and aim to determine the production and mortality of calves of the year.

Finally, monthly reports are returned from each guard post. These reports summarise the numbers of vicuna encountered during routine guard patrols. The objectives of these reports are not particularly well defined.

We have concentrated on evaluating the General Census only, for the techniques used are similar to those on the Special Censuses and therefore conclusions on the one will apply to the others.

## 3.4 The General Census

The General Census entails a total count of the entire Management Area. The census is carried out on foot by census teams of 3-4 people. The objective is to search the Management Area and count all the vicuna within it.

Over the years, the General Census has undergone repeated refinement. The following description therefore refers primarily to the 1980 General Census and not necessarily to previous censuses.

### The Management Area

The Management Area (Figure I and Table I) is defined as the total area served by the network of guard posts. The Management Area is divided into three Sectors each of which is divided into Divisions. A Division is the area patroled by one guard post. The boundaries of all the Divisions are well known and are now accurately mapped.

Each Division contains a number of Sites, of variable area. The Site boundaries are based on drainage lines, ridge tops and other natural features of the landscape, roads and tracks. The boundaries of all the Sites are now accurately mapped at a scale of 1:25000.

The Sites are the basic counting units for the General Census. The census teams, one to each Sector, visit each Site in turn and count the number of vicuna in it. Census returns are later compiled for each Site, Division and Sector.

There is still considerable confusion over the actual area (hectares) of the individual Divisions and Sectors within the Management Area. Two estimates of area are in use, the "total area" and the "area of vicuna habitat". The hectares given in Table I refer to the areas of vicuna habitat.

There is also confusion as to how these areas were measured. However, this matter will be resolved quite soon since the hectares of each Site, Division and Sector are in the process of being measured accurately by planimetry.

## Administration and Personnel

Sr. D. Hoces, head of the Division of Management, is in charge of the General Census. Sr. Hoces is a biologist trained at the University of San Marcos and has over six years experience at Pampa Galeras. He has taken part in all the General Censuses whilst attached to the sub-project.

Sr. Hoces is responsible for all aspects of the General Census including the checking and compilation of the data.

Sr. Hoces is assisted by two other graduates, Sr. H. Galvan (University of Ayaucho) and Sr. W.R. Herrera (University of Ica). Sr. Galvan and Sr. Herrera joined the sub-project in 1980. They had been trained by Sr. Hoces prior to commencing census work. The 1980 General Census is their first major census exercise.

Sres. Hoces, Herrera and Galvan are each in charge of a counting team of two guards. Each team counts one complete Sector of the Management Area.

Within each team, one guard acts as the counter, the other as the spotter while the team chief writes down the observations on data sheets. The counters are men of considerable experience, not only in counting but also in their Sectors. They are Sr. S. Torres (14 years counting experience), Sr. J. Marca (14 years) and Sr. E. Cusi (7 years).

## Timing

The General Census is carried out in September/October each year. The census lasts some 30-40 days and involves some 6-8 hours walking each day.

## Mapping of the Site Boundaries

1980 is the first year in which the boundaries of the individual Sites have been mapped accurately. A trained surveyor from the Project Headquarters in Lima is in charge of the mapping. The surveyor himself mapped all the Sites in the Sector Central Galeras (the most important Sector) and trained Sres. Hoces and Galvan to map in their Sectors. Each Site is mapped individually when reached by the census team.

On completion of the General Census, the surveyor will be measuring the exact areas of each Site, Division and Sector.

Counting

On entering a Site, the 3-4 man counting team proceeds slowly, on foot, from vantage point to vantage point. At each point they halt for as long as is required to count all the vicuna and domestic stock in that part of the Site being surveyed. The counter scans the area with binoculars (Leitz 7*50) and counts all groups, calling out his counts to the team leader who writes them on data sheets.

Vicuna are classified as family groups, male groups or "solitary and/or unidentified". In family groups, the young of the year are counted separately from the adults. In the male and "undifferentiated" groups, only the group size is recorded.

The counter also records any other wild animals and any domestic stock (sheep, alpacas, llamas, donkeys, horses, cows, goats and pigs) distinguishing between domesticated and feral animals.

After counting at a particular vantage point, the team moves onto the next one, ensuring that the entire Site is searched. The track through the Site is mapped along with the points from which they counted. The total time spent counting is also recorded.

Groups of animals moving out of the Site in response to the counting team are counted as being "in" the Site. Great care is taken to keep track of such a group if it moves into a Site which is to be counted next. This avoids the possibility of double counting groups moving in response to the teams.

Double Counting

Entire Divisions are subject to check by double counting after the General Census has been completed. The teams change Sectors, and each counts one Division using exactly the same method as it used in its original Sector.

Data Compilation

The field data are recorded separately for each Site counted. The team leader first compiles the data for each Site, signing off every data sheet once it is compiled. The sheets are then turned over to Sr. Hoces who, with the Secretariat of the Division of Management, completes the final compilations.

The data are compiled separately for each Division, and are then summarised for each Sector and for the whole Management Area. The vicuna data are presented as follows:-

number of family groups
number of males in family groups (one to each group)
total number of females
total number of young of the year
mean size of family groups

number of male groups
total number of males in male groups
mean size of male groups

number of undifferentiated individuals

total number of vicuna

## SECTION 4

## EVALUATION OF THE 1980 GENERAL CENSUS

### 4.1 Introduction

This evaluation of the 1980 General Census was considered necessary because of the large discrepancy between the previous census results and those from an aerial sample count made in April 1980. In our evaluation of the 1980 General Census, we have therefore concentrated on bias, precision and misrepresentation.

In our investigation of bias, we have searched for evidence of gross underestimates or gross overestimates in the census results. If the aerial estimate of vicuna numbers is correct, then somewhere in the method of the General Census is a flaw which leads to a three times overestimation of vicuna numbers.

In our investigation of precision, we have calculated the statistical error of the General Census. Were this error very large, the discrepancy between the aerial and ground estimates might be due to error rather than to bias.

In our investigation into misrepresentation, we have searched for evidence of gross falsification in the collection and compilation of the data. Accusations of falsification of the results of the General Census have been implied, and were directly stated to us by Sr. Benavides in our meeting with him in Lima.

### 4.2 General Considerations about Bias

Bias in a census is an error in a consistent direction which results in either an overestimate or in an underestimate of animal numbers. Bias can arise from numerous causes and it must be borne in mind that it is practically impossible to design a census - ground or air - that is completely free of any bias whatsoever. It is important, therefore, to adopt a common sense and practical approach to the problem of bias.

(a) Be aware of the major sources of bias and design the census to minimise them. In theory, it does not matter if a census has an inherent bias of 400% for the bias can always be corrected after the census (see (c) below). However, the results of a census become most unreliable when biases of this magnitude are corrected, for the results depend more on the estimation of the bias than on the census itself.

It is therefore practical common sense to keep the biases under control.

(b) The biases must be held constant while a census is in progress (and they must be held constant from census to census if census results are to be compared). A series of biased censuses will yield perfectly valid estimates of population trends so long as the biases are always constant.

(c) Estimate, through careful experimentation, the magnitude of the total bias in the census and then correct the census results. So long as the biases are reasonable, 20% or so, this is the most practical and effective method for dealing with them.

In the following evaluation of bias in the General Census, we have drawn on our own experience and commonsense, and on our direct experience of counting in the field with the sub-project's census teams.

## 4.3 Potential Source of Bias in the General Census

### Experience of the Counting Teams

We were very favourably impressed with the general level of experience of the counting teams and with the high degree of motivation evident in all the people involved in the General Census.

In particular, the counters and spotters were very experienced in their jobs and seemed to possess excellent knowledge of the vicuna and of the areas in which they were counting.

### Timing of the Census

The time of year at which a census is carried out can influence the amount of bias in the results. For example, the animals may be less accessable at some times of the year than at others, or they may be less easy to count because of the nature of the background. Furthermore, the proportion of certain age groups, especially the young of the year, will vary throughout the year and may greatly influence the bias of the results.

The General Census is always carried out in September/October each year, a timing selected for many reasons. The weather is clear and dry, so cross country travel on foot is possible everywhere. It is at the end of the dry season so mortality of the young of the year has stabilised. In addition, it is still possible to tell apart the young of the year and the adults. Accordingly, the proportion of young yields an estimate of recruitment.

We therefore consider that the census is well timed with respect to the annual breeding cycle, the opportunities for accurate counting of animals and the ease of travelling cross country on foot. Any bias in the results arising from the timing of the census will be constant year by year and the census results will therefore be strictly comparable.

### The Site Boundaries

The boundaries of the Sites are based on natural features in the landscape such as ridge tops and drainage lines, and on roads and tracks. There are a number of aspects to the Site boundaries which could lead to bias in the results of the General Census:

(a) Are the Sites mapped accurately?
- From our experience in the field with the counting teams and with the surveyor, we are sure that the Sites are being mapped accurately and that no areas are being missed.

(b) Can the counting teams identify the Site boundaries from the map?
- From our experience in the field with the counting teams, it was quite clear that they were able to read the maps and relate the mapped boundaries to the physical features of the landscape. We saw no evidence that areas were missed or double counted through inexperience at map reading.

(c) How do the Site boundaries relate to vicuna territories?
- Ideally, the Site boundaries should be physical barriers to vicuna, such as steep ridges, so that each Site contains a self-contained number of vicuna. This is obviously impossible, and inevitably there are movements of vicuna across the boundaries between the Sites.

  Franklin (1974) presents some very relevant data on the relationship between landscape features and the feeding and sleeping territories of vicuna. The sleeping territories, unused during the day, tend to be on ridges which therefore form excellent boundaries for Sites since there will be a low probability of movement across them during the day. In contrast, the feeding territories are on the slopes, flats and bottom lands and tend to be bounded by drainage lines and roads, precisely the features used for Site boundaries.

  We estimated from the maps of Sites available to us that no more than one third of the boundaries were on ridges which, during the day, contain few vicunas. The remainder were based of features which are likely to coincide with the boundaries of feeding territories.

(d) How easy is it to determine if a group of vicuna is "in" or "out" of a Site?
- In the field, it was extremely easy to tell immediately whether or not a group of vicuna was "in" a Site.

Movements of Animals

Movements of animals across Site boundaries will only influence the bias of the census if they are made in response to the counting teams. Natural movements of animals will influence the error rather than the bias, for on average the numbers of animals moving into a Site will be offset by the numbers moving out.

However, strong negative bias will arise if animals consistently move out of Sites in response to the counting team. We feel, however, that this source of bias is small. First, the animals show little response to the presence of the counting team so long as it moves slowly and carefully through the Site. Second, it is extremely easy to see moving groups of vicuna. The procedure followed by the counting teams is to count any group seen inside a Site, even if it subsequently moves out of the Site.

In contrast, a strong positive bias will arise if animals moving in response to the team in one Site are then counted again in a neighbouring one. The procedure followed by the counting teams is to note carefully any group moving from a Site into one which is to be counted next. Great care is taken to track these groups so as to avoid double counting. From what we saw in the field, this procedure works satisfactorily.

There is, however, one set of circumstances under which counting becomes very difficult, when the team encounters a number of groups drinking along a stretch of river which happens to be a Site boundary. There is considerable confusion as to which Site each group belongs, and there is a tendency to count all the groups as "in". This will not matter so long as the Site sharing the river boundary is to be counted next, but it can obviously lead to double counting if it is not. This is the only situation we came across where overcounting may occur.

## Counting the Animals

Counting vicuna entails first spotting a group and then counting the number of animals in it. Both of these activities can be influenced by a wide variety of factors, all of which will tend to produce a negative bias in the census results leading to an underestimate of the true number of animals present. These factors include the habitat and background, the time of day, the presence of domestic stock, the number of hours already spent in the field and the number of days that the census has been in operation.

Groups of vicuna are extremely easy to spot on the flats and bottom lands, and we found we were able to spot groups in these habitats at approximately the same speed as the counter. The situation was very different with groups on the more rocky slopes and ridges. Although the counter seemed able to pick them out as easily as he did those in other habitats, we had to spend quite some minutes before we were able to locate the groups.

Census work commences at around eight in the morning, by which time most of the vicunas have moved off their sleeping territories onto the flats and bottom lands. Nonetheless, there is undoubtedly a greater proportion of animals on the slopes during the first few hours of each day's work compared to the later hours, so there may be a variably negative bias arising from the diurnal movements of the animals. However, the skill of the counters would appear to overcome this.

Once the groups had been spotted, we found we were able to count them as easily as the counter, and our counts were in close agreement. In only one case did we count more animals that the counter: 6 animals instead of 5. Marked bias in counting was not therefore apparant.

There are other influences on counting which we were not able to study at first hand. For example, the presence of domestic stock which must detract from the time spent searching for vicunas. We would also expect that towards the end of the day, and towards the end of the census, there would be a strong tendency to move more quickly and count the Sites less effectively. However, the double counts (Section 4.7) suggest that this source of bias is small, for the double counts are made at the end of the General Census when the teams have been in the field for 30 - 40 days.

## Age and Sex Classes

The distinction between male and female groups is not all that straightforward. A large group of 10 - 15 animals without any young is almost certainly a male group, while a small group of 5 - 6 animals with two young is certainly a female group. However, there are also indeterminate groups, without young, which must be classified as male or female groups.

We were unable to determine the criteria used for these small groups without young. The counters seemed totally sure of their identification but were unable to convince us why they were so sure. Furthermore, if they (the counters) were not sure, then the group was counted under the category of "undifferentiated".

Any bias in these identifications will bias the recorded sex ratio of the adults, which will in turn influence the conclusions drawn about the population dynamics of the vicuna.

We were also worried about the classification of young of the year. Once again, very small animals are obviously young of the year, but what about intermediate sized animals? Any bias in the classification of the young of the year will have an enormous effect on the calculation of recruitment. For example, we will show in Section 6 that a bias of only 15% in this classification is enough to account for the apparently high rate of increase in the vicuna.

### 4.4 The Magnitude of Bias in the General Census

The magnitude of the total bias in the General Census was examined in a single exercise in which three Sites in Jassu Division (Sector Central Galeras) were recounted by the same census team three days after the original count. We accompanied the census team during this exercise. The objective was to determine whether there was an inherent bias in the General Census of a magnitude adequate to account for the discrepancy between the aerial and ground counts. The Sites were selected only when we reached the field and the results are shown in Table 2.

Due to our presence, 17% more time was spent on the recount than on the original count. This extra time was required for us to spot the animals and because we were not quite as practised as were the guards. 11% more animals were counted. This suggests that the General Census may have a negative bias of around 11%, the size of the bias being mainly a function of the speed with which the sites were counted.

While this makes sense intuitively, inspection of the results suggests otherwise. 5% fewer animals in family groups (male, females and young) were recorded on the recount while 98% more bachelor males were recorded (Table 2). Bachelor males are less tied to territories than are the family groups (Franklin 1974) and they wander much more widely. The discrepancy between the two counts may therefore reflect error rather than bias.

This can be checked using the regression equation between double counts in 36 Sites carried out as part of the normal double counting procedures (Section 4.5, Table 4). The regression equation is:

$$y = 0.48 + 1.02\ x$$

where x is the first count and y is the second count. Table 3 compares the observed second counts of family groups, male groups and total animals against the estimates calculated from the regression equation. In all cases, the observed second counts were significantly different from the estimates.

This demonstrates that the difference between the first and second counts in this double counting exercise were larger than would be expected on the basis of the calculated error in the census. Accordingly, we can conclude that this

double counting exercise has demonstrated a negative bias in the first counts of these three Sites.

However, three Sites are not a representative enough sample on which to base a firm conclusion about bias in the General Census. Further experimentation is obviously called for (Section 5.3).

## 4.5 The Precision of the General Census

A total of five Divisions have been double counted, two in 1977 and three in 1978 (no double counts were made in 1979). These double counts were made after the General Census was completed, in each case by a different team to the one making the original count.

The regression analysis between these five double counts is presented in Figure 2 and Table 4. The overall difference between the five counts was only 6%, a very close correspondence in view of the fact that the double counts were made by teams who had already been working in the field for 30 - 40 days.

On the null hypothesis of perfect correspondence between the two sets of double counts, the regression equation should have the form:

$$y = 0 + 1.0 \cdot x$$

where y is the second count and x is the first count. Table 4 shows that the calculated values of the intercept and the slope were not significantly different from those expected on the basis of the null hypothesis.

Any difference between the counts is therefore due to error, which is calculated to be +/- 15%. While this is somewhat higher than desirable, it must be remembered that the error can be estimated from only five sets of data. The calculated size of the error will undoubtedly become smaller once more data are available.

The same analysis was carried out on individual Sites within the Divisions that were double counted (Fig. 3 and Table 4). However, of the 140 or so Sites concerned, only 36 could be exactly identified on the two sets of data. This problem over the somewhat superficial use of Site names is referred to again in the next Section. It has caused great difficulties in the analysis of the census data from Pampa Galeras.

This analysis of 36 Sites showed an even greater correspondence between the double counts (2%). The regression equation has the form:

$$y = 0.48 + 1.02 \cdot x$$

and neither the intercept nor the slope are significantly different from those expected on the null hypothesis of perfect correspondence.

The standard error of the regression slope is +/- 2.6%, considerably less than the standard error calculated from the data from whole Divisions. While this reduction in the size of the standard error is largely due to the extra degrees of freedom (34 versus 3), it probably reflects better the overall error in the General Census.

## 4.6 Misrepresentation in the Data

In our analysis of the increase in the numbers of vicuna in Pampa Galeras (Section 6) we examined 45 sets of data from eight Divisions (Tables 10 - 12). We made spot checks of calculations and compilations on 10 of these data sets, while five where checked in total detail, from the original field data sheets right through to the final, compiled reports.

While errors in addition and compilation were found, we calculate that the total error induced in the final census results is no more than +/- 0.05%. Furthermore, we were unable to find the slightest evidence whatsoever that the results were misrepresented or falsified in any way. We conclude that the published results truely reflect the data collected and written down in the field.

We came across only one quite inexplicable procedure which was to include into the final census results the numbers of animals translocated and shot. We failed to be convinced of the rationale for this, even though immense pains were taken to explain it.

## 4.7 Conclusions

Our evaluation of the 1980 General Census of vicuna in Pampa Galeras leads us to some very simple conclusions.

ONE The General Census is being carried out in an eminently sensible manner by people who know what they are doing, who are aware of the problems involved and who are highly motivated. Our recommendations are minor (Section 5), and they are put forward with the intention of improving the efficiency of the General Census and of making it more generally applicable to areas other than Pampa Galeras.

TWO We failed to find any evidence of gross bias in the method used. Although the General Census certainly yields a conservative estimate of the numbers of vicuna in the Management Area, it is unlikely that the numbers are underestimated by more than 10%.

THREE The series of double counts indicate that the General Census gives repeatable results. The statistical error of the General Census is larger than desirable but this is more a function of the paucity of data than an inherent flaw in the census itself.

FOUR There was no evidence whatsoever of gross misrepresentation or falsification of the census data.

# SECTION 5

## RECOMMENDATIONS ON THE GENERAL CENSUS

### 5.1 Alternative Census Methods

There are a number of alternative ground census methods that could be used in Pampa Galeras, for example strip transeek. However, we feel that since the existing method gives reliable results, and since it is very familiar to, and well understood by, all the people involved, there is no reason for changing it.

The same applies to aerial census methods, which will be discussed in more detail later (Section 7). Pampa Galeras is ideal for ground counting, for the country is open and the animals are easy to approach and count.

We therefore recommend that the present method used on the General Census is maintained at Pampa Galeras.

### 5.2 Field Procedures

#### Movement of Animals

We wish to stress the importance of following the existing procedures with respect to animals which move as a direct result of the presence of the census teams. Any animals seen in a Site must be counted as "in", even if they move into a neighbouring Site. If the group moves to a Site which is to be counted next, then it must be noted carefully to avoid double counting.

All other movements must be ignored as they will not influence the bias in the census. This is particularly true with male groups, many of which are easily identified. It does not matter if the same group of males is counted in five different Sites so long as its presence in those Sites is not due to the movements of the counting team.

#### Double Counting

We wish to stress the importance of carrying out checks by double counts of whole Divisions after the General Census is completed, for this is the only way to measure the statistical error of the General Census. Ideally, three Divisions,
one in each Sector, should be recounted each time. The new double count data can then be analysed along with the existing data to give a more precise estimate of the census error. Simple linear regression analysis is all that is required to calculate the error of the census.

#### Numbering the Sites

We recommend very strongly that the individual Sites in each Division should be numbered to overcome the considerable confusion arising from using names. Names tend to change, and different teams use different names for the same Sites while others use the same names for different Sites. Spanish names

interchange randomly with vernacular names, and often new names suddenly appear in the records only to vanish again without trace.

The individual Sites are now mapped, so it makes even more sense to number them and thus avoid further confusion. We suggest a nine digit number which will identify the Sub-Project, the Sector, the Division and the Site, as follows:

example: 01-02-01-001

| digits | | | |
|---|---|---|---|
| 1 - 2 | Sub-Project | 01 | identifies sub-project Pampa Galeras |
| 3 - 4 | Sector | 02 | identifies Sector Huanaco Pampa |
| 5 - 6 | Division | 01 | identifies Division Pedregal |
| 7 - 9 | Site | 001 | identifies the Site around the guard post |

## 5.3 The Investigation of Total Bias in the General Census

We recommend very strongly that a rigorous investigation is carried out to measure the magnitude of bias in the General Census. The objective of these experiments is two fold: first, to investigate the bias in the General Census at Pampa Galeras; second, to aid in the design of censuses in other areas.

The detailed design of the experiments and the level of analysis required must await an exhaustive investigation of the results of the 1980 General Census. Therefore, guidelines only will be presented here.

The basic experiment is to count a number of Sites in exactly the same way as they are counted in the General Census, and then to recount them very intensively. A comparison of the double counts will reveal the magnitude of any bias. (We are applying here the point raised in Section 4.2 (c), namely that bias is not that important so long as it is maintained constant and so long as it is measured in such a way that it can be corrected).

It is important to distinguish clearly between the objectives of the double counts of Divisions and the objectives of these experiments. The double counts of Divisions answer the question "what is the error in our General Census?" Error here is used in the statistical sense, and reflects the variations in the census results from "natural" factors, such as animals moving around. It is obvious that the results from a Division will be different if it is counted a week earlier or a week later, or by a different team, or in a different order. The double counts measure the size of this difference, in other words the error in the census.

In contrast, the experiments will answer the question "How much bias is there in our method?" Here we wish to compare the results obtained using the General Census method against those from the most careful and intensive count that we can possibly carry out. We realise that with the existing constraints on manpower and time it is impossible to search every square metre of the Management Area and count, double count and triple count every group of animals. Therefore, we will use the results of these experiments to measure the magnitude of any bias, and then correct the results from the General Census.

The first step is to find out if there is a problem. We recommend that the initial experiments are made in the Central Sector, not only for convenience but also because it is the most important area from the point of view of

management. We suggest that 20 Sites in the Central Sector are selected at ramdom and that a census team counts each, in exactly the same way as they do on the General Census and also as intensively as possible. It is important to randomise not only the order in which the Sites are counted but also the order in which the "normal" and "intensive" counts are made.

Simple regression analysis of the kind presented in Table 4 will demonstrate whether or not bias is present and, if so, its magnitude. The null hypothesis of the experiment is that the "normal" and "intensive" counts will return exactly the same results. Bias will be shown if the slope of the regression between the two sets of data differs significantly from the expected value of 1.0.

The next step is considerably more complicated and will entail the detailed analysis of the 1980 census results, the existing double counts of Divisions and the experiments outlined above. All these data must be investigated to answer the following questions:

does the magnitude of the bias vary with the density of the animals?
- i.e. are more animals missed when there are more to be counted.

does the recorded density of animals vary with the time of day?
- i.e. are they more visible at some times of day than at others.

does the recorded density of animals vary with the size of the Site?
- i.e. are bigger Sites searched less intensively than smaller ones.

does the recorded density of animals vary with the number of days that the team has been working?
- i.e. do the teams get tired and work less efficiently towards the end of the census.

does the recorded density of animals vary with the habitat of the Sites?
- i.e. are some habitats easier to count than others.

does the recorded density of animals vary with the kind of Site boundaries?
- i.e. do animals slip away unnoticed more easily in some Sites than in others.

The final experiments into the magnitude of bias will have to reflect the relative importance of these factors, and the services of a competent statistician will be required to design the experiments and analyse the results.

## 5.4 Bias in Recording Age and Sex Ratios

We recommend very strongly that a rigorous investigation is carried out into the magnitude of any bias in the recorded age and sex ratios of the vicuna. Bias in these ratios will lead to erroneous calculations of recruitment, mortality and sustainable yield.

An indication of the possible magnitude of this source of bias is given by the records of shot animals. Some 15% of c. 4700 "males" were in fact females.

It may be possible to check these biases during the capture operations. All that is required is to count the groups within the capture enclosure and allocate them to age and sex classes in the same way as on the General Census. The animals can then be aged and sexed once they are caught, the objective being to check the visual classification.

However, better data will be obtained during the shooting operations. The animals must be classified by age and sex before shooting, using the same criteria as applied during the General Census. These field criteria can then be checked by post mortem examination. It is particularly important to check for bias in Sectors Huanco Pampa and Condor Cocha (Section 6.3).

## 5.5 Sample Counting in Pampa Galeras

The work load involved in the General Census is gradually increasing. In 1974, for example, 28 working days were required for the General Census compared with 99 days in 1979. Not only have new Divisions been added to the Management Area, and more are planned, but the existing Divisions are also being searched more thoroughly.

Apart from the increasing workload, the General Census is not equally efficient in all part of the Management Area. For example, in the Sectors Central Galeras and Condor Cocha (Table 5), 28% of the working days are required to count 43% of the animals compared with 39% of the working days to count but 25% of the animals.

These are two solutions to these problems:

(a) Train additional census teams.

(b) Utilise a method of sample counting.

Training additional census teams has the disadvantage of introducing further statistical error into the census. However, additional teams may be required anyway, especially for census operations in other Project areas. The problems of training the teams and ensuring they reach standards comparable to the existing teams will have to be tackled.

We feel, however, that sample counting in Pampa Galeras will immediately solve many of the problems. Sample counting, as its name suggests, involves counting only a sample of an area rather than the whole area. Since the Management Area is already divided into Sectors, Divisions and Sites, we will base our analysis of the potential benefits of sample counting on this structure.

The individual Sites can be considered as sample units. A sample count will entail counting a random sample of these units (Sites) rather than every one of them as at present. The total number of animals in the entire Management Area will then be estimated from the numbers counted in this sample of units (Sites). The mathematics for estimating the total numbers are very straightforward indeed (Norton-Griffiths 1978).

The important question, then, is how big must the sample be? The size of the sample depends upon the required precision of the estimate, and in general a very precise estimate requires a larger sample than a less precise one. We will assume here that the minimum acceptable precision is +/- 5% of the estimate.

We have used the raw field data from the 1979 General Census for our preliminary calculations (Tables 6 - 8), and have had to make the assumption that all the Sites within each Division are of the same size. This we know not to be true, and the implications of this assumption are discussed later.

Tables 6 and 7 show for each Division and Sector the number of Sites (N), the total number of animals (Y), the mean number of animals per Site ($\bar{y}$) and the variance of the mean number of animals per Site ($s_y^2$).

Then:-

1. population estimate $\hat{Y} = N \cdot \bar{y}$
2. variance of $\hat{Y}$, $Var(\hat{Y}) = N(N-n)/n.s_y^2$
3. standard error of $\hat{Y}$, $SE(\hat{Y}) = \sqrt{Var(\hat{Y})}$

Knowing N, $\bar{y}$ and $s_y^2$ from the 1979 data, equation (2) can be solved for different values of n to find the smallest value so that

$$SE(\hat{Y}) \leqslant \hat{Y} \cdot 0.05$$

where n is the number of Sites counted.

The solutions for each Division and Sector are given in Tables 6 & 7, n being the number of Sites which must be counted and f being the sample fraction $f = n/N \cdot 100\%$). $SE(\hat{Y})$ gives the predicted standard error of the estimate of total numbers of vicuna.

We have simulated two sampling strategies.

A. sample independently within each Division so that the estimate of vicuna within each Division has a standard error of $\leqslant 5\%$.

B. sample independently within each Sector, so that the estimate of vicuna within each Sector has a standard error of $\leqslant 5\%$.

Strategy A (Table 6)

With few exceptions, the required sample fractions are in the order of 45 - 55%. Divisions Pampa Galeras and Osconta require higher sample fractions while Jassu and Condor Cocha require quite small sample fractions. The precisions of the estimates for each Sector will all be better than 3% while that for the entire Management Area will be better than 2%. The overall sampling fraction for the Management Area will be 46%.

Strategy B (Table 7)

The three Sectors all require sampling fractions of around 50%. The precision of the estimate for the entire Management Area will be better than 3% and the overall sampling fraction will be 45%.

The results of the two sampling strategies are compared in Table 8. Clearly, Strategy A is the most efficient. The overall sampling fraction is the same as with Strategy B, but independent estimates are obtained for each Division as well as for each Sector and for the Management Area. Furthermore, the estimates for the Sectors and the Management Area will be more precise than with Strategy B.

This simple exercise demonstrates clearly that the numbers of vicuna in each Division and Sector, and in the whole Management Area, can be estimated by sample counting with precisions better than +/- 5% for approximately one half of the field effort currently expended on the General Census.

However, these calculations have been based on the assumption that the Sites within each Division are all of the same size. This assumption has the effect of overestimating the term $s_y^2$, the variance of the mean number of animals per Site. Accordingly, the estimates of the required sampling fractions are probably larger than necessary.
This can only be settled by simulating a sample count using the 1980 census data. The numbers of animals in each Site and the areas of each Site are now known, so it will be straightforward to calculate the sample fraction required in each division. The mathematics change somewhat in that the formulae for unequal sized sampling units must be used (Norton-Griffiths 1978).

We therefore recommend that sample counting is considered very seriously by the Pampa Galeras sub-project. Sample counting will lead to a marked increase in the efficiency of the General Census.

Implementation of Sample Counting

The implementation of a sample count will entail a certain retraining of the census teams. However, the field methods of counting will be exactly the same as those used at present so there should be few difficulties.

Although the final design of the sample count must await the analysis of the 1980 total count, it will be possible to design the count to be self-correcting for bias. The procedure will be somewhat as follows:-

1. Analyse the 1980 total count to calculate the mean and variance of the numbers of vicuna per Site, using the formulae for unequalled sized sampling units.
2. Calculate the sample fraction required in each Division to give a standard error of each estimate of less than 5%.
3. Select the required number of Sites in each Division at random and count them using the same field methods as at present.
4. Calculate the number of Sites that must be double counted in order to estimate the magnitude of any bias with a precision of 2%.
5. Count these Sites, calculate the bias and correct if necessary.

Finally, it will be of advantage to maintain the system of total counting, at least in some Sectors, but not on an annual basis. A good census design would be to hold total counts every five years - the next one in 1985 - and use sample counting in the intervening years.

## 5.6 Further Use of the Mapped and Numbered Sites

We have already made the recommendation that numbering the Sites will greatly increase the efficiency with which data can be recorded, tabulated and retrieved. The mapped and numbered Sites can also be used as a framework for further research and for management. For example:-

(a) sample counting

The Sites can be used as a framework of sampling units for designing a sample count (Section 5.5). Once they are numbered, random number tables can be used for selecting the samples to be counted.

(b) density distribution maps

The framework of Sites can be used to map the density distribution of vicuna throughout the Management Area. Variations in density will be shown clearly, and will give initial insights into the environmental and ecological constraints to the density distribution of the animals.

(c) habitat utilisation

The University of La Molina is presently compiling from aerial photographs a habitat map for the Management Area (Section 7). This habitat map can be overlaid with the map of the Site boundaries and each Site can be categorised by the proportion of different habitat types occurring within them. Each Site can be categorised further on the basis of other environmental attributes, for example the presence of permanent rivers, the presence and density of settlements, the altitude, the rainfall and the steepness of the slopes.The observed densities of vicuna within each Site can then be related to these environmental and ecological attributes, either singly or through multivariate analyses. These analyses will help formulate important hypotheses about the basic ecology of the vicuna.

(d) competition

Studies of competition between vicuna and domestic stock can be carried out in Sites selected for the observed densities of each. If coupled with measurements of primary production and offtake, such studies will yield important insights into the dynamics of the relationships between stock and vicuna.

(e) population dynamics

Sites can be used as sampling units for collecting field data on the recruitment and mortality of vicuna. If the Sites are selected first for variations in habitat features and vicuna density, the studies of population dynamics can be related directly to these important factors.

(f) management

The Sites can be used as the framework for all capture and culling operations. Records of the numbers captured or shot, and the post mortem studies, can be referenced directly to the Sites. The same Sites can then be used for monitoring the response of the population and of the rangeland to management activities.

(g) general reporting

All biological reports including those of short-term phenomena such as poaching activities, predator kills and animals found dead, can be referenced to Sites as a basis for compilation and analysis.

(h) monthly reports

The guard patrols can be organised so that certain Sites are visited and counted routinely each month. This could form the basis for the extensive monitoring of recruitment and mortality, seasonal movements of stock and competition between stock and vicuna. It would also ensure that the patrols are in fact carried out.

## 5.7 Census of Domestic Stock

We feel that the census of domestic stock should be taken out of the General Census. Time spent counting stock inevitably reduces the time available for counting vicuna. It is also difficult to count large herds of stock once they are out grazing.

We recommend, therefore, that the annual stock census should be organised as a separate exercise altogether. The best approach would be to count the animals in their enclosures before they are let out to graze. The cooperation of the campesinas will be essential for this to be successful.

The stock census will also have to be related to the seasonal patterns of movement, and we suggest that the census is carried out at the time of year when stock densities are at their highest.

It will be important to monitor the seasonal patterns of stock movements, especially if competition between vicuna and domestic stock is to be studied. This could be done quite easily during the course of the regular guard patrols (Section 5.6 (h)).

## 5.8 The Special Censuses and the Monthly Guard Post Reports

The Special Censuses for production and mortality of young animals should be based on Sites selected for variations in vicuna density. These population parameters can then be related directly to the density of the animals.

Similarly, the monthly reports from guard posts should involve routine counts within selected Sites. The objectives of these monthly reports must be defined much more clearly.

# SECTION 6

## THE PRE - 1980 CENSUS DATA

### 6.1 Introduction

While we are confident that the 1980 General Census will return useful and reliable results on the numbers of vicuna in the Pampa Galeras Management Area, the same is not necessarily true of the pre-1980 census data. These data, going back in some cases to the early 1960s, are of considerable importance to the sub-project, for they are the only source of information on the rates of mortality and recruitment. These parameters must be known in order to estimate the yields of vicuna sustainable under different management programmes.

Considerable doubt has been expressed about the published data on vicuna numbers. The trouble has been not so much with the census figures themselves but more with the way in which they have been reported. The area censused has increased year by year but this increase has not been documented properly. In addition, the areas (Sectors and Divisions) within which the results have been compiled and reported have been changed arbitrarily with little formal documentation. For example, between 1977 and 1978 (Table 10), the numbers of vicuna in the Reserve National apparently decreased from some 10,000 to 5,000 while the numbers in Division Ayhuamarca increased from some 2,000 to 9,000. These changes are difficult to explain biologically. In fact, the boundaries had been redrawn, but with no proper documentation.

Three names keep recurring in the sub-project's reports on vicuna numbers, the Reserve National, the Zona Rigida and the Zona Influencia. With the exception of the Reserve National, everyone has slightly different opinions as to the definition of the Zona Rigida and the Zona Influencia, and there is no formal documentation on the boundaries or the areas of these two Zones. All this has lead to considerable confusion over the interpretation of the published results.

To add to the confusion, the numbers of vicuna captured and shot are sometimes added into the census figures and are sometimes left out. Furthermore, it turns out that there are no exact records of where all the animals were shot.

We have compiled three series of data for our evaluation of the pre-1980 census results. These are:-

1. the total number of vicuna counted

2. the numbers counted in eight selected Divisions between 1974 and 1980

3. the numbers counted in the Reserve National (6,500 hectares).

We encountered considerable difficulties in pulling these data together. We are not confident that our compilations are free of errors, and we realise that a considerable amount of work must still be carried out to reorganise these data.

We can identify four "causes" underlying the recorded increase in the numbers of vicuna. These are:-

1. biological increase
2. increase in census area
3. increase in census efficiency
4. immigration

Of these, we feel that immigration is unlikely to be important except on a very local scale. All the evidence points to vicuna beig highly territorial, yet the hypothesis of immigration requires many hundreds of vicuna to migrate many tens of kilometres in response to the establishment of a guard post and anti-poaching patrols.

In our evaluation of the pre-1980 census data, we have therefore concentrated on trying to reconcile the observed increase with the biological potential of the vicuna and the changes in census area and census efficiency.

## 6.2 The Census Data - Rates of Increase

Table 9 shows the total numbers of vicuna counted each year and the number of Sectors, Divisions and hectares covered by the General Census. The gradual increase in the Management Area is indicated clearly. The overall density of vicuna within the Management Area shows a steady increase up to 1977 after which it declines. However, this decline is not "real" in terms of animals dying. It is an artifact of the data in that new Divisions with very low densities were added to the Management Area after 1977. For example, Division Soras was counted for the first time in 1979 and had a vicuna density of 2.5 $km^{-2}$. This depressed the overall density within the Management Area.

Tables 10-12 show the observed vicuna numbers within eight selected Divisions of three Sectors from 1974-1979/80. These Divisions were selected for an unbroken run of results from the same area (hectares). All Sectors show a continuous increase in vicuna density with the exception of Sector Central Galeras where densities decreased markedly after 1978 (Table 13).

Finally, Table 14 shows the densities of vicuna within the 6,500 hectare Reserve National between 1969 and 1980. Densities increased up to 1978, after which they declined.

The mean rates of increase for these sets of data are given in Table 15. The increases for the entire Mangement Area, for the Sector Central Galeras and for the Reserve National are all very similar and range between 19% and 21% per annum. The rates for Sector Huanaco Pampa and Sector Condor Cocha are much higher, 36% and 31% respectively.

Table 16 shows the proportions of males, females, young of the year and "undifferentiated" animals, from the census returns of the eight selected Divisions. Females are more abundant than males, and this unequal sex ratio is also found in the young. Of 106 young of the year captured for translocation, 55% were females.

The ratios in the last column of Table 16 were derived by pooling all the age and sex data. Using the ratios of 0.29 female young per female and 0.24 male

young per female, and assuming no mortality whatsoever after the General Census (apart from the mortality of the young born in the following year), the potential rate of increase of vicuna in the Management Area can be calculated to be 28% per annum.

The observed rates of increase in the whole Management Area, in Sector Central Galeras and in the Reserve National are all less than 28%. Mortality of adults and young of the year is therefore occuring, and can be estimated from the census figures. However, the rates observed in Huanaco Pampa and Condor Cocha are higher than 28%, so some further explanation on this must be sought. It is interesting, though, that these rates are similar to that observed in Lauca National Park, Chile.

## 6.3 Bias in the Classification of Age and Sex Classes

Any bias in the classification of age and sex classes will influence the calculated mortality rates and the calculated rates of increase. To demonstrate the potential influence of bias, we have adjusted the figures in the last column of Table 16 to correct for an assumed bias of 15% in the classification of the young of the year. The proportions of males, females and young of the year become 34:38:24 respectively, and the female young per female and the male young per female become 0.34 and 0.29 respectively. Assuming again no mortality whatsoever following the General Census, the rate of increase is calculated to be 34% per annum.

We can therefore put forward the following argument. In Huanaco Pampa and Condor Cocha, the densities of vicuna are low and the observed rates of increase are high. Presumably, therefore, resources are superabundant and the population is increasing rapidly with very low rates of mortality. As a consequence, the young of the year are growing (physically) extremely fast, and a proportion of them are being misclassified as adults in the General Census. The same may also be occuring in Central Galeras.

It is therefore possible that the rates of recruitment are being underestimated because the young of the year are being misclassified. Furthermore, the proportion of females may be biased as well. These potential biases must be investigated and, as discussed in Section 5.4, the best way of doing this is to shoot a small sample of family groups and check them through post mortem examination.

## 6.4 Increase in Census Area and Census Efficiency

Any increase in census area and census efficiency will inflate the observed rates of increase. The increase in census area (Table 9) has been corrected in Tables 10-13. However, there has probably been an increase in census efficiency since the individual Divisions are now being counted more carefully than previously. Unfortunately, the area counted each year, or at least the area searched, has not been recorded, so we have attempted to use the number of Sites mentioned on the field data sheets and the number of days worked as an index of census efficiency.

### Number of Sites

The number of Sites counted in each Division each year did not prove to be a useful index of census efficiency. The problems met with variable Site names have been mentioned already (Section 5.2). The number of Sites also reflects

the number of animals, for there has been a tendency to sub-divide Sites as the numbers of animals have increased.

Table 13 shows the nature of the problem. In Sector Central Galeras, for example, the number of Sites remained the same in 1976 and 1977, yet the numbers of vicuna counted increased. In contrast, Site numbers increased from 1978 to 1979 while numbers of animals fell. And Site numbers fell from 1975 to 1976 while animal numbers increased. The same patterns may be discerned in the other Sectors.

Number of Days

The number of days spent counting also did not prove to be a useful index of census efficiency. It was quite difficult to determine what a "day" signified, for the dead time spent walking between counting areas was not recorded. Furthermore, the number of days was greatly influenced in those years (not recorded) when vehicles were available for travelling between counting areas. Table 13 shows the same mixed up patterns of numbers counted and days spent counting as have been seen with the Sites.

Conclusion

We have attempted to determine an index of census efficiency from the data on the number of Sites visited, the days spent counting and the animals counted, but have failed. A number of indices suggested themselves, but none were readily defensible.

## 6.5 General Conclusions

ONE Immigration is unlikely to be a major influence on the observed rates of increase in vicuna at Pampa Galeras.

TWO The effect on population estimates of increases to the Management Area can be adjusted for.

THREE The influence of any increase in census efficiency cannot be adjusted for with the existing data. With great difficulty, it may be possible to reconstruct the earlier censuses from the original field data sheets, the existing mapped Sites and with the help of the field personnel involved.

FOUR Small biases in the classification of the ages and sexes of animals will strongly influence the estimates of recruitment, mortality and the potential rates of increase.

FIVE The observed rates of increase in the Sector Central Galeras and in the Reserve National are compatible with the estimated rates of recruitment (subject to FOUR above).

SIX The observed rates of increase in Sectors Huanaco Pampa and Condor Cocha are incompatible with the estimated rates of recruitment. However, the rates of recruitment may themselves be underestimated.

# SECTION 7

## AERIAL SURVEY OF VICUNA

### 7.1 Introduction - Why Use Aerial Survey?

Considerable interest has been raised in the possibility of using aerial survey methods for estimating the numbers of vicuna in Pampa Galeras. One survey has been carried out already (Eltringham 1980) although with somewhat controversial results.

Aerial survey has the appeal of being 'modern' and 'high technology', but there are many drawbacks. It must be clearly understood that aerial surveys are only useful when ground surveys cannot be employed. Aerial surveys always give biased results and they always lead to an underestimate of animal numbers. The art of aerial survey is to minimise and correct the biases inherent in the method, and the best way of doing so is to compare aerial estimates against those obtained from well organised ground counts.

There is another point about aerial surveys. They are seductively easy to carry out and accordingly they are very easy to do really badly. The reality is very different. Aerial surveys require a high standard of training for both pilots and observers. They require highly expensive equipment. Most important of all, the air crews must be in constant practice to maintain efficiency. An aerial survey programme is not something to be embarked on lightly for it entails a major commitment of funds and personnel.

### 7.2. Bias in Aerial Survey of Vicuna

Eltringham (1980) made an aerial survey of vicuna in Pampa Galeras in April 1980. The aircraft used was a Twin Otter, flying at an average ground speed of around 240 kph and at 500 feet above ground level. The counting strip was 279 meters wide and one observer was used, (Table 17).

We carried out some test flying in Pampa Galeras in a turbocharged, STOL equipped Cessna 206 which was also fitted with an oxygen system. Ground speed was somewhat lower, around 200 kph, and two observers each had strips calibrated to 250 meters in width at a flying height of 500 feet above ground level. At the lower flying heights of 200 feet above ground level the observer's strips were 100 meters in width. Height control was roughly maintained by reference to the pressure altimeter and by reference to the size of the aircraft's shadow on the ground.

#### Eltringham's Survey

The biases in Eltringham's survey were analysed for each of his strata (Sectors) and for the whole Management Area by comparing his estimates of numbers and group sizes against those recorded on the 1979 General Census (Table 18). Overall, only 25% of the animals were recorded. Analysing the data in more detail shows that the source of bias came more from missing groups of animals rather than from undercounting the number of animals in the groups actually seen. Only 33% of family groups were recorded, but Eltringham's group size was within 11% of the ground census. The data for

male groups was similar except that the mean group size was larger than that recorded during the General Census.

Eltringham used a group size of 15 as a cut-off point to distinguish between male and family groups, so this may have influenced his average group sizes. However, his proportion of females with calves was 11.6%. His survey was carried out in April, at a time when the vicuna are breeding, so this figure appears to be somewhat low, especially since the proportion of female with young recorded on the General Census the previous September/October was 31.7%. It would appear, therefore, that Eltringham was missing significant numbers of young animals.

Transect Test Flying

The problem therefore is one of spotting groups rather than of counting the animals once the groups are spotted. Our transect test flying had the objective of testing whether it was possible to reduce this source of bias. Transects were flown at two heights, 500 feet and 200 feet, and we counted only the number of groups, not the number of individuals (Table 19).

At 500 feet and with a 250 meter counting strip (either side of the aircraft), our bias was of the same order of magnitude as was Eltringham's. In fact, our bias was larger, and we missed more groups even though we were flying considerably more slowly. This was probably due to two factors. First, our observers (Torres and Schutz) were much less experienced than was Eltringham, even though they had both spent the previous two weeks in the field with vicuna. Second, the area was considerably drier than when Eltringham made his survey, so the animals may have been less visible.

However, at 200 feet above ground level and with a 100 meter counting strip either side of the aircraft our bias was considerably less, and only 10 - 15% of the groups were missed.

These tests were carried out only to give an indication as to whether it was even possible to reduce the bias in an aerial survey of vicuna. They do not measure the actual bias neither do they indicate accurately the reduction in bias from reduced flying height and strip width. All that the tests show is that the problem is open to solution.

Block Counting

As an additional exercise, two total counts of a small block were made from the air. The block was an individual Site which had been counted twice on the ground, once during the General Census and once by ourselves during the recount exercise (Section 4.4). The two ground counts returned estimates of 150 animals and 147 animals. The two aerial total counts, made at approximately 200 - 300 feet above ground level, returned estimates of 75 and 79 animals. The bias in these block counts was therefore 52%.

## 7.3 The Design of an Aerial Survey of Vicuna in Pampa Galeras

### Equipment

We consider that the turbocharged, STOL (short take-off and landing) equipped Cessna 206 is a safe aircraft in which to carry out an extensive, low level aerial survey of vicuna in Pampa Galeras. The oxygen system is an additional advantage. However, the aircraft (hired from Aero-Condor in Nazca) would have to be fitted with a radar altimeter and with full crew intercom. 35mm cameras would also be needed as well as small tape recorders with batteries and cassettes.

### Aircrew

The pilot would be supplied by the operators of the aircraft while the observers should be drawn from the most experienced vicuna counters on the project staff at Pampa Galeras.

The services of an expatriate expert in aerial survey would be required, for there is no expertise in this technique in Peru. The expert would need to organise the training of the observers and the test flying for determining flying height and strip width. He would also design and implement the survey, and work up and report the results. He would be needed in all for about eight weeks.

### Training

A training programme would be necessary for both pilot and observers. The pilot should be trained to contour fly by reference to the radar altimeter and to navigate at low level. The observers should be trained to spot, photograph and count groups of vicuna and record their data unambiguously.

### Type of Census

We recommend that strip transect sampling should be used, for the biases are lower than with block counting. Furthermore, the aircraft is not suited to block counting. Systematic sampling would not be required since distribution data are already available from the General Census. The transects should therefore be located randomly within the Management Area.

### Selection of Flying Height and Strip Width

We consider that a flying height of 200 feet above ground level does not have adequate safety margins for extensive survey work in Pampa Galeras. 300 feet is probably the minimum safe height at which to fly.

The strip must be narrow in order to minimise bias, probably between 75 - 100 meters.

Considerable test flying would be required to select the combination of flying height and strip width compatible with safety yet with low bias. One of the objectives of the test flying would be to measure the bias at the selected height and strip width. The bias would then be corrected after the survey.

Sample Size

The sample sizes given in Table 20 have been calculated to yield estimates of vicuna numbers within each Sector with errors of less than 5%. The calculations are made on the assumption of a strip width of 100 meters either side of the aircraft, 200 meters in total. The variance of the mean number of animals per transect has been calculated from the data collected by us on our test flying.

The calculations suggest that a 20% sample would be required in Central Galeras and that a 15% sample is required elsewhere. These calculations would have to be repeated once more data are available from the programme of test flying.

Number of aircraft hours

We calculate from the required sample sizes that 21 hours of flying would be required for the survey and a further 21 hours for transit to and from Nazca and Pampa Galeras. Since the oxygen lasts only three hours, a total of 7 days will be required for the survey, only one flight being made each day.

We further estimate that the programme of training and test flying would require an additional 30 aircraft hours and 7 days work.

Timing

We recommend that any aerial survey be carried out as close to, or at the same time as, the General Census so that the ground counts are more comparable to the aerial estimates. We recommend further that any aerial census avoid the period April through June: the larger proportion of young present at that time will introduce additional errors into the aerial counts.

The census exercise can probably be completed within an eight week period, thus:

| | |
|---|---|
| Briefing and travel between P.G. and Nazca | 1 week |
| Training and test flying | 2 weeks |
| Census operations | 2 weeks |
| Waiting for colour film to be processed | 1 week |
| Analysis and reporting | 2 weeks |

Costs

Costs are calculated in Table 22. Provision has been made for price increases in the costs of equipment and aircraft charter rates and for search and rescue capabilities.

Search and Rescue

An extensive, low level aerial survey of Pampa Galeras is very much more dangerous than more normal aerial survey work, a worrying aspect is the present lack of Search and Rescue capabilities. We feel that Search and Rescue should be taken seriously, and recommend the following as minimum precautions:-

1. The survey aircraft should be equipped for ground to air communication with the headquarters at Pampa Galeras and with vehicles in the field.

2. An aircraft for Search and Rescue must be on standby at Nazca during all training and census operations. This aircraft should have the flight plan for each day's operations, and must also be equipped for air to ground communication with the headquarters at Pampa Galeras and with project vehicles in the field.

3. The headquarters at Pampa Galeras should also have the flight plan for each day's operations. Furthermore, one vehicle should be in the field every day in the general area of the aircraft's operations. This vehicle must be equipped for ground to ground and ground to air communication.

## 7.4 Conclusions

We are of the opinion that a second aerial survey of vicuna in Pampa Galeras is unnecessary for the following reasons :-

1) The area is ideally suited for ground counting and the present General Census is well organised and gives repeatable and relatively unbiased results. Furthermore, the other census activities at Pampa Galeras (studies of population dynamics, habitat selection and competition) are equally well suited for ground counts.

2) Since there is no expertise in aerial census in Peru, an expatriate expert will be required in addition to an extensive and costly training programme for Peruvian observers and pilots.

3) Since the biases in aerial survey of vicuna are not yet measured and documented adequately, an extensive and costly series of test flights must be carried out before an aerial survey can be embarked upon.

4) Since there are no aircraft equipped for aerial survey, costly equipment must be obtained and fitted into locally available charter aircraft.

5) Since the bias in the aerial survey can be corrected only by comparing the aerial estimates against the ground estimates, the final corrected aerial estimate will be exactly the same, numerically, as the ground estimate.

A single aerial survey of Pampa Galeras is therefore neither necessary nor cost effective. We therefore recommend very strongly that the plans for an aerial survey be shelved.

However, a case could be made for developing an aerial survey capability within the Project itself. The survey team would carry out aerial estimates of vicuna not only in Pampa Galeras but also in other Project areas. Surveys of domestic stock and of land use could be included into its programme in addition to surveys within other National Parks and Reserves.

Such a programme would entail considerable capital expenditure, since the Project would have to acquire its own aircraft and equipment. Overheads would also increase to accommodate the maintenance and operation of the aircraft and the services of a full time pilot. In addition, a very extensive training programme would be required before the team became fully operational.

# SECTION 8

## MORTALITY, PRIMARY PRODUCTION AND CARRYING CAPACITY

### 8.1 Introduction

There has been considerable controversy over the condition of the rangeland at Pampa Galeras, especially in the immediate vicinity of the National Reserve of Pampa Galeras (NRPG) itself. The controversy centres around the possibility that the range has become overgrazed and degraded.

We have evaluated the available information on range condition and trend in Sector Central Galeras to see if it supports this hypothesis. In particular, we have searched for evidence of gross range deterioration and a consequently gross impact on the vicuna population.

We have made use of the available data on rainfall, net above ground production and plant basal cover. In addition, we have made some very preliminary calculations of the quantity of primary production available to the vicuna and we have related these to the observed patterns of mortality. Finally, we have used the census data to make first approximations of the theoretical carrying capacity of the rangelands.

(a) rainfall

Annual rainfalls (Figure 5) and mean monthly rainfalls (Figure 4) have been taken from Florez (1980). These figures apparently refer to the meteorological station at Pampa Galeras.

(b) net above ground primary production (NPP) and basal plant cover

Data for NPP, expressed as kilograms of dry matter per hectare per year, have been supplied to us by Dr. Hofmann for the years 1974 - 1980. The data were obtained from exclosure plots but no detailed information was provided on the methods used.

We have used these data (Table 23) to establish a relationship between NPP and rainfall for the years 1975 - 1980 (Figure 6). The NPP figure for 1974 was not included in the regression set since it was somewhat high and we suspect that accumulated, dead material from previous growth may have been included in this first year's clip.

The relationship has the form

$$\text{NPP (kg ha y}^{-1}) = 119 \ . \ 0.47 \text{ rainfall (mm a}^{-1})$$

where $r = 0.55$ and $r^2 = 0.31$. We then calculated a value of NPP for each year from 1967, using Florez' rainfall data.

Dr. Hofmann also provided us with estimates of the basal plant cover, measured from line transects both inside and outside the National Reserve.

(c) census data for Sector Central Galeras 1974 - 1980

We have calculated the rates of adult mortality from the census data for the Sector Central Galeras (Annex 1) using the relationship

$$\text{adult mortality } \% = (A_t - A{+}y_{t-1}) \;/\; A{+}y_{t-1} \cdot 100$$

where A is the number of adults and A+y is the number of adults plus young in years t and t-1 respectively. Sinclair (1978) discusses the use of this expression. It defines adult mortality as the difference between the number of adults recorded during one General Census ($A_t$) and the numbers of adults plus young recorded during the previous General Census ($A{+}y_{t-1}$).

(d) census data for NRPG (1967-1980) and for the three Sectors (1974-1979)

We have calculated the theoretical carrying capacity (K) from the census data for the NRPG, for the three Sectors in the Management Area and, for comparative purposes, for Lauca National Park, Chile (data from Brack 1980). The method used was that of Morisita (1965), discussed by Caughley (1977).

$$(N_{t+1} - N_t) \;/\; N_t = a - b \cdot N_{t+1}$$

where $b = a / K$, $a = e^{rm} - 1$ and N is the population size (or density) at years t and t-1 respectively.

This method can be applied to populations exhibiting exponential growth (Table 24 and Figure II), and it relies on the rate of the logistic model of population growth.

## 8.2 Rainfall, Range Condition and Adult Mortality

Rainfall at Pampa Galeras (Figure 4) is unevenly distributed throughout the year. Over 70% of the rain falls during the January to March rainy season, the period May to October being effectively dry.

Mean annual rainfall over the fourteen year period 1967-1980 (Figure 5) is 417 mm $a^{-1}$ with a standard deviation of 43%. Rainfall has shown a marked decline since 1973, from a 1967/72 average of 555mm $a^{-1}$ (standard deviation 32%) to a 1973/80 average of 313 mm $a^{-1}$ (standard deviation 29%).

In contrast, the densities of vicuna in the NRPG have built up steadily since 1967 to a peak of 76 to the square kilometre in 1978. Thereafter, densities have declined to a 1980 level of 68 $km^{-2}$. Table 23 expresses the NPP calculated from the NPP/rainfall regression in terms of kilograms of dry matter available per day to each vicuna. Prior to 1975, when the population was expanding rapidly, there was considerably more NPP per animal than in more recent years. We do not know the daily requirements of vicuna in terms of NPP. However, using a mean body mass of 50 kg (Walker 1964) and a mean daily requirement of 2% of body mass per day, an estimate of daily requirements can be calculated as 1 kg per vicuna per day. Table 23 shows that production just about equals requirements at the present time.

The relationship between monthly rainfalls and basal cover is shown in Figure 7. Basal cover clearly increases in response to rainfall and then decreases during the long, dry season. This undoubtedly reflects an increase in plant

growth following rainfall and a decrease in standing crop during the dry season as plant material is eaten down. However, there is a clear trend of decreasing plant basal cover since 1976, although the cover appears to have stabilised since the middle of 1977.

In our calculations of adult mortality (Table 25), we have differentiated between natural mortality and mortality from shooting/capture. The results are summarised in Table 26, along with the number of young per 100 females.

There is a clear pattern of higher mortality rates at higher densities (Figure 8), the relationship being

$$\text{adult mortality } \% = -16.3+1.35 \cdot \text{density}$$

with $r = 0.79$ and $r^2 = 0.62$. Furthermore, the number of young per 100 females shows a strong negative relationship to density (Figure 9), the relationship being

$$\text{young: 100 females} = 64.6 - 0.84 \cdot \text{density}$$

with $r = -0.76$

There is also a strong negative relationship between the rate of adult mortality and the kilograms of NPP available per vicuna per day (Figure 10), the relationship being

$$\text{adult mortality } \% = 33.7 - 13.8 \cdot \text{kg animal } d^{-1}$$

with $r = -0.67$.

The following points must be borne in mind when interpreting these analyses:

(a) the problems with compiling and evaluating the census data themselves,

(b) NPP does not measure the food supply of vicuna, it measures only the total production. The abundance and quality of food remains unknown,

(c) clippings from exclosure plots do not measure the production of the rangeland under the contemporary rates of stocking.

We are therefore aware that we must be very cautious in our interpretation of these preliminary calculations. Nonetheless, neither the data on NPP nor the data on basal cover support the hypothesis of a heavily overgrazed or degraded rangeland. Instead, they show a clear cut almost classical picture of a population expanding towards, and stabilising at, its ecological carrying capacity. The population expanded rapidly under conditions of abundant resources and consequentially low rates of adult mortality. As resources became more limited, through population increase and through environmental fluctuations, mortality rates increased and population change first declined to zero and then fell.

It is interesting in this respect to note that Florez' (1980) evaluation of the state of the rangelands at Pampa Galeras mirrors these general conclusions.

## 8.3 Carrying Capacity

Carrying capacity (K) is a somewhat nebulous term in that everyone knows what it is but no one quite knows how to define it. Indeed, Caughley (1979) defines two different kinds of carrying capacities, the "ecological" carrying capacity and the "economic" carrying capacity. The ecological carrying capacity is that reached by a population when left alone to its own devices, and is typified by a large number of animals (relatively speaking) and a relatively low standing crop of plant biomass. In contrast, the "economic" carrying capacity is that maintained by management to sustain some desired offtake of animals; it is typified by fewer animals and a relatively higher biomass of plants. Caughley points out that, though these two kinds of carrying capacity both represent stable relationships between the relative biomasses of plants and animals, they are fundamentally different concepts which should not be confused.

We are concerned here with the ecological carrying capacity at Pampa Galeras, and we have calculated the theoretical values for the NRPG, the three Sectors in the Management Area and, for comparative purposes, for Lauca National Park, Chile (Table 27).

We have based these calculations on the logistic model of population growth, and the calculated values are therefore somewhat theoretical in that they are not based on hard data; namely the requirements of vicuna, the production of food for them to eat, and the relationship between production and offtake. Instead, they are simply statistical projections based on the past history of the populations. While it is true that this past history integrates all the factors influencing the populations in a single value, the population size at time t, it must be borne in mind that - as with all regression estimates - it is dangerous to predict values that lie outside the range of the data set. Accordingly, estimates of K calculated from the logistic model cannot take into account any changes in the interactions between vicuna and the rangelands or between vicuna and domestic stock that might occur in the future. These estimates are only valid if "everything remains the same".

Nevertheless, the calculated values of K are all of the same order of magnitude and suggest that the rangelands in each of the three Sectors of the Management Area are all of the same general quality. Theoretically, the present Management Area will support some 205,000 vicuna. At the present rates of increase, these carrying capacities will be reached by 1986/87.

These points are well illustrated by the more detailed data from the NRPG itself. The theoretical value of K is at a density of 89 vicuna to the square kilometer, while Florez (1980) suggests an optimal density of 83 vicuna to the square kilometre. Mean NPP over the fourteen years of rainfall records has been 417 mm $a^{-1}$ which will support a density of 86 vicuna $km^{-2}$. All these estimates are in close agreement, yet we can see at a glance from Figure 5 that vicuna densities in the NRPG commenced a decline after a peak density of 76 $km^{-2}$. The reason for this is that the environmental conditions have changed and therefore the estimates based on the past behaviour of the population are invalidated.

It is interesting in this respect to recalculate K for the NRPG using the data for 1976 to 1978. K is found to be 79.6 vicuna $km^{-2}$, a reasonable fit to the observed peak density of 76.3 $km^{-2}$.

## 8.4 Conclusions

ONE In the NRPG, the general picture is one of a rapid population increase at a time of abundant resources gradually slowing down, and then reversing, as resources became more and more scarce. The data suggest that density dependent regulation, mediaed by adult mortality, is taking place, aided by the cropping programme in the area.

TWO The data on NPP seem to reflect the current densities of vicuna. NPP has obviously been much higher in the past, and less of the production has been taken off. Inevitably, this will have caused a reduction in the ground cover which is very evident visually, and the data on basal cover show this. This does not mean, however, that the range is in any way heavily over-grazed or permanently degraded. Vicuna appear to be responding very quickly to changing levels of NPP as evidenced by the relationship between adult mortality rates and the resources available to each individual.

THREE The data on NPP were obtained from exclosure plots. They do not therefore measure either the total production of the range under existing stocking levels nor the production of food for the vicuna. Furthermore, the offtake by domestic stock has not been taken into account since data are as yet unavailable.

FOUR The theoretical carrying capacities (K) calculated for the three Sectors of the Management Area are derived from the past history of the populations and not from hard data on production, offtake and requirements. They must therefore be interpreted with caution.

Nonetheless, the close agreement between the calculated K values for the three Sectors suggests that the rangelands of Pampa Galeras are all of the same general quality.

## 8.5 Recommendations

ONE We feel that it is essential to study the dynamics of the production and offtake of food by vicuna and by domestic stock in order to determine the critical resources for vicuna, the critical times of year when they are in limited supply, the section of the population most at risk and the competition between stock and vicuna for these critical resources. These studies will also lead to more objective estimates of carrying capacity.

The delineation of habitat types from aerial photography and ground control currently underway by the University of La Molina is an important first step in stratifying the habitat, but is by itself inadequate. The most important aspects of the study are:-

(a) food
The food of vicuna must be defined. This can be done by stomach content and fecal pellet analysis (Gwynne and Bell 1968), by observations of grazing behaviour in different habitat types and by observations on captive animals. The definition of food must cover plant parts as well as plant species.

(b) production and offtake of food
Production and offtake of food must be measured under different densities of vicuna and vicuna/stock combinations. This is done best by short term exclosure plots from which can be measured standing crop, production, offtake and regrowth on a monthly basis, during the growing season and especially during the non growing season. The methods of Grimsdell and Bell (1975) and Sinclair (1977) are very appropriate to the Pampa Galeras situation.

The objective of this part of the study will be to relate production and offtake to environmental variation, such as rainfall, and to variations in vicuna density, for there are bound to be synergistic relationships between offtake and production (McNaughton 1976).

(c) food quality
The quality of the food (protein, carbohydrate, digestibility) must be measured by chemical analysis throughout the year.

(d) requirements
The minimum requirements of vicuna must be established, and linked to studies of body condition (Sinclair 1977).

TWO We recommend very strongly that much more attention is paid to studies of the population dynamics of the vicuna. We feel these studies are urgent in view of the major programme of utilisation that is being planned for implementation. In particular, the age structure of the population must be obtained, not only to investigate possible biases in the field indentification of age and sex classes (Section 5.4) but also for estimating the mortality and survival rates of different segments of the population.

The shot and captured animals are the only source of data on reproductive status, age and body condition, and full use must be made of them. The present study of cementum rings in vicuna teeth, for example, is only valuable if linked to obvious, and easily recorded field criteria of age.

There is a grave risk that unless these studies are undertaken rapidly, the dynamics of the vicuna population will be so altered by the planned management programme that it will be impossible either to determine their impact on the population or to predict the response of the population. The studies of Sinclair (1977) and Caughley (1977) are useful guides for planning such studies.

# SECTION 9

# MANAGEMENT AND UTILISATION

## 9.1 Introduction

The Special Project for the Rational Utilisation of Vicuna in Peru has always had two major objectives. First, to build up the stocks of vicuna through conservation efforts and programmes of reintroduction; second, to utilise the vicuna for meat, hides and fur once viable stocks are established.

The conservation objectives have been spectacularly successful at the Pampa Galeras sub-project. The stocks of vicuna have built up extremely rapidly and the theoretical carrying capacities may be reached by 1986/87. The sub-project is now planning to shift the emphasis of their management more towards active utilisation while still maintaining strict conservation oriented goals.

We have therefore evaluated the existing information on the population dynamics of the vicuna in order to assess the biological and the economic bases on which a programme to harvest vicuna may be designed. We have followed closely the concepts set out by Caughley (1977), a book which we recommend as essential reading for everyone concerned with the management of vicuna.

## 9.2 Basic Concepts

When a population is at the carrying capacity of its environment, the numbers are stable and unchanging. The rate of increase of the population is zero (r=0), and resources are just adequate to replace the animals lost through natural mortality. If the population is displaced to below the carrying capacity, and then left alone, the resources released by the displacement fuels an immediate increase in numbers back up to the carrying capacity.

Within reason, the further the population is displaced from its steady state the more abundant per animal are the resources released by the displacement. Accordingly, the rate of increase in numbers following a displacement is greater for larger displacements than for smaller ones.

It follows, therefore, that population must first be reduced in numbers to below its steady state before any yield can be harvested. Once the reduction has been carried out, a sustained yield (SY) harvest is that which maintains the population at its new, lower level. In other words, an SY harvest is one that keeps the rate of population increase at zero.

A number of important corollaries follow from these simple concepts:-

(a) for each level, or density, to which a population is reduced, there is an appropriate SY which will maintain the population rate of increase at zero.

(b) for each level of SY, there are two levels of density from which the SY can be harvested: either a small proportion of a numerically large population which is increasing slowly, or a large proportion of a numerically small population which is increasing rapidly.

(c) there is only one level of density at which a maximum sustained yield (MSY) can be harvested.

The pertinent question for Pampa Galeras, therefore, is how big should the initial reduction be and what proportion should be harvested subsequently to provide the MSY?

## 9.3 First Approximations of K, $r_m$ and MSY for Pampa Galeras

Caughley (1977) shows that the MSY can be derived in a very straightforward manner from the logistic model of population growth. The MSY is obtained by harvesting a population reduced to one half of its carrying capacity (K/2) at a rate equal to one half of its intrinsic (maximum) rate of increase ($r_m/2$).

We have therefore made a first approximation to the values of K, $r_m$ and MSY in our calculations set out in Table 27, summarising the results into Table 28.

The carrying capacity for the whole Management Area is theoretically some 205,000 animals. A reduction to one half of this number would permit a maximum sustained yield of 19,000 animals.

In Sectors Huanaco Pampa and Condor Cocha, the present (1979) stocks are still below one half of the theoretical K required for an MSY. Stocks in these two Sectors must be allowed to increase before any harvesting takes place. This is not to say that the existing stocks cannot support an SY, only that the SY will be less than the MSY.

The situation is different in Sector Central Galeras where existing stocks are above those required for the theoretical MSY. An initial reduction of 3,800 vicuna would bring the population down to the required level of 14,000 from which an MSY of 3,400 animals could theoretically be harvested annually.

We have already pointed out in Section 8.4 that the present carrying capacity in Sector Central Galeras is probably lower than that calculated in Tables 27 and 28. This shows the shortcomings inherent in the logistic model (Section 9.4), and these calculations MUST be repeated once all the 1980 census data are available.

## 9.4 The Design of a Harvesting Programme

Caughley (1977) emphasises that managing a wildlife population for MSY harvesting calls for a little bit more than applied numerology. Many factors must be taken into account, including the selection of a model to design, implement and monitor the harvesting programme, the selection of inputs into the model and the selection of the harvesting strategies themselves.

### a management model

Harvesting vicuna at Pampa Galeras will require a formal, management model. We are not suggesting that a mathematical model will give all the answers at a press of a button. What we do claim is that a formal, structured model will form a rigorous intellectual framework around which harvesting strategies can be designed, implemented, monitored and refined. Without some formal, structured plan, management practices are likely to be erratic and inconsistent.

The simplistic use of the logistic model of population growth with which we have made the first approximations of carrying capacity, $r_m$ and MSY is clearly inadequate for Pampa Galeras. The logistic model does not readily accommodate a number of important inputs, neither is it easy to use for testing, or simulating, harvesting strategies.

Some form of interactive model is required, which must at least accommodate the following major inputs:-

(a) primary production as a function of environmental variation (rainfall) and varying offtake rates by vicuna and domestic stock.

(b) population dynamics of both vicuna and domestic stock.

(c) harvesting strategies for vicuna and, ideally, for domestic stock.

The interactive model described by Caughley (1977) would suit the Pampa Galeras situation. It is simple enough to "run" on a desk top calculator yet sophisticated enough to take the range of inputs described above.

overall management strategy

There are two quite different strategies for harvesting a wildlife population, the "average" strategy and the "tracking" strategy. The average strategy relies on calculating a harvesting rate from a selected density of animals and then applying this harvest rate year after year. This strategy is best suited to conditions where management has been applied for many years and where the situation can be considered to be basically "under control".

In contrast, the tracking strategy relies on careful monitoring of the results of the harvesting, as well as other factors, and harvesting rates are readjusted on a year by year basis. In Pampa Galeras, where the skills of management have to be developed and refined along with the management itself, and where there are still quite some inadequacies in the data necessary to calculate harvesting rates, the tracking strategy is much more appropriate. It will require more effort and will initially result in lower yields, but it will have greater inbuilt safety margins and be more in line with the conservation aspects of the sub-project.

The implications of adopting a tracking strategy are twofold. First, careful monitoring must be designed and implemented at the same time as the management programme. Second, the management model must be able to accept updated information.

environmental monitoring

An important point to clarify before any detailed planning can start concerns the long term pattern of rainfall in the Pampa Galeras region. The fourteen years of rainfall data (Figure 10) show that there has been a marked decrease over the last few years, with rainfall apparently stabilising at a lower level, compared to previous years, since 1973.

It is important to determine if this lower rainfall level is "normal" or whether the earlier, higher rainfall is "normal", or indeed whether the rainfall has always fluctuated in this way. The implication of this is that the management model must take into account from the start the expected range

of variability in rainfall and the associated variations in the abundance of resources.

We have already stressed (Section 8.6) the importance of monitoring the production and offtake of food and we have outlined possible methods for doing so (Section 5.6). Fluctuations in food supply will directly influence K and $r_m$, and thus the level of harvesting.

domestic stock

Once vicuna numbers are reduced to one half of carrying capacity and harvesting at one half of $r_m$ has started, it is obviously important to ensure that the resources released to fuel population increase in vicuna are not utilised by some other segment of the grazing fauna, for example domestic stock. Were this to happen, both K and $r_m$ for vicuna would be depressed. Continued harvesting at the previous MSY would then drive the vicuna towards extinction.

This highlights the importance of domestic stock in the management of vicuna, and raises two important questions. First, do vicuna and domestic stock compete with each other for resources, and if so to what extent? Second, can the project enforce any control over grazing by domestic stock

Although domestic stock are counted during the General Census, we were unable to locate any compiled data on their numbers in the various Divisions. Furthermore, we were given to understand that stock move up to the Puna in the wet season and move off the Puna to the valleys during the dry season. If this is so, the data available may not be particularly relevant.

It is interesting, however, to note that the vicuna populations in each Division underwent rapid increase once conservation measures were enforced (anti-poaching). Even though resources were superabundant, the rapid build up of vicuna numbers demonstrates that there must have been resources available to the vicuna to fuel their population increases, resources that were not being used by domestic stock.

There are a number of perfectly plausible hypotheses about the relationships between vicuna and domestic stock, each of which will have important implications for the management of the vicuna. Among these are: -

(a) Vicuna and stock do not compete for resources. Vicuna have therefore increased independently to domestic stock.

(b) Stock numbers are regulated by factors other than the abundance of grazing resources on the Puna, for example grazing resources during the dry season in the valleys. The increase of vicuna is therefore independent from the domestic stock.

(c) The domestic stock have been maintained, by management, at the "economic" carrying capacity of the Puna (see Caughley 1979). The vicuna have increased by utilising the "extra" resources at the expense of the domestic stock.

(d) Vicuna and domestic stock compete directly for resources at some critical time of the year, for example the dry season.

We have already stressed the vital importance of studying the relationships between vicuna and domestic stock. The initial plans for harvesting vicuna must take into account the lack of data on this important interaction. Furthermore, the management model must be able to accommodate the interaction once data are available.

The second question about the control of grazing is much more difficult, for obviously the willingness of the campesinas to cooperate will be itself determined by the proven ability of the project to return economic benefits for their cooperation. At the moment, there would appear to be little possibility of enforcing any control over grazing by domestic stock and the initial management plan must take this into account. Furthermore, the management model must be able to accommodate cooperation at a later date.

population dynamics of vicuna

The population dynamics of the vicuna, especially the ways in which the population responds to harvesting, will form the most important of the inputs to the management model. At the present time the available data are somewhat scanty. We have been able to make some first approximations of adult mortality rates and the rates of increase and harvesting, but they are clearly inadequate for designing a major harvesting programme.

We have already discussed the range of studies which we consider to be of vital importance (Section 8.5). These studies will fulfil two important functions. First, they will provide the data from which the initial harvesting rates can be calculated. Second, they will provide monitoring data for continuously refining the harvesting strategies.

Naturally, the same points are equally applicable to domestic stock.

sex selective harvesting

Sex selective harvesting is widespread among pastoralists and ranchers, and for very good reasons. By culling males more heavily than females, thus biasing the sex ratio in favour of females, the resources available per individual are diverted to the most productive individuals in the herd, namely the females. (The most extreme example of sex selective harvesting is a dairy herd which may well have no adult males at all). By diverting resources in this way, the potential of the herd to increase when resources become abundant is greatly enhanced.

The same principle holds true for sex selective harvesting of wildlife populations. Caughley (1977) discusses the concept in detail, and points out that the critical factor is the number of males necessary to maintain the fecundity of the population. Caughley demonstrates that the MSY can be greatly increased by sex selective harvesting. For example, in a population with parameters similar to the vicuna, a shift in the sex ratio of females from 55% to 80% will approximately double the MSY.

The necessary data from which an optimum sex ration can be calculated has yet to be collected at Pampa Galeras. Nonetheless, the management model must be able to accommodate sex selective harvesting once the relevant data are obtained.

There is, however, a cost implication to sex selective harvesting. It calls for a much higher level of competence in the field and for much higher levels of training.

net economic gains

Although the MSY harvesting strategy provides the greatest numerical offtake of vicuna, this does not necessarily imply that the MSY will yield the highest net economic gains. The costs of harvesting increase dramatically as the densities of animals decrease. It is therefore quite possible that higher economic returns will be gained by harvesting fewer animals from a larger population.

## 9.5 Conclusions

We are aware of the pressures to continue commercial harvesting at Pampa Galeras. Some 4,800 animals have been shot already, and during our visit we heard of plans to shoot an additional 6,000 animals in the coming year (1980/81).

These pressures must be resisted very forcibly by the Project Management:-

1. There is no evidence that the range is becoming heavily overgrazed or degraded. Instead, the data support the hypothesis that density dependent regulation, aided (perhaps fortuitously) by the culling programme, is taking place,

2. There is as yet no structured management model on which to base the design, implementation, monitoring and refinement of harvesting strategies,

3. There remain major inadequacies in the data which must be rectified before a harvesting strategy can be designed; these particularly concern the population dynamics of vicuna, the production and offtake of food and the degree of competition between vicuna and domestic stock.

No attempts should therefore be made for the present time to harvest vicuna at rates even approaching those of the theoretical MSY. Instead, a more conservative cropping programme should be adopted which has the priority objective of obtaining scientific data while at the same time maintaining the flow of vicuna products for the benefit of the local people.

An annual harvest of 1,000 animals from the Sector Central Galeras will meet these important criteria:-

1. It is conservative and therefore in line with the policy guidance given in the World Conservation Strategy.

2. It will maintain a flow of vicuna products for the benefit of the local people in that part of the high Andes.

3. It will provide a solid statistical sample on which future management decisions can be based.

4. It will enable the Project Management to develop and refine their field techniques, and their processing and marketing techniques.

9.6 Recommendations

We therefore recommend the following:-

ONE Pressures to continue, or expand, large scale commercial harvesting must be resisted very forcibly by the Project Management.

TWO A very conservative harvesting programme should be adopted with the over-riding priority objective of obtaining scientific data on which the future management of the vicuna population can be based.

THREE The scientific objectives of the harvesting should be to:-

(i) obtain data on the age, structure growth and nutrition of vicuna;

(ii) arrive at more exact estimates of K, $r_m$ and MSY by monitoring carefully the response of the vicuna to the annual harvest;

(iii) check any biases inherent in the field classification of age and sex classes;

(iv) obtain the data required for calculating the optimum ratios for sex selective harvesting.

FOUR These objectives will be met by harvesting a FIXED number of vicuna from the population each year for three successive years. A harvest of 1,000 animals from the Sector Central Galeras, will provide a sound statistical sample on which solid management decisions may be based. Of these 1,000 animals, 700 should be females and 300 should be males.

FIVE Technically, the individuals should be selected at random from the population. However, this is extremely difficult to achieve with animals living in small tight groups. Therefore, whole groups, male and female, should be selected at random for culling. This will yield unbiased data and will have the additional advantage of minimising disturbance.

SIX Every animal should be assessed for age, sex, reproductive status and growth parameters. As far as is practicable, every animal, especially the females, should be subjected to a full post-mortem analysis of reproductive and nutritional condition.

SEVEN This harvesting programme must be integrated very closely with studies into the production and offtake of food and with studies into the competition between vicuna and domestic stock.

EIGHT These studies into population dynamics, population monitoring, range production and offtake, and competition should be designed, directed and integrated from Pampa Galeras itself. We feel, however, that there is no single person at Pampa Galeras who has the range of experience and expertise for this. Dr. Brack, the Executive Director of the Project, could certainly fulfil this role but he has to administer and direct the entire project and divide his time between Pampa Galeras and the other sub-projects. We recommend therefore that serious consideration is given to appointing a Senior Scientist to the Pampa Galeras sub-project.

# ANNEX I

## Age and Sex Classes in the Three Sectors

FM = males in family groups (I per group)
FF = adult females
YY = young
MFG = mean family group size
MG = number of male groups
MM = number of batchellors
MMG = mean batchellor group size
UN = undi fferentiated adults

### I. Sector Central Galeras (all three Divisions)

| year | FM | FF | YY | MFG | MG | MM | MMG | UN |
|---|---|---|---|---|---|---|---|---|
| 1974 | 1316 | 4047 | 2375 | 5.9 | 166 | 2628 | 15.8 | 440 |
| 1975 | 1989 | 5563 | 3171 | 5.4 | 105 | 2903 | 27.6 | 525 |
| 1976 | 2326 | 6760 | 3807 | 5.5 | 159 | 3796 | 23.9 | 714 |
| 1977 | 2965 | 8463 | 4126 | 5.2 | 163 | 4396 | 27.0 | 505 |
| 1978 | 3448 | 9213 | 4723 | 5.0 | 228 | 4232 | 18.6 | 1385 |
| 1979 | 2474 | 7499 | 1858 | 4.8 | 219 | 5449 | 24.9 | 872 |

2. Sector Huanaco Pampa (Divisions Pedregal and Huanaco Pampa)

| year | FM | FF | YY | MFG | MG | MM | MMG | UN |
|---|---|---|---|---|---|---|---|---|
| 1974 | 104 | 389 | 172 | 6.4 | 12 | 206 | 17.2 | 44 |
| 1975 | 230 | 774 | 230 | 5.4 | 22 | 469 | 21.3 | 49 |
| 1976 | 378 | 1128 | 684 | 5.8 | 19 | 388 | 20.4 | 183 |
| 1977 | 489 | 1402 | 798 | 5.5 | 29 | 677 | 23.3 | 157 |
| 1978 | 520 | 1553 | 879 | 5.7 | 31 | 704 | 22.7 | 211 |
| 1979 | 1059 | 2825 | 1505 | 5.1 | 55 | 1181 | 21.5 | 266 |

3. Sector Condor Cocha (Divisions Tipicocha, Condorcocha and Sawacocha)

| year | FM | FF | YY | MFG | MG | MM | MMG | UN |
|---|---|---|---|---|---|---|---|---|
| * 1974 | (101) | (445) | (209) | 7.5 | (20) | (402) | (20.0) | (42) |
| 1975 | 261 | ....1451.... | | 6.6 | | 271 | | 33 |
| 1976 | 402 | 1243 | 547 | 5.5 | 35 | 613 | 17.5 | 224 |
| 1977 | 613 | 1827 | 877 | 5.4 | 25 | 580 | 23.2 | 250 |
| 1978 | 862 | 2166 | 1173 | 4.9 | 60 | 1236 | 20.6 | 354 |
| 1979 | 1484 | 4195 | 1239 | 4.7 | 66 | 1378 | 20.9 | 336 |

* Division Condor Cocha only

# FIGURE 1. MANAGEMENT AREA OF PAMPA GALERAS

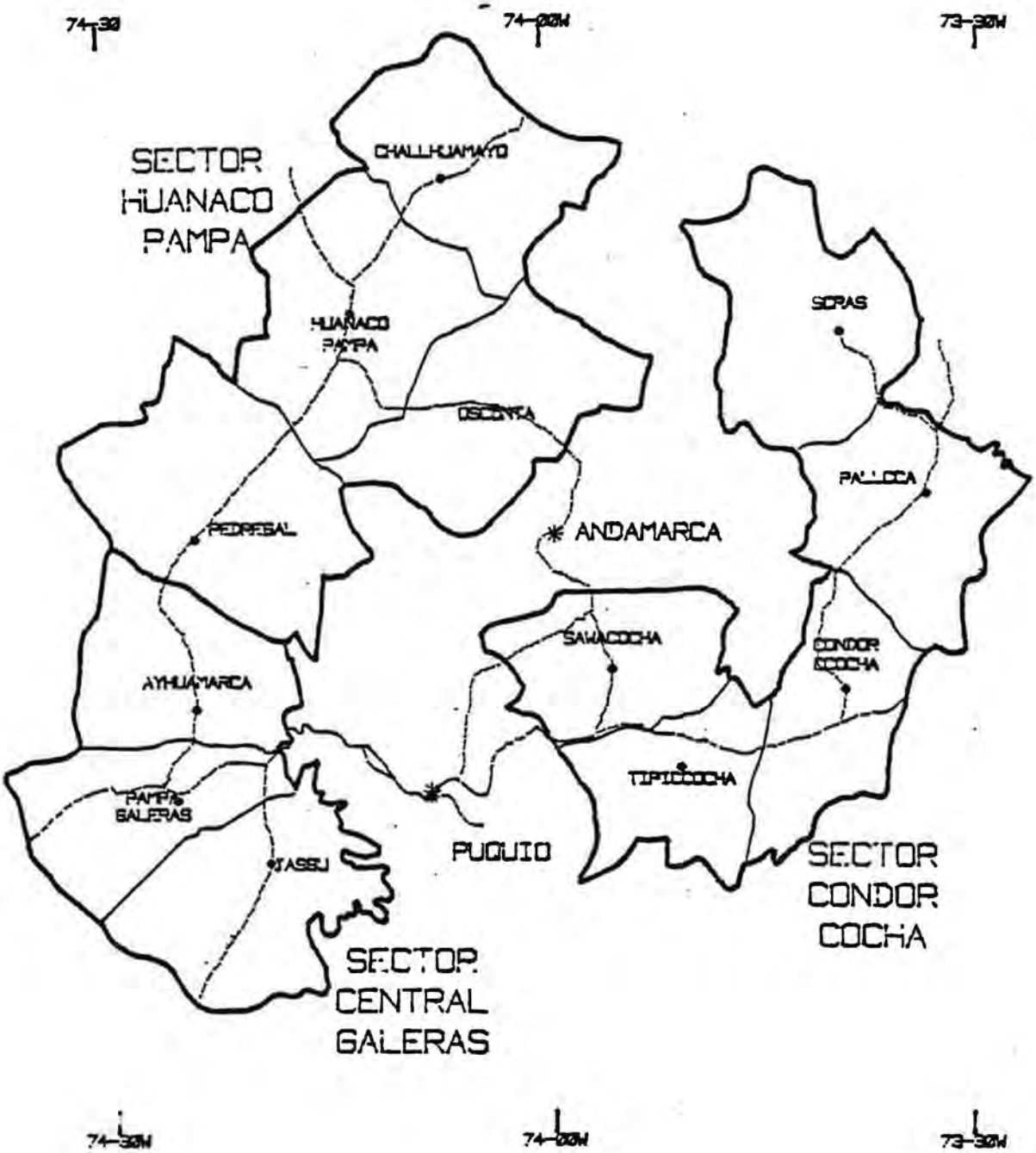
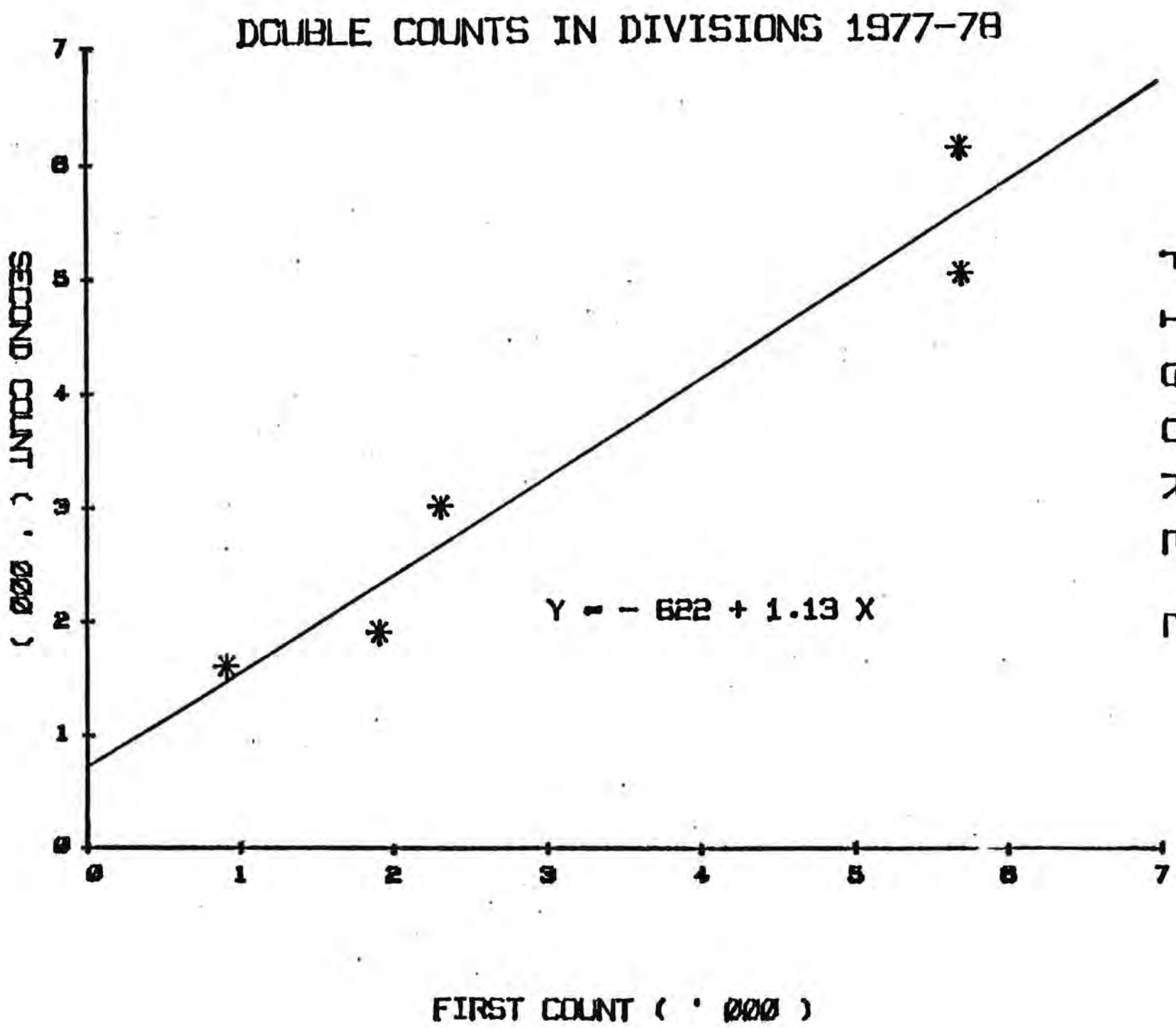
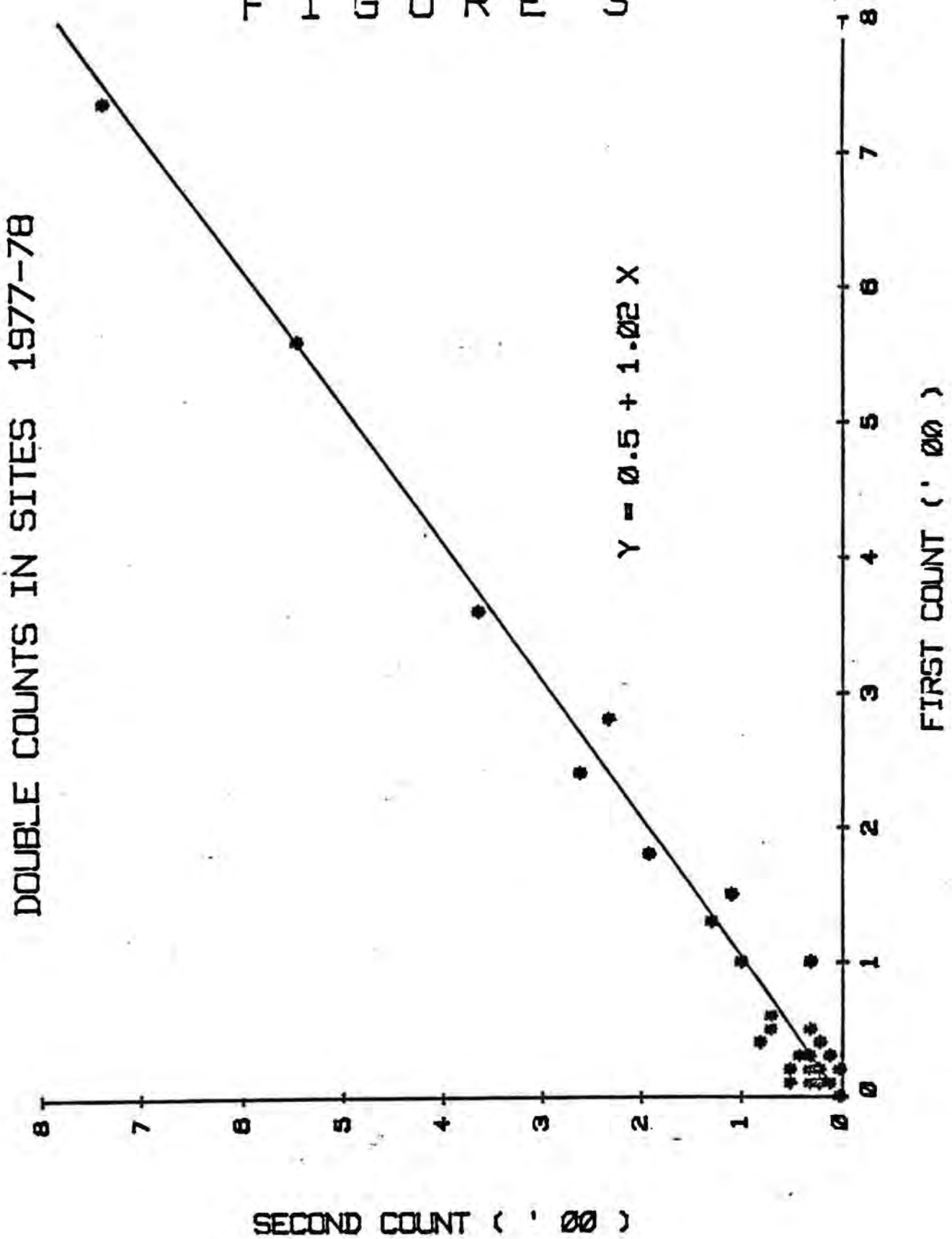


FIGURE 2


DOUBLE COUNTS IN DIVISIONS 1977-78
Y = - 622 + 1.13 X
SECOND COUNT ( ' 000 )
FIRST COUNT ( ' 000 )
0
1
2
3
4
5
6
7

# FIGURE 3


DOUBLE COUNTS IN SITES 1977-78
Y = 0.5 + 1.02 X
FIRST COUNT ( ' 00 )
SECOND COUNT ( ' 00 )
0
1
2
3
4
5
6
7
8

# FIGURE 4

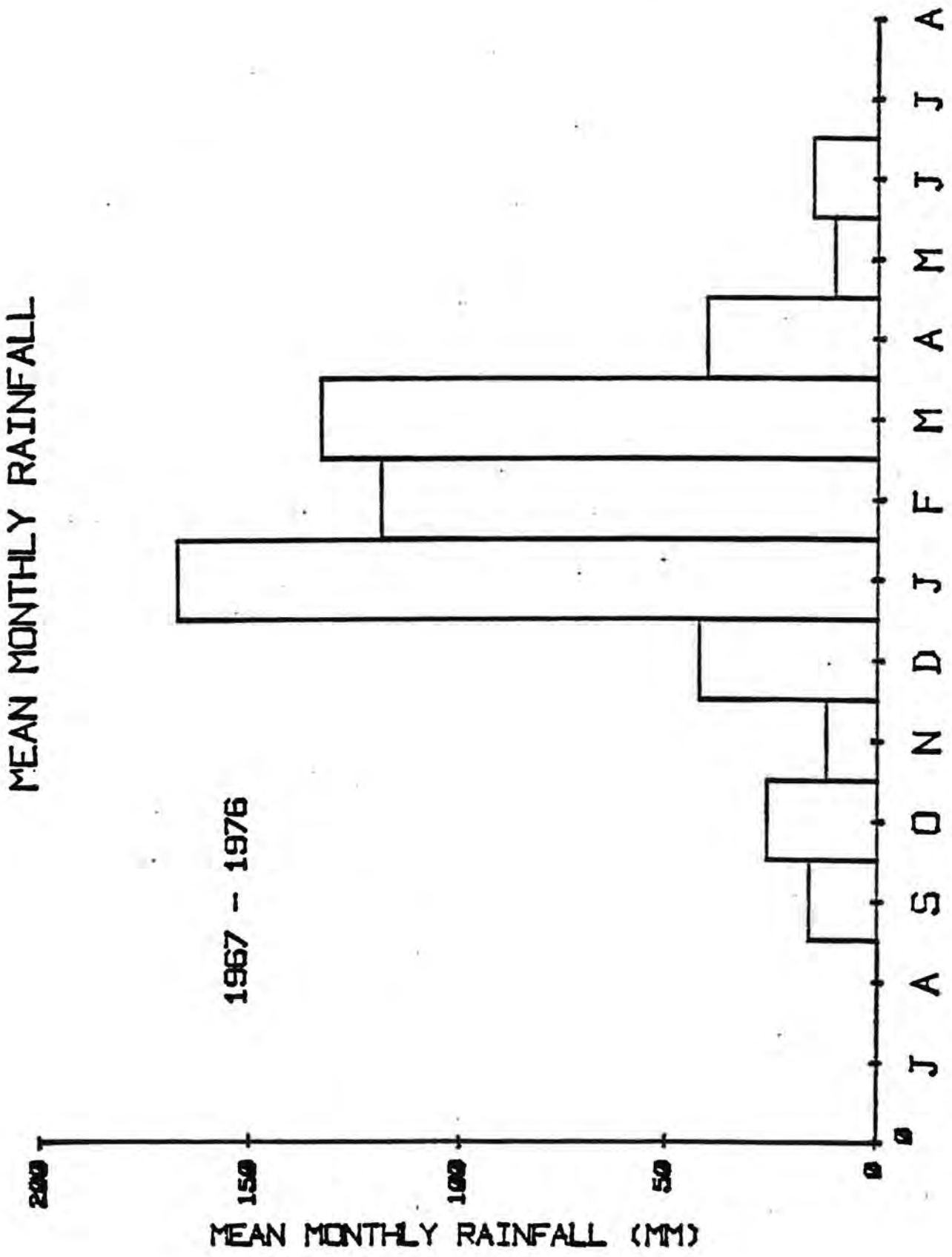
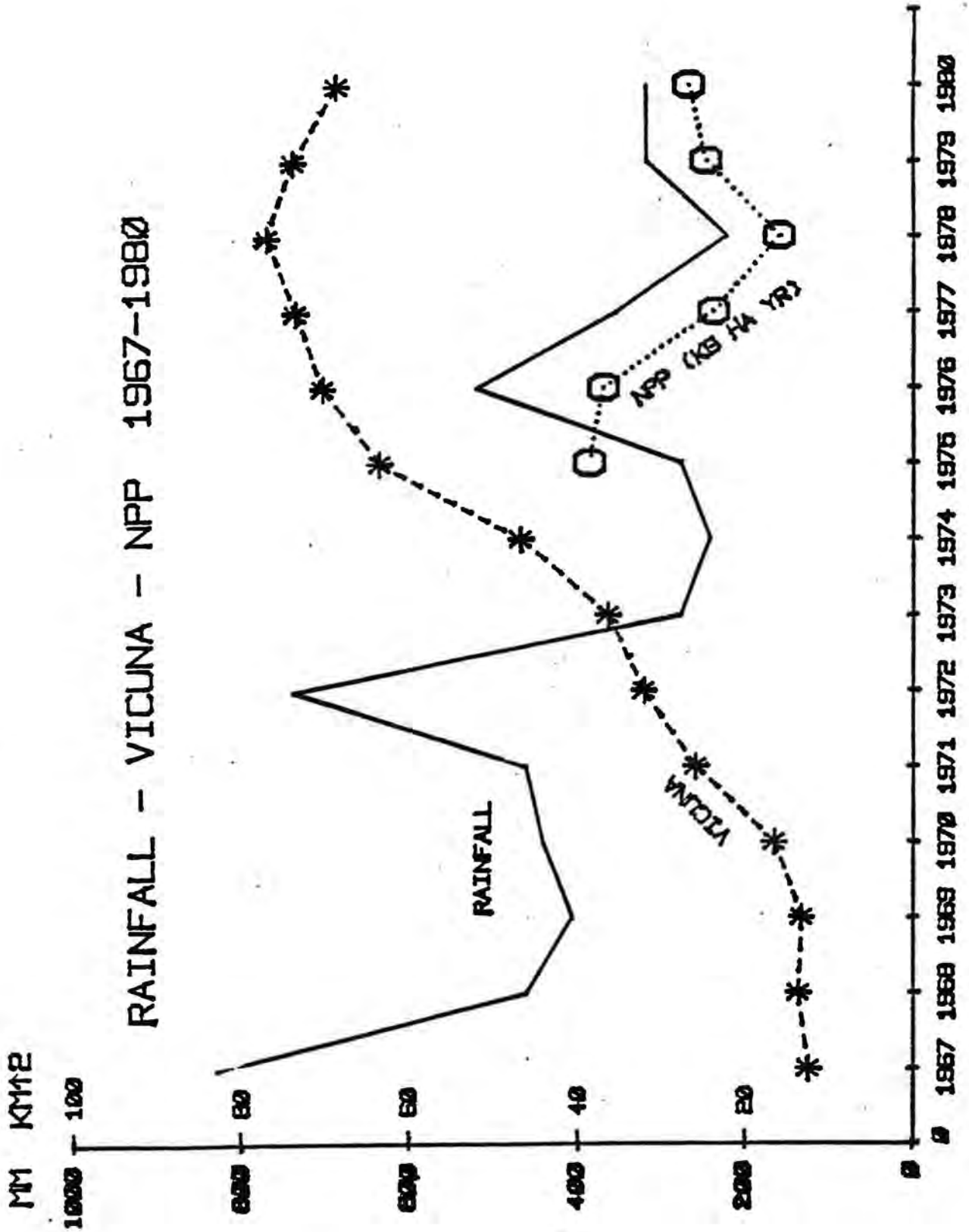

MEAN MONTHLY RAINFALL
1967 - 1976
200
150
100
50
0
MEAN MONTHLY RAINFALL (MM)
0
J
A
S
O
N
D
J
F
M
A
M
J
J
A

FIGURE 5


RAINFALL - VICUNA - NPP 1967-1980
MM KM^2
RAINFALL
VICUNA
NPP (KG/HA YR)
1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980

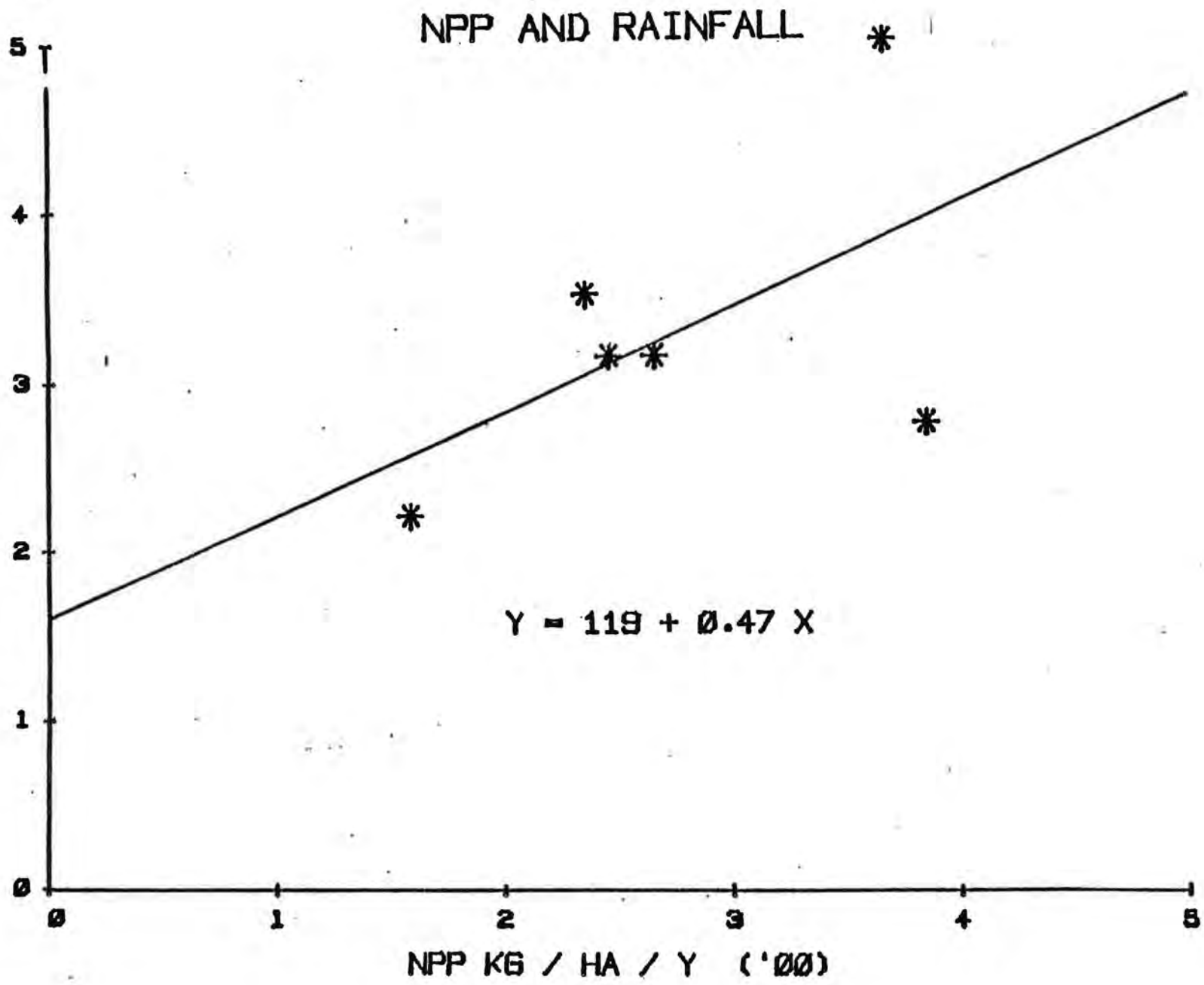
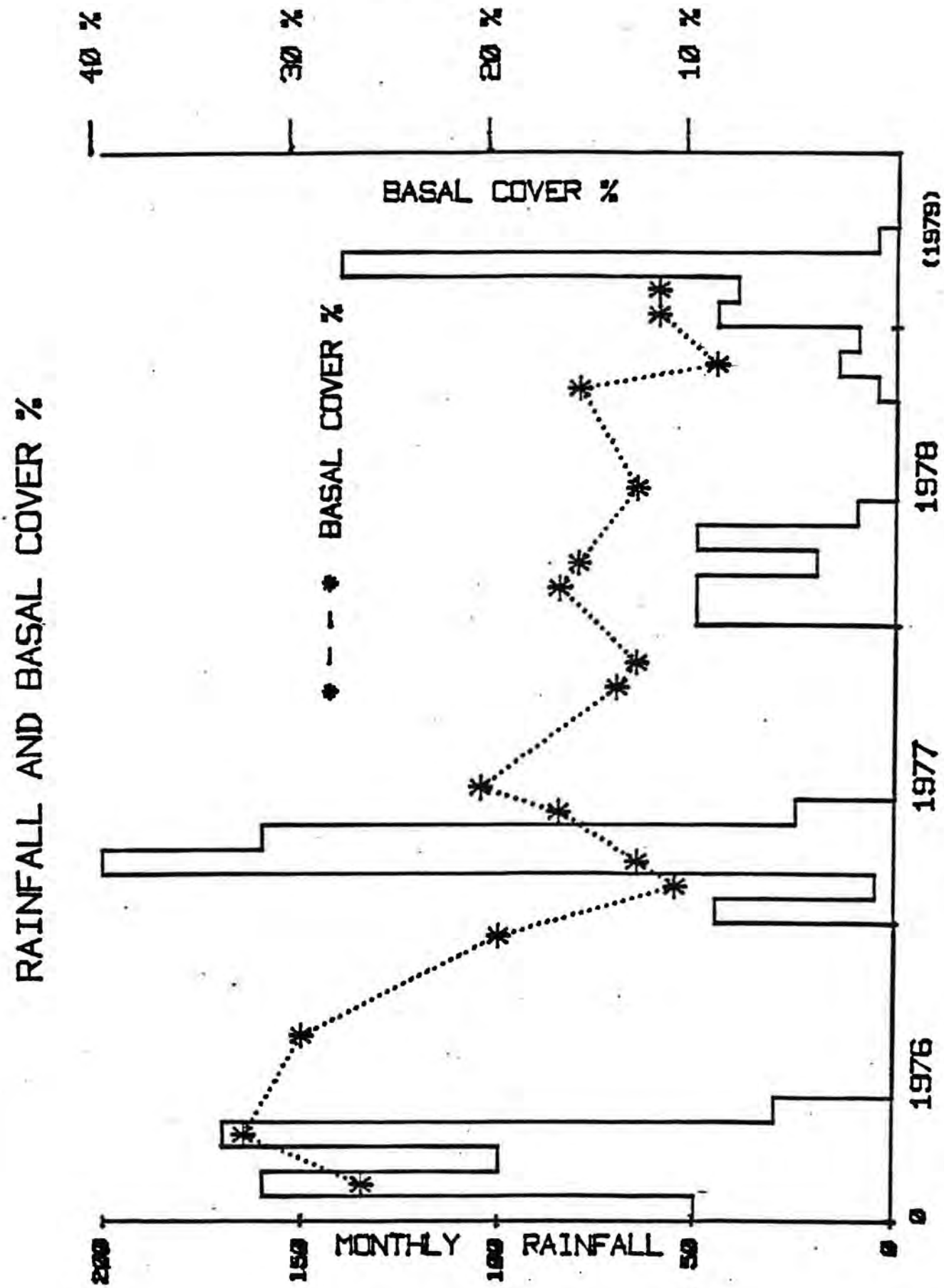



FIGURE 6

FIGURE 7


RAINFALL AND BASAL COVER %
40 %
30 %
20 %
10 %
BASAL COVER %
* - - - * BASAL COVER %
1976
1977
1978
(1979)
200
150
100
50
0
MONTHLY RAINFALL

# F I G U R E 8

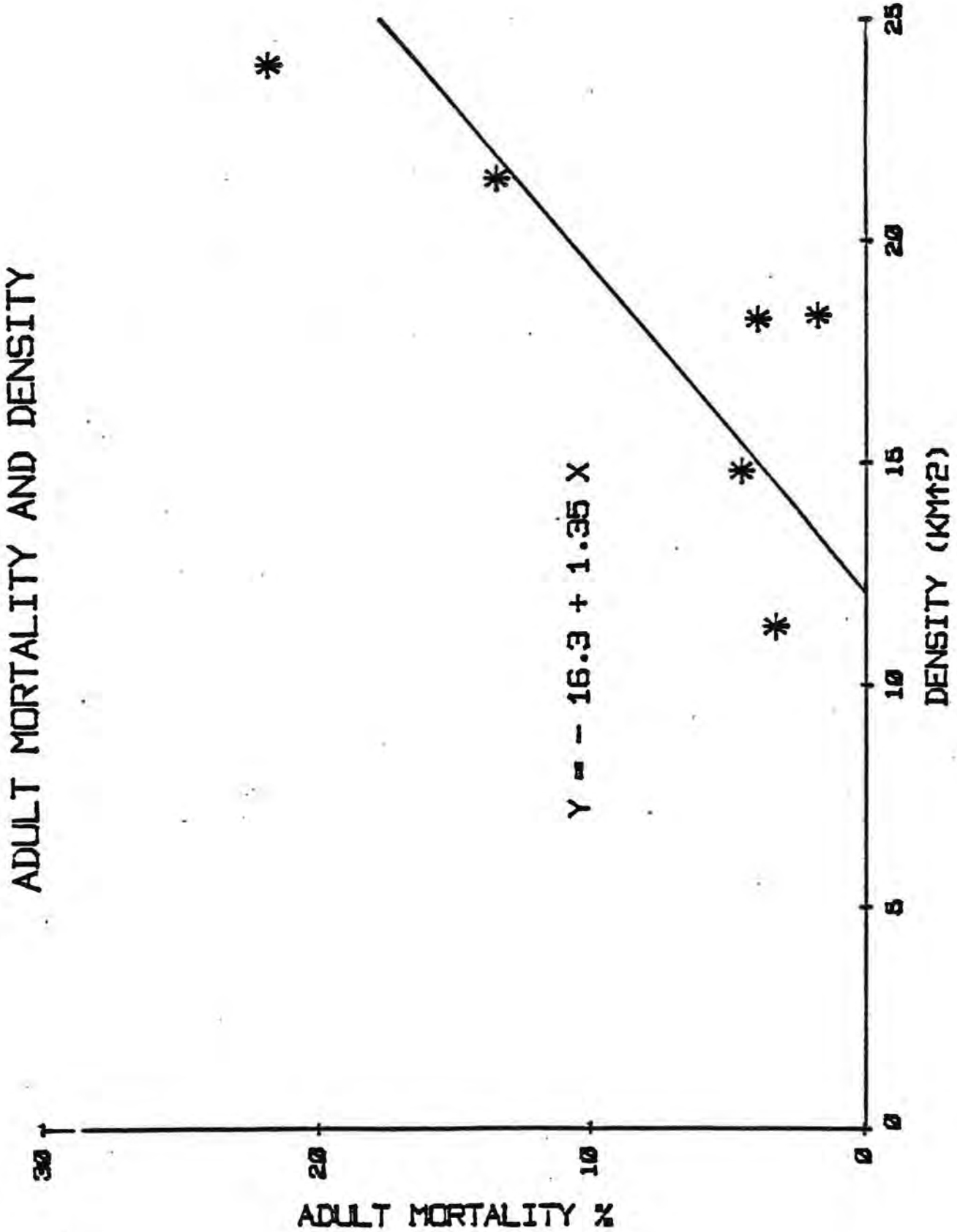
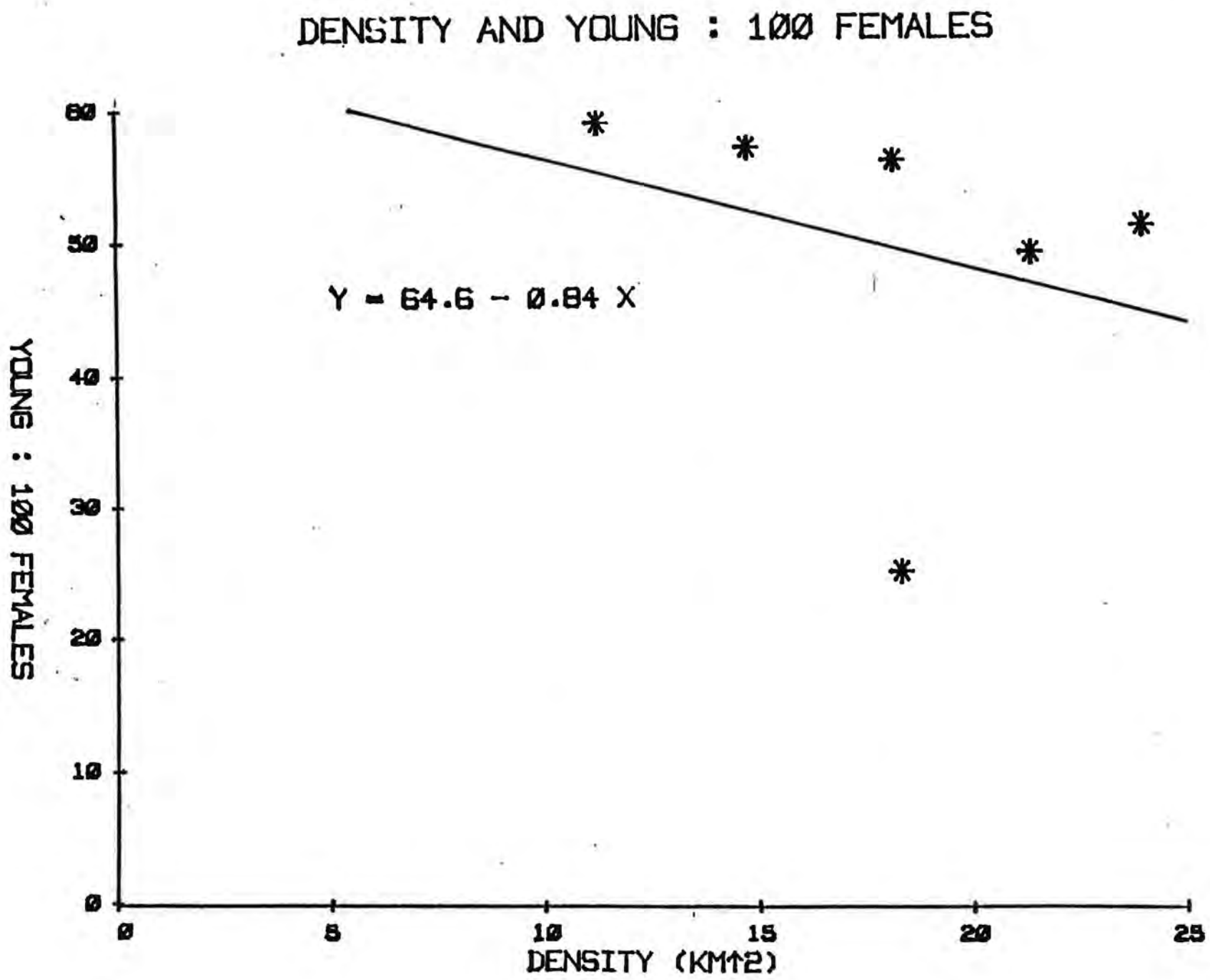
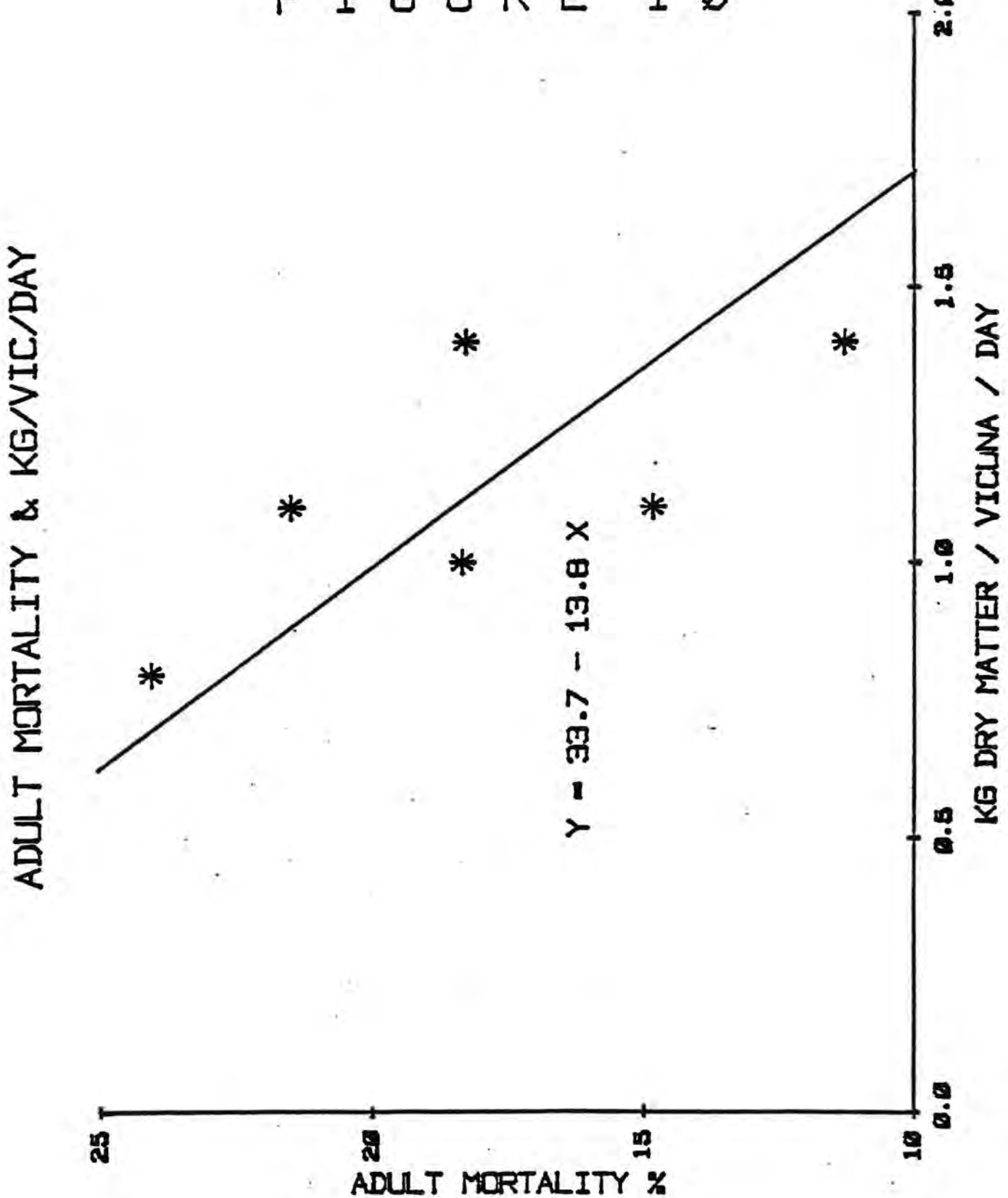

ADULT MORTALITY AND DENSITY
Y = - 16.3 + 1.35 X
ADULT MORTALITY %
DENSITY (KM^2)
0
10
20
30
0
5
10
15
20
25

FIGURE 9


DENSITY AND YOUNG : 100 FEMALES
Y = 64.6 - 0.84 X
YOUNG : 100 FEMALES
DENSITY (KM↑2)
0
10
20
30
40
50
60
0
5
10
15
20
25

# F I G U R E 1 Ø


ADULT MORTALITY & KG/VIC/DAY
Y = 33.7 - 13.8 X
ADULT MORTALITY %
25
20
15
10
KG DRY MATTER / VICUNA / DAY
0.0
0.5
1.0
1.5
2.0

# FIGURE 11

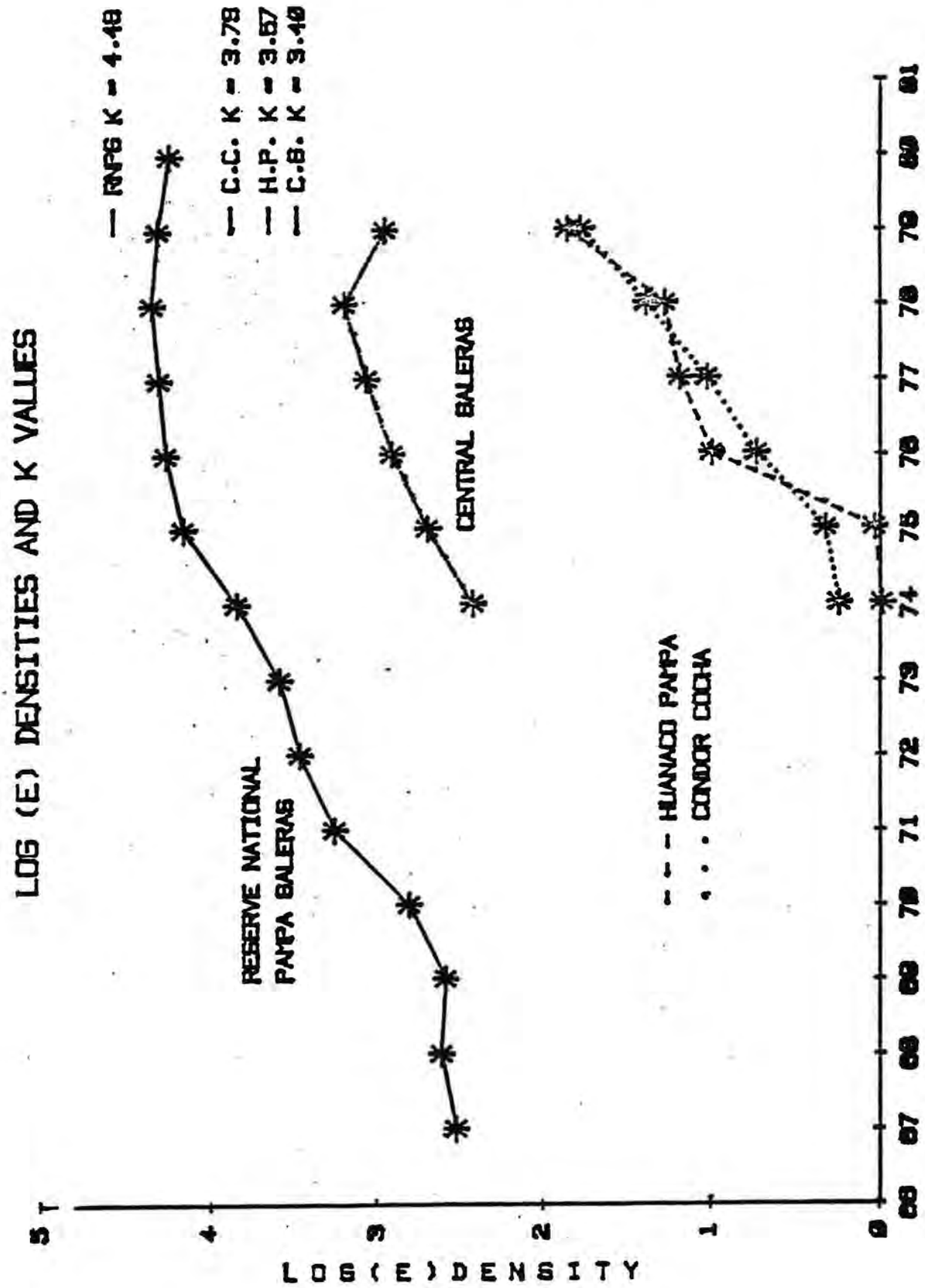

LOG (E) DENSITIES AND K VALUES
RNPG K = 4.48
C.C. K = 3.78
H.P. K = 3.57
C.B. K = 3.40
RESERVE NATIONAL
PAMPA BALERAS
CENTRAL BALERAS
HUANACO PAMPA
CONDOR COCHA
LOG(E)DENSITY
5
4
3
2
1
0
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81

TABLE I

Management Area, Sectors and Divisions
At Pampa Galeras

| Sector | Division | Hectares [a] | |
|---|---|---|---|
| Central Galeras | RNPG[b] | 6,500 | |
| | Jassu Grande | 33,300 | |
| | Ayhuamarca | 55,900 | 95,700 |
| Huanaco Pampa | Pedregal | 53,200 | |
| | Huanacopampa | 53,600 | |
| | Osconta | 46,800 | |
| | Challhuamayo | 42,500 | 196,100 |
| Condor Cocha | Tipicocha | 35,600 | |
| | Sawacocha | 52,100 | |
| | Condorcocha | 58,100 | |
| | Pallca | 49,900 | |
| | Soras | 45,500 | 240,700 |
| Management Area | | | 532,500 |

(a) hectares of vicuna habitat

(b) Reserve National Pampa Galeras

## TABLE 2

Double Counting Exercise on the 1980 General Census

counts of vicuna in 3 sites at Jassu Grande

| | general census | double count | |
|---|---|---|---|
| date | 25.09.80 | 28.09.80 | |
| Family Groups | | | |
| number | 46 | 42 | |
| males | 46 | 42 | |
| females | 135 | 130 | |
| young | 35 | 33 | |
| group size | 4.7 | 4.9 | |
| Others | | | |
| batchellors | 37 | 79 | |
| unidentified | 4 | 2 | |
| Totals | | | |
| in families | 216 | 205 | - 11% |
| others | 41 | 81 | + 98% |
| all vicuna | 257 | 286 | + 11% |
| Time spent counting (minutes) | 150 | 176 | + 17% |

TABLE 3

Test of Bias in the Double Counts on the 1980 General Census

numbers of vicuna

| | families | batchellors | total |
|---|---|---|---|
| first count (a) | 216 | 41 | 257 |
| estimate (b) | 221 | 42 | 263 |
| s.e. | 5.7 | 1.0 | 5.9 |
| second count (c) | 205 | 81 | 286 |
| difference | -16 | +40 | +29 |
| t value | 2.81 | 39.0 | 3.90 |
| p value | <0.01 | <0.001 | <0.001 |
| bias % | 5% | 93% | 11% |

(a) from General Census 25.09.80

(b) estimated from the regression eguation $y = 0.48 + 1.02x$ (Table 4)

(c) from double count exercise 28.09.80

## TABLE 4

Analysis of Double Counts in Divisions and Sites,
General Censuses 1978 and 1979

| | divisions | sites |
|---|---|---|
| number | 5 | 36 |
| a | -662.55 | 0.48 |
| s.e.a | 639.85 | 4.78 |
| t a = o | 1.04 | 0.10 |
| p | ns | ns |
| b | 1.13 | 1.02 |
| s.e.b | 0.16 | 0.03 |
| t b = 1 | 0.81 | 0.67 |
| p = | ns | ns |
| s.e. % b | 14.5% | 2.6% |
| mean of first count (x) | 3512 | 94.1 |
| s.e.x | 867 | 26.2 |
| mean of second count (y) | 3300 | 96.2 |
| s.e.y | 1008 | 26.9 |
| difference % (x - y) / x . 100 | - 6% | + 2% |

a = y intercept

b = slope of regression line

TABLE 5

Counting Effort in Each Sector In The
1979 General Census

| | Central Galeras | Huanaco Pampa | Condor Cocha | Management Area |
|---|---|---|---|---|
| divisions | 3 | 4 | 5 | 12 |
| hectares | 95,700 | 196,100 | 240,700 | 532,500 |
| vicuna | 18,152 | 13,317 | 10,432 | 41,901 |
| days | 28 | 33 | 38 | 99 |
| % hectares | 18% | 37% | 45% | |
| % vicuna | 43% | 32% | 25% | |
| % days | 28% | 33% | 39% | |

## TABLE 6

Sampling Strategi es Based on the 1979 General Census

Strategy A : Sample within each Division so that SE $(\hat{Y}) \leqslant 5\%$

| DIVISIONS | N | Y | $\bar{y}$ | $Sy^2$ | n | f | $SE(\hat{Y})\%$ |
|---|---|---|---|---|---|---|---|
| Pampa Galeras | 29 | 4749 | 164 | 11232 | 25 | 0.86 | 4.8 |
| Ayhuamarca | 138 | 7248 | 53 | 884 | 67 | 0.49 | 4.9 |
| Jassu | 98 | 6155 | 63 | 417 | 30 | 0.31 | 4.9 |
| Osconta | 50 | 4414 | 88 | 2145 | 35 | 0.70 | 4.9 |
| Pedregal | 82 | 4861 | 59 | 324 | 26 | 0.32 | 4.9 |
| Huanacopampa | 57 | 1975 | 35 | 157 | 28 | 0.49 | 4.9 |
| Chalhuamayo | 42 | 2067 | 49 | 290 | 23 | 0.55 | 4.9 |
| Soras | 49 | 1052 | 22 | 54 | 24 | 0.49 | 5.0 |
| Tipicocha | 45 | 3260 | 72 | 581 | 23 | 0.51 | 4.9 |
| Sawacocha | 48 | 3615 | 75 | 593 | 23 | 0.48 | 4.9 |
| Condorcocha | 40 | 1757 | 44 | 47 | 8 | 0.20 | 4.9 |
| Pallca | 30 | 748 | 25 | 36 | 14 | 0.47 | 4.7 |
| Sectors | | | | | | | |
| Central Galeras | 265 | 18152 | | | 122 | 0.46 | 2.9 |
| Huanaco Pampa | 231 | 13317 | | | 112 | 0.48 | 2.6 |
| Condor Cocha | 212 | 10432 | | | 92 | 0.43 | 2.5 |
| Management Area | 708 | 41901 | | | 326 | 0.46 | 1.2 |

N = number of sites : Y = number of vicuna : $\bar{y}$ = mean vicuna per Site : $Sy^2$ = variance of $\bar{y}$ : n = number of sites sampled : f = n/N : $SE(\hat{Y})\%$ = standard error of the population estimate $\hat{Y}$

## TABLE 7

Sampling Strategi es Based on the 1979 General Census

Strategy B : Sample within each Sector so that $SE(\hat{Y}) \leqslant 5\%$

| SECTORS | N | Y | $\bar{y}$ | $Sy^2$ | n | f | $SE(\hat{Y})\%$ |
|---|---|---|---|---|---|---|---|
| Central Galeras | 265 | 18152 | 68 | 3113 | 133 | 0.50 | 4.9 |
| Huanaco Pampa | 231 | 13317 | 58 | 918 | 75 | 0.32 | 5.0 |
| Condor Cocha | 212 | 10422 | 49 | 1348 | 109 | 0.51 | 5.0 |
| Management Area | 708 | 41901 | | | 317 | 0.45 | 2.9 |

Legend as in Table 6

## TABLE 8

Sampling Strategies for Pampa Galeras Based on the 1979 General Census

Comparison between the two strategies

| | STRATEGY A | | | STRATEGY B | | |
|---|---|---|---|---|---|---|
| | n | f | SE($\hat{Y}$)% | n | f | SE($\hat{Y}$)% |
| Central Galeras | 122 | 0.46 | 2.9 | 133 | 0.50 | 4.9 |
| Huanaco Pampa | 112 | 0.48 | 2.6 | 75 | 0.32 | 5.0 |
| Condor Cocha | 92 | 0.43 | 2.5 | 109 | 0.51 | 5.0 |
| Management Area | 326 | 0.46 | 1.2 | 317 | 0.45 | 2.9 |

n = number of sites counted : f = n/N : SE($\hat{Y}$)% = standard error of the population estimate $\hat{Y}$

## TABLE 9

Increases to the Management Area 1974 - 1980

| YEAR | Sectors | Divisions | Hectares | Vicuna[a] |
|---|---|---|---|---|
| 1974 | 3 | 7 | 296,200 | 4.3 |
| 1975 | 3 | 8 | 348,300 | 5.1 |
| 1976 | 3 | 9 | 395,100 | 5.9 |
| 1977 | 3 | 11 | 487,500 | 5.8 |
| 1978 | 3 | 11 | 487,500 | 6.7 |
| 1979 | 3 | 12 | 532,500 | 6.3 |
| 1980 | 3 | 12 | 532,500 | |

(a) density $Km^{-2}$

TABLE 10

Sector Central Galeras - Census Totals 1974 - 1980

| | Pampa Galeras | Ayhuamarca | Jassu Grande | Totals |
|---|---|---|---|---|
| ha | 6,500 | 55,900 | 33,300 | 95,700 |
| 1974 | 4775 | 1493 | 4538 | 10806 |
| 1975 | 7510 | 1837 | 4804 | 14151 |
| 1976 | 8754 | 2856 | 5793 | 17403 |
| 1977 | 10102 | 2283 | 5716 | 20454 (a) |
| 1978 | 4961 | 9426 | 8614 | 23001 |
| 1979 | 4749 | 7248 | 6155 | 18152 |
| 1980 | 4412 | 7256 | (6563)(b) | (18231) |

(a) corrected for 13% undercount

(b) estimated from overall proportion to Sector totals (1980 results not available at time of writing)

TABLE 11

Sector Huanaco Pampa - Census Totals 1974 - 1979
For Selected Divisions

| | Pedregal | Huanaco Pampa | Totals |
|---|---|---|---|
| ha | 53,200 | 53,600 | 106,800 |
| 1974 | 566 | 349 | 915 |
| 1975 | 1511 | 241 | 1752 |
| 1976 | 2255 | 506 | 2761 |
| 1977 | 2422 | 1101 | 3523 |
| 1978 | 3024 | 843 | 3867 |
| 1979 | 4861 | 1975 | 6836 |

TABLE 12

Sector Condor Cocha - Census Totals 1974 - 1979

For Selected Divisions

| | Tipicocha | Condorcocha | Sawacocha | Totals |
|---|---|---|---|---|
| ha | 35,600 | 58,100 | 52,100 | 145,800 |
| 1974 | ..... 1199 ..... | | | |
| 1975 | 772 | 539 | 702 | 2013 |
| 1976 | 1261 | 609 | 1159 | 3029 |
| 1977 | 1389 | 939 | 1819 | 4147 |
| 1978 | 1936 | 914 | 2941 | 5791 |
| 1979 | 3260 | 1757 | 3615 | 8632 |

## TABLE 13

Census Effort in Eight Selected Divisions 1974 - 1979

| SECTOR | | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|
| Central | d | 11.3 | 14.8 | 18.2 | 21.4 | 24.0 | 19.0 |
| Galeras | D | 17 | 18 | 18 | 28 | 26 | 28 |
| | S | 92 | 136 | 118 | 118 | 159 | 265 |
| Huanaco | d | 0.9 | 1.6 | 2.6 | 3.3 | 3.6 | 6.4 |
| Pampa | D | 7 | 8 | 9 | 12 | 15 | 19 |
| | S | 27 | 38 | 27 | 57 | 92 | 139 |
| Condor | d | 1.3 | 1.4 | 2.1 | 2.8 | 4.0 | 5.9 |
| Cocha | D | - | - | 15 | 25 | 23 | 19 |
| | S | - | - | 82 | 83 | 141 | 133 |

d : density of vicuna $Km^{-2}$

D : days spent counting

S : number of sites counted

TABLE 14

Densities of Vicuna ($Km^{-2}$) in the Reserve National Pampa Galeras 1967 - 1980

| | RNPG |
|---|---|
| 1967 | 12.5 |
| 1968 | 13.7 |
| 1969 | 13.3 |
| 1970 | 16.6 |
| 1971 | 26.0 |
| 1972 | 32.0 |
| 1973 | 36.4 |
| 1974 | 46.5 |
| 1975 | 63.1 |
| 1976 | 69.9 |
| 1977 | 73.0 |
| 1978 | 76.0 |
| 1979 | 73.1 |
| 1980 | 67.9 |

## TABLE 15

Annual Rates of Increase of Vicuna at Pampa Galeras and Other Areas

| Area | Years | Number | r[a] |
|---|---|---|---|
| Management Area | 1968/75 | 8 | 0.19 |
| NRPG | 1969/78 | 11 | 0.21 |
| Central Galeras | 1974/78 | 5 | 0.19 |
| Huanaco Pampa | 1974/79 | 6 | 0.36 |
| Condor Cocha | 1974/79 | 6 | 0.31 |
| Lauca N.P. [a] | 1973/78 | 6 | 0.36 |
| R.N. Ulla Ulla[c] | 1965/79 | 15 | 0.17 |

(a) $\log_e y = a + b.t$ where y = density or numbers, t = years (starting at t = 1) and annual rate of increase r = b

(b) and (c) data from Brack (1980)

TABLE 16

Proportions of Males, Females and Young

combined census data from entire Management Area 1974 - 1978

| | Central Galeras | Huanaco Pampa | Condor Cocha | Management Area |
|---|---|---|---|---|
| Males | 0.35 | 0.32 | 0.34 | 0.35 |
| Females | 0.40 | 0.41 | 0.40 | 0.40 |
| Young | 0.21 | 0.22 | 0.20 | 0.21 |
| Unidentified | 0.04 | 0.05 | 0.06 | 0.04 |

TABLE 17

Average Ground Speeds, Heights and Strip Widths on Aerial Surveys of Vicuna

| | April 1980 | October 1980 "high" | October 1980 "low" |
|---|---|---|---|
| Height (feet agl) | 500 | 500 | 200 |
| Ground Speed (Kph) | 260 | 200 | 200 |
| Strip Width (meters) | 275 | 250 | 100 |
| Observers | 1 | 2 | 2 |
| Total Strip (Meters) | 275 | 500 | 200 |
| Aircraft | Twin Otter | Cessna T.206 | Cessna T.206 |

## TABLE 18

Analysis of Bias in the April 1980 Aerial Census

| STRATUM | | "A" C.Galeras | "B" H. Pampa | "C" C.Cocha | Management Area |
|---|---|---|---|---|---|
| AREA ($Km^2$) | Aerial Census | 996 | 2049 | 1633 | 4678 |
| | Ground Census | 957 | 1961 | 2407 | 5325 |
| TOTAL VICUNA | A | 4.02 | 2.62 | 1.30 | 2.46 |
| (density) | G | 18.97 | 6.40 | 5.90 | 9.65 |
| | % Missed | 79% | 59% | 78% | 75% |
| FEMALE GROUPS | A | 0.72 | 0.45 | 0.21 | 0.48 |
| (density) | G | 2.59 | 0.99 | 1.02 | 1.44 |
| | % Missed | 72% | 55% | 80% | 67% |
| GROUP SIZE | A | 4.42 | 3.96 | 4.26 | 4.26 |
| | G | 4.80 | 5.10 | 4.70 | 4.81 |
| | % Missed | 8% | 22% | 9% | 11% |
| MALE GROUPS | A | 0.02 | 0.03 | 0.02 | 0.02 |
| (density) | G | 0.23 | 0.05 | 0.05 | 0.10 |
| | % Missed | 91% | 40% | 60% | 80% |
| GROUP SIZE | A | 38.0 | 23.3 | 21.50 | 27.0 |
| | G | 24.9 | 21.5 | 20.90 | 23.6 |
| | % overestimated | 53% | 8% | 3% | 14% |

A : estimated from aerial survey

G : from 1979 General Census

## TABLE 19

### Analysis of the Influence of Height and Strip Width on Bias in Aerial Counting of Vicuna

| | April 1980 | October 1980 | |
|---|---|---|---|
| | | high | low |
| Height (f agl) | 500 | 500 | 200 |
| Strip Width (m) | 275 | 250 | 100 |
| Stratum "A" : Central Galeras | | | |
| vicuna groups $Km^{-2}$ | 0.73 | 0.56 | 2.40 |
| 1979 General Census | 2.82 | 2.82 | 2.82 |
| % Missed | 74% | 80% | 15% |
| Stratum "B" Huanaco Pampa | | | |
| vicuna groups $Km^{-2}$ | 0.56 | 0.47 | 0.94 |
| 1979 General Census | 1.04 | 1.04 | 1.04 |
| % Missed | 46% | 55% | 10% |

## TABLE 20

Calculation of Sample Size for an Aerial Census of Vicuna at Pampa Galeras

| | CENTRAL GALERAS | H. PAMPA & C. COCHA |
|---|---|---|
| $\bar{y}$ mean per transect | 90 | 50 |
| $Sy^2$ variance | 980 | 200 |
| N total number of transects | 200 | 260 |
| $\hat{Y}$ population estimate | 18,000 | 13,000 |
| n number of transects sampled | 40 | 30 |
| $SE(\hat{Y})\%$ s.e. of population estimate | 4.9% | 4.9% |
| f sample fraction (n/N) | 0.20 | 0.12 |
| Area $Km^2$ | 1000 | 4500 |
| Area Sampled $Km^2$ | 200 | 540 |
| Width of Strip Km | 0.2 | 0.2 |
| L1 transect length Km | 1000 | 2700 |
| L2 between transects Km | 100 | 300 |
| L total length Km | 1100 | 3000 |
| H1 flying hours (L/200) | 6 | 15 |
| d duration of flight (hours) | 3 | 3 |
| D number of days (H1/d) | 2 | 5 |
| H2 number of transit hours (D * 3) | 6 | 15 |
| H total flying hours | 12 | 30 |

TABLE 21

Total Days and Flying Hours for Aerial Census of Vicuna at Pampa Galeras

| | Central Galeras | Huanaco Pampa & Condor Cocha | Management Area |
|---|---|---|---|
| transect flying | 6 | 15 | 21 |
| transit | 6 | 15 | 21 |
| contingency | 3 | 5 | 8 |
| training | | | 30 |
| TOTAL HOURS | 15 | 35 | 80 |
| days | 2 | 5 | 7 |
| contingency | 1 | 1 | 2 |
| training | | | 7 |
| TOTAL DAYS | 3 | 6 | 16 |

TABLE 22

Cost Estimates for Aerial Survey of Vicuna at Pampa Galeras

| | U.S.$ | |
|---|---|---|
| 1. Personnel | | |
| Senior Consultant (3 months) | 10,000 | |
| Air fares and local travel | 5,000 | |
| Per diems | 3,000 | |
| Salaries and per-diems for 2 observers | ? | |
| Sub-total | | 18,000 |
| 2. Equipment | | |
| King Gold Crown Radar Altimeter (fitted) | 8,000 | |
| Hire and fitting crew intercom | 2,000 | |
| Hire of cameras, tape recorders | ? | |
| Sub-total | | 10,000 |
| 3. Flying ( $225 per hour) | | |
| training : 30 hours | 6,750 | |
| census : 50 hours | 11,250 | |
| Sub-total | | 18,000 |
| 4. Miscellaneous | | |
| Data sheets, tapes, batteries, films, reporting | 3,000 | 3,000 |
| 5. Provision for Search and Rescue | | |
| Hire of radio equipment (ground-air) and provision for standby aircraft | 20,000 | 20,000 |

TOTAL ESTIMATED COST $69,000 + 20% contingencies = $83,000

TABLE 23

Rainfall, NPP and Vicuna Densities
Reserve National Pampa Galeras 1967-1980

| YEAR | RAIN[a] | NPP[b] | E.NPP[c] | VICUNA[d] | AVAILABILITY[e] |
|---|---|---|---|---|---|
| 1967 | 830 | | 510 | 12.5 | 11.2 |
| 1968 | 460 | | 336 | 13.7 | 6.7 |
| 1969 | 405 | | 310 | 13.3 | 6.4 |
| 1970 | 440 | | 327 | 16.6 | 5.4 |
| 1971 | 460 | | 336 | 26.0 | 3.5 |
| 1972 | 735 | | 466 | 32.2 | 4.0 |
| 1973 | 725 | | 249 | 36.4 | 1.9 |
| 1974 | 240 | (405) | 232 | 46.5 | 1.4 |
| 1975 | 275 | 384 | 249 | 63.1 | 1.1 |
| 1976 | 515 | 367 | 362 | 69.9 | 1.4 |
| 1977 | 350 | 235 | 284 | 73.0 | 1.1 |
| 1978 | 220 | 158 | 223 | 76.3 | 0.8 |
| 1979 | 315 | 245 | 268 | 73.1 | 1.0 |
| 1980 | 315 | 265 | 268 | 67.9 | 1.1 |

(a) rainfall (mm) from Florez (1980)

(b) data supplied by Dr. Hofmann : Kg ha $y^{-1}$ dry matter

(c) estimated from regression analysis rain : NPP 1975 - 1980 (Fig.6)

(d) General Census RNPG : density $Km^{-2}$

(e) Kg per vicuna per day

TABLE 24

Density Data Used for First Approximations to K, $r_m$ and MSY

| YEAR | NRPG | Sectors Central | H.Pampa | C.Cocha |
|---|---|---|---|---|
| 1967 | 12.5 | | | |
| 1968 | 13.7 | | | |
| 1969 | 13.3 | | | |
| 1970 | 16.6 | | | |
| 1971 | 26.0 | | | |
| 1972 | 32.2 | | | |
| 1973 | 36.4 | | | |
| 1974 | 46.5 | 11.3 | 0.9 | 1.3 |
| 1975 | 63.1 | 14.8 | 1.6 | 1.4 |
| 1976 | 69.9 | 18.2 | 2.6 | 2.1 |
| 1977 | 73.0 | 21.4 | 3.3 | 2.8 |
| 1978 | 76.3 | 24.0 | 3.6 | 4.0 |
| 1979 | 73.1 | 19.0 | 6.4 | 5.9 |
| 1980 | 67.9 | | | |

TABLE 25

Calculation of Adult Mortality for Sector
Central Galeras 1975 - 1980

| Year (t) | At[a] | A+y t-1[b] | diff[c] | sh/cp[d] | diff[e] | mortality[f] | total[g] |
|---|---|---|---|---|---|---|---|
| 1974 | 8431 | | | | | | |
| 1975 | 10455 | 10806 | - 351 | | | 0.033 | 0.033 |
| 1976 | 12882 | 13626 | - 744 | | | 0.045 | 0.045 |
| 1977 | 15823 | 16689 | - 866 | 210 | 656 | 0.039 | 0.052 |
| 1978 | 16893 | 19949 | -3056 | 400 | 2656 | 0.133 | 0.153 |
| 1979 | 15442 | 21616 | -6174 | 1558 | 4616 | 0.214 | 0.286 |
| * 1980 | 9842 | 11431 | -1589 | 1390 | 199 | 0.017 | 0.139 |

* data for NRPG and Ayhuamarca ONLY

(a) adults in that year

(b) adults + young in previous year

(c) difference b - a

(d) numbers shot or captured

(e) difference c-d = adults dying of natural causes

(f) natural mortality e/b per year t-1

(g) total mortality c/b for year t-1

TABLE 26

Adult Mortality and Young per 100 Females
in Sector Central Galeras 1974–1979

| year | density | adult mortality | young : 100 females |
|---|---|---|---|
| 1974 | 11.3 | 3.3% | 59 |
| 1975 | 14.8 | 4.5% | 57 |
| 1976 | 18.2 | 3.9% | 56 |
| 1977 | 21.4 | 13.3% | 49 |
| 1978 | 24.0 | 21.5% | 51 |
| 1979 | 18.3 | 1.7% | 25 |

## TABLE 27

Calculation of K and $r_m$ for Pampa Galeras and Lauca NP

| | Sectors | | | | |
|---|---|---|---|---|---|
| | RNPG | G.Galeras | H. Pampa | C.Cocha | Lauca NP |
| years | 1971/78 | 1974/78 | 1975/79 | 1976/79 | 1973/78 |
| a | 0.536 | 0.609 | 0.462 | 0.401 | 0.336 |
| b | - 0.006 | -0.020 | -0.013 | -0.009 | - 2.6 E-5 |
| K density | 89.4 | 30.5 | 35.5 | 44.6 | 2.7 |
| K numbers | 5,809 | 28,710 | 69,600 | 106,600 | 12,904 |
| $r_m$ | 0.430 | 0.476 | 0.380 | 0.337 | 0.289 |

$$(Nt+1 - Nt) / Nt = a - b \cdot Nt+1$$

$$b = a/K$$

$$a = e^{rm} - 1$$

## TABLE 28

Calculation of MSY for Pampa Galeras

| | Central Galeras | Huanaco Pampa | Condor Cocha | Management Area |
|---|---|---|---|---|
| density at K | 30.0 | 35.5 | 44.3 | 38.5 |
| 1979 density | 19.0 | 6.4 | 5.9 | 8.5 |
| numbers at K | 28,700 | 69,600 | 106,600 | 204,900 |
| 1979 numbers | 18,200 | 12,600 | 14,200 | 45,000 |
| numbers at K/2 | 14,400 | 34,800 | 53,300 | 102,500 |
| initial reduction | 3,800 | - | - | |
| $H = r_m/2$ | 0.236 | 0.190 | 0.169 | 0.185 |
| MSY[a] | 3,400 | 6,600 | 9,000 | 19,000 |
| SY[b] at 1979 numbers | 3,140 | 3,920 | 4,160 | 11,200 |

(a) $MSY = \frac{1}{2}.r_m \cdot \frac{1}{2}.K$

(b) SY (at any population level) = $r_m \cdot N(K-N/K)$

H = instantaneous rate of harvesting

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# POSITION STATEMENT ON VICUNA BY THE INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES (IUCN) AND WORLD WILDLIFE FUND (WWF)

## Background

IUCN and WWF have been closely involved for more than 15 years in supporting and advising the Governments of Argentina, Bolivia, Chile and Peru in the conservation of the vicuña, a wild relative of the camel found only in the high Andean region of South America. National and international efforts have been successful in bringing about a seven fold increase in the world population of vicuña since 1970, most notably in the Pampa Galeras range in Peru. The Government of Peru, with the support of a number of international organisations, has introduced a management programme in the Pampa Galeras region. From the start, the objective of this management proposal was to assure the survival of the vicuña in large enough numbers so that some could be translocated to other areas, and so that a controlled harvest could be made for the benefit of the local people. In its initial stages, the programme concentrated on conserving vicuña and building up their stocks, but for the last five years has included translocation and the culling of animals to investigate the potential of using hides, wool and meat for the benefit of the local people.

This culling has now become a source of controversy in and outside Peru, and within conservation circles. Criticisms have been made of the way in which vicuñas have been harvested, and doubt has been thrown upon the need for culling and the true extent of the recovery in vicuña numbers in the Pampa Galeras. At the invitation of the Government of Peru, and with the financial support of the German Agency for Technical Cooperation (GTZ), IUCN and WWF organised an independent evaluation mission in September/October 1980 to ascertain the facts, especially the number of animals. The mission's report is being issued by IUCN and WWF after careful scrutiny by leading experts in this field.

The purpose of this statement is to explain the position of IUCN and WWF on vicuña conservation in general and on the Pampa Galeras project in particular. Their position is based on the policy conclusions of the World Conservation Strategy published in 1980 by IUCN, WWF and the United Nations Environment Programme, and on the facts, especially those brought to light by the mission to Peru.

## The World Conservation Strategy

The World Conservation Strategy states the three objectives of conservation: to maintain ecological processes and life support systems; to preserve genetic diversity; and to ensure sustainable utilization of species and ecosystems. The first objective is of relevance but not directly at issue in the present

controversy. The second objective has already been locally secured, notably in the Pampa Galeras area, through the conservation efforts of the South American governments in the last 15 years, however, the vicuña remains vulnerable and must continue to be carefully managed throughout its range. The third objective is central to the vicuña issue: the World Conservation Strategy makes clear that sustainable utilisation is not only compatible with conservation, it is a legitimate purpose of conservation. Sustainable utilisation - which usually involves the carefully-managed harvesting of animals - is the best means by which some wild species and ecosystems can contribute to the well-being of mankind and help development, in many cases for the benefit of the poorest people in developing countries. As the strategy emphasises, conservation must make a contribution to development if it is to be credible and successful.

## The Vicuña in South America

Some basic facts about the vicuña in South America are as follows:

- the Governments of Bolivia, Chile and Peru, as well as Ecuador, are committed to the conservation of the vicuña by their adherence to the Convention for the Conservation and Management of Vicuna signed in Lima on 20 December, 1979, which replaced an earlier agreement signed ten years previously; the treaty is open for the signature of Argentina which was a signatory to the previous treaty;

- the Governments concerned have all taken measures nationally to protect the vicuña within their borders, especially through the creation of reserves;

- all the Governments are signatories to the Convention on International Trade in Endangered Species of Wild Fauna and Flora which binds them not to trade internationally in vicuña products (for Argentina, which has ratified only recently, the treaty enters into force on 8 April, 1981);

- the best estimates of the population of vicuña in 1965, 1970 and 1980 as provided by experts, including members of IUCN's Specialist Group on South American camelids, are:

| | 1965 | 1970 | 1980 |
|---|---|---|---|
| Argentina | 100 | several 100 | 3,000-5,000 |
| Bolivia | 1,000 | 1,000- 1,500 | 3,700 |
| Chile | 100 | 450- 650 | 7,400 |
| Peru | 5,000 | 5,000-10,000 | 60,000 |
| Estimated total (approx.) | 6,000 | 10,000 | 70,000-77,000 |

The Vicuña in the Pampa Galeras

The IUCN/WWF mission to Peru worked in the Pampa Galeras National Reserve and the related controlled management area in 1980. The facts reported by the mission are as follows:

- the census of vicuña carried out in September and October 1980 by the management authorities on the ground was observed by the mission and gave accurate results, possibly slightly under-estimating the total number of vicuña recorded at 48,153. A previous estimate of 15,000, based upon an aerial sample count undertaken in April 1980, was seriously in error; the IUCN/WWF mission showed that the survey techniques grossly underestimated the true number of vicuña;

- vicuña populations are increasing at an average annual rate of 19%;

- 2,100 animals were shot in 1980 and nearly 750 relocated to other reserves;

- the data presently available do not suggest that the population of vicuña is yet at a level where the pastures are seriously overgrazed or degraded, and that in most of the range the carrying capacity does not appear to have been reached.

IUCN and WWF appreciate that it may be necessary that some vicuña continue to be harvested in order to provide essential scientific data to achieve the original objectives of the Pampa Galeras Project. Nevertheless, IUCN and WWF consider it essential, if there is to be a cull, that it be carefully controlled, humane, scientifically based and kept at a very conservative level, pending the accumulation of the essential, additional scientific information on which any larger cull can be planned and implemented. Additionally, IUCN and WWF believe that any such cull should be associated with an expanded programme for re-location of the vicuña from Pampa Galeras to other areas, experimental sheering of wool from live vicuña, proper monitoring of the effects of the management programme (including effective control over the marketing of wool) and continued efforts to protect and manage the area, including strong protection against poaching. In short, a cull, if conducted, should be placed on a sound, scientific footing. A cull conducted in such a manner, would be consistent with the World Conservation Strategy and with the original objectives of the Pampa Galeras Project, thus enabling the Government of Peru to honour the Agreement it reached with the local people in the area that - when vicuña populations would allow - they would receive the benefits from any legal trade in vicuña products.

Recommendations to the Government of Peru

The IUCN/WWF mission also found that important scientific data upon which a cull should be based were absent. As a result, IUCN and WWF are recommending the Peruvian authorities that:

- a programme to gather these data, e.g. on the population dynamics of vicuña and their relationship with the range condition, is essential.
- any culling operations should be integrated with this scientific programme guided by its findings, strictly controlled and implemented for the benefit of local communities;
- if there is a cull, it should be held at a minimum level, pending the accumulation of scientific data.

These and other recommendations are contained in a letter sent to the Minister of Agriculture along with a copy of the mission's report. IUCN and WWF propose to monitor the situation and continue to advise the authorities accordingly.

Conclusion

In conclusion, IUCN and WWF emphasise the following:

- the recent recovery in vicuña numbers represents an all-too-rare example of a successful conservation project, for which the Governments and others concerned deserve full credit,
- the utilization of vicuña on a sustainable basis can be a legitimate part of their conservation,
- any culling of vicuña should be humane, subject to strict control, and scientifically based,
- the principal beneficiaries of vicuña utilization should be the local people concerned in the rural communities of the high Andes.

Gland, 23.2.81