HUNTING PATTERNS AND WILDLIFE DENSITIES
IN FORESTS OF DIFFERENT LEVELS OF ACCESS
IN THE UPPER BARAM,
SARAWAK

Cynthia Chin

Kota Samarahan
2002
HUNTING PATTERNS AND WILDLIFE DENSITIES IN FORESTS OF DIFFERENT LEVELS OF ACCESS IN THE UPPER BARAM, SARAWAK

CYNTHIA CHIN

THESIS SUBMITTED IN FULFILMENT FOR THE REQUIREMENT OF MASTER OF SCIENCE

FACULTY OF RESOURCE SCIENCE AND TECHNOLOGY
UNIVERSITI MALAYSIA SARAWAK (UNIMAS)
KOTA SAMARAHAN

2002
DECLARATION

I hereby declare that the work in this thesis is my own original work, except where it is expressly stated otherwise, and that no part of it has been submitted to this or any other University for any degree, diploma or qualification.

Cynthia L.M. Chin
ABSTRACT

The problem of roads in previously inaccessible forest areas have proven to be a serious conservation issue in tropical forests worldwide. While increased access allows greater mobility for rural communities, and for technology to reach these communities, it has also led to greater hunting pressures on wildlife in tropical forests. This study examined the effects of logging access on hunting patterns and wildlife abundance in three study sites in the Upper Baraun region of Sarawak. The hypothesis tested was that populations of game animals increase in areas of tropical forest following the advent of logging roads. Surveys were conducted in similar unlogged habitat in three sites; and all areas were occupied by Penan communities. The main difference between the three sites was level of access via logging road. Data were collected from July 1999 to June 2000. Data collection lasted from seven to 14 days each trip. Surveys on the hunting patterns of each community, as well as line transect surveys for wildlife were done. Correlation and regression analyses; and the Kolmogorov-Smirnov and Kruskal-Wallis tests were applied to data collected. Results showed that as levels of accessibility increased, hunting pressure increased, and hunting success decreased; and that as hunting pressure increased, wildlife diversity and relative abundance declined. The null hypothesis was disproved.
ACKNOWLEDGEMENTS

So many people have helped to make this project possible that it is impossible to express my thanks to everyone by name.

My list must start with Dr. Elizabeth L. Bennett, whose previous work was the inspiration for this project, and whose advice, friendship, guidance and supervision have seen this study from conception to completion.

My supervisor throughout this project was Dr. Andrew Alek Tuen. I am most grateful to him for his advice, help and patience.

My utmost gratitude goes to Susan Musis, who is the most faithful and dedicated person I have ever had the privilege to work with. Your dedication to data collection is unmatched. Thank you, Su, for your help; and for our little competitions in the field. You were great. Your eating prowess and remarkable ability to hide food remain unmatched.

For sparing me their time, liaising with and introducing me to the Penan and their family in Long Lallang; and for their friendship, hospitality and great dinners in Marudi, my heartfelt thanks go to Petenus and Maggie Jaya. Without their help, contact with the communities in the study area would have been near impossible. My gratitude also goes to Tama and Sina Pun Menga for opening up their home to me, and for their great hospitality and generosity.

For their encouragement, enlightening advice and moral support, I thank Dr. Madhu Rao at WCS, New York; and Dr. Melvin Gumala of the Sarawak Forest Department.

Funding for the project was supported by the National Parks and Wildlife Division (NPWD) of the Sarawak Forest Department. Additional assistance was given by the Wildlife Conservation Society (WCS). Thanks also go to En. Sapan Hj. Ahmad, Senior Assistant Director of NPWD; and to Mr. Oswald Braken Tisen, Assistant Director of Wildlife (NPWD), for their support for this project. Thanks also go to the Health Department, Marudi Office for providing information on population statistics of the Upper Baram District.

To my family and friends, who not only bore with my constant absence, but encouraged and supported to pursue my dreams. Most of all, I thank God for making all things possible.
# Table of Contents

| Declaration | ii |
| Abstract | iii |
| Acknowledgements | iv |
| Table of Contents | v |
| List of Figures | xi |
| List of Tables | xiv |

## Chapter 1: Introduction

1.1 Setting the Scene | 1 |
1.2 Hunting and Wildlife | 2 |
1.3 Measuring the Sustainability of Hunting | 4 |
1.4 Why Hunting is Less Sustainable Today | 5 |
1.5 Hunting and Wildlife in Sarawak
   1.5.1 Physical Geography | 8 |
   1.5.2 Climate | 9 |
   1.5.3 The People | 9 |
   1.5.4 The Penan | 9 |
   1.5.5 General Hunting Patterns | 11 |
   1.5.6 Hunting in Logging Concessions | 13 |
1.6 Aims and Objectives | 14 |
Summary | 16 |

## Chapter 2: Study Area

2.1 Introduction | 18 |
2.2 Long Sabai
   2.2.1 The Penan Community | 20 |
   2.2.2 Forest Type | 21 |
2.3 Long Main
   2.3.1 The Penan Community
   2.3.2 Forest Type

2.4 Ba’Boi
   2.4.1 The Penan Community
   2.4.2 Forest Type

Summary

CHAPTER 3 METHODS

3.1 Introduction

3.2 Local Community Hunting Patterns
   3.2.1 Introduction
   3.2.2 General Hunting Interviews
   3.2.3 Individual Hunting Interviews
   3.2.4 Hunting Pressure
   3.2.5 Hunting Success
   3.2.6 Hunting Frequency
   3.2.7 Hunting Area
   3.2.8 Diet

3.3 Wildlife Surveys
   3.3.1 Introduction
   3.3.2 Line Transect Surveys
   3.3.3 Tracks and Signs
   3.3.4 Fruit Availability

3.4 Data Analysis

Summary

CHAPTER 4 HUNTING PATTERNS

4.1 Introduction
4.2 Long Sabai
  4.2.1 Overall Hunting Patterns
  4.2.2 Hunting Pressure
  4.2.3 Hunting Area
  4.2.4 Hunting Success
  4.2.5 Species Hunted
  4.2.6 Hunting Frequency
  4.2.7 Diet

4.3 Long Main
  4.3.1 Overall Hunting Patterns
  4.3.2 Hunting Pressure
  4.3.3 Hunting Area
  4.3.4 Hunting Success
  4.3.5 Species Hunted
  4.3.6 Hunting Frequency
  4.3.7 Diet

4.4 Ba’Buboi
  4.4.1 Overall Hunting Patterns
  4.4.2 Hunting Pressure
  4.4.3 Hunting Area
  4.4.4 Hunting Success
  4.4.5 Species Hunted
  4.4.6 Hunting Frequency
  4.4.7 Diet

4.5 Discussion: Comparing Sites
  4.5.1 Introduction
  4.5.2 Hunting Techniques and Their Relative Successes
  4.5.3 Access and Hunting Pressure
CHAPTER 5  WILDLIFE DIVERSITY AND ABUNDANCE

5.1 Introduction

5.2 Long Sabai
  5.2.1 Primates
  5.2.2 Squirrels and Tree Shrews
  5.2.3 Ungulates
  5.2.4 Carnivores
  5.2.5 Hornbills
  5.2.6 Pheasants and Partridges

5.3 Long Main
  5.3.1 Primates
  5.3.2 Squirrels and Tree Shrews
  5.3.3 Ungulates
  5.3.4 Carnivores
  5.3.5 Hornbills
  5.3.6 Pheasants and Partridges

5.4 Bu'Buboi
  5.4.1 Primates
  5.4.2 Squirrels and Tree Shrews
  5.4.3 Ungulates
7.1 Introduction

7.2 Current and Recommended Strategies
  7.2.1 Current Policy
  7.2.2 Implementation of Current Policy
  7.2.3 Are Current Measures Effective?
  7.2.4 Further Conservation Needs

7.3 Conclusion

Summary

REFERENCES

APPENDICES
LIST OF FIGURES

1.1 Sarawak, Malaysia
1.2 The Upper Barun, Limbang and Balui Watersheds
2.1 Long Sabai, Long Main and Ba' Buboi in the Upper Barun
3.1a A diagrammatic example of the method used for estimating hunting area – radial points indicating a hunting area
3.1b A diagrammatic example of the method used for estimating hunting area – projected hunting area
4.1 Different hunting techniques used in hunts surveyed at Long Sabai (n = 17)
4.2 Proportion (by biomass) of the different species hunted at Long Sabai
4.3 Composition of meats at Long Sabai
4.4 Percentage of different species of wild meat consumed in Long Sabai
4.5 Different hunting techniques used in hunts surveyed at Long Main (n = 44)
4.6 Proportion (by biomass) of the different species hunted at Long Main
4.7 Composition of meats at Long Main
4.8 Percentage of different species of wild meat consumed in Long Main
4.9 Different hunting techniques used in hunts surveyed at Ba' Buboi (n = 21)
4.10 Proportion (by biomass) of the different species hunted at Ba' Buboi
4.11 Meats containing wild meat at Ba' Buboi
4.12 Composition of meats in Ba' Buboi
4.13 Comparing wild meat consumption at Long Sabai, Long Main and Ba' Buboi
5.1 Relative primate abundance at Long Sabai, Total survey distance = 30km
5.2 Relative squirrel abundance at Long Sabai, Total survey distance = 30km
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3</td>
<td>Relative hornbill abundance recorded from sightings at Long Sabai. Total survey distance = 300km</td>
</tr>
<tr>
<td>5.4</td>
<td>Relative abundance of squirrels and tree shrews abundance at Long Main. Total survey distance = 94km</td>
</tr>
<tr>
<td>5.5</td>
<td>Relative hornbill abundance recorded from sightings at Long Main. Total survey distance = 14km</td>
</tr>
<tr>
<td>5.6</td>
<td>Relative squirrel abundance at Ba’i Buboi. Total survey distance = 2665km</td>
</tr>
<tr>
<td>5.7</td>
<td>Relative hornbill abundance recorded from sightings at Ba’i Buboi. Total survey distance = 2665km</td>
</tr>
<tr>
<td>5.8</td>
<td>Relative primate abundance at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.9a</td>
<td>Abundance of different primate species at Long Sabai, Long Main and Ba’i Buboi (individuals/km)</td>
</tr>
<tr>
<td>5.9b</td>
<td>Comparing primate species at Long Sabai, Long Main and Ba’i Buboi (groups/km)</td>
</tr>
<tr>
<td>5.10</td>
<td>Relative abundance of squirrels at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.11</td>
<td>Comparing indices for different squirrel categories at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.12</td>
<td>Relative indices of <em>Muntiacus</em> sp. and <em>Tragulus</em> sp. at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.13</td>
<td>Relative abundance of ungulates at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.14</td>
<td>Relative abundance of ungulate tracks and signs at Long Sabai, Long Main and Ba’i Buboi (% of 25m x 4m wide portions of transect)</td>
</tr>
<tr>
<td>5.15</td>
<td>Relative abundance of tracks and signs of <em>H. malayanus</em> and wild cat at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.16</td>
<td>Overall relative hornbill abundance at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.17</td>
<td>Relative abundance of hornbill species at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.18</td>
<td>Relative abundance of phasianids at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>5.19</td>
<td>Relative abundance of <em>A. argus</em> and <em>R. roulai</em> at Long Sabai, Long Main and Ba’i Buboi</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>5.20</td>
<td>A. argus calls at Long Sabai, Long Main and Ba'Buboi</td>
</tr>
<tr>
<td>5.21</td>
<td>Relative abundance of all game species at Long Sabai, Long Main and Ba'Buboi</td>
</tr>
<tr>
<td>6.1</td>
<td>The relationship between relative wildlife abundance and hunting pressure at Long Sabai, Long Main and Ba'Buboi</td>
</tr>
<tr>
<td></td>
<td>a. Hunting pressure vs. relative density of all species recorded</td>
</tr>
<tr>
<td></td>
<td>b. Hunting pressure vs. relative abundance of primate groups</td>
</tr>
<tr>
<td></td>
<td>c. Hunting pressure vs. relative abundance of hornbills</td>
</tr>
<tr>
<td></td>
<td>d. Relative abundance of bearded pig (Sus barbatus) in 25-x-4m wide portions of transects</td>
</tr>
<tr>
<td></td>
<td>e. Relative abundance of Muntiacus and Tragulus species tricks and signs in 25-x-4m wide portions of transects</td>
</tr>
<tr>
<td></td>
<td>f. Hunting pressure vs. number of A. argus calls</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Community and Data Survey Schedule</td>
</tr>
<tr>
<td>4.1</td>
<td>Overall hunting pressure for Long Sabai</td>
</tr>
<tr>
<td>4.2</td>
<td>Number and biomass (kg) of species hunted at Long Sabai</td>
</tr>
<tr>
<td>4.3</td>
<td>Overall hunting pressure for Long Main</td>
</tr>
<tr>
<td>4.4</td>
<td>Hunting success and hunting frequency overall, excluding traps, and for traps only at Long Main</td>
</tr>
<tr>
<td>4.5</td>
<td>Number and biomass (kg) of species hunted at Long Main</td>
</tr>
<tr>
<td>4.6</td>
<td>Overall hunting pressure for Ba’Buboi</td>
</tr>
<tr>
<td>4.7</td>
<td>Number and biomass (kg) of species hunted at Ba’Buboi</td>
</tr>
<tr>
<td>4.8a</td>
<td>Accuracy of shots fired by hunters in Long Sabai, Long Main and Ba’Buboi, from general hunting interviews</td>
</tr>
<tr>
<td>4.8b</td>
<td>Hunter perception of success of hunting trips, from general hunting interviews</td>
</tr>
<tr>
<td>4.9</td>
<td>Accuracy of hunters during trips where prey were detected</td>
</tr>
<tr>
<td>4.10</td>
<td>Comparing the different hunting techniques used at Long Sabai, Long Main and Ba’Buboi</td>
</tr>
<tr>
<td>4.11</td>
<td>Comparing the successes of the different hunting techniques used at Long Sabai, Long Main and Ba’Buboi</td>
</tr>
<tr>
<td>4.12</td>
<td>Comparing access, hunting pressure and hunting success at Long Sabai, Long Main and Ba’Buboi</td>
</tr>
<tr>
<td>4.13</td>
<td>Correlation-Regression table for hunting pressure and other factors</td>
</tr>
<tr>
<td>4.14</td>
<td>Kruskal-Wallis Test for significance of differences between sites for ERR, hunting pressure and diet data</td>
</tr>
<tr>
<td>4.15</td>
<td>Comparing hunting frequency, animals hunted and diet at Long Sabai, Long Main and Ba’Buboi</td>
</tr>
<tr>
<td>4.16</td>
<td>Correlation-Regression table for hunting frequency and ERR, and for diet</td>
</tr>
<tr>
<td>4.17</td>
<td>The Kolmogorov-Smirnov Test for normality for diet data from Long Sabai, Long Main and Ba’Buboi</td>
</tr>
<tr>
<td>5.1</td>
<td>Presence and relative abundance of angulates at Long Sabai. Total survey distance = 30km</td>
</tr>
<tr>
<td>5.2</td>
<td>Indices of carnivore signs at Long Sabai. Total survey distance = 79</td>
</tr>
</tbody>
</table>
5.3 Relative abundance of primates at Long Sabai. Total survey distance = 30km

5.4 Presence and relative abundance of ungulates at Long Main. Total survey distance = 14km

5.5 Indices of carnivore signs at Long Main. Total survey distance = 14km

5.6 Relative abundance of pheasants at Long Main. Total survey distance = 14km

5.7 Presence and relative abundance of ungulates at Ba’ Baboi. Total survey distance = 26.63km

5.8 Indices of indices of carnivore signs at Ba’ Baboi. Total survey distance = 26.63km

5.9 Relative abundance of pheasants at Ba’ Baboi. Total survey distance = 26.63km

5.10 Index of fruit availability at Long Sabai, Long Main and Ba’ Baboi

5.11 Kruskal-Wallis Test for significance between sites for species at Long Sabai, Long Main and Ba’ Baboi

5.12 Kolmogorov-Smirnov test of normality of primate data

5.13 Kolmogorov-Smirnov test of normality of squirrel data

5.14 Kolmogorov-Smirnov test of normality of Mantelius sp. and Tragulus sp. data

5.15 Kolmogorov-Smirnov test of normality of hornbill data

5.16 Kolmogorov-Smirnov test of normality of pheasants and partridges data

6.1 Correlation-Regression table for hunting pressure and relative abundance of different taxonomic groups

6.2 Correlation-Regression table for ERR and wildlife data

6.3 Densities of wildlife in different areas of primary forest in Sarawak

Total survey distance =
Chapter 1
Introduction

1.1 Setting the Scene

The use of wildlife as a resource is ubiquitous in human culture. Technology has fueled the course of human cultural evolution to a point that often seems cut off from nature, but the use of wildlife is still prevalent throughout the world, especially in tropical forests. In such forests, wildlife is used for a variety of reasons, including the following:

Culture. Wildlife is an integral part of the cultures of people who inhabit tropical forests. In many indigenous cultures, for example, wildlife forms the basis of legends, beliefs, and art. Traditional dances are often founded on the majesty of a certain species of wildlife, e.g., during the ceremony of singing souls, the Manobo Indians of South America hunt sloths, a species not hunted at any other time (Romanoff, 1984); and in Papua New Guinea, feathers of birds of paradise are used in traditional costumes during special ceremonies (Nightingale, 1992). Hunting often symbolizes the achievement of manhood in many cultures; and the use of animal trophies such as feathers, teeth, claws, and skins as part of traditional and ceremonial costumes, or as personal adornment is common in cultures throughout the tropics (Mittermeier, 1987; Bennett and Robinson, 2000a; Robinson and Bennett, 2000a).

As a source of food. In at least 62 countries, wildlife and fish make up a minimum of 20% of animal protein in human diets (Prescott-Allen and Prescott-Allee, 1982; Redford, 1993; Townsend, 2000). In Nicaragua, wildlife constitutes 98% of meat and fish consumed by Mosquito Indians (Nieto-Tschamann, 1987). In Kenya, over 13,600 animals are hunted from one single forest patch each year (FitzGibbon et al., 2000).

Economy. Income is derived from selling wildlife for meat, skins, trophies, or as pets (Mittermeier, 1987; Bennett and Robinson, 2000a; Robinson and Bennett, 2000b). In Peru, wild meat worth more than US$17,000 is sold per year (Bohmer et al., 1994). In the Central African Republic, local hunters can earn up to US$9.30 a week in an area where local wages range between US$2 to US$13 a week (Noss, 2000).

Hunting as a form of pest control. In areas opened up for agriculture and livestock, wildlife can be significant pests. Pest problems in such areas are often reduced by hunting (Jorgenson, 2000; Lee, 2000). In Mexico, wildlife hunted as pests by Maya hunters are often subsequently consumed or sold (Jorgenson, 2000).
1.2 HUNTING AND WILDLIFE

Humans have been hunting wildlife for thousands of years. In central Amazonia, paleoanthropologists believe the first people arrived at least 10,000 years ago (Roosevelt et al., 1996). In tropical central Africa, evidence of human presence can be traced back 40,000 years (Bahamonde, 1993), and during that time, humans are believed to have hunted. This has led to the extinction of some species. For example, in Madagascar, 14 species of lemurs have gone extinct since the arrival of man some 1,500-2,000 years ago (Walker, 1967; Tattersall, 1982; Sussman et al., 1985). For extant species, hunting must have been sustainable in the past. Recent studies, however, have suggested that present hunting rates are not sustainable in many tropical regions, even when the resources are being harvested by local inhabitants (Mittermeier, 1987; Wilkie and Carpenter, 1999; Bennett and Robinson, 2000b; Eves and Ruggiero, 2000; papers in Robinson and Bennett, 2000b).

Today, hunters take vast numbers of animals each year. In Congo, at least a million tonnes of wild meat are consumed every year (Wilkie and Carpenter, 1999; Robinson and Bennett, in press). Redford (1992) estimates that 1.4 million individual mammals are killed in rural Brazil each year. Indeed, the range of many extant species has decreased drastically due mainly to hunting. Some have recently been reduced to local extinction. In south-eastern Peru, constant hunting pressure in Manu Biosphere Reserve has resulted in the local extinction of large game species (Mitchell and Luna, 1991). In the Guineo-Congolian rainforest in Africa, hunting is predicted to be a greater threat to the survival of primates than anywhere else in the world (Mittermeier, 1987).

Both population density and harvest rates are dynamic through time. This is because production varies with population density, and hunting effort varies with hunting success (Robinson and Redford, 1994). Production is defined by population densities of animals and per capita reproductive rates (Bennett and Robinson, 2000b), and represents the natural addition to a wildlife population (Banks and Mosher, 1988). So, hunting success will be high if population densities are high. For example, a common pattern is for harvest to exceed production for the initial period after hunting of a population has just begun. This results in lower population densities as well as hunting success, which in turn affect production and hunting effort (Robinson and Redford, 1994). Indeed, if populations are hunted down to 4% of carrying capacity, hunting will no longer be economically viable (Robinson and Redford, 1994). So hunting is not sustainable in the long term if biological and socio-economic needs are not met (Robinson, 1993).

The question then arises: What is sustainable hunting? Notwithstanding the factors above, hunting can be sustainable when:
- harvest does not exceed production (Bennett and Robinson, 2000a);
- harvest is driven by the demands of the consumer, and is restricted by incentives or disincentives like rules, regulations, taboos or enforcement;
- when harvest equals production, then sustainability is possible.

All three criteria in addition, wildlife protection is good, peace and co-existence is good (Robinson, 1993).

Hunting affects wildlife: whether animals are harvested or not.

Lowering of natural hunting is advisable. Moderate hunting pressure decreases or increases to 4% unsustainably, and increases (Bennett and Robinson).

Changing the age structure is proportion of initial 2000: Lebanon 95%; because hunters' age is less than 2000. The proportion usually refers to production of the population.

Changing the structure chooses large-bodied representation of large while of smaller Peres, 2000. Average overall biomass of the representation of Meffie and Carroll, 1994. O'Brien and Keanot, biological community subsistence hunter, e.g., as has happened a few times, individuals by hunting time (Bennett and Robinson, 1999).

Extirpating vulnerable extinction most use increase (Bednorz and example, in Sulavets, 2000a).
All three criteria must be met if hunting were to be considered sustainable. In addition, wildlife populations are made up of living individuals that interact with one another. The loss of these individuals will have wider and unknown repercussions on the ecological function of the group (Bennett and Robinson, 2000b). If the population of a species is reduced to such low numbers that it no longer interacts significantly with other species, it becomes ecologically extinct (Redford, 1992).

Hunting affects wildlife populations significantly in many ways, regardless of whether animals are hunted for trade, for sport or for subsistence. These include:

- **Lowering of natural population densities in the wild.** In tropical forests, hunting is additive to natural death rates. Redford (1992) estimates that even in moderate hunting pressure in neotropical forests, population densities of animals decrease by 80.7%. In areas of high hunting pressure, populations decrease up to 93.5%. In Africa, 48% of hunted species are hunted unsustainably; and in Asia, 71% of hunted species are hunted unsustainably (Bennett and Robinson, 2000b).

- **Changing the age structure of a population.** In heavily hunted areas, the proportion of animals in older age classes is reduced (Bodmer, 1995a; Hart, 2000; Leeuwengberg and Robinson, 2000; Peres, 2000). This is most likely because hunters prefer larger-sized individuals, although the mechanisms of population age structure are not well understood (Leeuwengberg and Robinson, 2000). The proportion of mature breeding adults is thus reduced; and as hunting usually reduces population densities to a fraction of the original, future production of the population decreases as well (Robinson and Redford, 1991).

- **Changing the structure of the biological community.** Because hunters tend to choose large-bodied prey (usually ungulates, primates and large rodents), the representation of larger individuals within the biological community decreases while that of smaller-bodied species increases (Bennett and Robinson, 2000a; Peres, 2000). Average body size of the community is thus reduced, reducing the overall biomass of the entire community (Puri, 1992; Hart, 2000) and changing the representation of the different guilds and trophic levels of the community (Meffe and Carroll, 1994; FitzGibbon, Mogaka and Fanahwe, 1995; Ness, 2000; O'Brien and Kinnaird, 2000). This in turn reduces the overall production of the biological community (Puri, 1992; Hart, 2000). As larger species are depleted, subsistence hunters are forced to consume larger numbers of smaller species, e.g., as has happened with the Yuruki Indians in Amazonia (Steamarin, 2000).

- **Reducing the average size of hunted species.** Selection of larger-bodied individuals by hunters can lead to a decrease in body-size of the species over time (Bennett and Robinson, 2000b). This appears to have been true for orangutans (Bennett, 1998).

- **Extirpating vulnerable species locally.** Heavy hunting can reduce species to local extinction. Most susceptible are those with low intrinsic rates of population increase (Bodmer and Puertas, 2000; Bodmer, 1995b; Bodmer et al., 1994). For example, in Sulawesi, babirusa and area ranges are shrinking due to hunting...
MEASURING THE SUSTAINABILITY OF HUNTING

Being able to measure hunting sustainability in tropical forests is crucial where wildlife conservation is to be balanced with the natural resource needs of local communities. However, it is extremely difficult to measure whether hunting is sustainable or not because to do so, one must understand: 1) the variation in hunting patterns of an area; 2) the population status of the hunted species and how that fluctuates over time; 3) natural productivity of these populations; and 4) how these populations respond to hunting (Robinson and Redford, 1994). The necessary data are not known for any tropical forest species.

Robinson and Redford (1994) considered five ways of assessing whether hunting is sustainable:

Comparisons of population density. This compares wildlife population densities between hunted and unhunted forests, and assumes that the differences in population between the two forest types reflect the intensity of hunting, thus allowing inference on the sustainability of hunting. However, this method does not take into account that population densities vary between sites, even in the absence of hunting; and that harvest also varies with population density. Hence, low populations in hunted areas do not necessarily mean that hunting is unsustainable.

Declines in population densities over time. This compares patterns of population densities in a single study site over time, and is perhaps more indicative of hunting sustainability. If the population of a species declines continuously in a hunted site, all other things being equal, then it may be inferred that hunting is not sustainable. However, long-term data on population densities within one area are required for this index, and those are seldom known.

Comparisons of hunting yields between sites. This can be measured in various ways: 1) comparing the number of animals killed per unit time at different sites, although this does not account for the number of hunters or their hunting effort; 2) comparing hunting yields per unit effort at different sites. Effort is calculated as the distance, frequency, duration of hunts or number of hunters. This method assumes that animal populations and hunting effort between sites are similar.

Changes in hunting yields over time. This method more strongly indicates whether harvests are sustainable. In general, constant declines in hunting yields indicate that densities of the harvested species are falling, and hunting of that species is not sustainable. However, it is important to take into account that populations newly exposed to hunting will always show an initial decline, so population declines must be continuous to be indicative of unsustainable harvest.

Also, the increases of animals will depend on the number of hunters.

Age structure can impact hunting so change sustainability. Higher mortality in younger animals, possibly because of the older age class of the population, as populations in tropical forest decline.

WHY HUNTING IS IMPORTANT

Today, hunting is a way of life for many indigenous peoples. Development in the tropics, with increased human activity, has led to increasing numbers of people and increased demand for natural resources. The carrying capacity of the forest is being exceeded, causing higher human density, and greater demand on the forest (Fitzhugh, 1986). Increase in human population density increase immigration into the tropical forest, leading to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes. Increased immigration, especially by non-indigenous people, has led to increased hunting pressure and decreased population sizes.
Also, the increasing warmness of animals to hunters, immigration and immigration of animals will also affect harvests. Changes in human communities, e.g., in the number of hunters, or increasing access also affects hunting yields.

**Age structure comparisons.** Age structures of hunted populations change with hunting; so changes in population age structure can be indicative of hunting sustainability. Hunted populations generally have lower numbers of older animals, possibly because the chances of surviving long are less. This decrease in the older age class is usually reflected in juveniles making up a higher proportion of the population. Unfortunately, data on complete age structures of wildlife populations in tropical forests are seldom available.

### 1.4 Why hunting is less sustainable today

Today, hunting is a much greater threat to wildlife than it was in the past. Studies have shown that current hunting is unsustainable in many tropical countries (Mittermeier, 1987; Redford, 1993; Wilkie and Carpenter, 1999; Bennett et al., 2000; Bennett and Robinson, 2000b; Eves and Ruggiero, 2000). Many factors contribute to this, including:

**Increasing human populations and immigration.** Human population densities have been increasing exponentially since the beginning of this century. Developments in technology, advances in medical science, better health and hygiene, and agricultural technology all have contributed to the extension of human life-span and decreased infant mortality. Hunting sustainability decreases with increases in effective human population density (Bennett and Robinson, 2000a; Bennett and Robinson, 2000b). This is because greater human densities lead to increasing needs for wildlife harvested. It then becomes more and more difficult to sustain the harvesting to meet these needs (Fa, 2000; FitzGibbon et al., 2000; Lee, 2000). For hunting to be sustainable, it must have been estimated that the carrying capacity of humans residing on wildlife is a maximum of one person per km² (Bennett and Robinson, 2000a). If this is exceeded, the resource base will continue to decline until wildlife populations are eventually depleted.

Higher human densities have a greater impact on tropical forests, either through greater demand on wildlife or more wildlife products, conversion or fragmentation of the forest (FitzGibbon et al., 2000; Leeuwenberg and Robinson, 2000).

Increased immigration also increases effective human density. Immigration in this context means outside people colonizing a forest area. Examples include colonists of non-indigenous descent in Amazonia (Stearn, 2000); logging staff immigrating into a concession area; (Auzel and Wilkie, 2000; Eves and Ruggiero, 2000; Robinson et al., 1999); or government translocation programmes (Bennett and Robinson, 2000b). Immigrants hunt a narrower range of species, depleting populations of favoured species, resulting in greater overharvest of less favourable ones by original residents (Redford and Robinson, 1987; Stearn, 2000). Also, they generally do not observe local customs or taboos that may oblige hunting zone rotation or outlaw camps to disperse hunting pressure.
(Redford and Robinson, 1987). Immigrants often convert forest habitats to different land-use, and regard certain species as "pests" to be eradicated in their converted patrones (Lee, 2000; Stearman, 2000).

Societarianism. Indigenous groups who move across the landscape are able to disperse hunting pressure on wildlife across a wide area. Increasing societarianism is often associated with government policy, mission stations and modern agriculture, all of which might allow people easier access to schools, markets and jobs, but they also accelerate local wildlife depletion (Bennett and Robinson, 2009a; Stearman, 2000).

Hunting technology. Traditionally, hunting was practiced using low-technology tools such as spears, bamboo or wooden traps, spears, blow-pipes and hunting dogs. With the advent of new hunting technology like shotguns, wire snares, four-wheel drive vehicles and powerful night-lights, hunting efficiency, the number of animals and diversity of species hunted, as well as the age-sex class within the hunted species increases (Bennett et al., 2000; Bennett and Robinson, 2000a). New hunting technology provide surpluses which can then be sold. This supplies demand of the wild meat trade, which generates the need for more supply (Boomer et al., 1994; Bennett et al., 2000).

Commercial trade. Wildlife is traded for its meat, skins, or trophies, for traditional medicine or as pets. As societies indigenous to tropical forests increasingly participate in a cash economy, wildlife is more sought after as the means to cash income, and hunting pressure increases (Auzel and Wilkie, 2000). As local people hunt more for commercial purposes, they sometimes turn to non-commercial, smaller and potentially less resilient species for their own subsistence (Bodmer and Puertas, 2000). In Sarawak, the wild meat trade reduces the populations of large ungulates. Consequently, local people increasingly hunt primates and large birds for subsistence (Caldescott, 1988; Bennett and Gumai, in press).

Income generated from the trade and from working in industries enable local hunters to supply themselves with improved hunting technologies, e.g., cartridges, batteries and outboard motors (Auzel and Wilkie, 2000; Bennett et al., 2000). Demand created by wealthy town consumers also encourages the supply of wildlife, be it meat, trophies or live animals. Demand can also be generated by logging company staff, whose income allows them to purchase wild meat from local hunters (Bennett and Robinson, 2000b).

Distance from "source" areas. Because they move across the landscape, species are able to recolonize areas where populations have been reduced by hunting. Areas from which recolonization occurs are known as "sources", and those where there is no net gain in populations are known as "sinks" (Pulliam, 1988; Merri and Carroll, 1994). If the distances between sources and sinks increase, then sustainability decreases (Bennett and Robinson, 2006a; Bodmer and Puertas, 2000; Fimbres et al., 2006; Hart, 2000; Hill and Padwe, 2000).

Naturally low biological production. In tropical forests, the biomass of large mammals is low. This is because there are no large open spaces of grassland for

large terrestrial animals. In other habitats, the biomass is high. Tropical forests are occupied by about 5% of the maximum species diversity, and estimates of sustainable hunting depend on the size of the population that can sustainably be harvested (e.g., in small patches, which can sustainably be harvested).
large terrestrial animals, such as ungulates, to browse. Low biomass of large animals also means that productivity of wild meat is low. Thus, the amount of wildlife that can be sustainably harvested from tropical forests is much less than in other biomes, e.g., tropical savannas. Natural biological production in tropical forests is so low that even low hunting pressures can reduce populations to about 30% of carrying capacity (Redford, 1992). In Manu forest, Peru, maximum sustainable harvest estimated was only 102 kg/km²/year (Robinson and Bennett, 2000b). This conforms with other areas of tropical forest known to be sustainably harvested. In general, harvests above 200kg/km²/year are not sustainable (Edwards, 1992; Auzel and Wilkie, 2000). The number of people who can survive on this amount of meat has been estimated to be one person/km²/year (Robinson and Bennett, 2000a). Thus, for harvests to be sustainable, human population density in tropical forests cannot exceed one person/km²/year. If this is exceeded, unless other sources of protein are found (e.g., domesticated meat, fish), wildlife populations will decrease and local forest communities will face a declining resource base.

Vulnerability to harvest. Certain species are less resilient to hunting than others. These include: 1) species with high intrinsic rates of increase (λmax) (Bodmer, 1985; Bodmer and Puertas, 2000); 2) species whose behaviour allows them to be easily hunted, e.g., those with loud calls (Bennett and Durham, 1995; Bennett et al., 1998; Fitz-Gibbon et al., 2000; O’Brien and Kinnaird, 2000); 3) species which are intrinsically rare (Hill and Padwe, 2000); and 4) species which favour undisturbed habitats (Auzel and Wilkie, 2000).

Access. The easier the access to a hunting area, the less sustainable hunting will be in that area. Access is a function of physical factors such as relief, distance, and physical barriers, and artificial infrastructure such as roads or other transport mechanisms (Bennett and Robinson, 2000a; Robinson and Bennett, 2000b). Ease of access allows outsiders to enter an area to hunt, placing more pressure on local wildlife, as it proximity between hunting grounds and commercial markets also decreases sustainability (Auzel and Wilkie, 2000; Bennett and Gumal, in press). This proximity also allows local hunters to purchase cartridges and batteries for night-hunting (Bennett et al., 2000; Stearnman, 2000); and local communities in this situation tend to be more involved in a market economy, and their purchasing power as well as tendency to sell wild meat increases (Robinson et al., 1999; Auzel and Wilkie, 2000; Stearnman, 2000). Thus, access increases hunting rates by local communities as they increasingly hunt for sale (Auzel and Wilkie, 2000).

Logging. Recent studies on the relationship between hunting and wildlife abundance in tropical forests suggest that commercial timber harvesting is one of the biggest factors of unsustainable hunting (Robinson et al., 1999; Wilkie and Carpenter, 1999; Auzel and Wilkie, 2000; Evans and Ruggiero, 2000; Bennett and Gumal, in press). In the absence of hunting, the commercial extraction of timber from tropical forests alters the abundance of species with the biological communities (Puig et al., 2000). Most species, including those preferred by hunters, do badly in logged areas; for example the anoa (Rhinolophus depressicornis) and babirusa (Babyrousa babyrousa) in Sulawesi (O’Brien and Kinnaird, in press). However, logged forests can also support significant populations of some
species of wildlife (Johns, 1997), including those species preferred by hunters. Hunters generally prefer large-bodied species because they provide the majority of meat in their diet, for example large ungulates like peccaries, other wild pigs and deer. These and other large species, for example flying squirrels, medium and small squirrels (Dahaban, 1996), some bulbul and spider hunters (Lambert, 1992), are often able to survive well in unfragmented logged forests. For large ungulates, logged over forest opens up the canopy, and this encourages denser undergrowth which provides food for them (Bennett and Dahaban, 1995; Frumhoff, 1995; Stuebing, 1995). Nevertheless, logging brings with it secondary effects which significantly reduce wildlife harvest rates and decrease hunting sustainability. This is because commercial logging opens up remote and previously inaccessible areas, bringing in hunters from other areas and changing local economies as well as patterns of resource consumption (Robinson et al., 1999).

Worldwide, logging opens up 50,000 to 59,000 km² of tropical forest annually (Whitmore and Carpenter, 1992; WRI, 1994; Johns, 1997). Logging activities create an extensive network of roads which link to other main road systems, serving as conduits for outside hunters and the commercial wild meat trade. Wild meat is transported from previously inaccessible forests to towns for sale. In the tropical forests of Africa, the annual harvest of wild meat is known to exceed one million metric tons, most of it coming from logged forests with increased access (Wilkie and Carpenter, 1999). This harvest is 20 to 50 times greater than that of subsistence harvests in the Amazon Basin. In 1996, the wild meat trade in Sarawak was estimated to be greater than 1,000 tons per year, with most of the meat transported to markets via logging roads (Wildlife Conservation Society and Sarawak Forest Department, 1996). Thus, logging per se is perhaps not as damaging to wildlife as its main secondary effect: increased access from logging roads. Access allows the inflow of hunters, whether they be town-hunters or logging staff. Hunters from town enter logging concessions for sport hunting or to hunt for the wildlife trade.

Commercial logging also leads to immigration of large numbers of logging staff into the forest. These outsiders often hunt for their own consumption, and put significant hunting pressure on local wildlife populations. For example, in a single logging camp of 648 people in the Republic of Congo, 8,251 individual animals were known to have been harvested in one single year. This amounted to 124 tons of wild meat (Auzel and Wilkie, 2000).

1.5 HUNTING AND WILDLIFE IN SARAWAK

1.5.1 Physical Geography

Sarawak is the largest of 13 states in Malaysia, and occupies approximately 124,450 km² (roughly 38% of Malaysia's total land area) along the north-western part of Borneo (Cramb and Dixon, 1988) (Figure 1.1).