SUBSISTENCE USE OF TERRESTRIAL AND AQUATIC ANIMAL RESOURCES IN THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA* OF LOWLAND BOLIVIA

by

KIMBERLY ANN WINTER

(Under the direction of Michael J. Conroy)

ABSTRACT

This study identifies terrestrial and aquatic resource management priorities for a proposed indigenous territory, the *Tierra Comunitaria de Origen Itonama* (TCOI), located in the lowland Amazonian floodplain of Beni, Bolivia. The research focused on extractive activities in the town of Bella Vista, and the objectives were: 1) to determine the species of terrestrial and aquatic fauna that were most frequently harvested for subsistence purposes by human residents, 2) to evaluate preferences and selectivity for particular species of terrestrial prey, 3) to quantify harvest of prey groups (birds, mammals, fish, reptiles) as a proportion of the local diet and economy, 4) to compare hunting, fishing, and production of livestock as sources of animal protein, and 5) to evaluate management of aquatic resources as represented by an indicator species, *Colossoma macropomum*. Research methods were interdisciplinary, and included interviews with residents of Bella Vista, transect surveys of terrestrial fauna, hunting and fishing activity reports, diet calendars, and collection of selected species. The results of interviews and harvest activity reports indicated that residents sometimes select or avoid certain species of prey according to cognitive preferences, rather than simply abundance or yield per unit of hunting effort, and those preferences may induce over-harvest. Ten species of mammals were identified as the most recognized and actively pursued terrestrial prey for human subsistence in Bella Vista: *Agouti paca, Dasypus novemcinctus, Tayassu pecari, Mazama americana, Tayassu tajacu, Blastocerus dichotomus, Tapirus terrestris, Dasyprocta variegata, Mazama gouazoubira,* and *Priodontes maximus*. Management efforts should focus on species that are most frequently exploited, are particular to certain habitats, and/or are vulnerable to depletion. Hunting and fishing activity reports and diet calendars demonstrated the economic and environmental significance of managing fish resources in particular for the subsistence of residents in the TCOI, and of protecting aquatic habitats from degradation due to deforestation and cattle ranching. Fisheries and aquatic resource management is promoted in a case study of *Colossoma macropomum,* the most important species of fish in the TCOI. Active, participatory, and adaptable management of natural resources in the TCOI will determine the survival of resident populations of fish, wildlife, and humans.

INDEX WORDS: Natural resource management, *Tierra Comunitaria de Origen Itonama,* Beni, Bolivia, Amazon floodplain, Wildlife, Fish, Subsistence, Indigenous territory, Harvest management, Hunting, Fishing, Optimal foraging, Sustainability, *Colossoma macropomum*

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KIMBERLY ANN WINTER

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KIMBERLY ANN WINTER

Approved:

Major Professor: Michael J. Conroy

Committee: Theodore L. Gragson
John P. Carroll
Robert J. Warren
C. Ronald Carroll

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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"…'conservation' is not a state of being. It is a response to people's perceptions about the state of their environment and its resources, and a willingness to modify their behaviors to adjust to new realities."

- William T. Vickers, 1994
"From opportunism to nascent conservation: the case of the Siona-Secoya"

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS v

LIST OF TABLES xi

LIST OF FIGURES xiii

CHAPTER

1 INTRODUCTION 1

Literature Cited 4

2 LITERATURE REVIEW AND CHAPTER ORGANIZATION 6

Introduction 6

Indigenous Territories and Struggles 6

Concept of Sustainable Use 8

Sustainable Use of Natural Resource for Subsistence 11

Optimal Foraging Theory 13

Species Lists and Local Diets 14

Pacú Fishery and Aquatic Resource Management 15

Chapter Organization 16

Literature Cited 19

3 RESEARCH LOCATION AND BACKGROUND 26

Introduction 26

Bolivia's Political History of Indigenous Rights 26

Tierra Comunitaria de Origen Itonama 28

Local Economy 30

Settlement of Bella Vista 31

Geographical and Ecological Characteristics of the TCOI 32

Literature Cited 36

4 EFFECTS OF HUNTER PREFERENCES AND PERCEPTIONS OF PREY POPULATION ABUNDANCE ON HARVEST IN THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA,* BOLIVIA 38

Introduction 39

Study Site 42

Methods 44

Results 49

Discussion 68

Conclusion 75

Literature Cited 78

5 TRADE-OFFS AT THE RURAL FRONTIER: USE OF FISH, WILDLIFE, AND LIVESTOCK RESOURCES ON THE AMAZON FLOODPLAIN OF BELLA VISTA, BOLIVIA 82

Introduction 83

Study Site 84

Methods 85

Results 86

Discussion 104

Conclusion 108

Literature Cited 110

6 *PACÚ* (*COLOSSOMA MACROPOMUM*) AS AN INDICATOR FOR AQUATIC RESOURCES OF THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA* IN BOLIVIA 114
Introduction 114
Study Site 115
Methods 116
Ecology of *Pacú* 116
Pacú Harvest in Amazonia and Bolivia 124
Threats to the *Pacú* Fishery 129
Discussion: Management Implications and Conservation of *Pacú* as an Aquatic Resource 135
Conclusion 139
Literature Cited 140
7 SYNTHESIS AND MANAGEMENT IMPLICATIONS FOR THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA* 143
Introduction 143
Chapter Synthesis 144
Conclusion 147
Literature Cited 149
APPENDICES
A HUNTER INTERVIEW QUESTIONS 150
B SAMPLE OF HUNTING ACTIVITY REPORT SHEET 154
C ESTIMATED AVERAGE WEIGHTS FOR FISH AND WILDLIFE SPECIES IN THE TCOI 155
D ETHNIC IDENTITY AND CONFLICT IN DESIGNATING THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA,* (TCOI) 157

LIST OF TABLES

4.1. Terrestrial wildlife with reported but unconfirmed presence near Bella Vista, Bolivia in 1999 50

4.2. Terrestrial wildlife with confirmed presence near Bella Vista, Bolivia in 1999 51

4.3. Categories of recognition and pursuit of prey species by hunters in Bella Vista, Bolivia in 1999 52

4.4. Species included in each recognition and pursuit category by hunters in Bella Vista in 1999 54

4.5. Category I: Species that were highly recognized and actively pursued by hunters in Bella Vista, Bolivia in 1999 56

4.6. Category II: Species that were highly recognized and moderately pursued by hunters in Bella Vista, Bolivia in 1999 58

4.7. Category III: Species that were highly recognized and rarely pursued by hunters in Bella Vista, Bolivia in 1999 61

4.8. Category IV: Species that were moderately recognized and rarely pursued by hunters in Bella Vista, Bolivia in 1999 63

4.9. Density, detection probabilities, and encounter rates for prey and non-prey in the Bella Vista hunting catchment from May – October, 1999 65

4.10. Species perceived as abundant, harvest intensity, and frequency of encounter in Bella Vista, Bolivia 75

5.1. Fish and wildlife species hunted, sold, and consumed in Bella Vista, Bolivia 88

5.2. Quantity of mammals harvested by participating households in Bella Vista, Bolivia.......... 91

5.3. Sex ratio of mammals harvested by participating households in Bella Vista, Bolivia 92

5.4. Quantity of fish harvested by participating households in Bella Vista, Bolivia 93

5.5. Quantity of birds harvested by participating households in Bella Vista, Bolivia 95

5.6. Monetary activity costs of hunting, fishing, or animal husbandry 101

5.7. Average costs and benefits of foraging versus purchasing flesh in each prey category 103

6.1. Plants of the várzea and consumption by pacú 119

6.2. Plant species consumed by pacú in Amazonian flooded forests 121

LIST OF FIGURES

3.1. Map of *Tierra Comunitaria de Origen Itonama* and *Reserva Forestal Itenez* in Bolivia 27

4.1. Spearman's rank correlation between perceptions of abundance and encounters during transect surveys in Bella Vista, 1999 66

4.2. Spearman's rank correlation between perceptions of abundance and number of animals harvested by sample households in Bella Vista, 1999..... 67

4.3. Spearman's rank correlation between number of animals harvested by sample households and encounters during transect surveys in Bella Vista, 1999 67

4.4. Effects of hunter preferences, perceptions of prey population abundance, and optimal foraging motivators on hunting choices 73

5.1. Relative proportions of wild prey harvested by sample households in Bella Vista, Bolivia (by number taken) 89

5.2. Relative proportions of wild prey harvested by sample households in Bella Vista, Bolivia (by biomass) 90

5.3. Wild-caught animals consumed by participating households in Bella Vista, Bolivia (in edible biomass) 96

5.4. Edible biomass of wild-caught and domesticated sources of animal protein that was consumed by residents of Bella Vista, Bolivia 97

5.5. Animals sold in Bella Vista from March to November 1999 (by number) 98

5.6. Animals sold in Bella Vista from March to November 1999 (by biomass)..... 98

CHAPTER 1

INTRODUCTION

Survival as a subsistence forager is predicated on the relationship between the natural environment and its human inhabitants. While historically human societies have exploited the bounty of the earth's natural resources without significant loss of food, human-caused extinctions of numerous species in the last century have shown that sources of wildlife for human subsistence may be finite. Habitat destruction, pollution, overexploitation, and manipulation of ecological relationships and communities threaten the viability of wild faunal populations. Undeniably, the survival of poor, subsistence foragers is intrinsically linked to management efforts that seek to ensure the perpetuity of the plants and animals that sustain them.

Recognition of the limited availability of land and other natural resources has inspired many indigenous groups to seek national and international assistance in protecting and managing the lands considered to be their cultural heritage (Clay 1988, Bunyard 1989, Redford and Padoch 1992, Alcorn 1993, Gaia Foundation 1993, Davis and Wali 1993, Redford and Stearman 1993, Peres 1994, Western et al. 1994, Conklin and Graham 1995, Stearman and Redford 1995, Campos Rozo 1996, Redford and Mansour 1996, Townsend 1996, CIDOB 1997, Chapin 1998, Robinson and Bennett 2000). Yet, as evidenced by the example provided by tribal reservations in the United States, merely providing land to indigenous peoples does not ensure that they will be provided the natural resources and management skills necessary for long-term survival. Formal recognition of indigenous territories must be accompanied by a comprehensive evaluation of the resident human population and their present and future requirements for land, fauna, flora, and other natural resources.

This dissertation project was initiated by invitation from indigenous leaders of the *Subcentral de Pueblos Indigenas Itonamas*, residents of a proposed indigenous territory named the *Tierra Comunitaria de Origen Itonama*, (TCOI) located in the lowland Amazon floodplain of Beni, Bolivia. Government recognition of indigenous territories in Bolivia requires a lengthy process of solicitation, land surveys, and studies of spatial and resource requirements (Cardenas Conde 1996, Sanchez de Lozada 1996, IFRACRUZ-CEJIS 1997, Superintendencia Forestal 1997, Marinissen 1998). This project was undertaken to evaluate the exploitation of faunal resources in the TCOI, focusing on terrestrial and aquatic prey species and their management in the town of Bella Vista. The objectives of this dissertation are:

1) To identify the species of terrestrial and aquatic fauna most frequently harvested as subsistence prey by residents of the TCOI;

2) To evaluate local preferences for terrestrial prey under an optimal foraging scheme;

3) To quantify harvest of prey groups (birds, mammals, fish, reptiles) as a proportion of the local diet and economy;

4) To compare fishing, hunting, and/or production of livestock as sources of animal protein;

5) To evaluate management of aquatic resources in the TCOI as represented by an indicator species, *Colossoma macropomum*;

6) To provide a preliminary framework for managing the TCOI, with the goal of ensuring that present and future requirements of the resident human population for animal protein and prey habitats are met.

The majority of field data for this dissertation were collected in the town and surrounding forests and rivers of Bella Vista, located in the southern portion of the TCOI. The river port of Bella Vista lies at the juncture of the Blanco and San Martín Rivers in the upper Amazon basin of Beni, Bolivia. This field site was selected because its social, economic, and ecological characteristics adequately represented those of other settlements in the TCOI, and because its size and permanence allowed me to observe a wide range of factors that may affect resource use in the region.

For this dissertation, I drew methods from both the social and natural sciences to more comprehensively describe the dynamics of human and animal populations in the TCOI. The specific methods included: interviews, participant-observations, transect surveys of terrestrial fauna using program DISTANCE sampling techniques (Thomas et al. 1998), count surveys, forager activity reports, diet calendars, and collection of fish otoliths from local catch. These methods provided me with a variety of data source options that I believe enhanced my effectiveness in representing the characteristics of the study area. Specific methods are described in greater detail in individual chapters after a review of the literature concerning this subject.

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CHAPTER 2

LITERATURE REVIEW AND CHAPTER ORGANIZATION

Introduction

This dissertation represents a holistic approach to topics related to management of natural resources in the *Tierra Comunitaria de Origen Itonama* (TCOI), including the establishment of indigenous territories, subsistence hunting, optimal foraging, and terrestrial and aquatic resource management. Much of the material is presented in individual chapters with greater depth and specificity. In this literature review, I will introduce some of these topics from the perspective of the dissertation, setting the framework for how each comprises an important element of natural resource use that may be useful in developing a preliminary management plan for the TCOI.

Indigenous Territories and Struggles

Natural resource management in indigenous territories has become a hotly debated issue, especially with respect to the question of who is made responsible for the control and management of traditional lands (Redford 1991, Redford and Stearman 1993, Conklin and Graham 1995). Although some traditional peoples struggle to obtain formal control over their land, oil and timber industries, poachers, and other invaders may take or destroy the natural resources upon which indigenous peoples depend, threatening their survival (Vickers 1991, Sponsel 1995, Riach 2001). Government protection of parks and native lands in underdeveloped countries is often insufficient due to lack of funding, technical training, and logistical support, leaving indigenous groups that are often the poorest class in society to fend for themselves and their livelihoods.

In some cases, the response to the land protection dilemma has been to turn over land titles to indigenous leaders, allowing them to assume full management authority over extant natural resources in specific territories (Fisher 1994). Although these lands are the natural heritage of native peoples and formal recognition of this fact is their prerogative, indigenous people must also adapt to an ever-changing sociopolitical and natural environment, acquire technical training in management, and be adequately empowered to implement management objectives. Global pressures and influences increasingly affect protection of native natural resources, and indigenous leaders must assimilate traditional practices with modern ones in order to ensure the perpetuity of the resources that they have struggled to own. The "ecologically noble savage" (Redford 1991) or “natural conservationist” (Conklin and Graham 1995) stereotypes, in which native peoples were deemed *ad hoc* conservationists, are no longer valid arguments for turning over lands to native groups with the ultimate goal of protecting natural resources. Native peoples maintain intimate contact with the natural world through their cultural worldviews and practices (Winter 1997a), however, external influences and economic demands may force them to extinguish their resources shortsightedly. Indigenous and non-indigenous peoples alike need to expand their knowledge of natural resource management to ensure the perpetuity of the resources upon which they depend for subsistence.

Local inhabitants of protected areas, whether of indigenous ethnicity or not, hold the key to cultural and environmental conservation (Winter 1997b), and their knowledge of faunal resources can and should supplement ecological data collected by trained researchers. Examples abound of successful natural resource management programs administered by local communities and native groups (Redford and Padoch 1992, Western et al. 1994, Redford and Mansour 1996, Campos Rozo et al. 1996, Townsend 1996, Fang et al. 1997, Robinson and Bennett 2000a). Ideally, local indigenous leaders should aspire to and receive training in ecological assessment and analysis so that they themselves may act using the most holistic information possible regarding natural resource management, rather than relying disproportionately on the government, or on assistance provided by outsiders. However, many indigenous groups lack the financial and educational support to attain this objective alone. To assist them, collaborative efforts between indigenous leaders and natural resource scientists provide both parties with a unique opportunity to learn from each other in the study and management of their local resources. Management protocol should be constantly updated with new data to effectuate adaptive management strategies by promoting realism, precision, and predictability in models (Conroy 1993, Williams and Johnson 1995). Governments should recognize the limitations of indigenous groups living in remote locations, providing them with training and logistical support when possible and encouraging collaborative efforts between trained scientists and local leaders.

Concept of Sustainable Use

Conservationists Pinchot and Roosevelt promoted the "wise use" of natural resources in the United States as early as 1910. The phrase "wise use" has evolved to "sustainable use" in recent terminology, referring to the goal of harvest management to prevent the overharvest of resources over time (Leopold 1933). Caughley (1977) further elaborated upon the concept of sustainability in discussing "conservation," which involves managing to raise the density of declining wildlife populations, and "sustainable yield," or exploiting populations without promoting declines.

McCullough (1979) proposed a general model of biological carrying capacity in which environmental constraints limit the continued growth of a given wildlife population over time. Theoretically, the optimal harvest could be obtained at the midpoint (50% of carrying capacity, or maximum sustained yield, MSY) of the logistic growth curve produced by the biological carrying capacity model. However, a sustained yield can be harvested from two density levels if the population is at carrying capacity and other assumptions hold true, and carrying capacity will fluctuate in a dynamic environment (Caughley 1976). In fisheries management, Beverton and Holt (1957) contributed a dynamic pool model to describe the potential sustainable catch, but the model assumed constant natural mortality, independent of density. In contrast, Errington (1946) recognized the density-dependent relationship between prey and predators under habitat constraints with the concepts of compensatory and noncompensatory predation. Compensatory predation involves increased mortality for prey as the environment limits their capacity for avoiding predators. Similarly, compensatory and additive mortality are used as theoretical guidelines for interpreting the effects of hunting mortality on game populations (Anderson and Burnham 1976). Under compensatory mortality, game populations are resilient to exploitation up to a certain level, beyond which they decline linearly as additive mortality takes over with increased hunting intensity (Anderson and Burnham 1976). Silliman and Gutsell (1958) observed that the maximum rate of exploitation is at least partially a function of a species' rate of production or biotic potential. These concepts have been elaborated upon in recent attempts to model the sustainability of subsistence harvest of wildlife populations in the tropics.

Robinson and Redford (1991b) modified a general MSY model using life history data for several tropical forest mammals from a number of available studies. In their model, population density and intrinsic rate of natural increase were used to calculate the maximum production (in number of animals per square kilometer) of each species under the best of all possible environmental conditions (Robinson and Redford 1991b). If maximum production occurs and hunting harvest has minimal effects on the population, Robinson and Redford's (1991b) MSY model produces the potential harvest (in numbers of animals per square kilometer) for that species that may be considered "sustainable" under the assumptions of: (1) density-dependent population growth, and (2) the proportion of the population that can be harvested without resulting in depletion (60% in very short-lived species, 40% in short-lived species, and 20% in long-lived species). The model also depends on the accuracy of parameters representing body mass, population density, and rate of population increase. Since body masses for the different species range widely according to the effects of age, habitat, and intensity of hunting pressure, the model is difficult to effectively implement without first collecting site-specific comprehensive life history data on each species. The Robinson and Redford (1991b) model has been used widely and generally to prove "sustainability" of harvest in various different tropical regions for many species, although the authors specified that it should be used only as a preliminary measure to compare actual harvest rates against those predicted by a maximum production model, and to stimulate further surveys and monitoring of actual prey populations.

Predictions of harvest levels that can be maintained without decimating prey populations have often been based on characteristics of animal populations at equilibrium in habitats assumed to be homogeneous (Robinson and Redford 1991b, 1997; Alvard 1993, 1994, 1995; Alvard et al. 1997) rather than a mosaic of inter-digitating microenvironments. Differential species vulnerability, hunting catchment size, initial abundance, habitat quality, source-sink dynamics, and size of the human population all may be important in determining the effects of harvest on local wildlife populations (Fitzgibbon et al. 1995, Alvard et al. 1997). Other important parameters may include changing animal population dynamics, life history characteristics, habitat disturbance for other extractive activities, habitat type, proximity to water or sources of forage, and dependency of human population on wild versus domestic sources of animal protein.
While many studies report depletion of prey populations in hunted areas relative to non-hunted areas, (Freese et al. 1982, Bodmer et al. 1988, 1994; Peres 1990, Fragoso 1991, Vickers 1991, Alvard 1993, 1994, 1995; Alvard et al. 1997, Redford 1992, Winterhalder and Lu 1997), few consider the potential interaction effects between different habitats, hunting intensities, time of year, and animal population dynamics on local game abundance (Townsend 1996, Hill et al. 1997, Peres 2000). Research in the Neotropics presents many logistical difficulties that are reflected in the paucity of information available on prey species and habitats. Although data collected in the past may have limited use in predicting sustainability in current environmental conditions, small-scale communities have been the most successful at promoting sustainable harvests (Hilborn et al. 1995). Harvest management strategies should be based on estimates of population abundance and identification of the needs of both wildlife and hunters (Strickland et al. 1996). Until more comprehensive studies are undertaken, species lists and initial models of harvest, consumption, and distribution of prey resources should be used as dynamic and adaptable predictive tools, rather than static prescriptions for management (Conroy 1993).

Sustainable Use of Natural Resources for Subsistence

Indigenous management programs are oftentimes concerned with the issue of "sustainability" of biodiversity with respect to exploitation of faunal resources (Robinson and Redford 1991a, Redford and Padoch 1992, Redford and Mansour 1996, Robinson and Bennett 2000a). Subsistence hunting has demonstrably caused depletion and local extinction of fish and wildlife populations in many parts of the world and is considered the second most important threat to the persistence, or "sustainability," of fauna in many tropical ecosystems, under habitat degradation and loss (Hilton-Taylor 2000). The implicit meaning of "sustainability" has been used to reference whether local populations of prey species are presently demonstrating the signs of depletion caused by current levels of hunting or fishing. Robinson and Redford (1991b) defined sustainable harvest as that which maintains the resource so that it can be exploited for human welfare, while conserving the exploited resource such that ecosystem functioning is unaffected over an unspecified time frame. In this dissertation, the term "sustainable" refers to the ability of an animal population to maintain a state of overall demographic and geographic equilibrium (including secondary characteristics such as age distribution, genetic composition, and spatial and temporal patterns of distribution), under changing levels of harvest pressure in a specified area over a particular period of time, such that the population is not threatened by immediate or subsequent extinction.

Residents of rural tropical areas, especially indigenous peoples, depend on access to abundant wild game to maintain their nutritional well-being (Vickers 1984, Redford and Robinson 1987, Stearman 1990, Townsend 1996, Bennett and Robinson 2000, Robinson and Bennett 2000b). In the state of Amazonas, Brazil alone, an estimated 3.5 million vertebrates (birds, mammals, reptiles) are killed annually for food (Redford and Robinson 1991). Although survival rates of prey populations during harvest may be at least partially compensated by corresponding changes in non-hunting mortality (compensatory mortality hypothesis) (Williams et al. 1996), the “carrying capacity of the forest” restricts the number of people that a tropical forest can support through harvest of local flora and fauna if biodiversity is to be conserved (Robinson and Bennett 2000b) and depletion prevented.

Resource use in abundant environments by a small group of consumers can be wasteful without significant impacts on game, a phenomenon referred to as "epiphenomenal conservation" (Hunn 1982). Game persistence despite heavy hunting pressure has been cited as a result of hunters intentionally conserving prey (Bunyard 1989). However, a small population of foragers can sustainably hunt without intentional conservation of game resources as long as the harvest of game is less than the net productivity of game populations (Alvard 1995, Bennett and Robinson 2000). Alvard (1993, 1994) argued that stable predator-prey conditions between human foragers and game in tropical ecosystems are a consequence of optimal foraging, low human population densities, limited technology, and highly mobile foraging patterns, rather than intentional conservation behavior. Prey-switching, alternative foods, and a higher intrinsic rate of population increase of preferred prey can contribute to species persistence despite heavy hunting pressure (Winterhalder and Lu 1997). Behavioral attributes and life history characteristics of species with a high intrinsic rate of increase (ie., an “r-selected” species), may provide these populations with greater compensatory resilience against over-harvest than a slowly reproducing, “K-selected” species (Bodmer et al. 1997). Getz and Haight (1989) proposed that conservation of prey would require hunters to employ tactics such as selective patch choice, interspecific prey choice, and non-random harvesting by age and sex. Conservation behavior may be defined as decisions that are immediately costly to the forager by having to forego hunting opportunities, but have the ultimate objective of increasing long-term harvest sustainability and overall prey production (Alvard 1993). Yet, conservation of prey resources is an infrequent motivator in the hunting strategies of subsistence foragers. “Sustainability” appears to be largely a by-product of foraging strategies that focus on optimizing hunting efficiency, prey switching when preferred populations decline, and opportunism, each of which may be evaluated under the tenets of optimal foraging theory.

Optimal Foraging Theory

The ecological model of optimal foraging theory has been applied to numerous studies of human subsistence hunting and fishing systems in the tropics (Hames and Vickers 1982, Hawkes et al. 1982, Belovsky et al. 1989, Bennett 1991, Zeleznik and Bennett 1991, Alvard 1993, 1994, 1995). Because their survival depends on successful foraging, rural residents must optimize their efforts to acquire natural resources provided by the local environment. Optimal foraging theory provides a method for studying the environmental parameters and other factors that constrain a forager's ability to exploit resources, such that hunter responses to changing conditions may be predicted (Hames and Vickers 1982).

Subsistence hunters attempting to optimize their foraging efforts may selectively search for large-bodied game rather than smaller game (Redford and Robinson 1987, Peres 1990). Large game animals will often be high-ranked in optimal diet terms, and as a result will frequently be identified by hunter-gatherers as preferred foods, regardless of their local abundance or quantitative contribution to the total diet (Hawkes et al. 1982, Bodmer et al. 1997). In general, most of the biomass consumed by rural peoples in the tropics is comprised of ungulates, primates, and rodents (Robinson and Bodmer 1999). Indigenous peoples reportedly hunt a larger range of species than do colonists (Redford 1993). Colonists reportedly rely more on fish or other sources of meat when depletion occurs, whereas indigenous peoples may switch to smaller, less-preferred species (Redford 1993).

Fluctuations in the encounter rate of preferred prey species and the use of modern hunting technologies will change the composition of a forager's diet (Pyke et al. 1977, Hames and Vickers 1982, Smith 1983), as hunters adapt their foraging efforts to the availability of preferred game species (Anderson 1978, Vickers 1980, Peres 1990). Vickers (1991) stated that kill rates for preferred prey, as a function of encounter rates, should be proportional to animal population densities in the area. However, Vickers' (1991) observation does not account for life history characteristics or behavioral attributes of prey that may affect encounter rates and predation.

Predation can affect the distribution of prey (MacArthur 1972), causing enhanced wariness and avoidance behavior in game populations located near human settlements (Werner et al. 1983, Hill et al. 1997). Additionally, locations of game in lowland regions vary in response to changes in river water levels during the year (Hiraoka 1995). Prey populations may be concentrated near particular flora during the ripening season of feed sources, dispersed as a result of changing ground conditions, or better accessed during fishing activities in backwaters (Hiraoka 1995). As availability of prey resources changes, patterns of use may also change accordingly (Manly et al. 1993).

Species Lists and Local Diets

Species lists of fauna in tropical terrestrial ecosystems have been generated in the last few decades, illustrating community composition and local levels of consumption to help in determining whether management action is necessary to conserve particular resources (Ayres et al. 1991, Glanz 1991, Vickers 1991, Redford 1992, Townsend 1996, Alvard et al. 1997, Bodmer et al. 1997, Muchaal and Ngandui 1999, Peres 2000, Mena et al. 2000, Fa 2000, Jorgenson 2000, Townsend 2000). Documentation of prey species exploited by local people residing in protected areas and indigenous territories provides invaluable information for management of faunal resources. While lists of the most frequently harvested prey have been generated primarily for the purpose of evaluating harvest sustainability, these lists also provide insight into faunal community composition and human dependence on particular prey types, which may assist resource managers in determining alternative management options if prey sources become threatened by local extinction and habitat changes such as the incursion of cattle ranching, timber extraction, or other development activities.

Diet composition for local peoples is also provided by species lists, which may indicate nutritional status of subsistence foragers (Dufour 1994) and may imply over-harvest and/or habitat degradation if protein intake is insufficient. Since many residents of tropical forests supplement their intake of wild animal protein with domestic sources, it is important to document and evaluate the levels of dependency on different types of animal protein when considering land allocation for subsistence purposes. In tropical savanna and floodplain environments such as those inhabited by the majority of residents in the TCOI, fish contribute a significant proportion of animal protein to the local diet.

Pacú Fishery and Aquatic Resource Management

Many indigenous peoples in the Americas rely on fish, rather than game, as their primary source of animal protein (Dufour 1990). The Bolivian Amazon is habitat to 501 documented species of freshwater fishes (Lauzanne et al. 1991, Sarmiento 1998, Chernoff et al. 2000). Despite the valiant efforts of several comprehensive studies of freshwater fishes in the Amazon Basin, (Lowe-McConnell 1975, Goulding 1980, Goulding 1981, Géry 1984, Junk 1984, Lowe-McConnell 1986, Lowe-McConnell 1987, Goulding et al. 1988, Lauzanne et al. 1990, Val and Almeida-Val 1995, Araujo-Lima and Goulding 1997, Barthem and Goulding 1997, Chernoff et al. 2000), a paucity of information exists regarding the presence, distribution, and life histories of most Amazonian fishes, especially for those inhabiting Bolivian tributaries. In 1996, Chernoff et al. (2000) surveyed the Tahuamanu and Manuripi rivers and their tributaries in the state of Pando. In 17 days they captured 313 species of ichthyofauna, 91 of which represented new records for Bolivia, in addition to several species that were new to science. Many fish studies in the Amazon have focused on the importance of particular commercial fishes, especially *pacú (Colossoma macropomum)* (Petrere 1983, Lauzanne et al. 1990, Isaac and Ruffino 1996, Loubens and Panfili 1997). In the capital city of Trinidad, Beni, Bolivia, Mander (1987) and Lauzanne et al. (1990) reported the principal fishes that comprised the commercial catch from 1986-1987, including *Pseudoplatystoma tigrinum* (48%), *Colossoma macropomum* (35%), *Pseudoplatystoma fasciatum* (10%), *Piaractus brachypomus* (3%), *Phractocephalus hemioliopterus* (2%), and 1% other species. Similarly, Chernoff et al. (2000) remarked that the 1996 market for fish in their Pando study was concentrated on the tiger catfishes (*Pseudoplatystoma* spp.), pacús, and pirañas (serrasalmines).

Bolivian fish habitats are threatened by deforestation, cattle ranching, and logging (Chernoff et al. 2000), much like in other areas and terrestrial habitats of the Amazon Basin (Araujo-Lima and Goulding 1997). Chernoff et al. (2000) identified three habitat classes that should be protected to ensure the survival of freshwater fishes, including the most important and highly endangered flooded areas (várzea, swamps, and forest lakes), followed by small tributaries and main river channels. *C. macropomum* exploit all three habitat categories throughout its life history, undergoing long migrations for feeding and spawning throughout the 4 main rivers, numerous tributaries, flooded forests, and lagoons of the TCOI. *C. macropomum* is an indicator species for the conservation of the lowland flooded forest and river ecosystems of the TCOI, and protection of *pacú* habitat in the Bolivian Amazon may simultaneously protect many other aquatic resources in the region.

In this dissertation, I focus on illustrating current exploitation of fauna to help in developing a management protocol for important terrestrial and aquatic prey resources of the TCOI. A management plan for the TCOI must include monitoring of aquatic and terrestrial resources, and must be adaptable to the dynamic social and ecological environment in which they survive. In the dissertation, I approach the issue of sustainability of the TCOI in terms of maintaining a sufficient supply of animal protein to residents while simultaneously protecting the terrestrial and aquatic habitats in which prey and human populations live and thrive. After an initial presentation of the preferences shown by residents for particular prey species and estimates of terrestrial prey density, I evaluate the importance of different prey groups to the local diet, economy, and environment, followed by suggestions on managing terrestrial and aquatic habitats to protect the natural resources of the TCOI.

Chapter Organization

In Chapter 3, I describe the study site and background of this research. First, I review the sociopolitical history of Bolivia that preceded the present demand for legal designation of the

TCOI. I then explain my role as an investigator and describe the economic and ecological characteristics of Bella Vista and the surrounding region.

Chapter 4 was created in journal manuscript format, and is titled, "Effects of hunter preferences and perceptions of prey population abundance on harvest in the *Tierra Comunitaria de Origen Itonama,* Bolivia." In that manuscript, I identify the species of terrestrial and aquatic fauna that are most frequently harvested as prey by residents of the TCOI. I then evaluate local preferences for terrestrial prey under an optimal foraging scheme. I conclude that while perceptions of abundance generally lead residents of Bella Vista to prefer "abundant" species to those less abundant, dietary preferences sometimes supercede the predictions of optimal foraging theory to include or exclude particular prey in the local diet. Preference-driven hunting threatens over-harvest of species that in reality are rare and could easily suffer depletion. I estimate the density of terrestrial avian and mammalian prey using program DISTANCE (Thomas et al. 1998), and briefly discuss the optimal foraging options available to hunters in the TCOI.

Chapter 5 is also written in journal manuscript format, and is titled, "Trade-offs at the rural frontier: use of fish, wildlife, and livestock resources on the Amazon floodplain of Bella Vista, Bolivia." In that chapter, I compare the dependency of residents on different sources of animal protein, including wildlife, fish, and livestock. I evaluate the trade-offs involved in managing the TCOI for domesticated versus wild animal populations, and make recommendations that should promote "sustainability" of those faunal resources based on current and expected patterns of use.

Chapter 6 is the last chapter created in journal manuscript format, and is titled, "*Pacú (Colossoma macropomum)* as an indicator for aquatic resources of the *Tierra Comunitaria de Origen Itonama* in Bolivia." In that manuscript, I focus on the ecology and management of fish and other aquatic resources in the TCOI as represented by a fruit-eating flooded forest fish called the *pacú*. The *pacú* serves as a proxy for aquatic resource management in the TCOI because it is harvested for subsistence and commercial purposes, and because it requires a diversity of habitats throughout its life history, including large migrations upriver during the dry season and into flooded forests to eat fruit during the wet season. The *pacú* is an indicator of the health of the lowland floodplain in the Amazon Basin, such that depletion of populations of this indicator species may forecast declines of fish and other aquatic fauna as well. The dissertation draws to a close in Chapter 7 with a brief summary of the results, and a synthesis tying together management issues and suggestions for the TCOI.

Appendix A includes the questions used during preliminary interviews with hunters. Appendix B is a sample of the data sheets provided to households so that they could record their hunting and fishing activities. Appendix C is a listing of species harvested and their estimated average weights.

Appendix D is a brief report of the political conflicts that erupted in Bella Vista during my fieldwork there. The report is my individual interpretation of events that occurred when representatives of the INRA initiated actual demarcation of TCOI boundaries. Although the information provided is not directly pertinent to the dissertation as a whole, I feel that it merited inclusion in the dissertation if for no other reason than to demonstrate the social politics involved in designating indigenous territories in Latin America. While contemporary North Americans generally support indigenous issues as an ethical concern as well as a byproduct of environmental conservation, in Latin America many indigenous groups continue to suffer class prejudices and persecution from the dominant society of their homelands. This phenomenon was demonstrated in Bella Vista during my time there, and I hope that with time, residents will understand that the protection of natural resources cannot occur without the simultaneous protection of cultural resources.

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CHAPTER 3

RESEARCH LOCATION AND BACKGROUND

Introduction

The research site for this study was located in the tropical state of Beni, Bolivia, in a region vibrant with rich cultural heritage and biological diversity (Figure 3.1). This chapter is dedicated to describing the social and ecological context of the project, and will illustrate why the results of this work may be of particular significance to indigenous leaders and natural resource managers in Bolivia. The political, cultural, and economic climate will be discussed first, followed by a characterization of the geographical and ecological environment of the *Tierra Comunitaria de Origen Itonama* (TCOI) of lowland Amazonian Bolivia.

Bolivia's Political History of Indigenous Rights

Bolivia gained independence from Spain in 1825, freeing Bolivians from years of Spanish control and extraction of natural resources such as gold and silver. After liberation, under the governments of Mariano Melgarejo and Aniceto Arce, the Bolivian national government expropriated land used by indigenous people throughout Bolivia, transferring those lands to the wealthy as *haciendas,* with indigenous residents kept on as indentured servants and share-croppers (IRFACRUZ-CEJIS 1997). The *Ley de Exvinculación de Tierras Comunitarias Indigenas* signed in 1874, legalized this process of expropriation (HYNB 2000).

The Revolution of 1952 erupted when laborers and farmers united to defend their civil rights, culminating in the Agrarian Reform Law of 1953. Under Article 57, Law #3464 enacted on August 2, 1953, indigenous peoples in Bolivia, considered as members of the peasant worker class, were regarded as owners of the land on which they resided. For highland agricultural groups such as the Aymara and the Quechua, the law presumably ensured perpetual use of

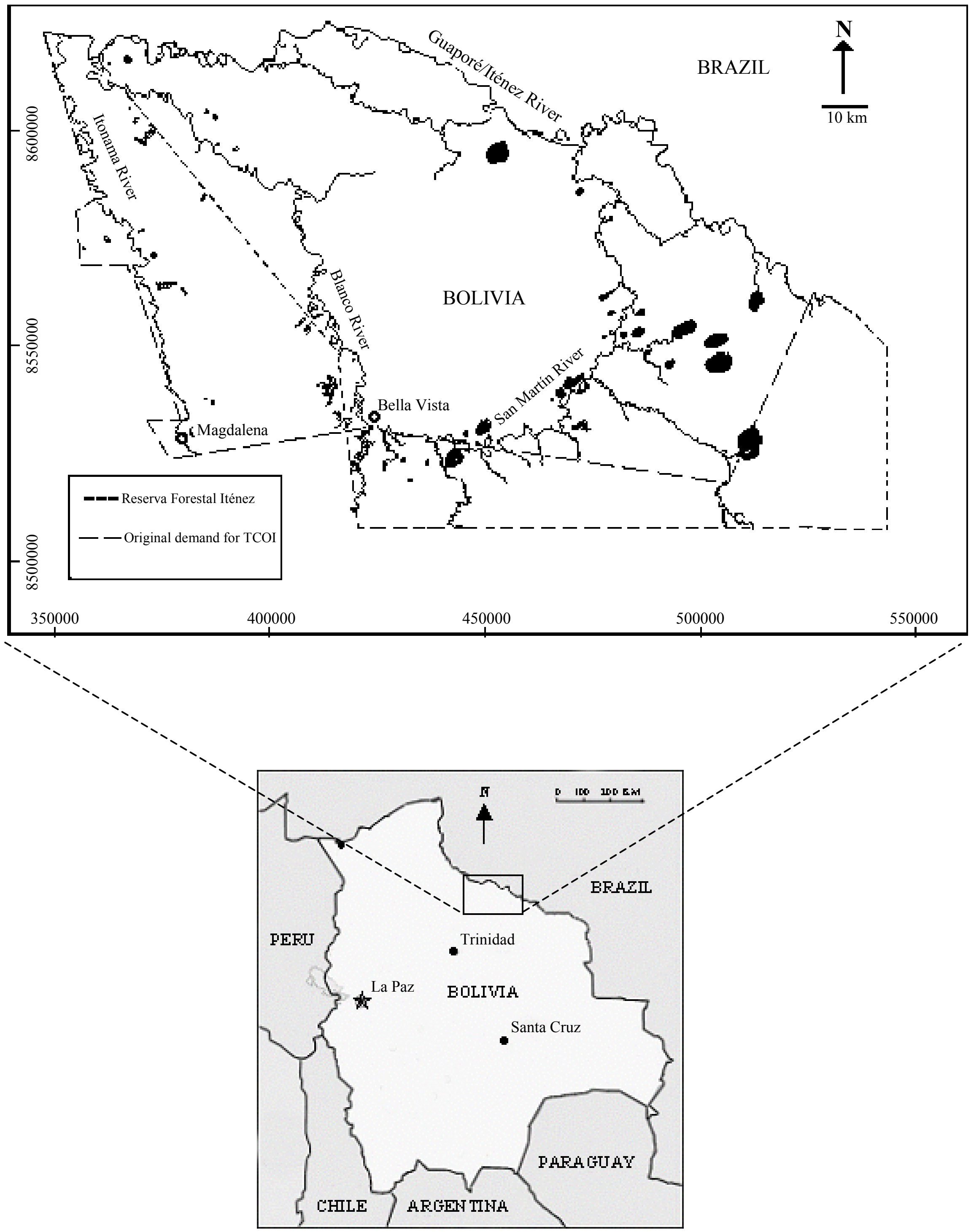

Figure 3.1. Map of *Tierra Comunitaria de Origen Itonama* and *Reserva Forestal Iténez* in Bolivia.

productive lands (IRFACRUZ-CEJIS 1997, TCA 1997). For Amazonian groups, however, the Agrarian Reform law permitted large expanses of the lowlands to be taken over by cattle ranchers, agribusinesses, and timber industries rather than the nomadic tribes that relied on these forested regions for their subsistence (IRFACRUZ-CEJIS 1997, TCA 1997). Afterwards, an estimated 550,000 peasants possessed 7% of cultivable land and pasture (22,350 km^2), while 40,000 industries owned 93% of cultivable land and pasture (267,150 km^2) (Urioste 1987).

Bolivia presently has approximately 33 indigenous groups, 16 of which are represented by nearly 60,000 residents in the state of Beni (TCA 1997). Approximately 8 indigenous tribes have gone extinct in the region since the European conquest, including: Araona, Tapacura, Manasí, Ticomeri, Mujanaes, Tiboita, Manosono, and Subirano (Denevan 1980). Supreme Resolution #2905862 of 1989, signed into law by former president Victor Paz Estenssoro, declared the importance of recognizing, designating, and assigning territorial titles to indigenous peoples of the Bolivian Amazon region (TCA 1997) to preserve their cultural heritage. In August of 1990, indigenous groups in Beni, Bolivia, realized the March for Territory and Dignity, which initiated a process for legally recognizing indigenous territories that culminated in the Law of National Service of the Agrarian Reform (*Ley de Servicio Nacional de Reforma Agraria,* SNRA, or Ley INRA) in October of 1996 (IRFACRUZ-CEJIS 1997). The SNRA is administered by the National Institute of the Agrarian Reform, *(Instituto Nacional de la Reforma Agraria*, INRA). The INRA classifies and titles collectively managed lands under 2 categories: "common lands", which may be collectively titled by groups of individuals, and "community lands of origin," or (*tierras comunitarias de origen*), which are inhabited by and titled to an indigenous group (IRFACRUZ-CEJIS). Neither category may be sold, inherited, or divided, but are exempt from taxation and are legally recognized as units or property by the Bolivian government.

<u>Tierra Comunitaria de Origen Itonama</u>

In 1996, three representatives of the *Sub-Central de Pueblos Indigenas Itonamas* (SCPII) and the *Central de Pueblos Indigenas del Beni* (CPIB) prepared a solicitation requesting formal designation of the *Tierra Comunitaria de Origen Itonama* (TCOI) from the national government of Bolivia. The present multi-ethnic culture of the TCOI is represented by indigenous groups such as the Mojeños, Tacanas, Chimanes, Movimas, Baures, Canichanas, Itonamas, Sirionó, Yuracarés, Chiquitanos, and Cayubabas, among others (Ligerón Casanova 1995a, Programa Indígena 1996), with a reported total population of 5,010 people (De Vries 1998).

The state of Beni covers 213,564 km^2, and is inhabited by 366,047 people for a density of 1.71 people/km^2 (HYNB 2000). Human density in the Itenez National Forest Reserve, which covers 80% of the TCOI, is very low at only 0.2 habitants/km^2, and more than 95% of its inhabitants are considered "poor" under Universal Human Rights categories (HYNB 2000). The TCOI is politically represented by the Itenez province in the municipality of Magdalena, for which 14.4-43.7% of residents live in conditions considered "very poor" (Programa Indígena 1996). Infant mortality for the Itenez province is 81%, which unfortunately, is one of the lowest rates for Beni and other states of Bolivia (INE 1999).

If titled, the TCOI would be declared communal property for which all residents would have tax-exempted subsistence use of the land and other resources. Designation by the INRA is a nine-step process including: a) demand for territory, b) admission of the demand by INRA, c) characterization of the land by the *Viceministerio de Asuntos Indigenas y Pueblos Originarios*, (VAIPO), d) georeferencing, e) identification of spatial needs, f) titling, g) acquisition of additional lands inside and h) outside of the original demand (De Vries 1998). After the 10-year process of TCO designation is completed, residents are given executive title to the land and are allowed to sell forestry concessions under certain restrictions (IRFACRUZ-CEJIS 1997).

In 1997, I was invited by representatives of SCPII and the indigenous leadership, (or *Cabildo Indigena*), of Bella Vista to begin research on the faunal resources of the TCOI, the results of which may be used in developing initial management plans for the region. In 1999, the INRA began georeferencing 12,273.63 km^2 surrounding the lowland Amazonian settlement of Bella Vista, Bolivia as part of the TCOI. In the same year, representatives from the Man and the

Biosphere (MAB) program of the United Nations Environment, Scientific, and Cultural Organization (UNESCO) Asociación Hombre y Naturaleza Bolivia (HYNB), arrived in Bella Vista to propose designating the area as a global biosphere reserve under the Man and the Biosphere (MAB) program. At the time of this printing, the proposed TCOI has been reduced to half of the original demand due to conflicts regarding its designation. Currently, MAB representatives have proposed that the remaining area be designated a state park with a multiple-use buffer zone that would be titled as communal land, or *tierra comunitaria de origen* (TCO) managed by state and indigenous governing units (Español Gonzalez, pers. comm.). For the purposes of this dissertation, "TCOI" will reference the area surrounding Bella Vista that will undergo designation and management as a protected area in the near future.

Local Economy

From the 19th century into the early 20th century, dispersed indigenous tribes in the lowlands of the Beni state of Bolivia were invaded by incursions of colonists searching for forests of Brazil nut *(Bertholletia excelsa)* and rubber trees *(Hevea brasiliensis)* (HYNB 2000). After the Revolution of 1952, colonists shifted their focus towards agriculture and the extraction of wildlife for commercial export (HYNB 2000). Although presidential Supreme Decree #22641 banned the commercial export of wildlife in 1990, settlements lining the rivers of Beni continue to rely on traditional swidden agriculture, rubber tapping, and Brazil nut extraction, as well as newer development activities such as cattle ranching, timber production, and extraction of palm hearts *(Euterpe precatoria)*. Local agriculture is predominated by food staples such as rice, corn, plantains (*Musa* sp.), and yucca; followed in importance by beans, sugar cane, chocolate, bananas, grapefruit, oranges, limes, watermelon, papaya, pineapple, mangos, peanuts, and other small scale crops (pers. obs., Programa Indígena 1996, HYNB 2000). Forest products include rubber, palm hearts, Brazil nuts, cacao *(Theobroma cacao), achachairu* (Rheedia spp.), and timber from *alizo (Myrica pubescens), paquio* (unknown sp.)*, almendrillo* (Leguminosae), *chonta (Astrocaryum macrocalyx), guitarrero (Didymopanax morototoni), tajibo (Tabebuia serratifolia),* *itauba (Mezilaurus itauba), cedro (Cedrela fissilis), canelón (Aniba guianensis), cuta (Astronium* spp.), *mara (Swieteneia macrophylla), sauco (Zanthoxylum* spp.), *sujo (Sterculia apetala), cambará (Vochysia haenkeana),* and *alcornoque* (Euphorbiaceae or Bignoniaceae) (K. Winter, Programa Indígena 1996, HYNB 2000). Local plant species highlighted for conservation by the Asociación Hombre y Naturaleza program in Bolivia include: *B. excelsa, yesquero (Cariniana estrellensis), cedro (C. fissilis* and *C. odorata), M. itauba, coquino (Pouteria nemorosa), S. macrophylla, E. precatoria, H. brasiliensis,* and *T. cacao* (HYNB 2000).

Settlement of Bella Vista

Bella Vista's airstrip lies at the geographic coordinates of 13º16'15"S latitude and 63º41' 29''W longitude, at 164 m above sea level, or masl. It was initially settled approximately 50 years ago by rubber tappers working for the Kómarec and Bruckner firm (Ligerón Casanova 1995b). The town was used as a military outpost commanded by Julio Serrate, and was officially founded in February of 1942 (Ligerón Casanova 1995b). Settlers were later joined by migrants arriving from nearby towns such as Baures, Magdalena, El Carmen, and Orobayaya, who were attracted to rubber-tapping and Brazil nut harvest in the area (Ligerón Casanova 1995b). Bella Vista is currently inhabited by approximately 1,500 residents (192 households) of indigenous and mestizo origin (other estimates place the population between 1,698-2,265 inhabitants, HYNB 2000), who extract forest resources such as wild game, timber, palm hearts, and rubber, engage in swidden agriculture, and fish the two rivers (Blanco and San Martín) that juncture at the town's port. Livestock production is common 45 km to the west of Bella Vista in the town of Magdalena, and is becoming an increasingly popular source of income and employment for local men, attracting interest in those who have the finances to clear and maintain pasture land. The most prominent resident and landowner in Bella Vista is Father José Manuel Barrios Fernández, who arrived in November of 1968. *Padre José* as he is affectionately called, is responsible for developing a health and educational infrastructure, directing a local orphanage, building a large Catholic church and accompanying free medical clinic, and instituting numerous rural development projects, cattle and water buffalo ranches, and agricultural enterprises for over 34 years.

Geographical and Ecological Characteristics of the TCOI

The original demand for the TCOI was located between the geographical coordinates of 13°20'0"S and 12°20'0"S latitude and 64°20'0"W and 62°40'0"W longitude (UTM 8520000-8620000 and 360000-530000), encompassing 12,273.63 km^2 of gallery forest, savanna, rivers and lagoons. Approximately 8,664 km^2 of the TCOI is considered to have high potential for forestry (0.11-0.14 m^3/km^2), with 3,609 km^2 as savanna and river without forestry potential (De Vries 1998). Over 80% of the TCOI overlays the Itenez National Forest Reserve (*Reserva Forestal Itenez*, RFI), including all land from the Blanco River northeast to the border with the state of Rondônia, Brazil at the Guápore River. Future designation of the TCOI will likely encompass the existing RFI, which is mostly undeveloped forest, lagoons, and rivers with small settlements located along waterways.

The settlement of Bella Vista lies at the juncture of savanna floodplain to the west that forms part of the expansive historical *Llanos de Mojos,* and several hundred square kilometers of undeveloped gallery forests to the east up to the Guaporé River. The *Llanos de Mojos* is characterized by 145,000 to 182,000 km^2 of flooded savanna, interspersed with patches of forest and rivers used as transportation conduits during the rainy season (Denevan 1966, HYNB 2000). The elevation of the *Llanos de Mojos* ranges only from 270-180 masl from south to north, at a 20 cm/km gradient (HYNB 2000). This floodplain in Beni, Bolivia is recognized as one of the most extensive and biologically productive zones of its kind in the world (Lauzanne et al. 1990).

Over 85% of the region lies atop acidic and mostly infertile soils characteristic of the Precambrian Shield, followed by a smaller proportion of Amazonian floodplain. The original demand for the TCOI included boundaries at four rivers, including a northern border with Brazil at the whitewater Guaporé River and a western boundary at the whitewater Itonamas River. Bella Vista lies at the western end of the blackwater San Martín River, which joins the whitewater

Blanco River at the Bella Vista port and flows northward toward the Guaporé (or Itenez) River, eventually uniting with the Amazon River in Brazil. Approximately half of the TCOI is flooded during the rainy season months of October through March, at which time rivers, ephemeral lagoons, and ponds dominate the landscape mosaic and accessibility out of the region is limited to boat or airplane. Rainfall for the region ranges between 1400 mm to 2500 mm annually (Programa Indígena 1996). The rainy season occurs between October and March, and the dry season lasts from June to August (Programa Indígena 1996). Water level changes during these seasons are clearly marked, with low waters occurring in September or October and high waters reaching their peak in February or March (Lauzanne et al. 1990). In Bella Vista, I measured a 1 m drop in water level at the juncture of the San Martín and Blanco rivers from June to November 1999. The average temperature in Bella Vista was 28ºC, with 80% humidity (AASANA 1999). This expansive zone of shallow depth and high average temperature provides a very favorable environment for fish production (Lauzanne et al. 1990), and supports a wide diversity of terrestrial flora and associated fauna, especially in the relatively undeveloped TCOI (see HYNB 2000 for a preliminary inventory).

The forested portion of the Amazonian floodplain in the TCOI may be classified into two types: "seasonal *várzea*," characterized by whitewater inundation; and a smaller area to the east corresponding to "seasonal *igapó,"* which is fed by blackwaters and clearwaters (Prance 1979). Junk (1984a) describes *várzea* as an integrated system of lakes, rivers, channels, backwaters, islands and levees that restrain flooded river water during the wet season and return it to the river channels when the dry season arrives. Water level fluctuations in Amazonian rivers and their adjacent floodplains can vary geographically from 5 to 20 m per year (Junk 1984b), causing distinct seasonal changes in the local environment (Araujo-Lima and Goulding 1997). (Lauzanne et al. 1990). Roche and Fernández (1988) noted that at peak highwaters, the Mamoré and Guaporé rivers at the northern border of Bolivia flood between 100,000 and 150,000 km^2 of land, including part of the *Llanos de Moxos* in Beni. Because *várzea* experience constantly changing hydrographic conditions as a result of wet and dry season water level fluctuations, they are described as a “mosaic of transient biotopes," translating to a diverse availability of plant and animal foods throughout the year (Junk 1984a).

Fluctuations in water levels cause two phases, one terrestrial and one aquatic, to be engaged in the ecology of Amazonian floodplains (Junk 1984b). In the aquatic phase, organic materials such as detritus, plant material, fruits, seeds, invertebrate animals, and other materials are transferred to water bodies (Junk, 1984b) through extensive rainfall and flooding, providing a mobile source of nutrients to the flora and fauna associated with them. Terrestrial fauna migrate to higher altitudes, concentrating densely in upland forests and onto terrestrial “islands” created by the surrounding floods, while populations of aquatic fauna disperse throughout the newly flooded forests, exploiting previously unavailable food sources such as fruits, nuts, and other organic materials. When the waters recede during the dry season, organic and inorganic materials are left behind on drying lands as part of the terrestrial phase (Junk 1984b). Land fauna disperse across the drying floodplains and forests, congregating at patchily distributed waterholes and rivers, while aquatic fauna, such as fish, are forced back into river channels by receding waters.

Despite their biodiversity, floodplains constitute only a small proportion of the Amazon Basin – just 2-3% of the total area (Goulding et al., 1996). The diversity of habitats available in the TCOI, half of which is floodplain, could support large populations of fish and wildlife. The TCOI includes savanna habitat, which can support larger standing biomasses of wildlife than forests (Robinson and Bennett 2000), a range of forest habitats, and flooded *várzea*. Mammals reportedly can produce an estimated standing biomass of 1,450 kg/km^2 (Eisenberg et al. 1979, Janson and Emmons 1990), a median value that is supported by a number of studies at other tropical sites (Robinson and Bennett 2000). Goulding et al. (1996) noted that Amazonian floodplains have a much higher diversity of fish, especially food fishes, than either the adjacent river channels or the tidal estuary. As a result, over 50 species of food fishes are harvested regularly from floodplain waters (Goulding et al.1996). In addition, the IUCN recognized both lowland tropical rainforest and grasslands in the top four habitat types with the largest numbers of threatened birds and mammals (Hilton-Taylor 2000). The existence of these critical habitats within the proposed boundaries of the TCOI emphasizes the importance of protecting them and in understanding the dynamics of their resident wildlife populations.

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CHAPTER 4

EFFECTS OF HUNTER PREFERENCES AND PERCEPTIONS OF PREY POPULATION ABUNDANCE ON HARVEST IN THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA,* BOLIVIA[1]

[1]Winter, K. A. To be submitted to *Human Ecology*.

Introduction

Residents of rural tropical areas, especially indigenous peoples, depend on continual access to abundant wild prey to maintain adequate nutritional health (Vickers 1984, Redford and Robinson 1987, Stearman 1990, Townsend 1996, Bennett et al. 2000, Robinson and Bennett 2000). Because their survival depends on successful foraging, rural residents must optimize their efforts to acquire limited natural resources by developing comprehensive knowledge about species' presence, absence, behavior, and other ecological characteristics that affect prey pursuit and capture. Forager behavior responds to changing environmental conditions by promoting the greatest potential for survival through awareness of prey abundance, habitats, potential harvest, locations, and seasonality (Smith 1983). While knowledge about the dynamics of local prey populations may guide foragers towards greater foraging efficiency, perceptions of animal abundance and preferences for certain prey types may also affect foraging strategies and subsequently, the prey populations themselves. In this chapter, I evaluate hunter perceptions of wildlife abundance and pursuit of preferred prey species as they relate to wildlife surveys and actual hunting activity in the hunting catchment of Bella Vista, a rural town in Amazonian Bolivia. These relationships are interpreted under the predictive framework of optimal foraging theory.

Optimal foraging results when benefits (energy, nutritional or dietary, time, income) of a particular foraging activity in a given area are optimized relative to the costs involved (energy, search time, handling time, financial expenses). The act of selecting a particular prey species over another is based on the benefits of the kill versus the costs to the individual forager (Stephens and Krebs 1986), such that species for which the forager incurs low costs relative to benefits may comprise the preferred prey in the forager's diet. Selection may occur when resources are used disproportionately to their availability (Manly et al. 1993). Subsistence hunters may selectively search for large-bodied prey rather than smaller prey (Redford and Robinson 1987, Peres 1990), because prey with large biomass are often ranked highly in optimal diet terms, regardless of their local abundance or contribution to the forager's total diet (Hawkes et al. 1982, Bodmer et al. 1997).

Preferences are shown when hunters select a particular resource over others when each is equally available (Johnson 1980). Preferences for certain prey may also result from behavioral or cultural cognitive motivators, such as increased social status from killing certain species, culinary appeal, and ritual kills. Cognitive preferences may drive hunters to over-harvest species that may be vulnerable to depletion by pursuing them despite noticeable changes in local abundance, or to under-harvest species for which a local aversion is present. Since humans adapt their foraging efforts to the availability of preferred prey species (Anderson 1978, Vickers 1980, Hames and Vickers 1982, Peres 1990), fluctuations in the encounter rate of preferred prey will modify the composition of a forager's diet as the effort required to obtain them changes (Pyke et al. 1977, Smith 1983). Optimality in this study was weighed mostly by hunter preferences based on biomass yield, availability, and/or culinary appeal.

As the structure of wildlife communities located adjacent to human settlements transforms over time due to concentrated harvest of prey species in areas proximate to hunter access points, habitat modification, and other extractive activities, hunters respond accordingly by changing their foraging strategies for particular prey. Increased encounter rates, or abundance of preferred prey may result in a more specialized forager diet, while scarcity of preferred prey may favor a generalized diet (MacArthur and Pianka 1966, Pyke et al. 1977, Smith 1983). Charnov (1976) predicted that the inclusion of a prey type in the diet under selective foraging depends exclusively on the availability of higher-ranked prey, rather than that of the lower-ranked prey. Under this perspective, the hunting effort is driven by the search for preferred prey, and pursuit of less-desired prey is passed by. However, the decision to switch from selective to opportunistic hunting of preferred prey may be a function not only of the availability of the preferred prey, but also that of the less-preferred prey (Schmidt 1998), which may be more easily encountered.

In general, most of the biomass consumed by rural peoples in the tropics is comprised of ungulates, primates, and rodents (Robinson and Bodmer 1999). However, Bodmer et al. (1997) found that actual harvest correlates more with the productivity of prey species than body size. Species with high productivity, shorter lifespans, and shorter generation times (such as brocket deer, peccaries, and large rodents), will have greater rebound capabilities from harvest than will species with low productivity, long lifespans, and long generation times (such as tapir, primates, and carnivores) (Bodmer et al. 1997, Winterhalder and Lu 1997).

Despite the common predilection to hunt species of greater biomass, the prey diet of many forest peoples is biased towards opportunistically killed animals rather than animals that are selectively pursued (Hames and Vickers 1982, Kaplan and Kopischke 1992, Alvard 1994). Although prey preferences exist, subsistence hunters tend to encounter prey opportunistically while traveling or engaging in work activities (Alvard 1994, Hiraoka 1995). Animals may be killed simply because they are encountered during the hunt or while foragers are engaging in other activities, rather than as a result of an intentional search. Human foraging strategies are also affected by behavioral constraints, including belief systems that favor or disfavor hunting particular species (such as taboos and superstitions), dietary preferences, perceptions about the abundance or rarity of prey populations, and intentional conservation to maximize foraging efforts into the future through wildlife management.

If opportunism drives hunter behavior, then the search effort, or cost, will be equal for both preferred and less-preferred prey species. Costs could include time, hunting equipment, and energy in the search and pursuit of captured species. If selectivity for preferred species based on behavioral constraints drives hunter behavior, then hunter investment will be greater through increased search and pursuit time and energetic costs. In both cases, the optimal foraging strategy will maximize the biomass rendered from each animal (see Appendix C for average animal weights), economic returns from its sale, dietary satisfaction from obtaining meats that are considered to be more delicious than others, and/or additional behavioral parameters that act as rewards to the hunter.

When wildlife populations become more or less abundant, hunter decisions to selectively pursue particular species or to opportunistically kill animals as they are encountered become important considerations for rural peoples and wildlife managers who strive to ensure the perpetuity of prey populations. This study integrates data provided by interviews with local hunters, transect surveys of terrestrial wildlife populations, and hunting activity records to evaluate the importance of particular prey species to residents of Bella Vista, and to predict how foraging decisions may be affecting the local prey populations upon which residents depend for subsistence. This study was conducted in collaboration with subsistence hunters and indigenous leaders in the small settlement of Bella Vista in the Bolivian Amazon, a representative community of the proposed *Tierra Comunitaria de Origen Itonama*, (TCOI).

Study Site

Bella Vista is the largest settlement within the original proposed boundaries of the 12,273.63 km^2 TCOI in the Itenez Province of the state of Beni, Bolivia. It was colonized approximately 50 years ago as a rubber-tapping outpost and was subsequently developed as a port of export for the commercial wildlife trade in Bolivia. In November 1990, the trade in wildlife and wildlife parts was banned under Supreme Decree #22641 by President Jaime Paz Zamora, in accordance with the Convention on the International Trade of Endangered Species (CITES). As a consequence of the ban, the commercial trade in wildlife and wildlife parts is no longer an incentive for pursuing certain animals such as felids, primates, otters, and parrots, and hunting efforts are now focused primarily on species that provide meat for subsistence purposes. Presently, approximately 1,500 people reside in 192 households of Bella Vista, subsisting on hunting and fishing, agriculture, cattle ranching, small-scale timber extraction, petty commodity sales, barge construction, palm heart extraction, Brazil nut collection, and rubber tapping.

Bella Vista is located at the juncture of the San Martín and Blanco rivers. These rivers divide the landscape into 240 km^2 of savanna and várzea to the west, and over 380 km^2 of virtually uninhabited forest, várzea, floodplain savanna, and lagoons northeastward to the Guaporé River at the Bolivia-Brazil border. Annual temperatures in the Itenez Province range from 24-27º C, and annual precipitation ranges from 140-250 cm (Programa Indígena 1996). Seasons are marked by a rainy season from October through March and a dry season from June through August (Programa Indígena 1996). Dry season temperatures average about 28º C with an average of 80% humidity in Bella Vista in 1999 (AASANA 1999). The region lies on part of the Precambrian or Brazilian Shield, and is characterized by humid Amazonian forest, predominantly evergreen humid and subhumid forests, gallery forest, riverine forest, transitional savanna, savanna or pampa, wetlands, and lagoons (Programa Indígena 1996). During the rainy season, lowland savannas and swamps are flooded extensively, and forests are isolated as small islands of vegetation. Roadways into the area are subsequently inundated, and transportation to or from Bella Vista is restricted during that time to boat or airplane. As a result of this physical isolation from larger markets, the diets of residents is comprised primarily of local wildlife and fish, as well as the fruits and vegetables provided by swidden, (or slash-and-burn), agriculture (rice, corn, yucca, plantains, beans, sugar cane, banana, grapefruit, oranges, cacao, papaya, pineapple, watermelon, and mango).

Hunting by indigenous foragers in the Neotropics is usually concentrated in an immediate area of 10 km around settlements (Alvard 1993, Alvard et al. 1997, Vickers 1980). Hunters in Bella Vista concentrated their efforts within a 12-km^2 hunting catchment, traveling upriver during the wet season for larger prey such as the Brazilian tapir *(Tapirus terrestris)* or marsh deer *(Blastocerus dichotomus),* and across the dried savanna by foot, horseback, or bicycle during the dry season. The principal weapon used by hunters was the .22-caliber rifle, although some reported having or borrowing 16-gauge shotguns for killing large animals such as tapir. Although unreported to me in this study, crippling losses during hunts were likely to be high due to the limited power of the .22-caliber rifle. Norton and Thomas (1994) reported waterfowl crippling loss at 20-40%, while Byers and Dickson (2001) reported crippling losses by subsistence hunters to be 3-20%. Daytime hunting occurred while traveling to and engaging in other extractive activities such as agriculture, fishing, wood collection, rubber tapping *(Hevea brasiliensis)*, palm heart extraction from *asaí* (*Euterpe precatoria*), or Brazil nut *(Bertholletia excelsa)* harvesting, as well as during trips specifically for the purpose of food procurement.

Hunting excursions occurred primarily in the late afternoon or evening, lasting for 4-7 hours from dusk until the rising of the moon, since wildlife were believed to be scarce under moonlight. Hunters walked or rode bicycles 2-12 km into the forest from Bella Vista, then searched small trails or known areas near waterholes or fruiting trees such as the *bibosi* (*Ficus* sp.), *motacú* (*Attalea phalerata*), or *asaí,* known to attract wildlife when fruiting. Some trips lasted overnight with hunting into the early morning, and others involved boating upriver with a motor for several days in search of marsh deer, tapir, or other large, preferred prey, or while engaging in other activities such as timber or Brazil nut harvesting. Hunting parties were usually comprised of two men, but larger groups would form for longer trips.

Hunting in the wet season was more restricted to small islands of dry land as a result of flooding throughout the region, and occurred more frequently upriver from Bella Vista on the San Martín River at that time. Whereas in the wet season wildlife concentrated in upland areas, during the dry season water limitations caused wildlife to be more dispersed throughout their habitats. Dry season hunting focused on waterholes and other water sources in the forest east of Bella Vista, or in the drying savannas to the west and south.

Methods

I collected three types of data in this study. I used interviews with hunters (Appendix A), household hunting reports (Appendix B), and transect surveys of terrestrial wildlife in the local hunting catchment to assess the relationships between hunters' prey preferences, actual catch, and prey encounters in the area. Then, I analyzed the three data sets based on associations between them to identity patterns in hunter beliefs, hunter behaviors, and potential for prey encounters.

Interviews with Local Hunters

First, I conducted interviews with 21 members of hunting households (out of 192 total households) to assess local knowledge of wildlife populations and hunting behavior in Bella Vista. Participants were randomly selected as I walked house-to-house requesting volunteers for the study. I believe that the participants were representative of typical families in the Bella Vista area, as well as the other settlements of the TCOI. Since wildlife laws were not enforced in the region, there was little fear from local people of legal repercussions in their hunting and fishing activities. Their responses to my interview questions appeared to be open and uninfluenced by government restrictions on hunting certain wildlife. For example, they readily informed me if and when they had killed jaguar or other felids, and of any activities in the wildlife trade, despite the national ban.

Household sizes ranged from two to 24 members total, with an average of eight people per family unit. Each household contained between one and four active hunters, averaging two. Hunters in Bella Vista were predominantly male. Hunters voluntarily participated in the interviews, each man ranging from 23 to 77 years of age with an average age of 40 years. The average length of residency in Bella Vista was 25.3 years ($\pm$12 SD). Nine hunters were born and raised in Bella Vista, two were from Huacaraje, four from Magdalena, one from Baures, two from Versailles, one from El Carmen, one from Orobayaya, and one from Riberalta. All but the last location are small towns and settlements located within a few hundred kilometers of Bella Vista. Principal livelihoods consisted of farming (6), ranch labor (5), mechanics (2), carpentry (2), forestry (2), mercantile (1), fishing (2), and rubber and palm heart extraction (1).

The initial objective for conducting interviews was to determine the presence of terrestrial wildlife that may be harvested for utilitarian purposes such as for meat, skins, pet trade, ritual, or traditional medicines. Although the sale of pelts and other animal parts has not been common since the 1990 ban, some small-scale trade does occur when felids are killed for predator control. For example, the fat of jaguars is rendered and melted as oil for traditional medicine, and its pelt is sold to any available buyer. Spider monkeys (*Ateles paniscus*) are also sometimes used as a traditional remedy for rheumatism.

Each hunter was asked to view and identify laminated plates of colored illustrations and/or photographs of 45 mammals and 11 birds that may be found in the vicinity of Bella Vista (visuals modified from Emmons and Feer 1990, Del Hoyo et al. 1994, MacDonald 1995). For the mammals, I selected species that would be considered large enough to serve as prey, including animals heavier than 2 kg for most species, with the exception of squirrels (*Sciurus spadiceus*) and rabbits (*Sylvilagus brasiliensis*). Bolivia hosts at least 327 species of mammals (Anderson 1997), however, many mammalogists have noted a paucity of information regarding the presence and distribution of these species (Anderson et al. 1993, Voss and Emmons 1996). Range distributions for mammals potentially found within Itonama were taken from Emmons and Feer (1990) and Anderson (1997), to create a preliminary list of species for identification by local hunters. Hunters were then asked to provide the following information for each animal plate: local name of the animal, whether or not it is encountered in the region, whether or not it is hunted, the purpose of its harvest, the frequency of harvest, perceived abundance of animal, type of habitat and season in which it is encountered, and any other details the hunter would like to elaborate regarding the species.

Hunting Activity Reports

Next, I asked 15 different households to record daily hunting activities, including information regarding the species killed, locations, time spent in pursuit and capture, number of participants, type of technology used, and other prey seen but not killed during trips (Appendix A). Hunting activities were recorded from 15 August 1999 to 15 January 2000, with households participating for as few as three and as many as 20 weeks total. The 15 participating households documented 423 person-days of successful hunting activity out of 1,155 total person-days available during the period of study.

Animal Surveys

The last method of data collection involved clearing five transects in the forest for the purpose of surveying terrestrial wildlife during the dry season months from 31 May to 25 October 1999. Transect locations were selected using a stratified random design and ranged from 5.5 km to 10 km away from Bella Vista. They ranged between 2 km and 9 km away from each other (averaging 5 km distance) at their closest points. Each of the transects was 1500 m in length and 1 m in width, and was located in a straight trajectory within 100 m of a creek or other water source in the hunting catchment of Bella Vista. The "hunting catchment" is an area of utilitarian forest use within which residents will extract forest products such as wildlife, wood, fruit, rubber, and palm hearts, and in which they may slash and burn plots for agriculture. It covers an area of approximately 12 km^2 in a northeastwardly direction from the center of Bella Vista.

Surveys were conducted by two trained observers who walked transect trails at a steady pace using headlamps and flashlights to observe the surrounding forest up to 30 m on either side of the transect line. This sampling technique for encountering animals closely resembles the manner in which hunters walk through the forest during directed hunts for prey, except that surveys were restricted to the transect line and discharging firearms was prohibited during sampling. Actual observation widths varied due to heterogeneity in vegetative cover, but visibility up to 30 m on either side of the transect trail was possible at most observation points.

Sampling began approximately 1 hour after sunset, lasting from around 19:00 to 21:00 in the evening. Observers recorded data along each transect up to the 1,500 m mark, then moved 100 m away from the transect for 20 minutes to allow animals to resume normal activities. After this brief pause, observers resumed data collection from the end to the beginning of the transect. Animals of the same species that were observed within 100 m of earlier observations, or those suspected to be the same animal, were deleted from the analysis to avoid double-counting. The same procedure was repeated the following morning after sunrise without flashlights, sampling from approximately 07:00 to 09:00. A total of 32 sampling periods (15 evening and 17 morning surveys) were recorded for the five different transects, covering 48 km. Visible observations, eye shine, calls, and audible movements directly identified animals. Indirect means of identification included tracks, rubbings, chewed seeds, scat, burrows, feathers, fur, and trails. Only direct observations were used for survey count purposes, while indirect observations provided presence and absence data for certain species.

A subset of direct animal encounters on transect surveys (those within 30 m of either side of the line) was used to estimate densities, detection probabilities, and encounter rates. I recorded the perpendicular distance of each observation from the transect line for analysis using program DISTANCE Version 3.5 (Thomas et al. 1998). DISTANCE sampling employs three major assumptions: a) all animals located directly on the transect line are detected, b) animals are detected at their initial locations, and 3) distances between the line and the animal are recorded exactly (Buckland et al. 1993). Transect trails followed trajectories that were oriented by compass, and were cleared of debris and overhanging vegetation for visibility up to 25 m directly on the line. Leaves and fallen branches were removed during a short daytime period 2-3 days before surveys, minimizing noise from leaf litter and movement by observers. I believed animals were detected at their initial locations, especially for animals known to give a startled cry before fleeing (such as *Agouti paca*). The slow walking pace of observers and denseness of vegetation off transect lines made it relatively easy to hear or see movements by animals. Each observer was trained in distance estimation up to 30 m prior to sampling, and I was present for all observations to ensure standardization of data recording. For these reasons, the assumptions of DISTANCE sampling were believed to be valid during my surveys.

Results

Species Presence, Absence, and Pursuit

Table 4.1 is a list of 24 species that hunters recognized from the picture plates, but were not observed by me during the period of field study. In Table 4.2, I illustrate approximately 30 terrestrial wildlife species for which presence in the hunting catchment of Bella Vista was verified by transect surveys and post-kill visual identification. While I can confidently verify the presence of the species I encountered, I cannot confirm the absence of species that were not encountered during my field research, since they may be present, but elusive. Interestingly, all of the species for which presence was confirmed in Table 4.2 are included in categories of "most-preferred prey species" later in this analysis (Categories I and II and some of Category III in Tables 4.3 and 4.4). This increases my confidence that these species were locally abundant, or at least easily encountered, during my fieldwork in Bella Vista. Responses by hunters regarding recognition and pursuit of individual species indicated that prey preferences exist in the diets of Bella Vista's hunters. Additionally, the responses provide information regarding presence or rarity of animals believed to have ranges in the TCOI. Notably, all of the species included in the highest preference category were mammals.

Hunter Recognition and Pursuit Categories

I organized data regarding species recognition and pursuit into eight categories based on the percentage of responses (n = 21 hunter households) provided by study participants (Table 4.3). Each category represents a level of preference for particular prey that is contingent upon how much a hunter both recognized and pursued it. For six of the birds, I pooled species into three separate genera because participants did not distinguish between the color illustrations for naming purposes. As expected, species that were moderately or rarely recognized by study participants were, at best, only rarely pursued. Within each preference category, I described individual species according to the number of hunters who perceived the local prey population as

Table 4.1. Terrestrial wildlife with reported but unconfirmed presence near Bella Vista, Bolivia in 1999.

Species presence or absence not confirmed	Local common name	English name
Mammals		
Artiodactyls		
Odocoileus virginianus		white-tailed deer
Primates		
Samiri sciureus	chichilo	common squirrel monkey
Cebus albifrons	mono silvador	white-fronted capuchin monkey
Cebus moloch	mono titi	dusky titi monkey
Carnivores		
Leopardus weidii	gato gris, gato montes	margay
Lontra longicaudis	londra	neotropical otter
Cerdocyon thous	zorro	crab-eating fox
Chrysocyon brachyurus	borochi	maned wolf
Speothos venaticus		bush dog
Herpailurus yaguarondi		jaguarundi
Potos flavus	mono michi	kinkajou
Bassaricyon pabbii		olingo
Galictis vittata		grison
Procyon cancrivorous		crab-eating raccoon
Rodents		
Myocastor coypus	castor	nutria
Cavia sp.		cavia
Xenarths		
Dasypus septemcinctus	tatu chico, pejichi	seven-banded armadillo
Myrmecophga tridactyla	oso hormiguero	giant anteater
Bradypus variegatus	perezoso, perico	brown-throated three-toed sloth
Cyclopes didactylus	oso de oro	silky (pygmy) anteater
Lagomorphs		
Sylvilagus brasiliensis	tapiti	tapiti or Brazilian rabbit
Birds		
Crax fasciolata	pavichi	bare-faced curassow
Pipile cumanensis	pava campanilla	blue-throated piping guan
Pipile cujubi	pava campanilla	red-throated piping guan
Ortalis guttata	huaracachi	speckled chachalaca

Table 4.2. Terrestrial wildlife with confirmed presence near Bella Vista, Bolivia in 1999.

Species presence confirmed	Local common name	English name
Mammals		
<u>Artiodactyls</u>		
Tayassu pecari	puerco de tropa	white-lipped peccary
Tayassu tajacu	taitetu	collared peccary
Mazama americana	huasu	red brocket deer
Mazama gouazoubira	hurina	gray (brown) brocket deer
Blastocerus dichotomus	ciervo	marsh deer
<u>Perissodactyls</u>		
Tapirus terrestris	anta, tapir	tapir
<u>Primates</u>		
Alouatta caraya	mono manechi	black howler monkey
Ateles paniscus	marimono, mono negro	black spider monkey
Aotus azarae	mono nocturno, cuatro ojos	night monkey
Cebus apella	mono capuchin	capuchin monkey
<u>Carnivores</u>		
Panthera onca	jaguar, tigre	jaguar
Puma concolor	leon	puma, panther, cougar
Leopardus pardalis	gato montes, tigrecillo	ocelot
Nasua nasua	tejon	South American coati
Pteronura brasiliensis	lobo del rio, londra	giant otter
Eira barbara	melero	tayra
<u>Rodents</u>		
Agouti paca	jochi pintado	spotted paca
Dasyprocta variegata	jochi colorado	brown agouti
Hydrochaeris hydrochaeris	capiwara	capybara
Coendou prehensilis	puerco espino	Brazilian porcupine
Sciurus spadiceus	ardilla, masi	Southern Amazon red squirrel
<u>Xenarths</u>		
Priodontes maximus	tatu canasto, 15 kilos	giant armadillo
Dasypus novemcinctus	tatu	nine-banded armadillo
Tamandua tetradactyla	oso hormiga, oso bandero	southern tamandua
Birds		
Tinamus/Crypturellus	perdiz	tinamou
Penelope jacquacu	pava cotocolorada	Spix's guan
Penelope superciliaris	pava cotocolorada	rusty-margined guan
Mitu tuberosa	mutun	razor-billed curassow
Ara ararauna	paraba	scarlet macaw
Ara macao	paraba	blue and yellow macaw
Rhea americana	piyu	South American rhea
Odontophorus gujanensis	perdiz	marbled wood-quail
Columba sp.	torcasa	(pigeons and doves)

abundant or rare, the quantity encountered during surveys, and the number harvested by participating households. These subcategories allowed me to evaluate the relationships between species recognition and pursuit, perceptions of abundance, indicators of abundance (surveys), and actual harvests, in order to compare them to the predictions of optimal foraging theory.

Pursuit of Species and Perception of Animal Abundance

Optimal foraging theory suggests that hunter diet breadth is associated with the relative abundance of preferred prey in relation to less preferred prey. Here, I extend the definition of "prey" to include species that are not necessarily pursued for nutritional purposes, but may bring income to the hunter through sale as pets, for pelts, or for use in traditional medicine. In this analysis, I included only those species of Categories I-IV, because species listed in Categories V-VIII appeared to be those for which local hunters had little to no knowledge, and were not commonly pursued as prey items.

Table 4.3. Categories of recognition and pursuit of prey species by hunters in Bella Vista, Bolivia in 1999.

Category	Category description	Hunter recognition (%)	Pursuit of animal (%)	Mammal species (number)	Bird species (number)
I	Highly recognized, actively pursued	0.86-1.0	0.86-1.0	10	0
II	Highly recognized, moderately pursued	0.86-1.0	0.48-0.85	5	4
III	Highly recognized, rarely pursued	0.86-1.0	0.10-0.43	11	2
IV	Moderately recognized, rarely pursued	0.48-0.85	0.10-0.43	5	2
V	Moderately recognized, not pursued	0.48-0.85	< 0.10	1	0
VI	Rarely recognized, rarely pursued	0.10-0.43	0.10-0.43	4	0
VII	Rarely recognized, not pursued	0.10-0.43	< 0.10	5	1
VIII	Not recognized, not pursued	< 0.10	< 0.10	4	0
Total				45	9

I compared hunter perceptions of population abundance and pursuit provided during interviews with actual reported harvests to evaluate whether hunters specialized on certain prey species regardless of perceived abundance, or opportunistically harvested those that they perceived to be more frequently encountered in the hunting catchment. These comparisons illustrate the relationship between pursuing prey based on encounter rates, or opportunism, and preference for particular species without regard to perceived abundance, or diet selectivity. I supplemented data provided by interviews and harvest reports with count surveys on transects in the hunting catchment of Bella Vista.

Category I: Highly Recognized, Actively Pursued Species

Large mammals, especially ungulates, are the most important group of prey in terms of contribution of protein to total biomass consumed by inhabitants of tropical forests (Smith 1976, Ojasti 1984, Vickers 1984, Fa et al. 1995, Robinson and Bodmer 1999, Robinson and Bennett 2000). Preference Category I (Table 4.5) is comprised of 10 highly recognized and actively pursued species, including all of the ungulates present in the region: white-lipped peccary *(Tayassu pecari),* collared peccary *(Tayassu tajacu),* red brocket deer *(Mazama americana),* gray brocket deer *(Mazama gouazoubira),* marsh deer *(Blastocerus dichotomus)*, and Brazilian tapir *(Tapiris terrestris)*; in addition to the rodents spotted paca *(Agouti paca),* and brown agouti *(Dasyprocta variegata);* and the xenarths giant armadillo *(Priodontes maximus),* and nine-banded long-nosed armadillo *(Dasypus novemcinctus)*. All of these preferred prey species were hunted for nutritional purposes. These results agree with the findings of other researchers in the Neotropics who reported peccary, deer, and tapir as preferred prey (Wetterberg et al. 1976, Bodmer et al. 1988), in addition to agouti and armadillo (Townsend 1996, 2000). In the neighboring Sirionó Indigenous Territory, the 10 most important prey species in terms of harvested biomass included all of the animals listed in Category I for Bella Vista, with the exception of giant armadillo (Townsend 2000). In its place, the Sirionó included South American coati *(Nasua nasua)* as one of their ten most important prey animals (Townsend 2000).

Table 4.4. Species included in each recognition and pursuit category by hunters in Bella Vista in 1999.

Category I: Highly recognized and actively pursued	Category II: Highly recognized but moderately pursued	Category III: Highly recognized but rarely pursued	Category IV: Moderately recognized but rarely pursued	Category V: Moderately recognized and not pursued	Category VI: Rarely recognized and rarely pursued	Category VII: Rarely recognized and not pursued	Category VIII: Not recognized and not pursued
Artiodactyls *Tayassu pecari* *Tayassu tajacu* *Mazama americana* *Mazama gouazoubira* *Blastocerus dichotomus* Perissodactyls *Tapirus terrestris* Rodents *Agouti paca* *Dasyprocta variegata* Xenarths *Priodontes maximus* *Dasypus novemcinctus*	Primates *Ateles paniscus* Rodents *Sciurus spadiceus* Carnivores *Panthera onca* *Puma concolor* *Nasua nasua* Birds *Tinamus* and *Crypturellus* sp. *Penelope jacquacu* *P. superciliaris* *Mitu tuberosa* *Crax fasciolata*	Primates *Alouatta caraya* Rodents *Hydrochaeris hydrochaeris* *Coendou prehensilis* Carnivores *Leopardus pardalis* *Leopardus weidii* *Eira barbara* *Lontra longicaudis* *Pteronura brasiliensis* Xenarths *Dasypus septemcinctus* *Myrmecophaga tridactyla* *Tamandua tetradactyla* Birds *Ara ararauna* *Ara macao* *Rhea americana*	Primates *Aotus azarae* Carnivores *Cerdocyon thous* *Chrysocyon brachyurus* Xenarths *Bradypus variegatus* *Cyclopes didactylus* Birds *Pipile cumanensis* *Pipile cujubi* *Ortalis guttata*	Carnivores *Speothos venaticus*	Primates *Samiri sciureus* *Cebus apella* Artiodactyls *Odocoileus virginianus* Lagomorphs *Sylvilagus brasiliensis*	Primates *Cebus albifrons* *Cebus moloch* Carnivores *Herpailurus yaguarondi* *Potos flavus* *Bassaricyon pabbii* Birds *Odontophorus gujanensis*	Rodents *Myocastor coypus* *Cavia* sp. Carnivores *Galictis vittata* *Procyon cancrivorous*

Over 90% of the harvest of collared peccary, white-lipped peccary, red brocket deer, spotted paca, and brown agouti occurs in forested habitat of the Sirionó Indigenous Territory (Townsend 2000). Gray brocket deer are harvested 62% in forest habitat and 38% in savanna, Brazilian tapir occurs 75% in forest, 25% in savanna, and nine-banded long-nosed armadillo occur is 69% in forest, 31% in savanna (Townsend 2000). Because transects for this study were located exclusively in forest, count survey data for gray brocket deer, Brazilian tapir, and nine-banded long-nosed armadillo may have under-represented their populations in this region. Reported encounters for the other forest prey species should be more accurate indices of the actual populations.

Spotted paca was the most commonly encountered and frequently killed species in this category, true to hunter perceptions that it is a locally abundant species (at 86%). I observed 26 live animals during surveys, and participating hunters killed 32 throughout the study period. The yield of meat produced per person per hour of hunting was 5.06 kg, the third highest yield in Category I.

The second most frequently harvested species in this category was the nine-banded long-nosed armadillo, which was considered abundant by the greatest percentage of hunters (90%). Twenty-three nine-banded long-nosed armadillo were harvested by hunters and six were encountered live on transects. Yield of meat per person per hour of foraging for the nine-banded long-nosed armadillo was 4.79 kg.

Residents considered white-lipped peccary an ephemeral prey because encounters with their large groups are limited to brief annual or biannual migrations through the region. Although no white-lipped peccary were directly encountered during transect surveys, members of the sample households reported killing 15 animals during the period of study. For red brocket deer, almost equal numbers of hunters perceived them as abundant (52%) and rare (43%), many stating that encounters with them are infrequent. However, 10 red brocket deer were directly observed during transect surveys, and hunters brought in 12.

Table 4.5. Category I: Species that were highly recognized and actively pursued by hunters in Bella Vista, Bolivia in 1999.

Species name	Perceived as abundant[a] (%)	Perceived as rare[a] (%)	Encounters[b] (#)	Harvest[c] (#)	Average yield of meat (kg/ person/hr)	Reason for hunting
Tayassu pecari	0.67	0.33	0	15	3.66	meat
Tayassu tajacu	0.76	0.14	2	7	4.53	meat
Mazama americana	0.52	0.43	10	12	2.33	meat
Mazama gouazoubira	0.10	0.81	0	2	2.39	meat
Blastocerus dichotomus	0.71	0.14	0	7	2.40	meat
Tapirus terrestris	0.71	0.29	0	5	26.14	meat
Agouti paca	0.86	0.14	26	32	5.06	meat
Dasyprocta variegata	0.81	0.05	11	4	6.38	meat
Priodontes maximus	0.29	0.62	0	2	2.19	meat
Dasypus novemcinctus	0.90	0.05	6	23	4.79	meat
Total			55	109	$\overline{x}$ = 5.99	

[a]n = 21 hunter households interviewed.
[b]n = 32 transect surveys.
[c]n = 15 participating households.

Notably, all but two of the most-preferred, highest-ranking species were also the species considered very abundant (due to frequent encounter rates) by more than 50% of the hunters interviewed. The two exceptions, gray brocket deer and giant armadillo, were considered rare in the Bella Vista hunting catchment by more than 50% of hunter respondents (81% and 62%, respectively), although they were actively pursued when encountered by more than 86% of the respondents. Although neither of these two species was seen during diurnal and nocturnal transect surveys, hunters brought in two of each during this study.

Category II: Highly Recognized, Moderately Pursued Species

Preference Category II (Table 4.6) is composed of at least 9 highly recognized but only moderately pursued species, including five mammals: black spider monkeys *(Ateles paniscus),* southern Amazon red squirrel *(Sciurus spadiceus),* South American coati *(Nasua nasua),* jaguar *(Panthera onca)*, and panther *(Puma concolor)*; and at least four birds: *Tinamus* or *Crypturellus* species (the Tinamous), Spix's guan or rusty-margined guan *(Penelope jacquacu* or *P. superciliaris),* razor-billed curassow *(Mitu tuberosa),* and bare-faced curassow *(Crax fasciolata)*. The former three species of mammals and all of the birds were hunted occasionally for meat, with black spider monkeys and red squirrels also kept as pets. The two felids were exterminated on sight to prevent their predation on cattle and humans. Prior to the ban on wildlife trade, the sale of their pelts, bones, and fat was common, although their meat is considered inedible.

Black spider monkeys were considered locally abundant by 90% of hunters interviewed, and 10 were encountered during transect surveys. Several hunters remarked that the meat of black spider monkeys was also considered delicious, although few people consume it and others only use the animal as a pet. Primates in general were not considered a desirable food source in Bella Vista, despite the high frequency of encounter with troups and high yields of meat per unit of effort (12 kg for spider monkeys), and some respondents noted that they too closely resemble humans to be a viable food source. Nonetheless, hunters participating in this study brought in three black spider monkeys. At least one was killed specifically for use as a traditional remedy for an elderly member of the community.

Southern Amazon red squirrels were also considered abundant according to 81% of the hunters, who occasionally used it as a pet and remarked that it has delicious meat. However, Southern Amazon red squirrels were only harvested by 48% of the hunters interviewed, and only one was brought in during the course of this study. South American coatis were harvested by 81% of the hunters interviewed when they are encountered. Although none were seen during surveys, this species was frequently encountered in disturbed areas such as garden fields and

Table 4.6. Category II: Species that were highly recognized and moderately pursued by hunters in Bella Vista, Bolivia in 1999.

Species name	Perceived as abundant[a] (%)	Perceived as rare[a] (%)	Encounters[b] (#)	Harvest[c] (#)	Average yield of meat (kg/ person/hr)	Reason for hunting (not hunting)
Mammals						
Nasua nasua	0.95	0	0	9	0.34	meat
Ateles paniscus	0.90	0.05	10	3	12.00	meat, pet (resembles human)
Sciurus spadiceus	0.81	0.14	2	1	0.25	meat, pet
Panthera onca	0.81	0.10	0	1	d	predator control, pelts, medicine
Puma concolor	0.62	0.29	0	0	d	predator control, pelts
Birds						
Tinamus sp./ *Crypturellus* sp.	0.76	0.05	74	8	1.26	meat
Penelope jacquacu/ *P. superciliaris*	0.57	0.05	18	16	0.22	meat
Mitu tuberosa	0.62	0.05	3	9	0.14	meat
Crax fasciolata	0.48	0.05	0	0	d	meat
Total			107	47	$\bar{x}$ = 2.37	

[a]n = 21 hunter households interviewed.
[b]n = 32 transect surveys.
[c]n = 15 participating households.
d = data not available.

along trails, and hunters brought in nine animals. Those interviewed remarked that South American coati is not considered to be an important or appreciated food source, although it was considered abundant by 95% of the respondents. In contrast South American coati is highly favored by neighboring indigenous groups such as the Sirionó, and is one of their most important prey species (Townsend 2000).

Category III: Highly Recognized, Rarely Pursued Species

Category III (Table 4.7) includes at least 13 highly recognized, but rarely pursued species, including 11 mammals: black howler monkeys *(Alouatta caraya),* capybara *(Hydrochaeris hydrochaeris),* Brazilian porcupine *(Coendou prehensilis),* seven-banded armadillo *(Dasypus septemcinctus),* giant anteater *(Myrmecophaga tridactyla),* southern tamandua *(Tamandua tetradactyla),* ocelot *(Leopardus pardalis),* margay *(Leopardus weidii),* tayra *(Eira barbara),* neotropical otter *(Lontra longicaudis)*, and giant otter (*Pteronura brasiliensis);* and at least two bird species, macaw *(Ara ararauna, Ara macao)*, and South American rhea (*Rhea americana)*. These species were actively pursued by only 10-43% of hunter respondents, and only the birds were used for subsistence or medicinal purposes. Black howler monkeys, capybara, and Brazilian porcupines were believed to be highly abundant (by 95%, 100%, and 71% of hunters, respectively), but their meat was believed to be distasteful or not worth hunting when other animals were so readily available. An interesting topic for long-term research could investigate whether these species would enter into the local diet if preferred species became less abundant, such as appears to be the case for the harvest of capybara by the Siona-Secoya in Ecuador (Vickers 1994). Capybara is frequently hunted for its meat throughout most of the Amazon region (Alvard et al. 1997, Hiraoka 1995), especially in savanna and floodplain habitats (Ojasti 1991), but was avoided as a prey source in Bella Vista.

Seven-banded armadillo, while considered abundant by 81% of hunters, was killed by 33% not for meat, but because of the damage it does to roads and paths. Most respondents believed that this species eats the dead, has an unpleasant odor, and is distasteful to eat. This attitude contrasts sharply with the great preference respondents had for other armadillo meat, namely that of giant armadillo and nine-banded long-nosed armadillo. The two anteaters in this category, giant anteaters and southern tamandua, were considered rare by 67% and 57% of respondents, respectively, and were killed by less than 14% because of local superstitions regarding encounters with these species. The meat of southern tamandua was considered to be a remedy for heart problems by one respondent, and another considered encounters with giant anteaters to be a sign of bad luck.

Tayra were considered locally abundant by 76% of respondents, but were hunted by 29% and only then when preying upon chickens. The other two mustelids in this category, neotropical otter and giant otter, as well as two felids, ocelot and margay, were considered locally abundant by over 50% of hunters. Of these, respondents noted that in the past the mustelids were hunted by only 10% for their pelts, while the felids were hunted by 43% for pelts and 38% to protect livestock.

Only one of the species in Category III was encountered during transect surveys (Brazilian porcupine), and hunters harvested only two animals (macaws). Encounter failure could be attributed partly to the locations of transects, which would preclude detecting species such as capybara and otters that inhabit riverine habitats. Other species could have eluded encounters due to behavioral characteristics or local rarity, despite common recognition by residents of Bella Vista.

Table 4.7. Category III: Species that were highly recognized and rarely pursued by hunters in Bella Vista, Bolivia in 1999.

Species name	Perceived as abundant[a] (%)	Perceived as rare[a] (%)	Encounters[b] (#)	Harvest[c] (#)	Reason for hunting (not hunting)
Mammals					
Alouatta caraya	0.95	0	0	0	(other animals available)
Hydrochaeris hydrochaeris	1.00	0	0	0	(other animals available)
Coendou prehensilis	0.71	0.24	1	0	(other animals available)
Dasypus septemcinctus	0.81	0.19	0	0	damage control
Myrmecophaga tridactyla	0.33	0.67	0	0	superstition
Tamandua tetradactyla	0.38	0.57	0	0	superstition, medicinal
Leopardus pardalis	0.62	0.19	0	0	pelt, predator control
Leopardus weidii	0.57	0.19	0	0	pelt, predator control
Eira barbara	0.76	0.19	0	0	predator control
Lontra longicaudis	0.62	0.24	0	0	pelt
Pteronura brasiliensis	0.71	0.14	0	0	pelt
Birds					
Ara ararauna, A. macao.	0.57	0	0	2	meat, pets
Rhea americana	0.48	0.10	0	0	medicinal, plumes
Total			1	2	

[a]n = 21 hunter households interviewed.
[b]n = 32 transect surveys.
[c]n = 15 participating households.

Category IV: Moderately Recognized, Rarely Pursued Species

Category IV (Table 4.8) is comprised of seven moderately recognized but rarely pursued species, including five mammals: night monkeys (*Aotus azarae),* brown-throated three-toed sloth *(Bradypus variegates),* silky (or pygmy) anteater *(Cyclopes didactylus),* crab-eating fox *(Cerdocyon thous*, and maned wolf (*Chrysocyon brachyurus);* and at least two species of birds: blue-throated and red throated piping-guans (*Pipile cumanensis* and *P. cujubi),* and speckled chachalaca *(Ortalis guttata)*. Respondents commented that all of the mammalian species of Category IV are in danger of local extinction. Of them, night monkeys are only hunted by 14% of respondents, despite an almost even split between those who believe it to be locally abundant and locally rare. It is pursued mostly for the purpose of keeping it as a pet. Nine night monkeys were sighted during nocturnal transect surveys, making it one of the more frequently encountered species in the forest during this study, but apparently not one of the most preferred.

Brown-throated three-toed sloths are considered rare by 62% of respondents, and were hunted by only 48% of them. Silky anteaters were hunted by only 10% of respondents to keep as a pet because its small size and golden fur are considered good luck. Over 52% of respondents also considered it to be locally rare. Maned wolf are considered very rare by 71% of hunters interviewed, while 19% would kill them to use its pelt and bones as a remedy for rheumatism. Crab-eating fox were hunted by only 14% of hunters when they threaten chickens, and in the past, for its pelt. In this category, hunter participants harvested none of the mammals and only one bird, speckled chachalaca, during the study period.

Table 4.8. Category IV: Species that were moderately recognized and rarely pursued by hunters in Bella Vista, Bolivia in 1999.

Species name	Perceived as abundant[a] (%)	Perceived as rare[a] (%)	Encounters[b] (#)	Harvest[c] (#)	Reason for hunting
Mammals					
Aotus azarae	0.43	0.33	9	0	pet
Bradypus variegatus	0	0.62	0	0	not eaten
Cyclopes didactylus	0.05	0.52	0	0	adornment, pet, good luck
Cerdocyon thous	0.81	0.10	0	0	predator control, pelt
Chrysocyon brachyurus	0	0.71	0	0	medicinal, pelt
Birds					
Pipile cumanensis, P. cujubi	0.57	0	0	0	meat
Ortalis guttata	0.24	0	0	1	meat
Total			9	1	

[a]n = 21 hunter households interviewed.
[b]n = 32 transect surveys.
[c]n = 15 participating households.

Animal Encounters on Transects

A total of 292 direct and 62 indirect encounters with terrestrial fauna were registered during 57.25 hours and 48 km of transect surveys in the Bella Vista hunting catchment. The average time spent covering 3 km of transect during a survey was 2 hours. In the bird category, the number of direct encounters with prey species overshadowed those of non-prey species. Direct encounters with birds were recorded 149 times, including 141 encounters with at least 7 species of avian prey (identification of some was grouped to genus) and eight encounters with two species of non-prey (toucans). Although in preliminary interviews the family Columbidae (pigeons and doves) was not included as an avian prey group, it was added to the analysis of animal surveys due to the large quantities reportedly harvested by hunters and encountered on transects. For mammals, an almost equal proportion of direct encounters with prey and non-prey mammals occurred, including a total of 143 mammals for 67 encounters with seven prey species and 76 encounters with five non-prey species. Indirect encounters represented nine species of mammal and at least three bird species, all of which were considered prey species in the local diet. Encounters with birds dominated diurnal surveys of prey species (139 birds, 26 mammals), while nocturnal surveys primarily included mammals (41 mammals, 2 birds). Daytime surveys of non-prey reported 38 mammals and eight birds, while evening surveys found 38 non-prey mammals and no birds.

A total of 182 direct observations of terrestrial fauna were included in DISTANCE (Thomas et al. 1998) analyses (Table 4.9), including 52 mammals and 130 birds encountered within 30 m of the transect line. Transect width restrictions excluded black spider monkeys from analyses, but did not exclude any of the bird species encountered. Density estimations included categories for all prey, and subcategories for daytime prey, evening prey, avian prey, and mammalian prey. The uniform key function ($1/w$) with cosine series expansion [$\Sigma\, a_j \cos (j \vartheta y/w)$] was the model selected by the lowest AIC (Akaike's Information Criteria) for all prey analyses. For non-prey the number of observations was lower ($n = 64$), which may have caused inaccurate estimates in the analysis output. In the non-prey category, the negative exponent key function was used. Daytime and evening sub-categories of non-prey provided insufficient numbers of observations for DISTANCE analyses.

Table 4.9. Density, detection probabilities, and encounter rates for prey and non-prey in the Bella Vista hunting catchment from May - October, 1999.

Category for analysis	Density (#/km^2)	Lower confidence level	Upper confidence level	Coefficient of variation	Detection probability (%)	Encounter rate (#/transect)
All prey	152.62	109.76	212.21	0.1642	16.1	83.9
Prey birds	205.15	146.42	287.42	0.1637	15.1	84.9
Prey mammals	39.73	26.47	59.65	0.2032	29.5	70.5
Daytime prey	221.11	155.33	314.74	0.1710	18.0	82.0
Evening prey	66.29	38.93	112.90	0.2564	12.3	87.7
All non-prey	55.68	28.37	109.27	0.3425	71.7	28.3

Analyses of transect surveys using the DISTANCE program (Thomas et al. 1998) revealed a higher detection probability for mammals relative to birds, which had greater density and a higher encounter rate than mammals. Although density estimates and detection probabilities for all prey were considerably lower for nocturnal surveys, more prey mammals were encountered at night than prey birds. Density, detection, and encounter rates will affect the strategies that hunters will invoke to pursue particular prey over others and the timing of their pursuit activities.

Rank Correlation Analyses

I analyzed the abundance, encounter, and harvest data using a Spearman's rank correlation and Analysis of Variance (ANOVA) in SAS® (SAS Institute 1999), for the most preferred prey species that were hunted for meat. The analyses excluded white-lipped peccary, marsh deer, and Brazilian tapir because of behavioral and habitat differences that precluded them from being encountered during transect surveys. The ANOVA results were not significant ($P \leq 0.05$) between species . Spearman's rank correlation between hunter perceptions of animal abundance and actual encounters with species during transect surveys produced a weak correlation coefficient of 0.30 (p-value = 0.29) (Figure 4.1). Perceptions of abundance and actual harvest by hunter households gave a slightly stronger correlation of 0.39 (p-value = 0.17) (Figure 4.2). However, the strongest correlation was 0.59 (p-value = 0.02) between encounters with prey species during surveys and actual harvests by sample households (Figure 4.3). Data labels for the rank correlation graphs are as follows: *Tayassu tajacu* (Taya.), *Mazama americana* (M. ame.), *Mazama gouazoubira* (M. gou.), *Agouti paca* (Agou.), *Dasyprocta variegata* (D. var.), *Priodontes maximus* (Prio.), *Dasypus novemcinctus* (D. nov.), *Nasua nasua* (Nasu.), *Ateles paniscus* (Atel.), *Sciurus spadiceus* (Sciu.), *Tinamus* sp. (Tina.), *Penelope* sp. (Pene.), *Mitu tuberosa* (Mitu), and *Crax fasciolata* (Crax).

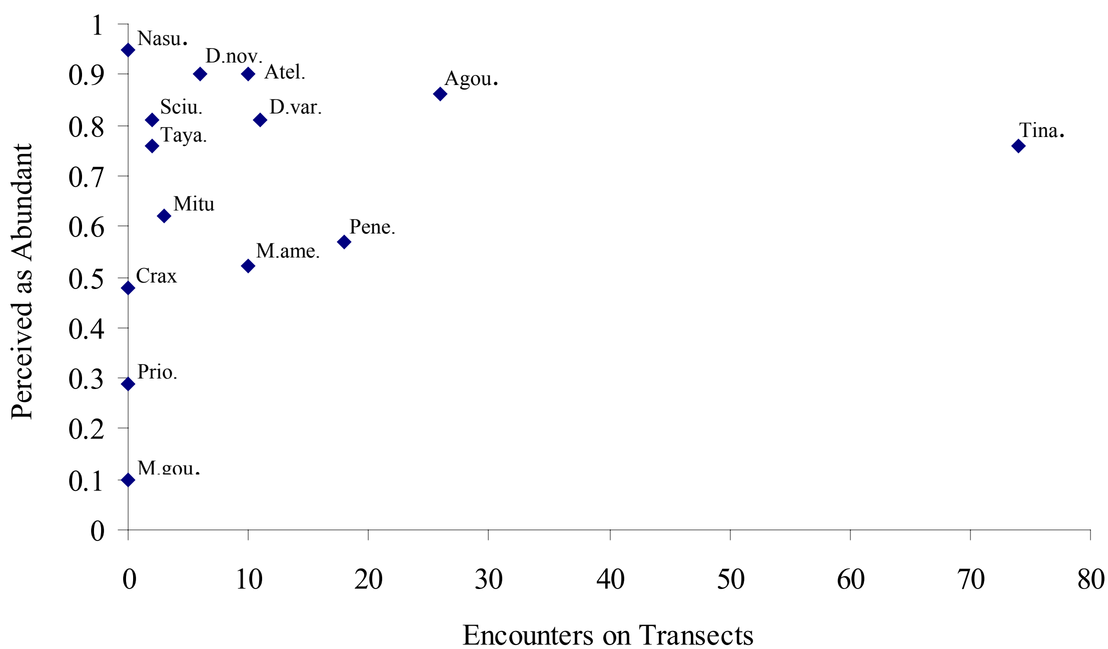

Figure 4.1. Spearman's rank correlation between perceptions of abundance and encounters during transect surveys in Bella Vista, 1999.

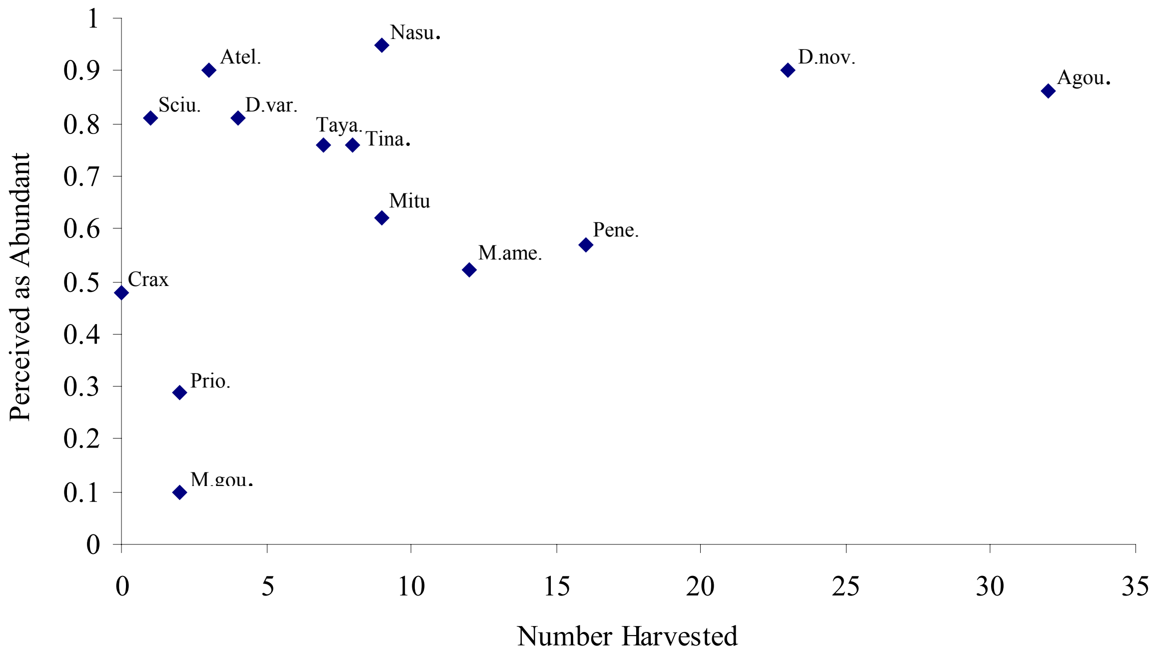

Figure 4.2. Spearman's rank correlation between perceptions of abundance and number of animals harvested by sample households in Bella Vista, 1999.

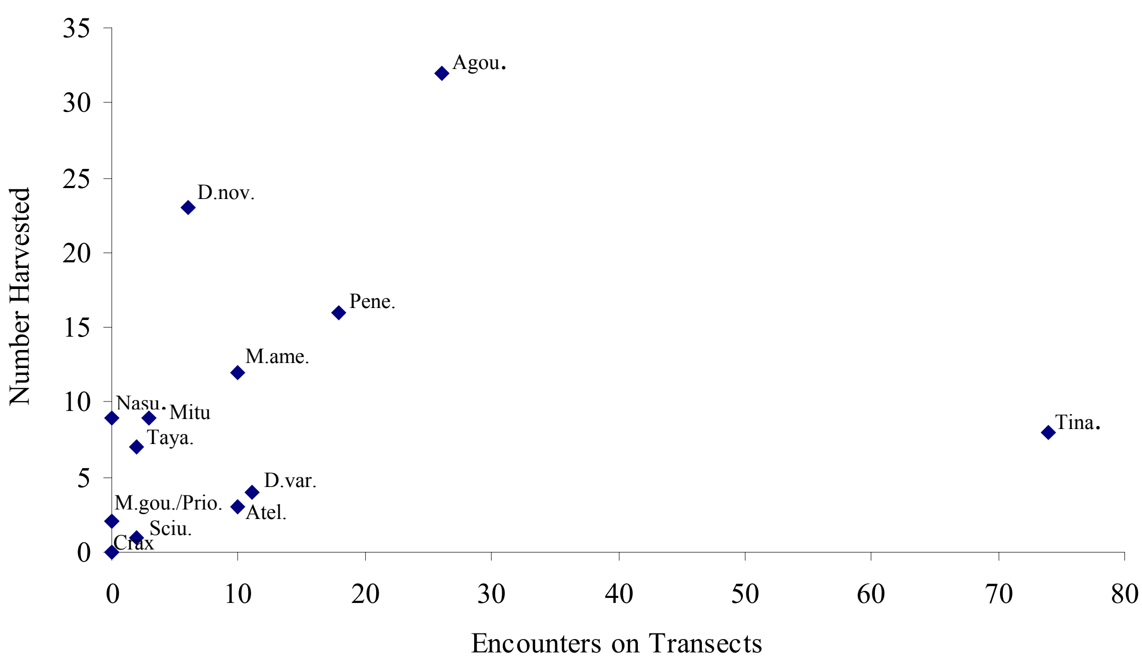

Figure 4.3. Spearman's rank correlation between number of animals harvested by sample households and encounters during transect surveys in Bella Vista, 1999.

Discussion

Optimal foraging theory predicts that animals with a high ratio of energetic or economic returns to costs (money, time, energy) incurred in capture will be pursued as preferred prey in the local diet. Hunting reports in Bella Vista empirically support optimal foraging theory in terms of yield of meat per unit of hunting effort for preferred prey categories. Animals in Category I were highly recognized, actively pursued, and produced an overall average of 5.99 kg/person/hr of hunting. Category II, which were highly recognized but only moderately pursued species, produced an overall average yield per unit of effort of only 2.37 kg/person/hr of hunting, which was positively biased by the high yield provided by spider monkeys. If spider monkeys were excluded from the list, the overall average yield would be only 0.44 kg/person/hr, which is a disincentive for hunting animals of Category II (including birds), for the optimal forager.

Foragers may develop preferences for certain species when provided with a diversity of available and abundant prey, and human behavior may influence hunting choices in an abundant forest environment by promoting selectivity for certain species according to dietary preferences, cultural influences, or socioeconomic motivators. Local availability of prey for hunters can vary as a result of harvest intensity, habitat differences, disturbance, season, time of day, accessibility, availability of forage and water, reproductive activities and other life history traits and behaviors. Seasonal effects that influence hunting strategies may include wet season flooding, which limits hunting activities to locations accessible by water and can include expanded access to interior flooded forests, flooded savanna, sites far upriver, and upland islands of dry land where prey are trapped on higher ground. In the dry season, hunters focus their efforts on prey habitats and water sources that are accessible by foot, bicycle, and horse, including the dry savanna and nearby forests. Low river levels constrict the hunting zone to local areas during the dry season with access limited to upriver sites unless land-based transportation routes are available. Macrohabitat differences for certain species would include forest, savanna, or riverside locations.

Habitat differences between prey species affected the hunting strategies employed by residents during this study. For example, marsh deer were almost exclusively found in savanna habitats rather than in the forested hunting catchment adjacent to Bella Vista. They were frequently harvested upriver during the rainy season when populations were concentrated in dry hills, or "islas," of the flooded savanna, and in the open savanna near waterholes during the dry season. As a result, I did not expect to encounter marsh deer during transect surveys in the forest near Bella Vista, and none were seen. Hunters, however, indicated a strong preference for marsh deer and Brazilian tapir, and they would travel upriver from Bella Vista for several days specifically to hunt these two species. Marsh deer and Brazilian tapir have the highest biomass of any species harvested by residents (approximately 80 kgs and 150 kgs, respectively), and gave high yields of meat per person per hour of hunting effort (2.40 kg and 26.14, respectively), justifying the selective effort and increased costs of hunting these species outside the hunting catchment of Bella Vista.

The majority of species listed through recognition and pursuit categories as preferred by hunters were also considered abundant and were frequently harvested, indicating that opportunism plays an important role in hunting strategies in Bella Vista. However, preferences were shown in the selective exclusion of certain species from harvests, despite frequent encounters with them. Almost all hunters reported an overall decrease in prey species over the last few years resulting from local development and extractive activities. Although it was difficult to estimate abundance for certain species using transect counts due to different habitats (marsh deer, Brazilian tapir) or behaviors (white-lipped peccary, red brocket deer, giant anteater), survey count data compared against actual hunter reports provided important insights into wildlife harvest in Bella Vista. For example, the prolific rodent, spotted paca, was the most frequently encountered and harvested species in accordance with the Bodmer et al. (1997) assertion that actual harvest correlates more with prey productivity than with body size. The correlation between encounter rate and number harvested was almost one for the spotted paca, indicating that they are harvested, at least in part, according to the frequency of encounters. The second most frequently harvested animal is another small but productive species, the nine-banded long-nosed armadillo, which was also considered highly abundant by hunters and was encountered several times during transect counts. Frequent encounters and dietary preference seemed to drive a high harvest of these species based on more on opportunism than biomass rendered.

Selective hunters will forego opportunities to take less preferred prey items by focusing the hunt on species that are considered to be more valuable. Since according to recognition and pursuit categories, the most preferred prey species of prey (Category I) are larger-bodied or highly productive mammals, it follows that selective searches for mammalian prey would occur in the evenings or during overnight stays in the forest, when mammals dominated animal encounters. Selective hunts may require a higher investment for a higher return in terms of biomass rendered, dietary preference, or economic benefit.

Larger ungulates such as red brocket deer, white-lipped peccary, collared peccary, and marsh deer were considered abundant, were hunted for meat, and in proportionately greater quantities than other less-preferred, less-abundant, or non-food prey species. With the exception of the red brocket deer, these species were not encountered frequently on transects, although the popular perception was that they were locally abundant. Frequent harvest despite infrequent encounters with these species may demonstrate an optimal foraging strategy of selectivity resulting from high biomass rendered per unit of hunting effort: 2.33 kg/person/hr for red brocket deer, 3.66 kg/person/hr for white-lipped peccary, 4.53 kg/person/hr for collared peccary, and 2.40 kg/person/hr for marsh deer. More information is needed to determine whether the perception of abundance can be validated with actual population estimates. Management efforts should focus on species subject to selective harvest and preferred prey status in the TCOI.

Preferences were also shown in selective non-harvests of a large rodent, the brown agouti, and the primate, the black spider monkey. Both species were considered locally abundant, were frequently encountered on transects, and had high yields of meat per unit of hunting effort

(6.38 kg/person/hr for brown agouti and 12 kg/person/hr for spider monkeys), yet neither was notably harvested, due to a local culinary aversion to their consumption. Although black howler monkeys and capybara were also highly abundant in the region (although due to their riverside habitats this was not noted on transects) and could provide high biomass returns relative to the costs of their procurement, they too were not harvested at all, again for reasons relating to culinary preference. Whereas in other tropical regions primate populations have been severely depleted by hunting (Peres 1990, Fa et al. 1995, Fitzgibbon et al. 1995), they remain locally abundant and relatively unhunted in Bella Vista.

Birds such as tinamous and guans were very abundant on transects, but they were harvested only at moderate levels, perhaps as a result of lower biomass returns relative to mammalian prey (1.26 kg/person/hr of hunting for tinamous and 0.22 kg/person/hr of hunting for guans). These prey comprised a lesser proportion of the local hunt as a consequence of selectivity favoring preferred prey species rather than lack of encounter opportunities. DISTANCE analyses also showed lower density but higher detection probability for non-prey species relative to prey species. Preferred prey species in the Bella Vista hunting catchment seem to be present in sufficient quantities to preclude the necessity of including less desirable species in the local subsistence diet, even when they are readily encountered.

Prohibition of the trade of pelts and other animal parts has likely favored the conservation of felids, mustelids, and other carnivores considered relatively abundant but not encountered on transects nor harvested for profit during this study. Species that were considered to be abundant but were not harvested or encountered may be those for which the economic or energetic returns were not sufficient to promote pursuit, were considered distasteful, or have not yet become part of the local hunt because selectivity for preferred species is still favored by adequate prey abundances. Hunting selectivity should favor the perpetuity of non-preferred prey species in the region if land development and habitat degradation continues to be slow.

In Figure 4.4, I use density of prey populations, optimal foraging motivators, hunter perceptions of animal population abundance, and animal encounters inputs to predict the inclusion or exclusion of prey species in the local hunt. Human behavioral motivators for selecting certain prey items over others may include the biomass of meat rendered per unit of effort in capture, taste or dietary preferences, and/or economic returns from selling meat. Economic returns from selling wild meat are assumed to be equivalent in the model, regardless of species. Hence, selectivity for certain prey is focused on biomass of meat rendered by an animal (size and weight factors), as well as dietary or culinary preference for certain meats over others.

The model predicts that hunters may hunt or not hunt a particular species depending on whether that species is perceived as abundant or rare, is encountered frequently or infrequently, and is profitable (in biomass, economic returns, or culinary preferences). If during transit between home and agricultural plots or other worksites in the forest, preferred prey are not easily encountered but less-preferred prey are readily available, opportunistic hunters may predictably include those items in the hunt. Abundant harvests of avifauna such as pigeons reflect the opportunistic nature of diurnal hunts in Bella Vista. Densities and encounter rates for birds were higher than those of mammals, promoting opportunistic harvest of birds despite lower returns in biomass. Prey-switching based on opportunism alleviates pressure on depleted populations of preferred prey by focusing harvest on less-desirable but more abundant species, while pursuit of preferred prey through selective hunting may result in local extinction of those species. Encounter rate and density do not necessarily promote hunter preference for certain prey, however, because no birds were included in the list of most-preferred prey (Category I), probably as a result of significantly lower biomass returns per unit of hunting effort.

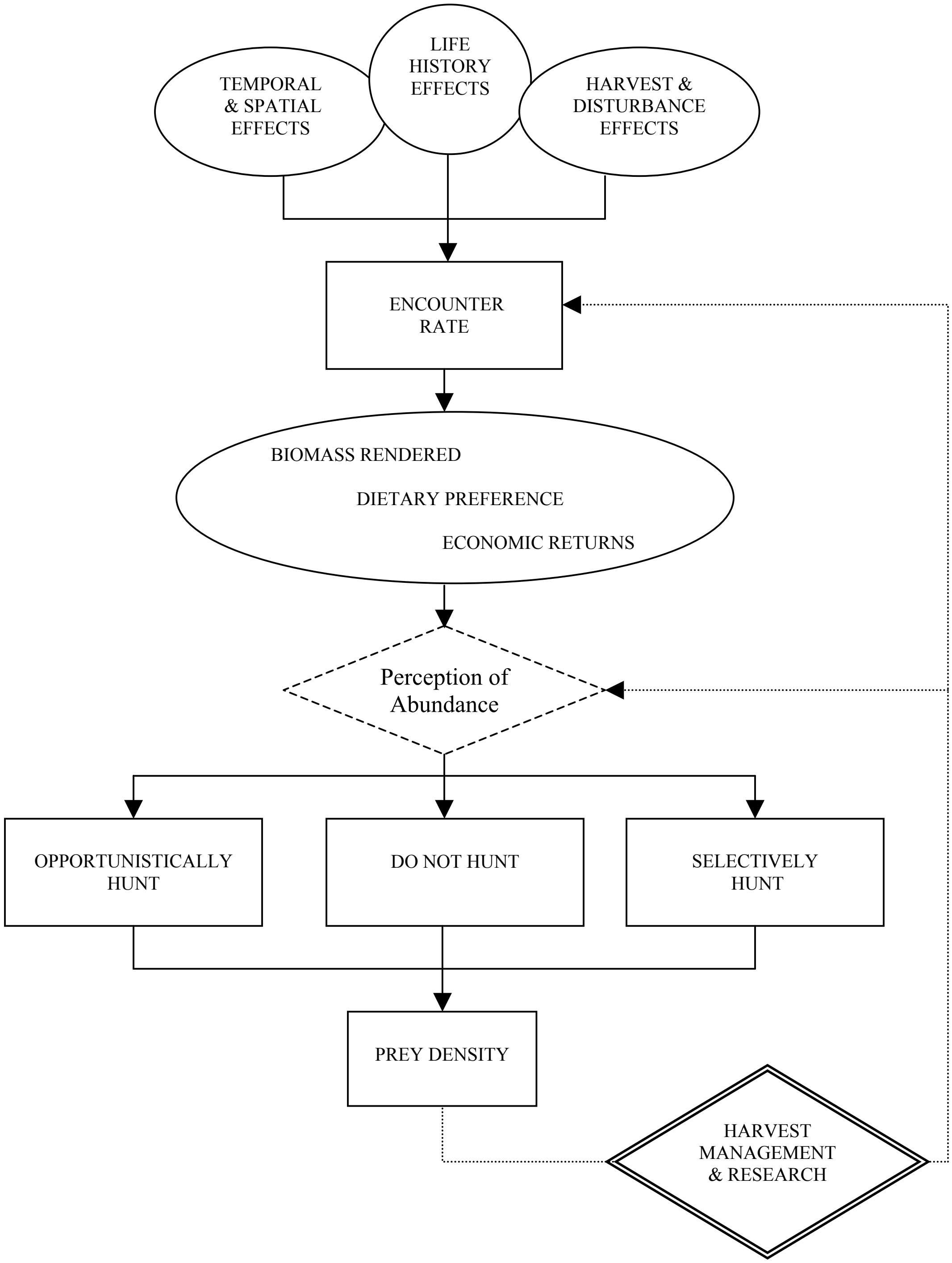

Figure 4.4. Effects of hunter preferences, perceptions of prey population abundance, and optimal foraging motivators on hunting choices.

In Figure 4.4 and Table 4.10, I provide important considerations for managing the faunal resources of the Bella Vista region. Species perceived as abundant which are subject to harvest pressure should be closely monitored to promote the sustainability of local populations. Species that were included in preferred prey categories (gray brocket deer and giant armadillo) despite perceived rarity, and which were not encountered during transect surveys, should be the focus of management concern and protective efforts to ensure that they will not become locally extirpated. Although neither of these two species was seen during diurnal and nocturnal transect surveys, hunters brought in two of each during this study. This may indicate that hunters are selectively pursuing these two species due to preferences for them and regardless of encounter rate, or that time lag effects between actual depletion and perception of over-harvest may play a part in hunter decisions. Harvesting these species, despite noticeable rarity and possible depletion, can have negative consequences for the sustainability of these particular prey populations and for the perpetuity of prey resources in general. It appears that a culinary preference for these two species in the local diet was a disincentive for conserving their populations or switching to a more locally abundant, but less-preferred, prey animal.

Table 4.10. Species perceived as abundant, harvest intensity, and frequency of encounter in Bella Vista, Bolivia.

	Encounters During Surveys		
	Abundant	Rare	Not encountered
Harvest Intensity			
High	*Mazama americana* *Agouti paca* *Dasypus novemcinctus* *Penelope* sp.	*Mitu tuberosa*	*Tayasu pecari*
Moderate	*Tinamus*	*Tayasu tajacu*	*Blastocerus dichotomus*[a] *Tapirus terrestris*[a] *Nasua nasua*
Low	*Dasyprocta variegata* *Ateles paniscus*	*Sciurus spadiceus*	*Panthera onca* *Ara* sp.
No harvest		*Coendou prehensilis*	*Puma concolor* *Alouatta caraya* *Hydrochaeris hydrochaeris* *Dasypus septemcinctus* *Leopardus pardalis* *Leopardus weidii* *Eira barbara* *Lontra longicaudis* *Pteronura brasiliensis* *Cerdocyon thous* *Pipile cumanensis* *Pipile cujubi*

[a] = Species that would not be found along transects due to habitat specificity (savanna and woodland for *B. dichotomus*, swampy forest for *T. terrestris*).

Conclusion

The future of wildlife communities in the TCOI will be determined by harvest management that can help guide local decisions concerning which species are hunted, when, and in what quantities. Ideally, animals that are widely recognized and actively pursued will also be those that are perceived to be abundant (with scientific data to support those perceptions), and have high benefits relative to costs in procurement. Selective hunting of preferred species at low to moderate levels should be accompanied by population monitoring, and evaluations of the effects of hunting and other factors, to ensure the perpetuity of preferred populations. Likewise, hunting of animals that are preferred as prey but demonstrate rarity should be regulated to prevent population depletion resulting from over-exploitation. Since perceptions of high abundance do not necessarily correlate to high encounter rates, or to high harvests, it is important to consider and further investigate the relationship between hunter perceptions of abundance, which are cognitive, and selectivity, or actual hunter behavior that results in pursuing certain prey over others.

This study demonstrates that prey preferences based on biomass, dietary considerations, and economic returns were important determinants of hunter behavior in Bella Vista, in addition to abundance and encounter rates of terrestrial wildlife. Selective hunting of prey that provide high benefits relative to procurement costs would be the optimal foraging strategy, provided that depletion of preferred prey populations did not result. Fortunately, most species preferred by residents were also considered locally abundant and easily procured, with the exception of two rare but still actively pursued species. It is important for wildlife managers and residents to consider the sustainability of harvest of species that were preferred but were less abundant locally, and to focus harvest management activities on prey populations for which little or no abundance data are available. Since hunters already have noted rarity in certain species, collaboration with them will help in the process of identifying species in danger of local depletion, and in determining how to restrict or adapt hunting activities to ensure the perpetuity of those important prey populations. Similarly, forests, savannas, and wetlands should be protected from unregulated burning, deforestation, and degradation from cattle ranching and other development activities to promote conservation of important wildlife habitats.

Collection of hunting activity data and monitoring of local wildlife populations will help managers make informed decisions regarding local prey, and management options should be continuously adapted to changing circumstances and resource demands. Decisions to ensure the sustainability of local wildlife populations should be based on hunting activity data, animal surveys in hunted and non-hunted areas, and participatory meetings with local hunting groups. Participatory management and harvest monitoring will promote feedback and collaboration, and should be implemented prior to, during, and following hunting sessions. Dynamic and interactive management, through continuous data updating that is responsive to changing conditions, will help residents of the TCOI to maintain wildlife populations that are ecologically balanced and that can serve the human demand for wild protein.

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CHAPTER 5

TRADE-OFFS AT THE RURAL FRONTIER: USE OF FISH, WILDLIFE, AND LIVESTOCK RESOURCES ON THE AMAZON FLOODPLAIN OF BELLA VISTA, BOLIVIA[1]

[1]Winter, K. A. To be submitted to *Conservation Biology.*

Introduction

Living in the frontier of undisturbed neotropical forest and developed lands requires that settlers decide the tradeoffs they are willing to accept in order to survive. Environmental degradation and local extinction of wild game following colonization of forested areas has been well documented (Peres 1990, Redford 1992, 1993; Lahm 1993, Fa et al. 1995, Fitzgibbon et al. 1995, Muchaal and Ngandjui 1999, Robinson and Bennett 2000a), especially when forests are cleared for livestock production and extraction of natural resources such as timber and petroleum (Posey et al. 1984, Hecht 1992, 1993, Vickers 1993). Game depletion occurs not only as a result of direct game harvest, but from alteration of the forest ecosystem through extraction of important predators, prey, competitors, parasites, pollinators, herbivores, nesting habitats, fruit and nut-bearing plants, and seed-dispersing species (Foster 1992, Redford 1992). Wild areas and the fish and wildlife they sustain can often be conserved when human populations are small, dispersed, and mobile; when the demand for wild animal protein is low relative to supply, and when the technology used for protein procurement is primitive and relatively inefficient (Vickers 1994, Alvard 1995, Robinson and Bodmer 1999, Stearman 2000). However, most residents of neotropical forests have access to firearms, flashlights, motors, and vehicles that greatly improve their efficiency in the pursuit and capture of prey, threatening the sustainability of local natural resources over time and making conservation without active and enforceable management an unrealistic objective.

Subsistence hunting and fishing activities are critical in sustaining human populations in remote areas of Amazonia. While the majority of case studies focus on subsistence hunting and fishing as the sole sources of animal protein for forest dwellers (Robinson and Redford 1991, Redford and Padoch 1992, Robinson and Bennett 2000a), many groups subsidize their intake of wild prey with livestock and poultry. Animal husbandry often involves a greater initial investment in maintenance and care, but the costs are tempered by the security of having a source of meat available when fish and game are scarce, or high-value capital to sell when needed

(Loker 1993). Integration into a market economy through colonization has caused some traditional peoples to invest less time in hunting and fishing, and more time in income-producing activities such as cash cropping, livestock production, and wage labor (Vickers 1993). These economic activities change the dynamics of natural landscapes and the relationships between local people and the flora and fauna upon which they depend. This paper presents the results of a study of local dependency on wild and domestic fauna for subsistence purposes by residents of a small, Amazonian settlement in the lowlands of Bolivia.

Study Site

In 1999, the *Instituto Nacional de la Reforma Agraria* (INRA) began the process of designating 12,273.63 km^2 surrounding the lowland Amazonian settlement of Bella Vista, Bolivia as the *Tierra Comunitaria de Origen Itonama* (TCOI), a multiple-use indigenous territory. Bella Vista was colonized approximately 50 years ago, and is currently inhabited by approximately 1,500 residents (192 households) of indigenous and mestizo origin. The settlement lies at the juncture of the *Llanos de Moxos* savanna floodplain, which lies to the west, and several hundred kilometers of undeveloped gallery forests to the east up to the border with the state of Rondônia, Brazil. Approximately half of the territory is flooded annually during the rainy season months of October through March, and rivers, ephemeral lagoons, and ponds form the landscape mosaic. The average temperature in Bella Vista in 1999 was 28º C, with 80% humidity (AASANA 1999). Annual rainfall for the region is 140-250 cm (Programa Indígena 1996).

Residents of Bella Vista extract forest resources such as wild game, timber, palm hearts, and rubber, engage in swidden agriculture, and fish the two rivers (Blanco and San Martín) that juncture at the town's port. Cattle production is common 45 km to the west of Bella Vista in the town of Magdalena, and is becoming an increasingly popular source of income and employment for local men, attracting interest in those who have the finances to clear and maintain pasture land. As part of the process of territorial designation, residents must decide how to best manage local natural resources to sustain both the human and animal populations that inhabit the region by creating a management plan. To assist them in that goal, I documented the harvest, consumption, and sale of fish, wildlife, and livestock in Bella Vista in order to examine present exploitation levels for fish, wildlife, and domestic animal populations in the TCOI; to evaluate the importance of each to the local diet and economy, and to provide suggestions for managing them efficiently for subsistence purposes.

Methods

Hunting and Fishing Activity Records

First, I enlisted the cooperation of women from 15 (out of 192 possible) different households in Bella Vista. Households were selected randomly from house-to-house visits in which I introduced the research project and objectives. I believe the households were typical of the region in their exploitation of animal resources, and participants willingly volunteered to collaborate with me. They recorded daily hunting and fishing activities, including information about species pursued, quantities harvested, locations, time spent in pursuit and capture, number of participants in each trip, hunting technology used, and other species seen but not pursued. Hunting and fishing activities were recorded from 15 August 1999 to 15 January 2000. Households participated for 3 to 20 weeks total ($\bar{x}$ = 11 weeks).

Diet Calendars

Some of the same women participants also filled out "diet calendars" to record the quantity and type of meat, fish, and/or eggs consumed daily, as well as whether it was killed, purchased, or given as a gift to the family. Members of 12 households participated. Household sizes ranged from three to nine members each ($\bar{x}$ = 7), for a total of 82 adults and children in the sample. In order to approximate the per capita consumption of animal protein in each household, children under the age of 12 were assumed to consume 2/3 the amount of animal protein of an adult. Diet calendars were recorded from 15 August 1999 to 15 January 2000. Households participated for 4 to 20 weeks total ($\bar{x}$ = 8 weeks).

Local Market Announcements

Lastly, I recorded the types and quantity of fish and meat offered to the Bella Vista community through public announcements over the town's loudspeaker and by word-of-mouth. Early morning announcements advertised fish and meat sold by individual houses, indicating what type of animal was being sold and where it could be purchased. Oftentimes, beef or water buffalo would be sold at a general market location for easier processing. Market announcements were recorded from 13 March to 2 November 1999 (33 weeks total).

Results

Harvest Activity Reported by Households

The 15 participating households documented 423 person-days of successful hunting and/or fishing activity out of 1,155 total person-days available during the period of study. In other words, participants pursued and were successful at obtaining wildlife and fish 37% of the time overall. The weighted average number of days of successful prey capture per household was 39 over the data collection period, with a high of 67 successful days out of 126 (53%) total recorded for one family, and a low of 3 days out of 21 (14%) total for another. The most successful household also brought in the largest harvest of 754 animals, including 707 fish, 21 birds, 16 mammals, and 10 reptiles over 18 weeks. Because households did not recognize crippling loss, or the numbers of animals injured but not retrieved, the actual number of animals killed was likely greater than the harvests recorded.

Hunting and fishing groups averaged two members in size and were predominantly men. Groups were often composed of friends and other extra-familiars, for as few as one and as many as 41 (wt. avr. 12) different contributors to a typical household's protein diet. The households bringing in the greatest diversity and number of prey animals were also those that included a large number and variety of participants in hunting and fishing trips. Overall, 111 different people participated in hunting and fishing activities for the 15 households. The weighted average time spent by hunting and fishing groups was 5.8 hours per trip. Some excursions lasted several days, which were recorded as 8 hours per day of activity multiplied by the total number of days.

In Bella Vista, 82 consumers chose to participate in reporting harvest and consumption of wild and domesticated prey. Foragers of each household utilized a core hunting and fishing catchment of approximately 452 km^2 of forest, savanna, and rivers, mostly to the north and east of the settlement. The proposed TCOI would encompass 12,273.63 km^2 of mostly undeveloped source habitat for wildlife and fish, with additional settlements tripling the current resident human population of Bella Vista. Therefore, I estimated that individual consumers could potentially exploit an average of 2.7 km^2/person for the entire TCOI. This is likely an overestimate, since only 50% of the territory is actually accessible for natural resource exploitation due to lack of transportation infrastructure, trail and road flooding during the wet season, and limited river access from low waters during the dry season. At the time of this printing, the proposed area to be encompassed by the TCOI had been reduced to approximately half of the original demand (Español Gonzalez 2002), which will significantly reduce access to certain resources.

Comparatively, Alvard et al. (1997) reported a catchment size of 314 km^2 for subsistence hunting in Peru by Piro and Machiguenga communities (191.5 and 85 consumers, respectively), and Vickers (1994) reported a hunting catchment of 1,150 km^2 for the Siona-Secoya (500 residents) of Amazonian Ecuador. These two examples average 2.3 km^2 of hunting area per consumer. Hill and Padwe (2000) estimated that "sustainable" harvest of terrestrial wildlife could be achieved if rural residents obtained 5 km^2/consumer.

Overall, participating households killed a total of 3,480 animals of 47 different species during the data collection period. Included in the harvest were 3002 fish (20 species), 192 birds (at least nine species), 157 river turtles (one species), 123 mammals (14 species), and 6 other reptiles (caiman, land tortoise, snake) (Table 5.1). Pursuit took place at 51 distinctly named hunting and fishing sites ($\overline{x}$ = 9 per household), which should be considered the minimum number possible since participants were not expected to enumerate every site used. Fish were

Table 5.1. Fish and wildlife species hunted, sold, and consumed in Bella Vista, Bolivia.

Species name	Local common name	English name
Mammals		
Tayassu pecari	puerco de tropa	white-lipped peccary
Tayassu tajacu	taitetú	collared peccary
Mazama americana	huasu	red brocket deer
Mazama gouazoubira	hurina	gray brocket deer
Blastocerus dichotomus	ciervo	marsh deer
Tapirus terrestris	anta, tapir	tapir
Ateles paniscus	marimono, mono negro	black spider monkey
Panthera onca	tigre, jaguar	jaguar
Nasua nasua	tejón	South American coati
Agouti paca	jochi pintado	spotted paca
Dasyprocta variegata	jochi colorado	brown agouti
Sciurus spadiceus	ardilla, masi	southern Amazon red squirrel
Priodontes maximus	tatú canasto, 15 kilos	giant armadillo
Dasypus novemcinctus	tatú	nine-banded long-nosed armadillo
Birds		
Tinamus/*Crypturellus* sp.	perdiz	tinamou
Penelope jacquacu	pava cotocolorada	Spix's guan
Penelope superciliaris	pava cotocolorada	rusty-margined guan
Mitu tuberosa	mutún	razor-billed curassow
Ara ararauna	paraba siete colores	scarlet macaw
Ara macao	paraba	blue and yellow macaw
Rhea americana	piyu	South American rhea
Columbidae	torcasa	(dove or pigeon)
Anatidae	pato del monte	(duck)
Crax fasciolata	pavichi	bare-faced curassow
Pipile cumanensis	pava campanilla	blue-throated piping guan
Pipile cujubi	pava campanilla	red-throated piping guan
Reptiles		
Podocnemis expansa	tataruga	(river turtle)
Podocnemis unifilis	peta (female), capitaré (male)	(river turtle)
Geochelone sp.	peta del monte	(land tortoise)
Caiman yacare	lagarto, caiman yacaré	Paraguayan caiman
Fish		
Cichla monoculus	tucunaré	peacock bass
Leporinus sp.	piau	
Mylossoma duriventre	pacupeba	silver dollar fish
Serrasalmus sp.	piraña	pirana
Prochilodus sp.	sábalo	sábalo
Colossoma macropomum	pacú	tambaqui
Hoplias malabaricus	bentón	tiger fish
Aequidens sp.	moshopa	
Pseudoplatystoma fasciatum	surubí	tiger catfish
Characidae	sardina	sardine
Hoplosternum sp.	buchere	hoplos
Plagioscion squamosissimus	curubina	corvina
(unknown species)	sati	
Hoplerythrinus initaeniatus	yayu	yarrow aimara
Pimelodina flavipinnis	blanquillo	(catfish)
Piaractus brachypomus	pirapatinga	red-belly or red pacu
Megalodorus irwini	peshijabón, tachaca	(catfish)
Cynodon gibbus	cachorro	black spot cashorro

harvested in the greatest number, comprising 86% of the total wild-caught animals. Birds came in a distant second at 5.5% of the total catch, followed by reptiles at 5%, and mammals at 3.5% (Figure 5.1).

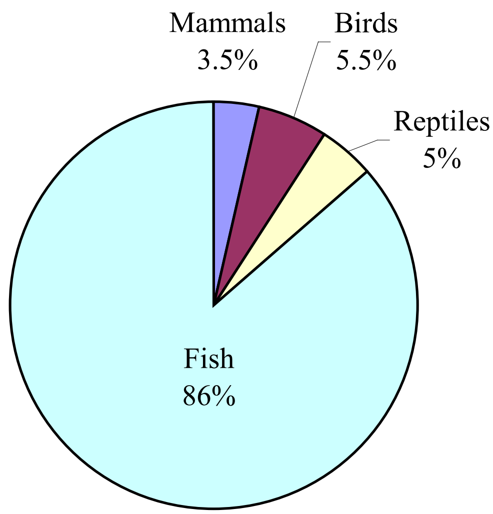

Figure 5.1. Relative proportions of wild prey harvested by sample households in Bella Vista, Bolivia (by number taken).

Mammal Harvest

When biomass is considered, the importance of fish is diminished slightly by that of wild-caught mammals (see Appendix C for estimated weight and biomass). In terms of estimated biomass by weight in kilograms, fish comprised 47% of the total harvest of wild-caught animals, followed closely by mammals at 35%, reptiles at 16%, and birds at 2% (Figure 5.2). Most of the mammals harvested were either the larger or more prolific members members of each family. Spotted paca (*Agouti paca*) were harvested in the greatest number, followed by nine-banded long-nosed armadillo (*Dasypus novemcinctus*), white-lipped peccary (*Tayassu pecari*), red brocket deer (*Mazama americana*), and South American coati (*Nasua nasua*) (Table 5.2). All of these species are encountered locally, although groups of *T. pecari* migrate through the area only once or twice annually. In biomass, tapirs (*Tapirus terrestris*) comprised the largest proportion of the harvest, followed by marsh deer (*Blastocerus dichotomus),* white-lipped peccary, red brocket deer, and spotted paca. Tapirs and marsh deer are frequently pursued outside of the immediate hunting catchment of Bella Vista, making evident the importance of source refuge habitats for animals that are preferred prey for residents. These species are found several kilometers upriver on the San Martín River in lowland, swampy forest near water for tapirs, and in open savanna near forest patches for marsh deer.

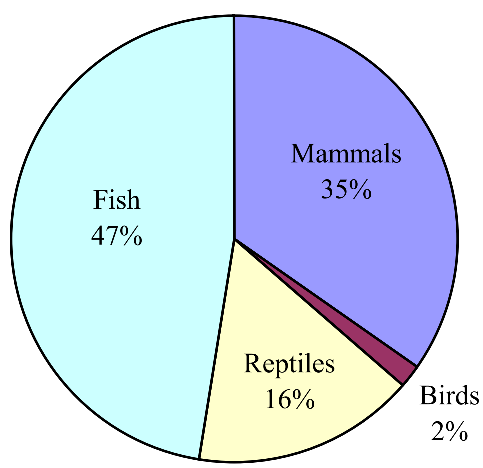

Figure 5.2. Relative proportions of wild prey harvested by sample households in Bella Vista, Bolivia (by biomass).

Table 5.2. Quantity of mammals harvested by participating households in Bella Vista, Bolivia.

Species	Number harvested	Proportion of total harvest	Biomass harvested (kg)	Proportion of total biomass
Agouti paca	32	0.26	256	0.09
Dasypus novemcinctus	23	0.19	92	0.03
Tayassu pecari	15	0.12	435	0.16
Mazama americana	12	0.10	336	0.12
Nasua nasua	9	0.07	36	0.01
Tayassu tajacu	7	0.06	133	0.05
Blastocerus dichotomus	7	0.06	560	0.20
Tapirus terrestris	5	0.04	750	0.27
Dasyprocta variegata	4	0.03	16	0
Ateles paniscus	3	0.02	24	0
Priodontes maximus	2	0.02	60	0.02
Mazama gouazoubira	2	0.02	36	0.01
Panthera onca	1	0	70	0.02
Sciurus spadiceus	1	0	0.5	0
Total	123	100.00	2,804.5	100.00

The reported proportion of females harvested for these mammalian prey species (Table 5.3) may be of concern for wildlife population viability in the region. The number of females taken is almost three times that of the males for spotted paca, and is double for nine-banded long-nosed armadillo and red brocket deer. These species are harvested in great quantities, and care should be taken to ensure that the proportions of males and females in the remaining population are able to sustain continued harvest over time. Although for most species the sex of the animal is unknown until it is actually killed, future management actions could restrict harvest during reproductive periods to protect females and young.

Table 5.3. Sex ratio of mammals harvested by participating households in Bella Vista, Bolivia.

Mammal	Number of females harvested	Number of males harvested	Total animals harvested
Agouti paca	23	8	32
Dasypus novemcinctus	15	8	23
Tayassu pecari	6	9	15
Mazama americana	8	4	12
Nasua nasua	5	4	9
Tayassu tajacu	2	5	7
Blastocerus dichotomus	4	3	7
Tapiris terrestris	1	4	5
Dasyprocta variegata	3	1	4
Ateles paniscus	2	1	3
Priodontes maximus	1	1	2
Mazama gouazoubira	1	1	2
Total harvest	71	49	121

Fish Harvest

The fish caught most frequently were *tucunaré* (*Cichla monoculus*), followed by *piau* (unidentified species), *pacupeba* (*Mylossoma duriventre*), *piraña* (*Serrasalmus* sp.), and *sábalo* (*Prochilodus lineatus*) (Table 5.4). In terms of biomass, *pacú* (*Colossoma macropomum*) was the most-harvested species by weight. *Pacú* are captured in schools at undisturbed bays and river junctures several kilometers up or downriver from Bella Vista, using gill nets of 12-22 cm stretched mesh size or with fruit-baited trotlines for catching individual fish. Fishing techniques for *pacú* require significant time and financial investments by fishers, and only a few locals engaged in its pursuit. The Bolivian government restricts *pacú* harvest during the dry season, prohibiting capture using gill nets during the months of lowest water levels. By contrast, *tucunaré, bentón* (*Hoplias malabaricus*), *surubí* (*Pseudoplatystoma fasciatum*), and *pacupeba* have unrestricted harvest, but distantly follow the *pacú* in biomass caught. These species can be caught economically using the hook and line, or by cast nets during shorter excursions at the San Martín and Blanco rivers and at the Bella Vista waterfront.

Table 5.4. Quantity of fish harvested by participating households in Bella Vista, Bolivia.

Local name (species)	Number harvested	Proportion of total harvest	Biomass harvested (kg)	Proportion of total biomass
Tucunaré (Cichla monoculus)	745	0.25	1117.50	0.29
Piau (Leporinus sp.*)*	487	0.16	48.75	0.01
Pacupeba (Mylossoma duriventre)	461	0.15	115.25	0.03
Piraña (Serrasalmus sp.*)*	433	0.14	108.25	0.03
Sabalo (Prochilodus sp.*)*	179	0.06	44.75	0.01
Pacú (Colossoma macropomum)	177	0.06	1947.00	0.51
Bentón (Hoplias malabaricus)	153	0.05	153.50	0.04
Moshopa (*Aequidens* sp.)	114	0.04	11.40	0
Surubí (Pseudoplatystoma fasciatum)	99	0.03	148.50	0.04
Sardina (Characidae)	42	0.01	4.20	0
Buchere (Hoplosternum sp.*)*	40	0.01	40.00	0.01
Curubina (Plagioscion squamosissimus)	24	0	12.00	0
Sati (unknown)	18	0	4.50	0
Yayu (Hoplerythrinus initaeniatus)	14	0	3.50	0
Blanquillo (Pimelodina flavipinnus)	8	0	4.00	0
Pirapatinga (Piaractus brachypomus)	6	0	60.00	0.02
Peshijabon or *tachaca (Megalodoras irwini)*	1	0	0.10	0
Cachorro (Cynodon gibbus)	1	0	0.25	0
Total	3,002	0.96	3,823.45	0.99

Reptile Harvest

The harvest of reptiles focused almost exclusively on one species of river turtle, the *peta* (*Podocnemis unifilis*), which is considered a regional dry season delicacy. They are hunted primarily from canoes using a .22-caliber rifle to shoot them as they sun themselves, or are captured by hand. Females are preferred due to their larger size, and both the whole animal and her eggs are actively and selectively pursued during hunting and fishing trips in the low water months of the dry season. During this study, 157 *peta* were taken, in addition to three terrestrial tortoises (*Geochelone* sp.), two caimans, and one unidentified snake. Participants also reported collecting 625 *peta* eggs and 800 eggs of the larger and more rare river turtle, the *tataruga (Podocnemis expansa)*.

Residents have noted severe declines in the number of turtles encountered in recent years, and a reduction in body sizes of those harvested. Although local people recognize that river turtle population decline and size reductions are a direct result of over-harvest during its reproductive season, the demand is still strong for turtle meat and eggs, requiring the Bolivian government to restrict harvest during certain dry season months. The restrictions are announced by the mayor's office in Bella Vista. Yet most residents are accustomed to eating turtles and their eggs and continue to consume them despite restrictions, shipping live animals by plane to relatives and friends in other towns. Similarly, Bolivian law prohibits harvest of caiman for the market in skins. A new program to encourage sustainable harvest of caiman is undergoing an experimental phase in indigenous territories only. Caiman is commonly used as fish bait, or for the small-scale illicit sale of skins.

Bird Harvest

Birds were often shot with .22-caliber rifles while hunters were traveling to and from work in the forest, or during searches directed towards mammalian game. The most frequently harvested birds were the small, but abundant dove or *torcasa* (Columbidae), followed by larger forest avifauna such as the Spix's and rusty-margined guans known as *pava cotocolorada (Penelope jacquacu* and *P. superciliaris)*, duck or *pato del monte* (Anatidae), razor-billed curassow or *mutún* (*Mitu tuberosa*), and tinamou or *perdiz* (*Tinamus* and *Crypturellus* sp.) (Table 5.5). Doves were taken in the largest biomass, followed by curassow, duck, guans, and tinamou. Larger-bodied species of avian prey may be more vulnerable to over-hunting as a result of lower productivity, and should be monitored closely to ensure that populations are not being depleted over time.

Table 5.5. Quantity of birds harvested by participating households in Bella Vista, Bolivia.

Species	Number harvested	Proportion of total harvest	Biomass harvested (kg)	Proportion of total biomass
Columbidae	136	0.71	34.00	0.27
Anatidae	20	0.10	40.00	0.32
Penelope jacquacu or *P. superciliaris*	16	0.08	12.00	0.10
Mitu tuberosa	9	0.05	31.50	0.25
Tinamus and *Crypturellus* sp.	8	0.04	6.00	0.05
Ara ararauna or *Ara macao*	2	0.01	1.50	0.01
(Unidentified sp.)	1	0	0.75	0
Total	192	0.99	125.75	100.00

Consumption of Animal Protein Reported in Diet Calendars

Residents consumed a per capita average of 210 g edible biomass of meat and 100 g edible biomass of fish daily, including animal protein in their diets for 95% of the total number of days recorded during this study. Members of households and associated hunting and fishing groups consumed most of the fish and game, while any surplus was sold or given to others. Lack of electricity for refrigeration precluded preserving meat or fish by any other means than salting or smoking for almost all residents of Bella Vista, and preserving was much less favored than eating a freshly caught animal.

Fishing accounted for 53% of the total edible biomass of wild-caught animal protein consumed by residents of Bella Vista during the dry season, while hunting accounted for 47%.

Consumption of wildlife included 22% mammals, 21% turtles, and 4% birds by weight in kilograms (Figure 5.3). If meats of domesticated origin (beef, pork, chicken, duck) are included in the assessment of meat consumption by residents of Bella Vista, the edible biomass of animals in the diet changes to 34% (539.17 kg) fish, 33% livestock (522.85 kg) , 14% (230 kg) wild mammals, 13% (211.20 kg) turtles, 4% (66.45 kg) chicken and duck, and 2% (37.55 kg) wild birds, for a total of 1607.22 kg consumed (Figure 5.4). A total of 2140 eggs from chickens, river turtles, ducks, and rhea were also eaten. River turtle eggs (2 species) were the most popular during the dry season, at 73% (1565) of the total, followed by 26% (560) chicken eggs, and negligible (<1%) proportions of eggs derived from ducks (Anatidae) (10) and South American rhea (*Rhea americana*) (5).

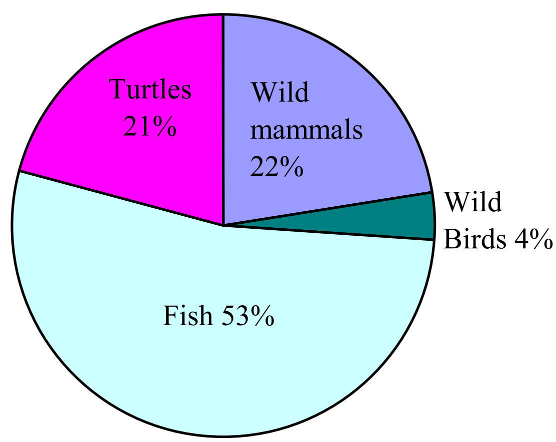

Figure 5.3. Wild-caught animals consumed by participating households in Bella Vista, Bolivia (in edible biomass).

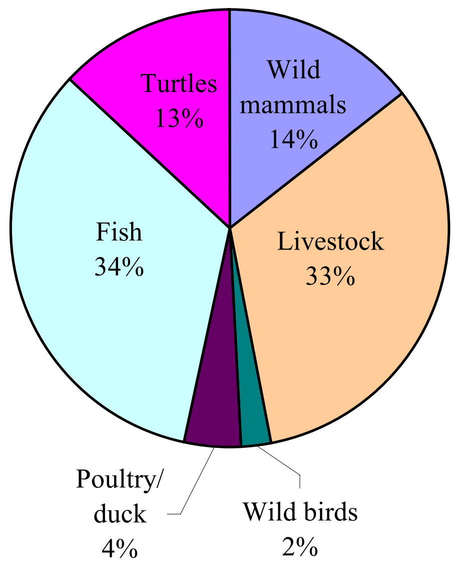

Figure 5.4. Edible biomass of wild-caught and domesticated sources of animal protein that was consumed by residents of Bella Vista, Bolivia.

Local Market Announcements

Out of a total of 231 days of recording fish and meat offered to the public over the loudspeaker, fish were offered 183 days, livestock 113 days, wild mammals 92 days, wild birds 29 days, and turtles 26 days. Fish were sold to the public in the greatest number at 82% (1802 fish), followed by wild mammals at 9% (211 animals), livestock at 5% (111 animals), and birds (54 birds) and turtles (45 turtles), both at 2% (Figure 5.5). In biomass, livestock comprised the greatest proportion of the quantity in kilograms sold at 59%, (20450 kg), followed by fish at 23% (7946 kg), wild mammals at 16%, (5649 kg), turtles at 1% (432 kg), and birds at less than 1% (59.75 kg) (Figure 5.6). An active informal market in fish and wild meat also existed however, with many items sold or traded to kin or neighbors without making a public announcement. Livestock were almost invariably announced, as the quantity of meat rendered required immediate distribution and preparation to prevent spoilage and the intention of slaughter was to generate income for the seller.

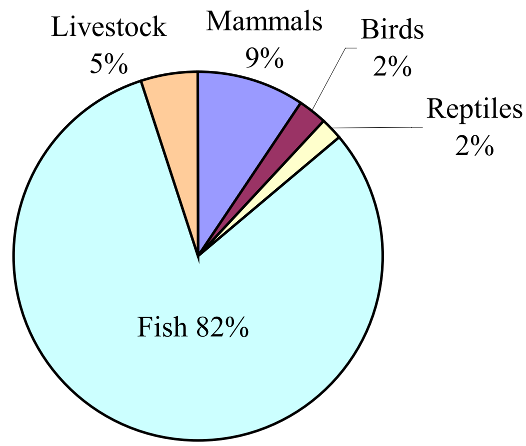

Figure 5.5: Animals sold in Bella Vista from March to November 1999 (by number).

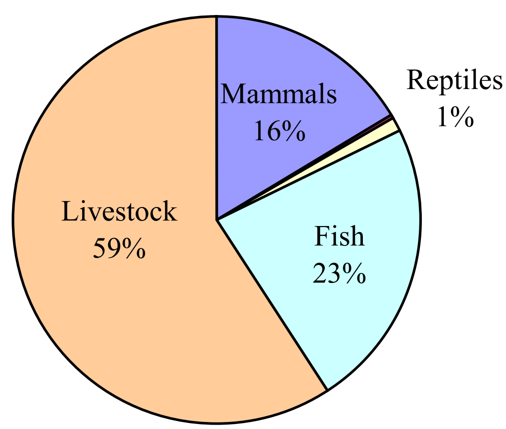

Figure 5.6. Animals sold in Bella Vista from March to November 1999 (by biomass).

Sale of Mammals

Approximately 48 individuals offered beef and buffalo meat over the loudspeaker from March to November, with at least 92 cows and 9 buffalo slaughtered over that time period. Pork was not as popular, with only 10 pigs sold from April to August. Sales of wild-caught mammals included white-lipped peccary in largest proportion, followed by spotted paca, collared peccary, red brocket deer, and marsh deer. In biomass of wild-caught mammals sold, white-lipped peccary was offered in the largest quantities, followed by marsh deer, Brazilian tapir, collared peccary, and red brocket deer. Most animals sold were brought in from much farther upstream, outside of the core 12 km^2 hunting catchment of Bella Vista. In order to obtain sufficient quantities of fish and game to be sold at the local market, hunters and fishers must travel away from Bella Vista in search of larger and more easily encountered animal populations. This phenomena is common in situations in which larger game are desired to generate income, and can have important consequences for game populations located far from human settlements (see also Muchaal and Ngandjui 1999). Hunting activities even at great distances from human settlements can significantly alter wildlife community structure, and care should be taken to monitor the effects of harvest at both immediate and distant hunting sites.

<u>Sale of Fish</u>

Since most fish were harvested and consumed by the same households, it is difficult to infer more about the quantity of fish caught based on market announcements. The small but abundant *piraña*, and larger species such as the *pacú*, *tucunaré*, and *surubí* were sold in the largest quantities. Fishermen brought in 789 *piraña* from March-August of 1999, 646 *pacú* (March-November), 160 *tucunaré* (May-September), and 112 *surubí* (May-August). In biomass harvested, *pacú* comprised the greatest proportion of the catch at 7,106 kg, followed by *tucunaré* (240 kg), the *pacú*-like *pirapatinga* (*Piaractus brachypomus*) (220 kg), *piraña* (197.25 kg), and *surubí* (168 kg).

Sale of Birds and Reptiles

Domesticated fowl such as chicken and ducks were usually raised and slaughtered in the same home, and were not generally offered to the public. Wild birds offered for sale included the small but abundant dove, which sold the greatest numbers, followed by piping guan or *pava campanilla (Pipile cumanensis* or *P. cujubi),* forest duck (Anatidae), Spix's and rusty margined guans, razor-billed curassow, tinamou, and bare-faced curassow, or *pavichi (Crax fasciolata)*. Although the animal itself was not consumed, 32 eggs of South American rhea were also collected and offered for sale. In biomass, duck was sold in the greatest quantity, followed by razor-billed curassow, the guans, doves, bare-faced curassow, and tinamous.

Turtles and turtle eggs were commonly collected and consumed by the same household, sold informally, or given to friends and kin. However, I recorded the formal sale of 39 whole turtles of *peta* (312 kg), 36 eggs, and six whole *tataruga* (120 kg). Actual harvest and sale of these reptiles was much larger than I was able to document, notably as a consequence of the government ban on their sale. Many were packaged and shipped to relatives in the capital city of Trinidad, or to surrounding towns where turtles had been locally extirpated by over-harvest.

Cost-Benefits of Hunting, Fishing, and Animal Husbandry

There are different activity costs involved in hunting, fishing, or raising sources of meat (Table 5.6). Although Table 5.6 illustrates the hourly costs (in monetary units of Bolivianos, or Bs) of each activity, in reality, animal husbandry will require long-term investment, while hunting and fishing activities may begin and end spontaneously with only a short-term expense to the forager. Foragers may choose to purchase meat, fish, and/or eggs if the costs of foraging are higher than earning the money to buy a desired prey item. However, high unemployment limits the amount of money available for purchasing meat, and most families preferred to save their finances for items that cannot be obtained through alternative means such as foraging.

In Table 5.6, I show that the initial material investments made could be diffused over a 36-month period of time, while the investment in live animals could be diffused only over a period of 12 months. I divided the monthly maintenance costs of hunting over the average number of terrestrial fauna that could be harvested each month, and the costs of fishing over the average number of fish that could be harvested, in order to calculate the monthly monetary costs of foraging versus purchasing meat or fish. For domestic animals, monthly maintenance costs are specific to each species, and could not spontaneously begin or end on an hourly basis, as is the case with hunting and fishing activities. For comparative purposes, I assumed that the maintenance costs of animal husbandry are a monthly expense, while the maintenance costs of hunting and fishing are hourly expenses.

Table 5.6. Monetary activity costs of hunting, fishing, or animal husbandry.

Initial investment for item	Cost (Bs)	Diffused investment costs (Bs)	Supplementary expenses	Monthly activity costs (Bs)	Hourly activity costs (Bs)
Hunting		(36 mos)			
.22-caliber rifle	1200	33.33	25 Bs/box of 25 cartridges	58.33	0.081
Flashlight	25	0.69	10 Bs/pair batteries	10.69	0.015
Bicycle	300	8.33		8.33	0.012
Fishing		(36 mos)			
Fish hook + line	4			4.00	0.005
Gill net	800	22.22		22.22	0.030
Cast net	500	13.89		13.89	0.020
Canoe	600	16.67		16.67	0.020
Boat motor	3000	83.33	4.5 Bs/L diesel (20L tank)	173.33	0.240
Animal Husbandry		(12 mos)			
Cattle	540 per head	45.00	Land (10ha/cow) currently free, 60Bs/annual vaccinations, 20Bs/mo/head/farm hands, equipment, fences	70.00	0.097 per head
Pig	50	4.17	Corn feed (20 Bs/32L)	24.17	0.034
Chicken	20	1.67	Rice, corn feed (8 Bs)	9.67	0.013
Duck	25	2.08	Rice, corn feed (8 Bs)	10.08	0.014

The costs incurred for hunting and fishing are lower than those for raising cattle, especially if one shares the more expensive equipment such as rifles and boat motors between friends and family members. Once the TCOI receives designation, land outside of the territory that was previously available for free will be subject to taxation, which will increase the expense involved in cattle ranching. In sharp contrast to cattle production, fishing at riverside with a hook and line is the most economical way to procure animal protein in Bella Vista.

In Table 5.7, I compare the time expenditure involved in foraging compared to purchasing meat or fish in Bella Vista. Since cattle are primarily maintained at small ranches upriver from Bella Vista, the time and expense involved in transporting them is much greater than that for smaller livestock such as pigs, and poultry. Hunting costs the forager a minimum of 0.081 and a maximum of 0.11 Bs/person/hr, depending on whether the hunters invests in a bicycle or travels by foot, and owns or borrows a rifle. Capturing turtles can be done by hand for no monetary expense, or up to 0.34 Bs/person/hr if a motorized canoe and rifle are used. Fishing can be done at shoreline with line and hook for as little as 0.005 Bs/person/hr, or upriver using a boat and nets for up to 0.32 Bs/person/hr.

I calculated the potential income per forager per trip by subtracting the average costs of hunting, fishing, or animal husbandry per trip from the average animal biomass obtained per person per trip, multiplying that amount by the sale price of meat or fish. The potential income is based on an assumption of procuring the average yield of meat/fish every hour for the average number of hours on a given foraging trip, and is unrealistic. For comparative purposes, however, it demonstrates a financial incentive that may be motivating the current trend in cattle production throughout the state of Beni, since the potential net income is high due to the animal's large mass and the market price of the meat.

Table 5.7. Average costs and benefits of foraging versus purchasing flesh in each prey category.

Prey category	Time spent foraging (hrs)	Number of foragers	Animal biomass obtained per trip (kg)	Biomass yield (kg/person/hr of foraging)	Sale price (Bs/kg)	Potential income per trip (Bs/ person)
Wild-caught						
Mammals	10.0	2	27.00	5.10	7.0	350.31
Birds	5.7	2	1.67	0.65	3.5	11.06
Fish	3.7	2	8.28	3.34	3.5	41.15
Reptiles	7.4	2	22.00	5.39	1.9	73.39
Domestic						
Cattle	10.0	2	170.00	8.5	8.0	672.24
Chicken	0.2	1	1.25	6.25	12.0	14.97
Duck	0.2	1	2.50	12.50	10.0	24.97
Pig	1.0	2	50.00	25.00	8.0	199.73

The results of Table 5.7 show that it is more cost effective to produce one's own chickens and ducks than to purchase them, and that pigs provide a large yield of meat per unit of foraging effort. The minimal expenses involved in raising pigs, chicken, and ducks in the household (Table 5.6) would seem to promote their production at a small scale. In Tables 5.6 and 5.7, I show that wildlife and fish produce smaller yields of flesh per unit of foraging effort than domestic animals, although at a lower maintenance cost. The market in Bella Vista does not promote selling wild-caught meat to generate income for purchasing domestic sources, because the income produced from domestic sources is much higher than that for wild-caught animals. Since income is a restrictive factor in purchasing meat and fish, the results of Table 5.7 show that residents could best serve their protein needs by exploiting animals that have a high yield of biomass per unit of effort, such as pigs, duck, cattle, chickens, turtles, wild mammals, fish, and wild birds, in that order. Taking the actual percentage of rendered meat from each animal type into account (0.33 for fish, 0.60 for mammals, 0.40 for birds, and 0.25 for turtles), changes the order slightly, to pig, cattle, duck, wild mammals, chickens, turtles, fish, and wild birds.

Discussion

As in many other regions of Amazonian South America, this study shows that fish are one of the most important natural resources for the subsistence of rural people inhabiting the floodplains of lowland Bolivia. The intake of fish compares to other peasant populations living in the floodplains of the Amazon basin, such as residents of San Jorge, Peru, who consumed 94-130 g/capita/day of fish (Hiraoka 1995). Fish were harvested in the largest quantities as a result of several factors. First of all, men, women, and children, can easily capture most species of fish (except *pacú*) along the riverbanks of the Blanco and San Martín Rivers at Bella Vista using simple and cheap technology such as hook and lines. Fishing requires minimal financial and time investments relative to hunting wildlife, and more participants are involved (including women and children), resulting in greater efficiency and reliability of capture efforts (Sponsel 1986), plus high returns throughout both wet and dry seasons. Data for a community of Peruvians in the floodplains of the Upper Amazon demonstrated that over the course of a year, fishing was six times more efficient than hunting in kilograms harvested per hour (Moran 1993). Although during my research, the yield per unit of effort for fish was lower than that for mammals, my study occurred during the dry season months of the year in Bella Vista. As a result, this study lacks data for the wet season, at which time terrestrial wildlife become difficult to find due to flooding, and hunting returns would be predictably lower.

Fish have higher annual production rates than wildlife, which makes them more abundant in time and more productive over time than game (Gragson 1992). Although the abundance of terrestrial game varies throughout dry and wet seasons as a consequence of fruiting times and water availability, fish availability is more reliable overall (Hiraoka 1995), even with changes in fish community composition due to migrations. Failure rates for fishing in South America, measured as the proportion of unsuccessful foraging trips relative to the total number of trips, have been reported as low as 13%, versus a 45% failure rate for hunting (Gragson 1992). Since residents of Bella Vista often hunted while fishing or engaging in other non-foraging activities, failure rates for either activity could not be accurately determined. However, fishing in Bella Vista did prove to be a highly productive foraging activity, and most participants returned home with at least one type of fish after each excursion.

Fish are important to local economies, providing high nutrition to families at minimal monetary and time costs, either through purchase, or pursuit and capture. Fish are a highly productive and reliable food source throughout the changing seasons, and fisheries are the primary economic resource of the Amazon floodplain (Goulding et al. 1996). Because populations of terrestrial fauna are easily depleted after colonization, wildlife alone may be insufficient to meet the annual animal protein demands of floodplain residents over time (Hiraoka 1995). As people considered poor under Universal Human Rights categories (HYNB 2000), residents of Bella Vista, Bolivia are faced with difficult budgetary restraints in purchasing meat in lieu of hunting and fishing themselves. In the nearby Sirionó territory, Townsend (2000) estimated that subsistence hunting and fishing saves families $871US/year. Meat consumption in Bella Vista compared similarly with quantities reported for the Yanömamo of Brazil, the Machiguenga and Piro of Peru, and the Waorani of Ecuador, for whom the per capita daily intake was 250 g meat (+130 g fish), 230 g meat, and 280 g meat, respectively (Chagnon and Hames 1979, Alvard 1993, Yost and Kelley 1983). Residents of Bella Vista subsidize their consumption of terrestrial wildlife with fish, livestock, and poultry, ensuring that local demands for animal protein will be met at any given point in time.

Bennett (2002) suggested that switching to intensive livestock production might be the only way to ensure a sustainable source of protein in tropical forest regions where wildlife populations are rapidly diminishing. However, case studies of cattle ranching for income production in the Amazon have shown that it is only a financially sustainable option if government subsidies and tax incentives are in place, as has been the case in Brazil. In Bolivia, land reform laws are beginning to be enforced on the rural frontier, requiring that landowners obtain title and pay taxes for land rather than allowing them to use lands without consequence as was the norm in previous years. In the town of Magdalena, 45 km to the west of Bella Vista, degradation of the land and rivers from development and cattle production has resulted in an almost non-existent fishery, demonstrating the incompatibility of fish and livestock production. Large species such as *pacú,* so common in Bella Vista's Blanco and San Martín rivers, are rare in Magdalena's large Itonamas River, and river turtle populations are unknown. Less than 10 cattle ranches have been established upriver from Bella Vista on the San Martín River, yet all of them are located at riverside for easy transportation access.

While wildlife and fish require minimal investment and low environmental impacts for high returns in animal protein, the rearing of livestock in the Amazonian floodplain can devastate river and terrestrial habitats for fish and wildlife populations, as well as drinking water supplies and agricultural lands. Degradation of nutrient-rich floodplain soils during the dry season can have deleterious effects on the floodplain during the wet season, when it provides critical habitats for fish spawning, feeding, and protection from predators (Junk 1984). Cattle and water buffalo are often brought to floodplain areas to graze at the beginning of the dry season. There, they begin to trample and consume shoreline vegetation, altering river banks and introducing large amounts of soil erosion to adjacent water bodies that forces young fishes to flee into muddy tributaries in search of undisturbed habitat (Araujo-Lima and Goulding 1997). Floating meadows, which serve as important nursery habitats for fish, can be consumed at the rate of 0.01 km^2 every 2 to 3 months of grazing (Araujo-Lima and Goulding 1997). Feces and urine introduced into the rivers increase levels of nitrogen and phosphorus, resulting in water pollution. Grazing also results in soil compaction, rendering land unproductive for agricultural use over time and forcing farmers to seek and clear other areas of forest for crop production.

Although livestock represented 59% of animal biomass sold and 33% of animal biomass consumed in Bella Vista, the income generated by cattle ranching benefits only a handful of wealthy residents and temporary employees, at the environmental expense of the entire community. Burning of savanna grasslands for cattle in Beni and adjacent state of Santa Cruz continues unabated every year, degrading land, water, and habitat for flora and fauna throughout the lowlands of Bolivia. In the month of August, 1999, 35,944 km^2 were destroyed in Santa Cruz as a result of uncontrolled burning for pasture and agricultural clearing (Heredia 1999). Deforestation occurs in Bolivia at a reported 1,500 km^2/yr (Heredia 1999), making it a persistent and pervasive threat both to the sustainability of fish and wildlife populations and to the rural peoples that depend on them for subsistence.

In stark contrast to the destructive characteristics of livestock production, fishing and hunting supplied 39% of animal biomass sold and 63% of animal biomass consumed in Bella Vista at without destroying vital habitats. Comparing the estimated consumption of mammals for all residents of Bella Vista with Robinson and Bennett's (2000b) model of maximum sustainable harvest (kg/km^2), the current demand for mammalian wildlife is within "sustainable" levels for the local hunting catchment. Although current hunting and fishing activities are presumably more sustainable, their impacts on fish and wildlife populations must be closely monitored to ensure the future viability of wild food resources. Species-specific management must account for the effects of harvest on larger, less-productive species, with tighter harvest restrictions for sensitive species, longer times allotted for population recuperation following hunting and fishing seasons, and protection of large areas of undisturbed source habitat. Habitats must also be monitored to ensure that harvest of fauna does not significantly alter the community structure of the forest by removal of important predators, prey, competitors, pollinators, herbivores, and seed-dispersers. Land tortoises, curassows, tinamous, primates, and ungulates have all been shown to have high susceptibility to depletion following hunting (Peres 2000). Adding to the list some larger fish such as the *pacú,* these vulnerable species also serve crucial roles in the tropical forest as seed dispersers (Redford 1992). This is especially true for distribution of palms, which are important to human settlers for food, construction materials, and natural remedies.

Although residents are accustomed to eating beef and water buffalo, the small-scale raising of chickens, ducks, and pigs holds more promise for the continued viability of the land in

Bella Vista. These animals require little maintenance and care, live in the yards of owners, and consume kitchen scraps. In return for the low investment, they supply a reliable source of animal protein from meat and eggs, and at a small scale, lower environmental impacts. Domestic rearing of important wild prey species such as the paca and the river turtle has been documented in other areas of the neotropics, and could provide an important alternative to over-harvest if funding and technical assistance were provided. Managers and researchers should focus immediate efforts on protecting and studying the population dynamics of the river turtle and to curtail depletion resulting from overharvest, aquatic habitat degradation, and lack of management. Studies in similar Amazonian environments can provide initial recommendations (Landeo 1997, Landeo-Sanchez 1997, Martinez and Rodriguez 1997, Soini 1997). Above all, residents should participate in the development of long-term planning for the use of natural resources in the TCOI, recognizing the trade-offs that will occur with each decision and learning from case studies in other areas of the Amazon Basin.

Conclusion

Successful management of faunal resources in the TCOI will require close monitoring of the decisions made by residents regarding the use of terrestrial and aquatic habitats. Cattle production may be incompatible with the local demand for fish and wildlife, agricultural activities, and long-term viability of the local environment. However, the demands that residents have for animal protein can continue to be met by available fauna if responsive, adaptable, and enforceable resource management is established in the territory. While the natural resources of the TCOI presently appear to be abundant, the future of those resources will be determined by the insight and adaptability of the people who need them to survive, and the managers who assist them in that endeavor. Residents of Bella Vista must now initiate protective measures to ensure that habitats for source populations of terrestrial and aquatic fauna are preserved, harvest levels are monitored and regulations enforced, and that land-use planning considers environmental effects as well as economic viability for all inhabitants of the region. Future research in the area should focus on these issues, as well as investigating alternatives to current foraging practices.

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CHAPTER 6

PACÚ (COLOSSOMA MACROPOMUM) AS AN INDICATOR FOR AQUATIC RESOURCES OF THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA* IN BOLIVIA

Introduction

The fish species *Colossoma macropomum,* commonly known in South America as *tambaqui, gamitana, cachama,* or *pacú*, is a commercially important traditional fish resource throughout the Amazon and Orinoco Basins, including Brazil, Venezuela, Colombia, Peru, and Bolivia. Fish has been the principal source of protein for inhabitants of the Amazon region (Junk 1984b), and *pacú* is the most important food fish in many regions of the Amazon (Smith 1981, Goulding et al. 1996, Araujo-Lima and Goulding 1997). *Pacú* inhabit a variety of floodplain forests and river types, making it a representative fish of the Amazonian and Orinocan watersheds and an indicator species for those biologically diverse aquatic ecosystems. The widest distribution of the migratory *pacú* occurs within 2 million km^2 of the 7 million km^2 Amazon Basin (Araujo-Lima and Goulding 1997), where adults feed on the fruits and seeds of plants in seasonally flooded forests, floodplains, and Amazonian “blackwater,” “clearwater,” and sediment-laden “whitewater” rivers (Sioli 1950, 1965a, 1965b).

In this paper, I describe the unique ecology of the *pacú* in the rivers and flooded forest habitats found within the proposed boundaries of the *Tierra Comunitaria de Origen Itonama* (TCOI) in the lowlands of Amazonian Bolivia (Figure 6.1). I present a case study of *pacú* exploitation for subsistence and commercial purposes by residents of Bella Vista, the largest human settlement found within the TCOI. I demonstrate that protection of *pacú* habitat within and outside the boundaries of the TCOI is critical for maintaining harvestable populations at both regional and international levels, and propose alternative management options to promote the sustainability of this ecologically and economically important fish resource in the northeastern Bolivian Amazon. Conserving *pacú* populations and the diverse habitats it exploits throughout its life history should simultaneously protect this indicator species as well as other aquatic flora and fauna in Bolivia's lowland flooded forests and rivers.

Study Site

This study was conducted in the river port town of Bella Vista, in the Itenez Province of the state of Beni, Bolivia. Bella Vista is located several hundred kilometers upriver from the Brazilian border in the Amazon Basin of Bolivia, at the juncture of the San Martín and Blanco rivers. It marks a transition in the landscape of the proposed *Tierra Comunitaria de Origen Itonama* from 240 km^2 of savanna and flooded forests to the west, and over 380 km^2 of virtually uninhabited upland forest, floodplain savanna, and lagoons northeastward to the Guaporé River at the border of Bolivia and Brazil. Annual temperatures in the Itenez province range from 24-27º C, and annual precipitation ranges from 140-250 cm (Programa Indígena 1996). Seasons are marked by a rainy season from October through March and a dry season from June through August (Programa Indígena 1996). Dry season temperatures in Bella Vista for 1999 averaged about 28° C (AASANA 1999) with an average of 80% humidity.

The region lies on part of the Precambrian or Brazilian Shield, and is characterized by humid amazonian forest, predominantly evergreen humid and subhumid forests, gallery forest, riverine forest, transitional savanna, savanna, wetlands, and lagoons (Programa Indígena 1996). During the rainy season, lowland savannas and swamps are flooded extensively and forests are isolated as small islands of vegetation. Roadways into the area are subsequently inundated, and travel to or from Bella Vista during that time is restricted to boat or airplane. Approximately 1,500 residents of the 192 households in Bella Vista subsist on hunting and fishing, agriculture, cattle-ranching, small-scale timber extraction, barge construction, petty commodity sales, and extraction of forest products such as palm hearts *(Euterpe precatoria)*, Brazil nuts *(Bertholletia excelsa)*, and rubber *(Hevea brasiliensis)*. The geographical isolation of Bella Vista from an adequate transportation infrastructure for much of the year due to flooding, and residents' reliance on non-monetary exchanges have resulted in limited financial resources for purchasing fish, meat, eggs, or other sources of protein. As a result, residents of Bella Vista depend on the abundance of fish and wildlife as a primary source of subsistence throughout the year.

Methods

From March to November 1999, I collected data on hunting and fishing activities by residents of Bella Vista. I enlisted a sample of 12 households to record their daily consumption of animal protein for approximately 4 months in order to evaluate the importance of fish and wildlife resources to local residents. During the same time period, 15 households recorded daily fish and wildlife harvest, some of which were already research participants. This information was supplemented by 8 months of data regarding fish, wildlife, and livestock offered for sale through public announcements. Finally, I collected *pacú* otoliths from the local catch to determine the age distribution of the harvested population. The results of this study are evaluated in a landscape context of fish resource management in Amazonia, and are compared to similar studies to provide a more holistic interpretation of the relationships between fish and aquatic habitats in the TCOI. For more comprehensive details concerning the diet and harvest data, see Winter (Chapter 5), and for a complete discussion of age distribution of the harvested *pacú* population, see Reinert and Winter (2002).

Ecology of *Pacú*

Distribution

The *pacú* belongs to the family Characidae, which represents almost half of all Amazonian ichthyofauna (Géry 1984), including 250 genera representing 1,000-2,000 species in South America (Lowe-McConnell 1975). It is a traditional fish resource, as documented by Alfred Russell Wallace who recorded eating *pacú* in the floodplains near Manaus, Brazil as early as the 1850s, and Veríssimo, who documented its consumption again in the late 1890s when the rubber boom was prominent (Araujo-Lima and Goulding 1997). The Amazon's 150,000 to

200,000 km^2 of floodplains provide the largest area of habitat for *pacú*, with numerous lakes, floating meadows, and seasonally inundated rainforests along main rivers and tributaries (Araujo-Lima and Goulding 1997). In Bolivia, populations of *pacú* are found in the rivers and flooded forests of the departments, or states, of Beni and Pando. The Madeira River of southwestern Brazil holds a greater distribution of the *pacú* than any other Amazon Basin tributary (Araujo-Lima and Goulding 1997), and is fed by four Bolivian rivers: the Madre de Dios, Beni, Mamoré, and Guaporé (Lauzanne et al. 1990). The latter three rivers are also the only sites in which the *pacú* is found above major cataracts (Araujo-Lima and Goulding 1997), all located within the state boundaries of Beni. The Blanco and San Martín rivers juncture at Bella Vista, flowing northward into the Guaporé and Mamoré rivers before becoming the Madeira River in Brazil. Consequently, good management of *pacú* populations in the TCOI is of extreme importance not only for Bolivian fisheries, but also for those located downstream in Brazil.

River Types

Pacú are found in three river types, described as "whitewaters," "blackwaters," and "clearwaters," all of which are represented in the TCOI. Junk (1984a) noted that highly productive whitewater rivers and associated *várzea* provide more than 90% of the total yield of Amazonian inland fisheries. Whitewater, or some ecological component associated with it, is reportedly the principal determinant of *pacú* distribution (Araujo-Lima and Goulding (1997), whereas less-productive, acidic blackwater rivers contribute a very small percentage of fish yields in the Amazon (Junk 1984b). However, Araujo-Lima and Goulding (1997) noted that during spawning and feeding migrations, the *pacú* is also highly abundant in less-productive, clearwater- and blackwater-associated flooded forests. In the Madeira River of Brazil, adult *pacú* migrate to blackwater and clearwater tributaries during the wet season to feed on fruits and seeds of the flooded forests (Araujo-Lima and Goulding 1997), returning to whitewater river channels as water levels recede during the dry season. At the port of Bella Vista, Bolivia, the Blanco River, characterized as a whitewater river type, merges with the San Martín, a blackwater type that is fed by the Negro River. *Pacú* harvest is concentrated on the Blanco River during dry season months, and on the San Martín River during the wet season. These rivers, combined with the flat topography of the *Llanos de Moxos* plains, expand during the wet season to flood thousands of kilometers of mostly undeveloped *várzea* habitat in the TCOI.

Pacú Diet

During high waters, *pacú* exploit all river types of the flooded forest, nourishing themselves on the abundant fruit and seed resources of forest flora. As the wet season turns to dry, *pacú* return to river channels where adults sustain themselves on fat reserves, and juveniles harvest micro-invertebrates, zooplankton, and other organic materials of the nutrient-rich whitewaters. The plant and invertebrate resources found in the rivers, backwaters, and flooded forests of undisturbed regions of the Amazonian watershed comprise the food supply for the *pacú* throughout its life cycle. As larvae (under 15 mm in length), *pacú* consume micro-invertebrates, preferring the copepods, chironomids, and cladocerans found in floating meadows and floodplain lakes (Araujo-Lima and Goulding 1997). Juvenile *pacú* (2-10 cm in length) also consume zooplankton, adding to their diets filamentous algae, wild rice (*Oryza glumaepatula* and *O. grandiglumes*), fleshy fruits and other seeds that become available during the wet season floods (Araujo-Lima and Goulding 1997).

An adult *pacú* feeds almost exclusively on fruits and seeds, and can grow 1.3 kg/yr, putting on at least 1 kg of flesh per 10 kg of food consumed (Araujo-Lima and Goulding 1997). Araujo-Lima and Goulding (1997) discovered that the *pacú* is the only large fish in the world that possesses both highly developed gill rakers and large molarlike teeth. This unique anatomical combination allows *pacú* to exploit the micro-invertebrates of floodplains, lakes, and floating meadows, as well as the fruits and seeds of flooded forests (Araujo-Lima and Goulding 1997). During high water periods, 94% of the total volume of food consumed by the *pacú* is comprised of fruits and seeds, with only 6% of the food derived from animal origins (Goulding 1980). In contrast, in low water seasons when fruits and seeds are less available and *pacú* rely mostly on fat stores for energy, 90% of the food ingested is derived from animal sources, whereas only 10% comes from fruits and seeds (Goulding 1980). Junk (1984a) reported over 24 species of trees and shrubs characteristic of seasonal várzea, 50% of which are consumed by *pacú* (see Table 6.1).

Table 6.1. Plants of the várzea and consumption by *pacú*.[a]

Species name	Family	Eaten by *pacú*?
Pseudobombax munguba	Bombacaceae	yes
Ceiba pentandra	Bombacaceae	no
Cassia grandis	Caesalpinaceae	no
Cratavea tapia	Capparidaceae	(some *Cratavia*)
Piranhea trifoliata	Euphorbiaceae	yes
Hura crepitans	Euphorbiaceae	no
Hevea brasiliensis	Euphorbiaceae	yes
Hevea spruceana	Euphorbiaceae	yes
Alchornea castaneaefolia	Euphorbiaceae	no
Euphorbiaceae sp.	Euphorbiaceae	(some Euphorbiaceae)
Gustava augusta	Lecythidaceae	yes
Couroupita subsessilis	Lecythidaceae	no
Carapa guianensis	Meliaceae	no
Pithecellobium niopoides	Mimosaceae	no
Cecropia sp.	Moraceae	yes
Ficus sp.	Moraceae	yes
Olmediophaena maxima	Moraceae	no
Eugenia inundata	Myrthaceae	yes
Euterpe oleraceae	Palmae	no
Bothriospora corymbosa	Rubiaceae	no
Calycophyllum spruceanum	Rubiaceae	(some *Calycophyllum*)
Salix humboldtiana	Salicaceae	no
Sterculia elata	Sterculiaceae	no
Vitex cymosa	Verbenaceae	Yes

[a]Sources: Honda 1974, Smith 1981, Junk 1984a, Killeen et al. 1993, Gentry 1996, Araujo-Lima and Goulding 1997.

In Table 6.2, I show 40 plant species eaten by *pacú* in Amazonian flooded forests in general, with 20 of them reportedly found in the state of Beni, Bolivia. Other popular Amazonian fishes rely on some of the same fruit and seed species as *pacú*, including members of the *Mylossoma, Myleus, Brycon,* and *Triportheus* genera (Araujo-Lima and Goulding 1997), as well as catfish of the families Doradidae, Auchenipteridae, and Pimelodidae (Junk, 1984b). Goulding (1980) reported that of the plant species consumed by *pacú* in the flooded forest of the Machado River of Brazil, almost two-thirds of the entire volume of fruits and seeds ingested were large, hard-shelled seeds from the rubber tree, *Hevea spruceana*, and a palm, *Astrocaryum jauary*. The *pacú* is uniquely suited as both a generalist and specialist consumer of flooded forest resources in the Amazonian floodplains, and is a keystone species of the flooded forest ecosystem for its contributions to the region's biodiversity via seed dispersal. The relationship between flooded forest plants and the fishes that consume them emphasizes the importance of protecting this ecosystem from development activities, not only for the sake of the *pacú*, but also for other Amazonian fishes and the plant species within it.

Migrations

Pacú and other commercially important species such as *Brycon* sp. and *Triportheus* sp. (Characidae); *Colossoma* sp. and *Mylossoma* sp. (Characidae); *Curimata* sp. (Curimatidae); *Semaprochilodus* sp. and *Prochilodus nigricans* (Prochilodontidae); *Leporinus* sp., *Schizodon fasciatus*, and *Rhytiodus* sp. (Anostomidae); *Hemiodus* sp. and *Anodus* sp. (Hemiodontidae) undergo dry season spawning migrations from floodplain lakes to river channels that can encompass several hundreds of kilometers (Junk 1984a,b; Goulding 1980). In the Amazon, *pacú* migrations occur within an average radius of only 300-500 km annually, whereas in the Paraná system, the migratory characins may travel from 800-1,600 km in a year (Araujo-Lima and Goulding 1997). These upstream migrations occur just as the river levels begin to rise around the month of November, with spawning occurring at the beginning of the floods (Araujo-Lima and Goulding 1997). Spawning is followed by feeding migrations upstream and into the flooded

Table 6.2. Plant species consumed by *pacú* in Amazonian flooded forests[a].

Species name	Family	Common Name (Brazil)	Common Name (Bolivia)	Found in Beni?
(unknown species)			pachio del bajo[b]	yes
(unknown species)			mangado[b]	yes
Victoria amazonica		vitoria regia[c]		yes
Spondias lutea	Anacardiaceae	taperebá[h]	casharoña del monte	(Pando dept.)
Tabebuia barbata	Bignoniaceae	capitarí[cd]		(*Tabebuia* sp.)
Pseudobombax munguba	Bombacaceae	munguba[cd]		unknown
Crataeva benthami	Capparidaceae	catauari[c]		(*Crataeva* sp.)
Alchornea schomburgkiana	Euphorbiaceae	supiarana		yes
Hevea brasiliensis	Euphorbiaceae	seringa[cd]	siringa	yes
Hevea spruceana	Euphorbiaceae	seringa barriguda[de]	siringa	unknown
Mabea sp.	Euphorbiaceae	taquarí[de]	piri, gabetillo del bajio, siringuilla	yes
Piranhea trifoliata	Euphorbiaceae	piranheira[cd]		unknown
Ricinus communis	Euphorbiaceae	carrapateira[g]		unknown
Eschweilera sp.	Lecythidaceae	castanharana	pokko	yes
Gustavia augusta	Lecythidaceae	mucurão[e]		yes
Campsiandra augustifolia	Leguminosae	acapurana[f]		unknown
Macrolobium acaciaefolium	Leguminosae	araparí[cd]		yes
Byrsonima sp.	Malpighiaceae	muruci[e]		yes
Mouriria cf. *ulei*	Melastomaceae	socoró[c]		unknown
Cecropia sp.	Moraceae	embaúba[cd]	ambaibo	yes
Ficus trigona	Moraceae	cachinguba	bibosi	yes
Psidium guineense	Myrtaceae		guayabillo[b]	yes
Eugenia inundata	Myrtaceae	goiaba-araçá[cd]		unknown
Eugenia sp.	Myrtaceae	araçá[e]	arrayán or coca silvestre	yes
Myrcia fallax	Myrtaceae	araçá[cd]		unknown
Psidium guajava	Myrtaceae		guayaba	yes
Astrocaryum jauary	Palmae	jauarí[cd]		unknown
Pyrenoglyphis (Bactris) maraja	Palmae	marajá[c]		unknown
Syragus speciosa	Palmae	pupunharana[c]		(*Syragus* sp.)
	Rubiaceae		mermelada[b]	yes
Calycophyllum spruceanum	Rubiaceae		guayabochi del bajo[b]	yes
Duroia duckei	Rubiaceae	apurui[e]		(*Duroia* sp.)
Duroia genipoides	Rubiaceae	curuí[c]		unknown
Genipa americana	Rubiaceae	jenipapo	bi	yes
Pouteria nemoroa	Sapotaceae		coquino[b]	yes
Gymnoluma glabrescens	Sapotaceae	camuri[cd]		unknown
Neolabatia cuprea	Sapotaceae	abiuarana[c]		unknown
Neolabatia sp.	Sapotaceae	abio		unknown
Simaba guianensis	Simarubaceae	cajurana[c]		(Pando dept.)
Vitex cimosa	Verbenaceae	tarumã[cd]	tarumá	yes

[a] Sources: LeCointe 1944, Honda 1974, Pereira 1974, Goulding 1980, Smith 1981, Killeen et al. 1993, Gentry 1996, Araujo-Lima and Goulding 1997, HYNB 2000.

[b] = Fruits noted as *pacú* bait used by local fishermen in Bella Vista, Bolivia (those with common names only were not identified taxonomically).

[c] = Species eaten by *pacú* as reported by Smith (1981) in the region of Itacoatiara, Amazonas.

[d] = Species reported by Araujo-Lima and Goulding (1997).

[e] = Species reported by Honda (1974).

[f] = Species reported by Goulding (1980).

[g] = Species reported by Pereira (1974).

[h] = Species reported by LeCointe (1944).

forests that also include many catfish such as *Brachyplatystoma flavicans, B. filamentosum, B. railbautii, Paulicea lutkeni, Pseudoplatystoma* sp. and *Hypophthalmus* sp. (Junk 1984b). Araujo-Lima and Goulding (1997) noted that river level is the principal factor influencing the availability of fruits and seeds for fish such as *pacú*, since most flooded-forest trees fruit during the high-water period of the wet season.

Effects of Water Levels

Water level fluctuations in Amazonian rivers and their adjacent floodplains can vary geographically from 5 to 20 m per year (Junk 1984b), causing distinct seasonal changes in the local environment (Araujo-Lima and Goulding 1997). In Beni, Bolivia, the rainy season occurs between October and March, and the dry season is from June to August (Programa Indígena 1996). Water level changes during these seasons are clearly marked, with low waters occurring in September or October and high waters reaching their peak in February or March (Lauzanne et al. 1990). The average rainfall for the capital city of Trinidad and surrounding regions is 1850 mm per year (Lauzanne et al. 1990), contributing to water levels throughout the upstream catchment of the *pacú* during juvenile and adult stages. Roche and Fernández (1988) noted that at peak highwaters, the Mamoré and Guaporé rivers flood between 100,000 and 150,000 km^2 of land, including part of the *Llanos de Moxos* floodplains of Beni. This expansive zone of shallow depth and high average temperature (26.5° C in Trinidad, 28° C in Bella Vista for 1999) provides a very favorable environment for fish production (Lauzanne et al. 1990). In Bella Vista, local harvest of *pacú* increases and decreases corresponding to river levels. During the dry season, other species of fish take precedence in the fishery while *pacú* undergo migrations.

Increased growth rates in *pacú* are correlated to the rate of rise of annual floods, especially during the highest water levels, followed by slower growth during the low-water period (Araujo-Lima and Goulding 1997, Issac and Ruffino 1996). Young *pacú* reach 290-313 g in the wild in the first year of life (Bayley 1983, 1988; Issac and Ruffino 1996). At 4 years of age, or approximately 55 cm in length, young *pacú* begin to migrate during the low-water period from their nursery habitats in the whitewater floodplains to the river channels (Araujo-Lima and Goulding 1997). The absolute growth rate is highest at 4-5 years of age, at which time the weight of a *pacú* increases 3.3 kg/yr, slowing by 9 years of age to 2 kg/yr (Araujo-Lima and Goulding 1997). After 13 years, *pacú* can reach at least 30 kg and 1 m in length (Goulding and Carvalho 1982, Petrere Jr. 1983, Issac and Ruffino 1996). Some of the largest *pacú* recorded recently by scientists were found in the Mamoré and Beni rivers near the city of Trinidad in Beni, Bolivia, where *pacú* were rarely harvested commercially until the mid-1970s (Araujo-Lima and Goulding 1997).

<u>*Pacú* Harvest in Amazonia and Bolivia</u>

Commercial Catch

Goulding et al. (1996) asserted that fish is the most economical and important source of animal protein in the central Amazon Basin, and has been so since the colonial settlement of the region. In the 1970s and 1980s, Amazonian fisheries provided a total annual yield of 200,000 tons of fish (Bayley and Petrere 1989). *Pacú* populations began to show signs of over-harvest with the development of gill-net technology in the 1970s, which drove the expansion of the *pacú* fishery to more than 40% of the total catch in Manaus, Brazil at that time (Araujo-Lima and Goulding 1997). In the late 1980s, 40-50% of the commercial catch in Porto Velho, Brazil was frugivorous and seed-eating fishes, with *pacú* being the most-exploited species (Goulding et al. 1996). The life history strategy of *pacú* requires a large, diverse habitat range and great investments of time and energy for growth and maturity (Araujo-Lima and Goulding 1997). As a result, populations of *pacú* are susceptible to declines resulting from overexploitation of different age and sex classes, as well as destruction of vital habitats throughout its range.

In 1895, Veríssimo recorded the most commonly exploited size classes of *pacú* at 50-60 cm in length (Araujo-Lima and Goulding 1997). Despite the high productivity of the Amazon Basin created by annual flooding in the wet season, Géry (1984) has noted that over-fishing has been evidenced by the smaller *pacú* caught every year, representing a trend towards younger classes in the commercial catch (Araujo-Lima and Goulding 1997). In the late 1990s, most *pacú* caught in Brazil were juveniles of less than 40 cm in length (Araujo-Lima and Goulding 1997). Prices for the *pacú* in the mid-1990s also rose dramatically with demand, with the average price for juvenile *pacú* set at approximately $2.60US/kg, up to $5.00-$8.75US/kg for fish longer than 50 cm (Araujo-Lima and Goulding 1997). In 1995, the rare adults of 20 kg were selling for $100US on the Manaus market, making it the most expensive fish sold (Araujo-Lima and Goulding 1997). Declines in the populations of large, adult *pacú* in Brazil and the high profits to be gained from their harvest have driven some Brazilian fishermen to cross recently into Bolivian rivers to catch larger *pacú* of between 50-85 cm in length.

In Bolivia, commercial markets for *pacú* originate principally at the port of Trinidad, the state capital of the state of Beni, where the transportation infrastructure is adequate for rapid distribution of fish to state capital markets in La Paz and Santa Cruz or ports in Brazil. Commercialization of fish resources in Beni has increased since the construction of a permanent road connecting Trinidad to the city of Santa Cruz, Bolivia, and has also been promoted by the British Mission to Bolivia (Lauzanne et al. 1990). Commercial fish harvests in Trinidad from January 1986 to May of 1987 produced 370 tons of fish composed of *Pseudoplatystoma tigrinum* or *chuncuina* (48% of the total catch*), pacú* (35%), *Pseudoplatystoma fasciatum* or *surubí* (10%), *Piaractus brachypomus* or *tambaqui* (3%), *Phractocephalus hemioliopterus* (2%), and 1% other species (Mander 1987). Of these, the first four species represented 97% of the total catch (Lauzanne et al. 1990). However, Lauzanne et al. (1990) estimated that the fisheries of Beni are underexploited, and that the high production potential of the large, inundated floodplain could sustain harvests up to 250,000 tons of fish per year. In the larger Bolivian cities, *pacú* fetch a price of approximately $15 Bolivianos ($2.50US) per kilogram, where it is considered a highly desirable and delicious fish. In the small, river settlements of Beni, *pacú* are sold for only $3.5BS/kg ($0.58US), in contrast to $8.5BS/kg ($1.42US) for beef or wild mammal meat. This makes *pacú* an economical and nutritious source of protein for poor residents of communities located far from large regional markets.

Local Fishing Technology

Pacú in Bella Vista primarily were caught using malladeras (gill nets) of 12-22 cm stretched mesh size, suspended with buoys and placed for a period of 1-2 days along the entrances to *bahias* (backwater bays known for good fish reproduction) on the San Martín and Blanco rivers. Gill nets of 25, 50, or 70 m length and 2.5 m width have been the most popular technology used to fish *pacú* in the Amazon Basin since the 1960s, when more durable synthetic line replaced nets made of cotton and natural fibers (Araujo-Lima and Goulding 1997, Smith 1981). The cost for a new 22 cm mesh, 70 m long *malladera* is $800BS, or about $133US.

Another fishing technology used for *pacú* is the *espinel* (trotline), upon which smaller individual lines with *anzuelos* (hooks) are strung from buoys connected by one main line 10 to several hundred meters in length, placed in the same river locations as the gill nets. Araujo-Lima and Goulding (1997) reported that trotlines are more effective for fishing the flooded forest during the wet season. However, in Bella Vista this technique is more common during the dry season. Local restrictions are imposed during dry season months to prevent over-harvest, requiring fishermen to refrain from gill-netting but allowing them to use *espinels* and *anzuelos* set overnight instead. Consequently, *pacú* harvests are much less productive and profitable during receding waters than the harvest of other fish species using *tarrafas* (cast nets) in the shallow river currents. New cast nets cost the fisher $500BS, or about $83US, and are quite efficient in catching the large catfish *surubí,* which is also a popular commercial fish in large city markets.

Hand *anzuelos* are the most frequently utilized fishing technology during the dry season for species more easily caught than *pacú*. Rapidly receding river levels (about a 1.0-m drop) concentrates fish into narrow river channels and pools, such that the focus of fish harvest in Bella Vista during those months changed to smaller fishes. Smaller species included (local names): *tucunaré (Cichla monoculus), piau (Leporinus* sp.*), pacupeba (Mylossoma duriventre), piraña*

(Serrasalmus sp*.), sábalo (Prochilodus lineatus), bentón (Hoplias malabaricus), moshopa* (*Aequidens* sp.), *sardina (Tetragonopterus* and *Triportheus* sp*.), curubina (Plagioscion squamosissimus), sati* (unknown), *yayu (Hoplerythrinus initaeniatus), blanquillo (Pimelodina flavipinnus)*, and other fishes easily caught on the shoreline with hook and lines; as well as *buchere (Hoplosternum* sp*.)*, which is stabbed at night using hand harpoons. By September, *anzuelo* fishing was rare, and residents began looking forward to purchasing fish from primary vendors who utilize wet season gill nets to harvest *pacú*.

Contribution of Fish to the Diet of Local Residents

Residents of Bella Vista rely upon wildlife, fish, and domestic livestock to meet the daily average per capita intake of 210 g of edible meat and 100 g of edible fish that I recorded during this study. This level of fish consumption lies within the 94-130 g/day reported for foraging groups in a similar floodplain environment in the Peruvian Amazon (Hiraoka 1995). Shrimpton et al. (1979) reported a daily consumption of fish for residents of Manaus, Brazil to be 155 g (or 56.575 kg/yr) per person in 1973 and 1974, and Junk (1984b) reported a daily intake of 200 g (or 73 kgs/yr) of fresh fish per person for Brazil as a whole. Junk (1984b) also reported the per capita consumption of fish in Manaus, Brazil to be about 55 kg per year for people of low income, 50.9 kg for middle income, and 38.4 kg for high-income persons. I estimate the per capita consumption of fish (as part of the total protein diet) averages approximately 37 kg per year for low-income residents of Bella Vista, based on dietary data provided to me by sample households during the 1999 field season.

Fish represented approximately 47% of the total biomass of wild animal protein harvested and 53% of the total edible biomass of wild animal protein consumed by my sample of Bella Vista residents in 1999. If domesticated animals such as livestock and poultry are included, fish comprise 34% of the total edible biomass of animal protein consumed by residents. *Pacú* comprised 51% of the total biomass of fish harvested during the study period, accentuating its importance to the local economy and diet.

Household interviews with residents of Bella Vista after hunting and fishing excursions allowed me to tabulate the biomass yields of fishing versus hunting. The biomass yield provided per person-hour of effort was relatively high for fish (3.34 kg, vs. 0.65 kg for birds, 5.1 kg for mammals, and 5.39 kg for reptiles) during the dry season months of this study, when *pacú* harvests are at their lowest levels. Throughout the seasons, fish is an energetically efficient source of protein for poor residents of Bella Vista and other remote, river communities of the Bolivian Amazon Basin. Smith (1981) reported yields of 6.3 kg of fish per hour of foraging effort for fishermen using gill nets in Itacoatiara, Brazil. Although the harvest of fish in Bella Vista is not as large and intensive as that of Itacoatiara, it is sufficient to supply one's own family as well as provide a surplus for sale to other community members. For some residents, fishing was a principal source of income. Public announcements of fish, wildlife, and livestock available for sale in Bella Vista during this study revealed that fish, almost exclusively *pacú*, comprised 23% of the total biomass sold.

Local Pacú Catch

During my research in 1999, I documented fish harvest by nine principal groups of *pacú* fishermen, each comprised of 2-3 members. Of these, only four groups fished weekly or biweekly as a source of primary income, especially during the wet season. In the rainy season months of this project, the average catch harvested by fishermen groups in Bella Vista was 14 *pacú* per trip, whereas in the entire dry season, the average catch was eight *pacú* per trip. The average weight of a *pacú* harvested from the San Martín and the Blanco rivers near Bella Vista during the 1999 field season was measured (using a hand scale) at approximately 12 kg, while average lengths reached 72.5 cm. Most harvested *pacú* in Bella Vista ranged between 60-80 cm long, which was double the lengths reported by Araujo-Lima and Goulding (1997) for Brazilian catches during the late 1990s. The average sale weight of fillets including bone was about 2-3 kg, while a whole fish without tail, head, or entrails was sold at an average weight of 6-7 kg. The largest *pacú* harvested from March to November of 1999 was 88 cm long, which may have weighed 16-17 kg or more and could have brought up to $8.75US/kg on the Brazilian market, according to market prices provided by Araujo-Lima and Goulding (1997). In the local economy of Bella Vista, *pacú* sell for the same price regardless of size, $3.5BS/kg ($0.58US/kg).

The "snapshot" analysis of 128 pairs of otoliths taken from the Bella Vista harvest appeared to indicate age structures characteristic of a lightly exploited *pacú* population, with older age classes (25-60 yrs) well represented in the catch. Additionally, the largest proportions of individuals caught were between the ages of 10-19 yrs, which is at least a few years past reproductive maturity (see Reinert and Winter 2002). While these findings agree with research showing relatively unexploited *pacú* populations on the neighboring Mamoré River near Trinidad, Beni, (Loubens and Panfili 1997), they are insufficient to conclude that levels of exploitation in Bella Vista are sustainable or have not already significantly impacted the regional population, as has been the case for severely reduced *pacú* stocks in the central Amazon of Brazil (Bayley 1981, Issac and Ruffino 1996, Araujo-Lima and Goulding 1997). Also, no data are yet available regarding *pacú* harvests in human settlements located far downstream from Bella Vista on the Blanco River. These harvests could potentially reflect higher levels of exploitation, and should be investigated further for comparative purposes. Interviews with residents of Bella Vista in 1998 and 1999 indicated that the local *pacú* fishery has indeed noticeably declined in recent years, forcing leaders to hold town meetings to determine causation.

Threats to the *Pacú* Fishery

In some regions of the Amazon, *pacú* has been the single most important commercial fish species for several decades (Araujo-Lima and Goulding 1997). In Bolivia, the demand for large, adult *pacú* has not reached the extraordinary levels that it has in Brazil. However, the impacts of *pacú* overexploitation have expanded far into Bolivian borders by both direct (poaching, overharvests) and indirect (cattle ranching, floodplain deforestation) means. Threats to the Bolivian *pacú* fishery, and suggestions on how to diminish some of them in the proposed *Tierra Comunitaria de Origen Itonama*, will be explained in subsequent sections.

Cattle Ranching and Deforestation

Goulding et al. (1996) asserted that Amazonian flooded forests are the most threatened of all distinct rainforest types in the Amazon Basin. One of the primary driving forces of floodplain forest destruction is deforestation for cattle ranching, whereas timber extraction, cacao plantations, and agricultural production produce much smaller impacts by comparison (Goulding et al. 1996). The highly productive floodplains of whitewater rivers historically have been sites of the greatest concentrations of human settlements (Meggers 1954), but they are in many ways the most vulnerable to wide-reaching overuse and destruction. Junk (1984a) noted that degradation of nutrient-rich *várzea* soils during the dry season can have very deleterious effects on flooded *várzea* habitat in the wet season -- when they are critical habitats for fish spawning, feeding, and protection from predators. Cattle ranching is the primary antagonist in the degradation of *várzea* habitats.

Ranchers bring cattle and water buffalo down to floodplain areas to graze at the beginning of the dry season, at which time the animals begin to trample and consume shoreline vegetation, altering riverbanks and introducing large amounts of soil erosion to adjacent water bodies. Woody shore areas, which serve as low-water refuges for *pacú*, may be destroyed or compacted, forcing young *pacú* to flee into muddy tributaries in search of undisturbed habitat (Araujo-Lima and Goulding 1997). Floating meadows that normally remain in floodplain lakes and alongside rivers, providing nursery habitats for *pacú* and many other fish species (Araujo-Lima and Goulding 1997), are rapidly consumed by the cattle, leaving young fish without adequate protection and food to develop into the next growing stage. A single cow or water buffalo can destroy more than 0.01 km^2 of floating meadow in 2-3 months of grazing (Araujo-Lima and Goulding 1997), thereby altering fish habitats and destroying habitat for both aquatic and terrestrial flora and fauna. After woody shores and floating meadows are decimated, the cattle or water buffalo are moved to yet another recently deforested grazing area to begin anew the cycle of destruction. As a result, large-scale ranching has been described as the greatest threat to the diverse fisheries of the Amazonian floodplain, which are its primary economic resource (Goulding et al. 1996).

The *pacú* fishery in the proposed *Tierra Comunitaria de Origen Itonama* faces the imminent threat of habitat destruction through cattle ranching to the west, east, and south of Bella Vista, both within and outside of the boundaries of the proposed territory. The town of Magdalena is only 45 km west of Bella Vista, and was founded by the Jesuits in 1720 as a mission outpost. Between Magdalena and Bella Vista lies approximately 180 km^2 of savanna and *várzea* habitat that extends from the TCOI's northern border with Brazil to its southern limit at Magdalena. The Itonamas River on the western side of this strip is almost entirely inhabited by ranches and small riverine communities, and the floodplain savanna is burned late in the dry season to create lush pastures for cattle when the rains begin in the wet season. The major source of income for residents of Magdalena comes from cattle ranching on floodplains, stretching as far away as the city of Trinidad, 220 km to the southwest. Fish harvests in the Itonamas River adjacent to Magdalena are poor and unproductive, and livestock such as cattle, chickens, and pigs are the principal sources of animal protein for its inhabitants. Harvests of *pacú* are rare to fishers of the Itonamas River.

The same pattern is created to the south and southeast of Bella Vista, just outside the border of the TCOI on the other side of the San Martín River. Cattle ranches are common, and large expanses of *várzea* and associated floodplains are widely used by ranchers, who later transport their cattle by truck or by foot to markets in Santa Cruz. Wherever floodplain exists in the TCOI, it has the potential for use in cattle production, and will threaten the *pacú* fishery for both the local human population as well as commercial fisheries throughout the Amazon region.

The floodplains of the TCOI lie adjacent to the San Martín, Blanco, and Itonamas Rivers, and their conservation as source habitats for the *pacú* and other important fish species should become a management priority in the future TCOI. These habitats are not only important to fisheries, but also to the plant and animal species that are unique to them. *Várzea* habitats must be protected during both wet and dry seasons, in order to afford protection to the flora and fauna that exploit them seasonally as well as year-round. Many *várzea* plants, such as the rubber tree and many species of palm (Palmae), are important not only to fish such as the *pacú*, but also serve as food for terrestrial wildlife and as a source of income and subsistence for the human population.

Poaching

As mentioned in previous sections, *pacú* have suffered overexploitation in many parts of Brazil, driving market prices to extraordinary levels and leaving a stock population comprised mostly of juveniles. In desperation, Brazilian fishermen have turned to Amazonian tributaries holding source populations of *pacú* in Bolivia, engaging in poaching of adult *pacú* in the states of Beni and Pando (Sarmiento 1998, Chernoff et al. 2000). However, poaching activities will only serve to further exhaust this precious fish resource for both countries if proactive management steps are not taken to prevent its demise.

The illegal harvest of *pacú* by Brazilians inside the proposed *Tierra Comunitaria de Origen Itonama* occurs mostly via the Guaporé River, which borders Brazil and Bolivia in the states of Beni and Pando. Previously, Brazilians entered the proposed TCOI by boat, traveling upriver down the Guaporé (Itenez) River to the whitewater Blanco River, and onward to the east from Bella Vista on the blackwater San Martín River. However, covert Brazilian fishermen have in the last few years entered the TCOI by airplane, traveling at least 90 km by air (about 5 days by boat) south of the Brazilian border to Bella Vista and beyond. Upriver to the east by boat (about 160 km) or airplane on the San Martín from Bella Vista, Brazilians can harvest a virtually unexploited population of *pacú*, since approximately 10 small human settlements and cattle ranches occur between Bella Vista and the eastern border of the TCOI.

On 12 January 1999, exasperated town leaders of Bella Vista confiscated a Brazilian fishing boat and all of its equipment at the port of Bella Vista in order to halt the illegal catch of *pacú* in their waters. They then demanded $10,000US in fines to return the equipment to the

Brazilian owner. In response, Brazilian fishermen now sneak into the proposed TCOI by air to harvest their catch of *pacú* clandestinely, flying upriver over the San Martín River to the airstrip of a struggling and virtually abandoned ecotourism site known as "Piraña," located halfway between Bella Vista and the easternmost boundary of the TCOI. Their activities have not gone unnoticed by residents of Bella Vista, and residents have reported spotting the Brazilians upriver on the San Martín during hunting and fishing excursions and wet season harvest of Brazil nuts upriver from Piraña. Town leaders have in the past unsuccessfully requested government and non-government institutions to assist them in the protection of their fish resources, however their physical isolation from the city of Trinidad and lack of an adequate communication infrastructure have made attempts to protect their natural resources difficult.

At the end of May 1999, representatives of the United Nations Educational, Scientific, and Cultural Organization, (UNESCO), arrived in Bella Vista to propose the designation of the region as an international ecological reserve under the Man and the Biosphere Program. Some town leaders with cattle ranches upstream contested UNESCO's proposal, fearing that they would no longer be allowed to continue to exploit the region's natural resources without enforcement of Bolivia's environmental laws. However, the leadership of Bella Vista has since collaborated with UNESCO, resulting in training and installation of several "river guards" on the San Martín and Blanco rivers (HYNB 2000). This collaboration continues to progress, but will require even more proactive conservation through government titling of the *Tierra Comunitaria de Origen Itonama*, and additional funding for the development of a natural resource management program, in order to be effective for conservation of the *pacú* fishery in this region.

Pacú Fishery Management

The *pacú* fishery in the proposed *Tierra Comunitaria de Origen Itonama* has been only modestly managed since its origins. As a consequence, the fishery is highly vulnerable to overexploitation, poaching, deforestation, and any other new threats that may present themselves. Regulation of the fishery has occurred haphazardly. State gill net regulations are presented to fishermen by local authorities, and they are ordered to change their practices only when it becomes reasonably evident that individual fishermen are marketing more *pacú* than normal. Brazilian fishermen continued to poach *pacú* upstream on the San Martín River for over 2 years before Bella Vista's leaders confiscated their equipment. Even in that case, the equipment remained in storage for over 6 months without resolution of the problem. Poachers responded by flying over the San Martín River by airplane to load their harvest of *pacú* without repercussions from local authorities. Residents of the TCOI have gained nothing, and they have been powerless to create and enforce laws to protect their natural resources under the current political structure.

Another management dilemma is faced when residents of Bella Vista sell surplus *pacú* to middlemen, who transport them to markets in Santa Cruz that sell *pacú* for up to 20BS/kg. Local authorities in 1999 expressed their chagrin at the extraction of local natural resources, and feared the creation of demand-based pricing of the *pacú* fishery. However, if a group of fishermen can demand much more than the local price of 3.5BS/kg of *pacú* from outsiders, there is little incentive for them to continue to provide fish at the lower price on the local market. Also, residents of Bella Vista, without clear ownership of faunal resources, have little reason to avoid overexploiting the abundant *pacú* fishery on the San Martín and Blanco Rivers. These are questions that must be addressed to protect the *pacú* fishery, and the local human population that depends upon it, during the process of titling the TCOI.

Political and economic forces are the greatest threats to the *pacú* fishery in the TCOI. Deforestation and destruction of *pacú* habitats driven by cattle ranching, overexploitation, poaching, and the lack of research, monitoring, and enforcement of a management plan for *pacú* in the TCOI can only point to the ultimate demise of the Bolivian *pacú* fishery, as has already been documented in Brazil. In the following discussion, I will propose some suggestions to sustain a more politically, economically, and ecologically positive future for Bolivian fisheries such as that of the *pacú*.

Discussion: Management Implications and Conservation of *Pacú* as an Aquatic Resource

Fish Reserves

Some authors have proposed alternatives to the current exploitation of *pacú* and the associated Amazonian flooded forests and floodplains that would provide opportunities to maintain populations of *pacú* at healthy and sustainable levels. The first and most ideal alternative would be the creation of "fish reserves" along the floodplains and rivers to protect *pacú* in habitats that are critical for reproduction and recruitment (Araujo-Lima and Goulding 1997, Chernoff et al. 2000). Over 400 km of the San Martín and Blanco rivers will be enclosed by the future boundaries of the *Tierra Comunitaria de Origen Itonama*, and although almost all human settlements are located along the rivers of the TCOI, certain areas could be easily zoned as fish reserves to be protected from development activities. These zones would be of special consideration for protection from cattle ranches, which are often located in slow-moving *bahia* backwaters because of the ease in which cattle may be loaded and unloaded from boats, and for the presence of aquatic vegetation and floating meadows for feeding. Fish reserves would protect the area's overall terrestrial and aquatic biodiversity, and would help populations of other migratory fishes throughout the rivers and tributaries of the Amazon Basin (Araujo-Lima and Goulding 1997).

A consideration for other migratory fishes as well, *pacú* reserves would need to incorporate spawning areas, nursery habitats, and feeding habitats for adults, and be flexible to seasonal movements related to fluctuations in water levels (Goulding et al. 1996). In the originally proposed TCOI, all the rivers and river types would be included as pacu habitat, as well as backwaters and bogs, flooded forests, and patches of fruit and seed-producing trees that are used by *pacú*. These swampy habitats and associated flora would enhance production of a number of fish species, as well as terrestrial wildlife that are preferred by local residents, including the Brazilian tapir *(Tapirus terrestris)*, spotted paca *(Agouti paca),* white-lipped peccary *(Tayassu pecari),* collared peccary *(Tayassu tajacu),* and large avifauna such as curassows (*Crax* sp.).

Fish Weirs and Mixed Fruit Orchards

In the nearby region of Baures just south of Bella Vista, investigators have discovered an estimated 1,515 km of fish weirs constructed of land ridges 1-2 m wide and 20-50 cm tall that traditionally were used to capture fish as floodwaters rose and fell (Erickson 2000, Mann 2000). Erickson (2000) suggested that the ponds created by the land barriers, which were abandoned around 1700, could have yielded about 1000 kg of fish per year in addition to producing large edible snails. Palms growing along the earthwork tops could have provided food, textiles, and building material, as well as serving as forage for wildlife and fish such as *pacú* (Erickson 2000).

The historical precedent for constructing areas specifically for fish production could be expanded to include mixed-fruit "fish orchards" on floodplains and upland forests (Araujo-Lima and Goulding 1997). These orchards would produce fruits for both human and fish consumption, providing economic benefits both through sales of the fruits themselves, and through *pacú* farming (Araujo-Lima and Goulding 1997). An additional advantage of fish farming is that it would use swampy areas inappropriate to agriculture and livestock production, and would not compete with those activities for land space (Junk 1984b). The areas could also serve as food plots for terrestrial wildlife. Junk (1984b) noted that, "whereas cattle-raising in the Amazon leads to extensive deforestation and environmental degradation, fish culture renders higher yields and has less impact on water and nutrient cycles than agriculture and animal husbandry." Since a variety of fruits are already cultivated as cash crops throughout the TCOI (HYNB 2000), this alternative may be more economically and ecologically feasible than current extractive activities in the region.

Government Incentives

Although cattle ranching has been encouraged and subsidized by the Brazilian government as an income-producing activity for residents of the Amazon floodplains, the last 20 years of resulting environmental destruction with little input to local economies have proven that the environmental costs are not worth the economic benefits of this activity. The Bolivian government also encourages development of its vast Amazonian frontier, although subsidies and other economic incentives have not been available due to a poor economy. In sharp contrast to cattle ranching, several centuries of fishing activity in the Amazon Basin have provided protein and income to all residents of the region, both rural and urban, young and old, poor and rich, without degrading either the rivers and surrounding environment or the populations of fishes themselves. The over-harvested Amazonian fisheries and coinciding degradation of important fish habitat in recent years alerts us to the devaluation of this natural resource provided for free by the Amazonian floodplains, and to the importance of actively managing it to sustain the demand for fish. Goulding et al. (1996) note that fish is the most valuable of all aquatic and floodplain resources harvested in the Amazon Basin, whether one considers rural peasants, small communities, urban centers, states, or the federal government. The *pacú* may be the first rainforest animal with the potential to out-produce cattle ranching (Araujo-Lima and Goulding 1997), providing we take steps today to manage and conserve the *pacú* fishery throughout its range. The Bolivian government can promote conservation of the fishery by discouraging cattle development in and near the TCOI, and by providing financial, logistical, and legal support for protection of fish and other aquatic resources.

Active and Adaptable Management

Residents of the *Tierra Comunitaria de Origen Itonama* and other areas of the Bolivian floodplains need to view the *pacú* as an economically important resource worthy of protection and active management. They can no longer merely react to incursions from outsiders such as Brazilian fishermen, cattle ranchers, and unethical middlemen, standing by as their *pacú* fishery is threatened. They can help to sustain *pacú* populations and their own demands for fish by maintaining stable local prices, while creating higher prices to outsiders and middlemen. They can also form a cooperative among resident fishermen to provide economic incentives for protection of the *pacú* fishery in Bella Vista and throughout the TCOI, using sound scientific monitoring of the *pacú* population and enforceable regulations.

Goulding et al. (1996) recognized the importance of a habitat component to a management plan for *pacú*. A variety of habitats must be considered in the management plan, based on sound ecological studies of the *pacú* throughout its range. Because of the large area encompassed by *pacú* migrations, management must include collaboration with inter-regional networks, with size and catch limits jointly set by different communities. Management must include a framework for habitat protection throughout the range of the *pacú*, be continuously updated and adapted to changing conditions, and have an objective and effective enforcement unit. Cooperative participation with UNESCO in the TCOI, as well as with local, regional, and state government and indigenous organizations, will serve critical roles in the protection of the *pacú* fishery in the TCOI, and communication between these parties must be encouraged.

Pacú as an Indicator Species

Fish populations in the Amazon – especially *pacú* with its diverse seasonal, geographical, and physical characteristics – can serve as an indicator species for the health of lowland Amazonian watersheds (Goulding et al. 1996). Araujo-Lima and Goulding (1997) asserted that, "dominating the big end of the 'nut-niche' linked to floodplain rainforests, the *pacú* is as much an evolutionary product of the rainforest as a fruit-eating monkey or bird." The *pacú* exploits a great variety of food sources and habitats throughout its lifetime, and degradation of those natural resources through farming, cattle ranching, logging, and over-harvest of *pacú* in particular, have resulted in drastic declines of this important fish resource in other parts of the Amazon Basin. The many roles that the *pacú* plays for floodplain ecosystems during its unique life history (as seed disperser, source of food and income, and indicator species for river health), stress the importance of further research and protection of this species for its own conservation as well as that of other floral and faunal resources throughout the Amazon.

Conclusion

Bolivia is the last frontier for many unique ecosystems in South America, and this is especially true for its vast expanses of undeveloped tropical savanna and flooded forests. When surrounding countries expend their own natural resources, they soon turn to Bolivia's bounty. Bolivians must be prepared to meet the challenge to maintain the incredible biodiversity of their floral and faunal resources through proactive management and conservation, while holding onto a vision of the future. The *pacú* fishery is one symbol of this struggle in the lowland Amazon Basin of Bolivia, and through increased research, protection, and management in the *Tierra Comunitaria de Origen Itonama*, proactive conservation of aquatic resources such as the *pacú* and its associated habitats may become a model for protecting other Amazonian ecosystems.

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CHAPTER 7

SYNTHESIS AND MANAGEMENT IMPLICATIONS FOR THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA*

Introduction

In this dissertation, I have presented preliminary data regarding hunting and fishing activities in only one settlement, Bella Vista, of the *Tierra Comunitaria de Origen Itonama* (TCOI) of Beni, Bolivia. Although the ecological and socioeconomic characteristics of Bella Vista were representative of other settlements in the TCOI, comprehensive assessments of natural resource use throughout the TCOI should be undertaken in order to create a more accurate and applicable management plan. These assessments should include the effects of temporal factors such as seasonality (wet and dry season); spatial factors such as access to transportation conduits (rivers, roads, airports), differential access during periods of flooding or drought, and proximity to human developments or national boundaries; habitat differences (forest versus savanna), river types (whitewater, blackwater, and clearwater); human population density; development and extractive activities (timber, palm heart harvest, cattle ranching, pasture burning, forest clearing, agriculture); and source-sink dynamics between animal populations in developed and undeveloped areas of the TCOI.

Comprehensive, collaborative studies by a team of scientists and local leaders could provide critical information regarding land and water use, animal population dynamics, and socioeconomic factors that will affect management of the TCOI. UNESCO's Man and the Biosphere Program provided a year 2000 project report (HYNB 2000) for the Itenez National Forest Reserve *(Reserva Forestal Itenez)* that should supplement this dissertation for initial data about the TCOI. A preliminary management framework should be implemented as soon as possible, to ensure that natural resources are considered and protected during the lengthy process of territorial designation. The framework should include local participation to establish management priorities, recognizing the human behavioral motivators for hunting particular species over others, and ways in which local residents are willing to modify their behavior if over-harvests of certain populations are indicated. Further research on species important to subsistence should provide improved estimates of density, abundance, and encounter rates during both wet and dry seasons. Because fish have been indicated as important sources of animal protein in the TCOI, management of aquatic environments will be integral to sustaining fish populations.

Adaptive management of the TCOI will incorporate data uncertainty, test preliminary hypotheses concerning subsistence use of animal populations, be flexible to changing parameters, and be based on scientific methodologies and techniques provided by continuing studies in the region (Holling 1978, Conroy and Smith 1994, Ellison 1996, Lancia et al. 1996). New data can help managers update initial models and provide guidance for developing management goals, monitoring harvests, and providing the scale at which management must be applied (Williams et al. 2002). These initial stages in developing management protocol for the TCOI must incorporate ideas such as optimal foraging and the economic forces that drive harvest of animal populations, as well as other issues such as development and cattle ranching discussed in this dissertation. A synthesis of the dissertation and additional recommendations follow.

Chapter Synthesis

In Chapter 4, I discussed the relationship between local knowledge of prey populations, perceptions of animal abundance that motivate subsistence hunters to pursue certain species over others, and animal surveys on transects. Eight prey preference categories were created so that animal population monitoring can focus on the species facing greater harvest demand and possible depletion. Large mammals, especially ungulates and xenarths, were considered the most important prey groups for human subsistence. Preferred species included collared peccary, white-lipped peccary, marsh deer, red brocket deer, gray brocket deer, Brazilian tapir, spotted paca, brown agouti, long-nosed nine-banded armadillo, and giant armadillo. Of the preferred species, white-lipped peccary are transient prey as a result of biannual migrations through the area. Marsh deer and tapir are specific to particular habitats, including savanna and wetlands respectively, that are located far from developed areas upstream from Bella Vista near the San Martín and Blanco rivers. Specific protection of undeveloped source habitats and active monitoring and regulation of hunter harvests will directly determine the future viability of populations of these three prey species, as is true to a lesser degree for all other prey.

Another management concern is harvest regulation and monitoring for species such as the giant armadillo and the gray brocket deer, which are considered locally rare but are still actively pursued by hunters. Since hunting activities are somewhat opportunistic, it will be difficult to oblige hunters to forego capture opportunities of these preferred species simply for the benefit of the animal populations. However, collaborative efforts and monitoring between hunter groups and managers, involving incentives and protection of prey resources from poachers, could encourage hunter cooperation. Alternatives to overexploitation of particular prey could include habitat enhancement for other preferred species, food plots, and captive-rearing; or switching diet emphasis to small-scale domestic animals such as pigs, chickens, and ducks. Regardless of the method employed, systematic studies of prey animal population dynamics must occur and participatory management should be initiated in the TCOI to protect animal resources for local subsistence.

I also evaluated the results of nocturnal and diurnal transect surveys in the hunting catchment of Bella Vista. Direct encounters with avian and mammalian species were almost equivalent in number. However, encounters with avian prey predominated in diurnal surveys and mammalian prey were encountered in greater proportions than birds during nocturnal surveys. Non-prey mammals were encountered in equal proportions during either diurnal or nocturnal surveys. The results of analyses using program DISTANCE version 3.5 (Thomas et al. 1998) indicated that prey birds are found in significantly higher densities than mammals, reflecting that opportunism drives hunters to harvest birds in large numbers, despite the fact that mammals are the preferred prey group of terrestrial fauna and contribute more biomass to the overall harvest. A diagrammatic model of hunting options may help to guide harvest management in the TCOI.

In Chapter 5, I compared local dependence on wild terrestrial, aquatic, and domestic fauna for subsistence and economic purposes, as exemplified by hunting and fishing activity reports, diet calendars, and market announcements. Fish was the most important faunal resource to residents of Bella Vista, both in number and biomass harvested and consumed, and was the most economical foraging option. Fish also comprised the greatest proportion of the local market of animal protein by number offered for sale, although in biomass livestock was proportionately higher. Mammals contributed a significant portion of the wild-caught harvest, consumption of animal protein in the local diet, and sale of meat at the Bella Vista market. Protective measures should be encouraged for source habitats such as savanna for marsh deer, and swampy areas that are suitable for fish nurseries and tapirs. Food plots could be created and maintained at low costs for other important species such as spotted paca, brocket deer, and peccaries. The relatively unregulated capture, consumption, and sale of river turtles and turtle eggs are a particular cause of concern in Bella Vista and the TCOI in general, because they are taken in considerably high numbers and populations have been noticeably depleted for several years without active management for their protection.

The importance of fish and associated aquatic habitats, especially for an indicator species known locally as the *pacú (Colossoma macropomum),* is discussed in Chapter 6. Monitoring and vigilance throughout the river systems of the TCOI to protect *pacú*, river turtles, and aquatic habitats will help to sustain these resources and the human populations that depend upon them both nutritionally and economically. In addition to harvest, the aquatic resources of the TCOI are vulnerable to habitat destruction and degradation caused by cattle ranching, forest clearing, and agriculture.

Chapters 5 and 6 demonstrate that cattle production is not a viable activity in the long term for residents of the TCOI, either for producing income or as a source of animal protein. As an income producer, cattle production benefits a few ranchers and temporary employees, while destroying large areas of potential wildlife habitat and polluting rivers. As a source of animal protein, cattle produce a high volume of biomass, but at an unsustainable cost. Active management of wild animal populations, source habitat protection and enhancement, and small-scale rearing of domestic animals would much better serve the human, wildlife, and fish inhabitants of the TCOI. In the year 2000, UNESCO's Man and the Biosphere Program in Bolivia began training river guards to patrol the river systems of the TCOI to prevent poaching and to better guard the aquatic resources of the TCOI (HYNB 2000). The UNESCO vigilance program should be supplemented by participatory environmental education, implementation of adaptive management regimes, and on-going research throughout the TCOI.

The majority of fieldwork for this study occurred during the dry season, with the starting date occurring during the transition months from wet to dry, and the ending date at the beginning of the new wet season. The reader should bear this in mind when interpreting the results of this research, since during the wet season, hunting and fishing and other extractive activities may assume different levels of importance to local residents than what was represented during the dry season from March to November of 1999. The conclusions and recommendations in this dissertation are products of one field season, and are intended to stimulate further conservation-minded investigations into the cultural and biological resources of the TCOI.

Conclusion

In this dissertation, I have discussed interconnected topics related to holistically managing the faunal resources of the TCOI. Active, participatory, and adaptable management of the natural resources of the TCOI will determine the survival of not only resident populations of wildlife and fish, but of the human inhabitants as well. Although it is human nature to extinguish local resources only to continue searching for less-exploited areas to fulfill our increasing demands, it is increasingly evident that the Earth is becoming an exhaustible resource for humankind. Unregulated exploitation of natural resources threatens the cultures inspired by local environments, the subsistence of human and animal populations, and our very existence as a species. The fundamental message for managing the natural resources of the TCOI is thus a universal recommendation for every inhabitant of the planet Earth: tread lightly, manage wisely, and respect Nature for the benefit of us all.

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APPENDIX A

HUNTER INTERVIEW QUESTIONS (IN ENGLISH)

Questions for Initial Interviews with Hunters (March 1999)

1. Interviewer
2. Date
3. Location
4. Name of person interviewed
5. Age
6. Sex
7. Permanent residence
8. Length of stay at this residence
9. Previous residence
10. Birthplace
11. Employment
12. Number of members in household
13. Number of hunters/fishers in household
14. Names
15. Ages
16. Can we interview them?
17. Can you show me (in photographs) which mammals, birds, and fish you catch?
18. Can you think of others that aren't represented in these examples?
19. Can you order these photographs according to the frequency in which you hunt the animals or capture the fish? (frequently, sometimes, rarely)
20. Why did you put them in these categories? (more easily caught, greater densities and/or abundance, more delicious meat, etc.)
21. Are there certain times of year in which you hunt/fish each species? (re-class the photos according to season)
22. Where do you find these animals? (macrohabitats)
23. In what type of habitats/vegetation/parts of the river could you find these animals? (in the river, forest, plain, savanna, flooded areas, etc.)
24. How many times per week/month do you go hunting/fishing?
25. How many hours/days do you spend for a hunting/fishing trip?
26. What firearms/technology do you use to hunt/fish?
27. Can you order these photographs according to the animals/fish you prefer to hunt/fish?
28. Why?
29. What do you do with the animal? (Eat it? Sell it? Sell its skin? Where? Use it as medicine?)
30. How far do you travel to find them, normally?
31. Where are they?
32. Are there times when these animals are not abundant?
33. When?
34. When the animals are not available, do you travel farther to find them?
35. (Yes) How far/to where?

36. (No) What do you do? Buy meat?
37. Alternatively, do you hunt a different type of animal?
38. What?
39. Where can you find this animal?
40. Why do you hunt/fish?
41. Have you noticed changes in the abundance of some animals in recent years?
42. What do you think has caused these changes?
43. How would you change this situation, if you could? Suggestions?
44. Could you notify me the next time you come home with a catch?
45. Could you preserve the skulls of the prey you capture?
46. Could we set a regular schedule to do interviews?

HUNTER INTERVIEW QUESTIONS (IN SPANISH)

Preguntas para Entrevistas Iniciales por Cazadores (Marzo de 1999)

1. Entrevistador
2. Fecha
3. Localidad
4. Nombre de la persona entrevistada
5. Edad
6. Sexo
7. Residencia permanente
8. Duracion de presencia en esta residencia
9. Residencia anterior
10. Lugar del nacimiento
11. Empleo
12. Número de miembros en casa
13. Número de cazadores/ pescadores en casa
14. Nombres
15. Edades
16. ¿Podemos entrevistar con ellos?
17. ¿Puede mostrarme (de fotografías) qué mamíferos, pájaros, y pez capturan?
18. ¿Puede pensar en otros que no estan representados en estas muestras?
19. ¿Puede ordenar estas fotografías según de que frecuencia se cazan los animales/ pescan los peces? (frecuentemente, a veces, raramente)
20. ¿Porqué los puso en estas categorías?
    (más fácil cazar, más densidades y/o abundancia, carne más sabrosa, etc.)
21. ¿Hay ciertos tiempos del año en que se caza/pesca cada especie?
    (re-clase las fotografías según su temporada)
22. ¿Dónde se halla estos animales? (macrohabitats)
23. ¿En qué tipos de habitats/vegetación/partes del río se puede encontrar estos animales?
    (al rio, bosque, pantano, sabana, areas inundadas etc.)
24. ¿Cuántos veces por semana/mes va usted a cazar/pescar?
25. ¿Cuántas horas/días gasta por un viaje a cazar/pescar?
26. ¿Qué armas/ tecnología usa para cazar/ pescar?
27. ¿Puede ordenar estas fotografías según los animales/peces que prefiere cazar/pescar?
28. ¿Porqué?
29. ¿Qué hace con el animal? (¿Lo come? ¿Lo vende? ¿Vende la piel? ¿Dónde? Lo usa como una medicina?)
30. ¿Hasta donde viaja para hallarlos normalmente?
31. ¿Dónde se localizan?
32. ¿Hay tiempos cuando estos animales no son abundantes?
33. ¿Cuándo?
34. ¿Cuando los animales no están disponibles, viaja más lejos para buscarlos?
35. ¿ (Sí) Que distancia/a dónde?
36. ¿ (Ninguno) Qué hace? ¿Compra carne?
37. ¿Caso contrario, caza otro tipo de animal?
38. ¿Qué?
39. ¿Dónde puede hallar este animal?
40. ¿Porqué usted realiza la caza/pesca?
41. ¿Se ha dado cuenta de cambios en la abundancia de algunos animales en los años recientes?
42. ¿Qué piensa que ha causado éstos cambios?

43. ¿Cómo cambiaría esta situación, si podía? ¿Sugerencias?
44. ¿Podría notificarme el próximo tiempo que viene al hogar con una captura?
45. ¿Puede preservar los cráneos de la presa que coge?
46. ¿Podemos instalar un horario regular para hacer entrevistas?

APPENDIX B

SAMPLE OF HUNTING ACTIVITY REPORT SHEET

Información de Sus Actividades de Caza y Pesca

Nombre de la Familia/Participante: ______________________________

Fecha	Nombre(s) de los cazadores /pescadores	Cuantas personas?	Proposito del viaje (cazar, pescar, sacar madera, ir al chaco, etc)	Cuantos horas o dias ha gastado en su viaje?	Transporte usado (a pie, canoa, motor, bicicleta)	Otros animals encontrados pero no matados	Nombre del animal matado	Cuantos matados?	Tecnica (.22 salon, anzuelo, etc.)	Lugar (sitio)	Sexo H/M	Madurez (adulto, joven)	Tenia huevos o cria?	Vendido o consumo personal?

APPENDIX C

ESTIMATED AVERAGE WEIGHTS FOR FISH AND WILDLIFE SPECIES IN THE TCOI

Species	Local Common Name	English Name	Average Estimated Weight (kgs)
Fish			
Hoplias malabaricus	Benton	Tiger fish	1
Pimelodina flavipinnus	Blanquillo	(catfish)	0.5
Hoplosternum sp.	Buchere	Hoplos	1
Plagioscion squamosissimus	Curubina	Corvina	0.5
(unknown)	Dorado	(unknown)	2
(*Aequidens* sp.)	Moshopa	(unknown)	0.1
Colossoma macropomum	Pacú	Pacu, tambaqui	11
Mylossoma duriventre	Pacupeba	Silver dollar fish	0.25
Megalodoras irwini	Peshijabon/tachaca	(catfish)	0.1
Leporinus sp.	Piau	(unknown)	0.1
Serrasalmus sp.	Piraña	Pirana	0.25
Piaractus brachypomus	Pirapitinga	Red belly or red pacu	10
Prochilodus sp.	Sábalo	Sábalo	0.25
Characidae	Sardina	Sardine	0.1
Pellona sp.	Sardinon	Sardine	0.1
(unknown)	Sati	(unknown)	0.25
Pseudoplatystoma fasciatum	Surubí	Tiger catfish	1.5
Cichla monoculus	Tucunaré	Peacock bass	1.5
Hoplerythrinus initaeniatus	Yayu	Yellow aimara	0.25
Mammals			
Tapiris terrestris	Anta	Brazilian tapir	150
Tayassu pecari	Puerco de tropa	White lipped peccary	29
Tayassu tajacu	Taitetú	Collared peccary	19
Blastocerus dichotomus	Ciervo	Marsh deer	80
Mazama americana	Huaso	Red brocket deer	28
Mazama gouazoubira	Hurina	Gray brocket deer	18
Agouti paca	Jochi pintado	Spotted paca	8
Dasyprocta variegata	Jochi colorado	Brown agouti	4
Ateles paniscus	Mono negro, araña	Black spider monkey	8
Dasypus novemcinctus	Tatú	Nine-banded armadillo	4
Priodontes maximus	Tatú 15 kgs, Tatú canasto	Giant armadillo	30
Nasua nasua	Tejón	South American coati	4
Sciurus spadiceus	Masi, ardilla	Bolivian squirrel	0.5
Panthera onca	Jaguar	Jaguar	70

(continued)

Species	Local Common Name	English Name	Average Estimated Weight (kgs)
Bos sp.	Carne de res	Zebu and Brahman cow	200
Bubalus sp.	Bufalo	Water buffalo	200
Ovis aries	Obeja	Sheep	
Sus domesticus	Puerco/chancho	Pig	25
Birds			
Gallus sp.	Pollo	Chicken	2
Anatidae	Pato	Duck	2
Mitu tuberosa	Mutún	Razor-billed curassow	3.5
Penelope sp.	Pava cotocolorada	(guan)	0.75
Tinamus/Crypturellus	Perdiz	(tinamou)	0.75
Columbidae	Torcasa	(doves, pigeons)	0.25
Reptiles			
Podocnemis unifilis	Peta	(river turtle)	8
Podocnemis expansa	Tataruga	(river turtle)	20
Geochelone sp.	Peta del monte	(land tortoise)	5

Biomass of flesh rendered from fish and game:

Fish	=	33%
Mammals	=	60%
Birds	=	40%
Turtles	=	25%

APPENDIX D

ETHNIC IDENTITY AND CONFLICT IN DESIGNATING THE *TIERRA COMUNITARIA DE ORIGEN ITONAMA*, (TCOI)

The struggle for territorial designation of the TCOI began in 1996, when representatives of the *Subcentral de Pueblos Indigenas Itonamas* (SCPII) of Magdalena presented a solicitation to the national government of Bolivia for the *Tierra Comunitaria de Origen Itonama*. The solicitation was signed by 64 residents of the region, who then waited for government institutions such as the *Viceministerio de Asuntos Indigenas y Pueblos Originarios* (VAIPO) and the *Instituto Nacional de la Reforma Agraria* (INRA) to conduct preliminary studies of the area's ecological, social, economic, cultural, and geographical characteristics for designation purposes. In August of 1999, land reform officials from the INRA arrived in Bella Vista to begin a public information campaign that included information gathering and land titling within the demanded territory of the TCOI. Their request that residents of Bella Vista decide whether to be referred to as "indigenous" or "peasant" for classification purposes unwittingly spurned a town conflict based on fear that development and progress would be usurped by a movement to return to the bow and arrow nomadic lifestyle of indigenous peoples in the region 100 years prior (eg., such as that illustrated by Denevan's 1966 manuscript "Nomads of the Long Bow" for the Sirionó).

In early 1999, Bella Vista appeared to be a peaceful, rural town comprised of people apathetic to the outside world and content with their frontier-like lifestyles. The arrival of the INRA representatives in late 1999 ruptured the fabric of friendly social relations and created an undercurrent of aggression and ethnic self-denial among residents based on the issue of ethnic identity. Although the majority of residents could trace their indigenous roots to neighboring tribes within the last 50 years, identification with indigenous ethnicity in this region was burdened with stereotypes of half-clothed "savages" later enculturated by Jesuit missionaries. Some individuals embraced their cultural history and joined local and regional indigenous confederations, while others denigrated the persistence of indigenous ethnicity, fearing that it would draw them into a lower social status despite their education, wealth, and position in society.

Fears from town authorities, especially wealthier landowners and cattle ranchers who until that time had not been forced to pay taxes for land use in the region, motivated them to petition representatives in the departmental capital to halt further assessment of the region as an indigenous territory. The president of the local civic committee was the primary antagonist in that endeavor. He searched for allies and provided misinformation to residents to stir them further into conflict. Although his mother was of Itonama indigenous roots and he intended to create a written history of the region’s culture, the civic president believed that to claim indigenous heritage was to throw oneself into the pit of discrimination and stifled development suffered by indigenous peoples throughout South America (pers. comm.). He ordered high school students to identify themselves as "indigenous" or "peasant" on several copies of a petition against indigenous designation that was sent to the national government (he claimed over 1000 signatures were gathered). Students who signed "indigenous" were derided by their fellow classmates.

Town meetings in which the topic of territorial designation was only discussed in disfavor resulted in rumor-spreading throughout the town, resulting in an explosion of aggressivity and discontent. Many asserted that they would banish the president and vice-president of the indigenous *Cabildo*, as well as myself due to my association with them, if the INRA persisted in geographically surveying the area as an indigenous territory. My intervention in the form of pleas that they reserve decision-making and conflict until they were informed of the advantages and disadvantages of either option were at first met with agreement. Soon afterwards however, town gossip placed me in the middle of the conflict with rumors that I was in favor of the indigenous designation, stood to benefit financially from the decision, came there as an assessor, worked for their government, was a spy, wanted to keep poor people from progressing, photographed people so I could claim they are indians, and/or should have otherwise stayed away from the issue. The last option was the most difficult to adhere to due to: a) my position as an invited researcher working for the benefit of those who demanded this area as a territory, b) my need to respond to the aggressive rumors and discrimination against me as a foreigner, and c) because much of the information that they needed to know about land reform was in my field library. In the end, I made a public offer of access to the books and information packets that I possessed concerning land reform, I finished the last few months of my animal surveys, and I presented some preliminary results in a public forum to alleviate local suspicions. Many residents apologized for their own behavior and that of their neighbors after seeing the presentation, and welcomed me back to the town for future projects.

In October of 1999, a small group of protesters rallied at the river port using firearms to block representatives of the INRA from traveling upriver to take geographic points for mapping purposes. On the same day, the indigenous president was forced at gunpoint into the mayor's office to witness the protests of the angry mob against representatives of the INRA. A lawyer from the INRA informed the mob that if surveyors were not allowed upriver at that time, individual residents would be required to pay for their own land surveys and titling. A compromise was met, requiring that non-indigenous residents of Bella Vista accompany the INRA surveyors on their trips. Only 4 days after the meeting, the new palm thatch roof at the home of the vice-president of the local indigenous group was set on fire. I returned home in early November of 1999.

This brief history is one example of the social conflicts that may arise when indigenous territories are designated in Latin America. Designation as an indigenous territory is advantageous from national and international perspectives for several reasons, including the political and financial benefits to residents through exemption from taxation, attractiveness to scientific investigations and funding, protection from outside encroachment, availability of assistance for residents in protecting natural resources and local sustainable development, and increased revenue from ecotourism. Disadvantages include the communal nature of an indigenous territory in which natural resources are equally shared and managed, and for some individuals, public recognition of indigenous ethnic origins. Whether or not residents of Bella Vista desire to be or not to be indigenous, the national government of Bolivia will arrive to title and tax the lands previously used by them as the free, wild, frontier of the Mojos savanna, (or *Llanos de Mojos*). Resistance by locals was inevitable, but the social conflict that resulted from realizing that natural resources were no longer free caused a cultural rift between those who believed those resources to be communal heritage, and those who desired them for personal and exclusive use.

At the time of this publication, the 12,000 km^2 area requested to become the TCOI has been reduced to approximately 5000 km^2 (Español Gonzalez, pers. comm.) that excludes the town of Bella Vista. The new area has been proposed to overlie an integrated management zone that would be managed by members of the indigenous leadership and other institutions. Outside of the zone and in place of the TCOI, the government may designate a core, protected area as a state park. Discussions continue at the time of this printing. It is hoped that consensus will be made between residents who identify themselves as indigenous and those who do not, since regardless of ethnicity, all depend on local natural resources for survival.