

The Pennsylvania State University

The Graduate School

College of the Liberal Arts

**HUNTING AND SUBSISTENCE AMONG THE MAYANGNA AND
MISKITO OF NICARAGUA'S BOSAWAS BIOSPHERE RESERVE**

A Thesis in

Anthropology

by

Jeremy M. Koster

© 2007 Jeremy M. Koster

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

May 2007

The thesis of Jeremy M. Koster was reviewed and approved* by the following:

Stephen J. Beckerman
Associate Professor of Anthropology
Thesis Adviser
Chair of Committee

Kenneth G. Hirth
Professor of Anthropology

Jeffrey A. Kurland
Associate Professor of Anthropology

Katriona Shea
Associate Professor of Biology

Nina G. Jablonski
Professor of Anthropology
Head of the Department of Anthropology

*Signatures are on file in the Graduate School.

ABSTRACT

This dissertation examines livelihoods and subsistence in the Bosawas Biosphere Reserve, Nicaragua, focusing in particular on hunting but also extending to horticulture, fishing, and time allocation to subsistence labor. It is based on thirteen months of fieldwork in two communities on the Lakus River, a tributary of the Coco River in northern Nicaragua. The communities, Arang Dak and Suma Pipi, are home to the Mayangna and Miskito, two of Nicaragua's most populous indigenous groups. Field methods employed in this study include focal observations of hunters, instantaneous scan sampling of household members, and considerable work with indigenous research assistants, who helped to monitor the harvest of fish and game, record daily food consumption in households, and map the locations of fields and kill sites.

Results of this research indicate that hunting in Bosawas is similar in many respects to hunting elsewhere in Neotropical rain forests. Hunting is primarily a male-oriented activity, kill sites are clustered near the communities, and mammals contribute most of the biomass in the harvest. However, the hunters in Arang Dak and Suma Pipi are unusual in their heavy reliance on hunting dogs, which contribute to 85% of the kills of mammalian prey. From an optimal foraging perspective, hunting with dogs includes costs that cannot be analyzed with the basic diet breadth model, and a modified model is presented that addresses these costs. Overall, hunters generally pursue prey types that conform to predictions derived from optimal foraging theory. However, they regularly bypass a few species that apparently belong in the optimal diet set, and possible explanations for these suboptimal decisions are discussed.

In total, the residents of Arang Dak and Suma Pipi caught 1,090 animals during the study period. The composition of the harvest varies seasonally and geographically, and some species are also closely associated with certain hunting technologies. Most of the animals are captured in a core hunting zone of 77.6 km², and many kill sites are close to anthropogenic habitats. Overall, the harvest of many species is lower than it is elsewhere in the Neotropics, but a sustainability assessment indicates that a few species might be hunted unsustainably in the core hunting zone. The continued survival of some species in the Lakus River watershed might depend on the maintenance of lightly-exploited tracts of forest outside the core hunting zone, and the implications of this possibility for wildlife management are discussed. In general, the Mayangna and Miskito are diverse in their economic and subsistence strategies, and this

dissertation highlights the role and importance of hunting in household economies. Finally, data on time allocation and fishing are presented in light of recent debates about subsistence activities across the lifespan.

Table of Contents

List of tables	vii
List of figures	ix
Acknowledgements	x
1. Introduction	1
2. Theoretical and ethnological background	7
2.1 <i>Introduction</i>	7
2.2 <i>Anthropological research on hunting in the humid Neotropics</i>	7
2.3 <i>Optimal foraging theory and the diet breadth model</i>	16
2.4.1 <i>Anthropological applications of the diet breadth model in the Neotropics</i> ...	18
2.4.2 <i>Hunting with dogs in the humid Neotropics</i>	20
2.5 <i>The Mayangna and Miskito in ethnological perspective</i>	28
2.6.1 <i>The Post-Contra War Situation</i>	33
2.6.2 <i>External interests in Arang Dak and Suma Pipi</i>	35
2.7 <i>Biophysical aspects of the Bosawas region</i>	36
3. Optimal foraging perspectives on hunting in Bosawas	39
3.1.1 <i>Ethnographic Literature on Hunting in the Bosawas region</i>	39
3.1.2 <i>An Ethnographic description of hunting with guns in Bosawas</i>	41
3.1.3 <i>An ethnographic description of hunting with dogs in Bosawas</i>	44
3.2.1 <i>Focal follow methods</i>	60
3.2.2 <i>Observer effects and representativeness of the sample</i>	64
3.3.1 <i>Results: Time allocation on intentional hunting trips</i>	66
3.3.2 <i>Guns versus dogs</i>	67
3.4.1 <i>Optimal foraging analysis: Defining terms</i>	69
3.4.2 <i>Optimal foraging analysis of hunting with dogs</i>	73
3.4.3 <i>The question of simultaneous search</i>	78
3.4.4 <i>Additional costs of hunting with dogs</i>	81
3.4.5 <i>“Recognition constraints” in optimal foraging models</i>	84
3.4.6 <i>A model of hunting with dogs in Neotropical rain forests</i>	87
3.4.7 <i>Optimal foraging analysis of the expanded model</i>	90
3.4.8 <i>Hunting with dogs but without steel tools in the pre-contact Neotropics</i>	93
3.5.1 <i>Concluding thoughts on the costs of hunting with dogs in the Neotropics</i>	97
3.6.1 <i>An optimal foraging analysis of hunting with rifles in the Bosawas Reserve</i> ..	99
3.6.2 <i>Partial preferences for capuchin and howler monkeys</i>	105
3.7.1 <i>Explaining suboptimal decisions by Mayangna and Miskito hunters</i>	108
3.7.2 <i>Revisiting the “Ecologically Noble Savage” hypothesis</i>	109
3.7.3 <i>The adequacy of the diet and the importance of taste to prey choice decisions</i>	112
3.7.4 <i>The role of uncalculated social costs in suboptimal foraging decisions</i>	116
3.7.5 <i>Concluding thoughts on suboptimal foraging decisions in Bosawas</i>	118

3.8.1	<i>A comparison of hunting with dogs and rifles</i>	119
3.8.2	<i>Comparative methods</i>	119
3.8.3	<i>Results: Reporting biases</i>	121
3.8.4	<i>Hunting yields by technology</i>	123
3.8.5	<i>The pros and cons of dogs and guns</i>	126
3.8.6	<i>A cross-cultural perspective on hunting returns in Bosawas</i>	129
3.9.1	<i>Conclusion</i>	132
4.	Characterizing the harvest: Technology, geography, and sustainability . .	133
4.1.1	<i>Methods: The harvest data</i>	134
4.1.2	<i>Methods: Sketch mapping and GIS</i>	137
4.2	<i>Characterizing the harvest</i>	141
4.3	<i>Harvest data by technology</i>	147
4.4	<i>Seasonality in the harvest</i>	152
4.5	<i>Cross-cultural perspectives on the harvest of mammals in Arang Dak and . . .</i>	157
	<i>Suma Pipi</i>	
4.6.1	<i>Indigenous agriculture and the hunting landscape</i>	163
4.6.2	<i>The geographic distribution of the harvest</i>	169
4.7	<i>The sustainability of subsistence hunting in the Neotropics</i>	177
4.8.1	<i>The sustainability of the harvest in Arang Dak and Suma Pipi</i>	180
4.8.2	<i>Sustainability assessment</i>	186
4.8.3	<i>Tapirs and source-sink hunting</i>	190
4.8.4	<i>Discussion of hunting sustainability</i>	191
4.9	<i>Conclusions</i>	195
5.	Time allocation and fishing across the lifespan	198
5.1	<i>Theoretical background</i>	198
5.2	<i>An overview of time allocation in Arang Dak and Suma Pipi</i>	201
5.3	<i>Time allocation methods</i>	206
5.4.1	<i>Time allocation results</i>	211
5.4.2	<i>Significance testing: Fisher's exact test</i>	214
5.4.3	<i>Sex-related differences in time allocation</i>	215
5.4.4	<i>Age-related differences in time allocation</i>	218
5.5	<i>Discussion of time allocation results</i>	221
5.6	<i>An ethnographic description of fishing in Bosawas</i>	223
5.7.1	<i>Age-specific and sex-specific fishing patterns</i>	232
5.7.2	<i>Discussion of age-related fishing patterns</i>	238
5.8	<i>Conclusions</i>	241
6.	Conclusions	243
	Appendix A: List of large mammals in Kipla Sait Tasbaika	249
	Appendix B: Household structure data for participating households	250
	Bibliography	257

List of Tables

2.1	Aversions to wild game meat in a cross-cultural sample of indigenous Neotropical societies	15
2.2	Key with references for Figure 2.1	24
3.1	Coding scheme for hunters' activities	62
3.2	Modifiers to the "pursuit-under" code	63
3.3	Time allocation by focal hunters on observed hunts	68
3.4	Pursuit times and outcomes used to estimate the profitability of prey types . . .	74
3.5	Calculation of the optimal diet breadth for hunters with dogs	77
3.6	Prey pursued by hunters when their dogs were elsewhere	80
3.7	Episodes of catching up to the dogs that did not result in positive identification of the animal	82
3.8	Animals corralled or treed by dogs, but not considered edible or not killable with available technologies	83
3.9	Parameters used to calculate the optimal diet breadth when hunting with dogs, including dog-related costs	92
3.10	Optimal diet breadth analysis assuming the use of stone tools is three times less efficient than steel tools	95
3.11	Optimal diet breadth analysis assuming the use of stone tools is ten times less efficient than steel tools	95
3.12	Encounters and pursuits by rifle hunters on 49 hunting trips (including 6 observed hunting trips)	100
3.13	Calculation of the optimal diet breadth for rifle hunters	102
3.14	Per capita consumption of wild meat of selected Neotropical societies	113
3.15	Per capita consumption of meat from domestic animals and wild fish and game for residents of Arang Dak	115
3.16	Mean hunting returns by hunting technology	122
3.17	Pros and cons of dogs and cons for factors other than differences in hunting yields	127
3.18	Mean hunting returns of Neotropical societies	131
4.1	Animals killed by residents of Arang Dak, 9/1/04-8/31/05	142
4.2	Animals killed by residents of Suma Pipi, 12/15/04-8/31/05	143
4.3	Harvest of prey species by technology	150
4.4	Distribution of kills by technology and taxonomic class	151
4.5	Monthly harvest of the eight species that contributed more than 100 kg of biomass to the harvest in Arang Dak (September 1, 2004 -August 31, 2005)	154
4.6	Comparison of dry season and rainy season harvests	154
4.7	Monthly harvest of agoutis by family in Arang Dak	156
4.8	The rank order of mammalian game in Arang Dak and Suma Pipi compared to a cross-cultural sample of eight indigenous Neotropical groups	159
4.9	Comparison of the harvest rates (number of animals taken per consumer-year) of common mammalian prey to a cross-cultural sample of Neotropical societies	162
4.10	Land cleared for agricultural use, separated by crop or combinations of crops	168
4.11	Harvest by land use zone on the TNC maps	171

4.12	Average distance from kill sites to the hunter's community of origin, by species	173
4.13	Reported densities of Baird's tapir elsewhere in Central America	185
4.14	Sustainability of harvest for mammalian prey	187
4.15	Overview of important Chapter 4 results	196
5.1	Coding scheme for time allocation observations	210
5.2	Number of observations by age and sex class used to calculate the Fisher's . . exact tests that are presented in Tables 5.3, 5.4, and 5.5	215
5.3	Minutes allocated to different activities (per 12.5 hour day) and results of Fisher's exact tests on differences between males and females of the same age class	217
5.4	Female time allocation by age class	220
5.5	Male time allocation by age class	220
5.6	Average productivity of fishing technologies in Arang Dak	234

List of Figures

1.1	A panoramic view of Arang Dak	5
2.1	Neotropical forest locations at which there are reports of hunting with dogs . .	23
2.2	The distribution of indigenous groups in the Mosquitia at the time of the	30
	18th century Miskito expansion	
3.1	A hunter watches his dogs pursue an agouti that they have corralled in a	50
	burrow.	
3.2	A hunter cuts a piece from a hunted paca's footpad to reward the dog	52
	responsible for locating the animal.	
3.3	The hierarchical decision-making process of foragers that must first devote . .	86
	time to recognizing their prey	
3.4	The hierarchical decision-making process of hunting with dogs	88
3.5	Proportion of pursuits upon encounter	104
4.1	The indigenous territory, Kipla Sait Tasbaika, with land use zones	138
4.2	Number of animals taken by day of the week	144
4.3	Biomass harvested by day of the week	144
4.4	Household harvest of consumed meat per day	148
4.5	Comparison of the monthly agouti harvest in Arang Dak and the agouti kills .	156
	made by two hunters (a father and son)	
4.6	Geographic distribution of kill sites	170
4.7	Harvested biomass by distance from the hunter's community of origin	171
4.8	Geographic distribution of primate kills	174
4.9	Geographic distribution of four hunters' kills in relation to their fields	176
4.10	The core hunting zone around Arang Dak and Suma Pipi	182
4.11	Locations of paca kills in the core hunting zone	189
4.12	Location of tapir kills in the core hunting zone	192
5.1	Time allocation by female age classes	212
5.2	Time allocation by male age classes	213
5.3	Daily harvest of fish per individual, according to household	224
5.4	Fishing harvest by technology in Arang Dak, 9/1/04-8/31/05	225
5.5	A young woman fishes with hook-and-line	225
5.6	A man fishes with bow and arrow	227
5.7	Harvested biomass of fish species in Arang Dak as a percentage of the total . .	231
	harvest	
5.8	Proportionate contributions by age and sex classes to the total harvest caught .	235
	with different fishing technologies	
5.9	Proportionate contributions of fishing technologies to the total harvest of fish	235
	by age and sex classes	
5.10	Harvest of fish by month and technology	237

Acknowledgements

This project kind of fell into my lap in 2002, and since then many people have helped me see it through to its completion. Although it would be difficult to mention them all, I would like to acknowledge a few individuals and organizations whose help was particularly appreciated.

First, I want to acknowledge the generous financial support for this research, without which this research would not have been possible. This research was supported by a Fulbright student grant, the National Science Foundation (Dissertation Improvement Award #0413037), the Hill Foundation at Penn State, and a William T. Sanders Dissertation Grant.

Second, I would like to thank the residents of Arang Dak and Suma Pipi. In retrospect, they probably had little idea what to expect when they first invited me to conduct my study, and I suspect that a few were probably surprised my frequent visits and insatiable curiosity. With few exceptions, though, the people welcomed me and my wife into their community, and their enthusiastic participation in the study exceeded even my most optimistic expectations. I will always have fond memories of my time in Nicaragua and the friendships I made. Special thanks go to my assistants for their dedication and service, including Genaro Smith, Wilmer Lopez, Esteban Carlos, Juan Francisco Lopez, Alfred Serapio, and Rojas Thamy.

This project started long before I actually left for Nicaragua, and I would like to acknowledge my friends in the anthropology department who patiently provided advice and a sense of perspective when I was designing this study. The graduate students in the department of anthropology are great colleagues, and while it is hard to single out just a few, Michael Aitkenhead, Abby Viall, Corey Sparks, Sam Sholtis, Leila Rodriguez, and Johanna Yngvason all went above and beyond the line of duty. Mike deserves special mention for coming to Nicaragua and letting himself get attacked by all the microbes and viruses that might otherwise have infected me instead. Also in the department, the administrative staff has helped me navigate unfamiliar institutional waters, and I am particularly indebted to Wendy Fultz, without whom my academic career might have been temporarily derailed on several occasions.

From other institutions, countless others have helped by responding to my queries and requests for assistance. Dr. Anthony Stocks and colleagues at Idaho State have been especially generous about first sharing their GIS files and then helping me figure out how I could put them to use. Several other people have helped me with GIS-related issues, including Peter Dana, Jeff Jenness, Yosef Bodovski, Jason Braunstein, Eric St. Clair, and Pete van Rossum. Among those

who kindly responded to general queries are David Stephens, Derek Smith, Jan Salick, Flora Lu, Mike Alvard, John Bock, Kim Hill, Jim Yost, Robert Carneiro, Ken Kensinger, Allyn Stearman, William Vickers, Ray Hames, Jean Jackson, Harald Beck, and Kristen Hawkes. Thanks also to Doug Stevens for unwitting inspiration.

It would be difficult to overstate my gratitude for the assistance of the Saint Louis Zoo and all those associated with *Proyecto Biodiversidad*, including Cheri Asa, Kimberly Williams-Guillen, John Polisar, Daniel Griffith, Karen Bauman, Louise Bradshaw, Gerardo Camilo, Amanda Zidek-Vanega, Maria Rosa Cordon, and Patricia McDaniel. Among other things, the Zoo provided invaluable logistical assistance, freely shared data and ideas, allowed me to use project facilities and equipment, and helped me with random bureaucratic tasks in Nicaragua. Many of the above also provided good company and a number of laughs while out in the field. Special thanks also go to Orlando, Fanor, and Windalin for carting me around inside the reserve.

A number of other folks provided assistance and good company in Nicaragua, and I want to thank Paule Gros and Menuka Scetbon-Didi for helping me out on a number of occasions. Edgard and Armando with TNC were also great to be around in the field.

I would like to thank my advisor, Stephen Beckerman, who has been an incredible mentor and friend throughout this whole process. He has been a fountain of good advice on grant proposals, research design, statistical analysis, and the often stark realities of fieldwork. Perhaps his greatest contribution was setting high expectations and then trusting that I would figure things out for myself. I also want to thank the other members of my committee, Jeffrey Kurland, Kenneth Hirth, and especially Katriona Shea, for their insight and feedback during the design stage of this project and for their thoughtful suggestions and commentary on the manuscript.

As usual, my mother attended to all manner of errands for me while I was out of the country, as did my in-laws. My father proofread and edited the manuscript. I also want to thank my family for their encouragement and support throughout my academic career, especially my sister, who long ago inspired me to get out and explore the world a bit.

Finally, nothing I could write would do justice to the gratitude that I feel for the support of my wife, Stefanie. She has been with me on this project from start to finish, and her contributions are indelibly stamped throughout. For these reasons and more, this dissertation is dedicated to her.

Chapter 1

Introduction

In the 1970s, when anthropologists increased their attention to hunting and fishing by indigenous societies in the lowland Neotropics, their interests were largely theoretical. At the time, many of the societies remained effectively isolated from the state-level societies beyond the edge of the forest, and lowland Latin America represented a laboratory of sorts in which ethnologists could test their hypotheses about the relationships between ecology, subsistence, social organization, and belief. That generation of research was perhaps the first to be rigorously quantitative, and some of the observational methods developed during that era are still used widely in ethnographic research (e.g. the time allocation methods of Johnson 1975). Although many important questions remain unanswered, the results of that early research helped establish a general point about indigenous rain forest peoples: despite residing in a wide variety of challenging environments, their subsistence strategies are commonly well-adapted to the demands of life in the forest (Beckerman 1993).

In recent decades, the interest in Neotropical indigenous societies shifted from theoretical to applied science. The impetus for this shift was the conservation movement in general and more specifically the emphasis on conserving Neotropical rain forests. As expanding populations and development contributed to rapid deforestation throughout the Neotropics, once-isolated indigenous societies found themselves increasingly involved in international conservation efforts (Alcorn 1993). Their relatively low-impact subsistence practices, described in detail by an earlier generation of anthropologists, were championed as the key to the sustainable use of forest resources, and indigenous peoples were themselves hailed as the ideal stewards for the remaining forests (Redford 1991). Subscribing to this perspective, some prominent international organizations, including The Nature Conservancy, prioritized legal efforts to gain legal title land for indigenous communities (Redford and Mansour 1996).

At the same time, conservationists recognized that indigenous societies were undergoing rapid changes, often in response to increased contact with external groups. Through these contacts, indigenous societies acquired new technologies, such as firearms and other extractive technologies, which dramatically altered indigenous subsistence practices (Hames 1979a; Stearman 2000). Meanwhile, indigenous societies have become increasingly integrated into

external market economies, and households now diversify and commercialize their use of natural resources in order to acquire the money needed to make purchases (Godoy et al. 2005). To the extent that this trend contributes toward additional forest clearance for cash crops and the hunting of game for sale to external markets, it is obviously a significant concern for conservationists. Additionally, some indigenous populations are growing rapidly through natural fertility, and conservationists worry that unchecked population growth might put unsustainable pressure on renewable natural resources (Robinson and Bennett 2000; cf. McSweeney 2005). For these reasons, conservationist organizations are working not only to protect the integrity of traditional indigenous homelands but also to partner with indigenous communities on the creation of sustainable management plans.

It was against this backdrop that I designed and conducted this study. Although the research was meant to be interesting theoretically, I wanted this project to have practical applications to the long-term conservation of the Bosawas Reserve and, by extension, the livelihoods of its inhabitants. Given those goals, perspectives drawn from human behavioral ecology seemed to offer a promising approach to the study of subsistence hunting in Bosawas. With its focus on the costs and benefits of decision-making, human behavioral ecology allows researchers to appreciate motivations of individuals whose interests might not be immediately obvious to outside conservationists. As a result, research in human behavioral ecology has contributed much to the question of natural resource conservation (Winterhalder and Smith 2000). Although some researchers demonstrate that indigenous peoples are not necessarily natural conservationists (Hames 1987; Alvard 1993a), related work shows that there are circumstances in which individuals with similar interests and goals can unite to promote the long-term conservation of communal resources (Smith and Wishnie 2000; Lu 2001). In some respects, the most significant challenge to conservation in Bosawas is to understand individual motivations and reconcile them to community interests.

Although deforestation represents the greatest threat to tropical biodiversity (Alvard et al. 1997), the conservation of wildlife in general and mammalian fauna in particular has become a central focus to conservationist efforts in the Neotropics. This attention to wildlife species stems not only from their vulnerability to rapid over-exploitation but also their importance to overall ecosystem dynamics, particularly the dispersal of seeds (Redford and Feinsinger 2001). The hunting of wildlife species is a controversial issue, as indigenous communities are sometimes

very adamant about their right to hunt, especially when the goal of that hunting is personal consumption, not commercial resale. In some cases, hunted game represents an important nutritional resource that cannot be easily replaced with alternatives (Milner-Gulland et al. 2003). At the same time, with the adoption of new technologies and the deforestation on the edge of their traditional homelands, the possibility of irrevocable over-harvesting by indigenous hunters is perhaps greater than ever before. Although some conservationists emphasize the value of protected areas without human use (Redford and Sanderson 2000), the reality is that large tracts of Neotropical forest are located in the traditional homelands of indigenous societies who cannot easily be relocated to create a human-free protected area. Accordingly, it is imperative that both conservation biologists and social scientists devote attention to patterns of wildlife extraction in order to understand not only the impacts on tropical ecosystems but also the ecological and cultural importance of hunting to these indigenous communities. Such work is especially valuable given the evidence that the status, behavior, and reproduction of wildlife species in anthropogenic habitats can differ dramatically from that observed at undisturbed forest sites (Escamilla et al. 2000). Conservation science at its best incorporates perspectives from biology, ecology, demography, and anthropology. One broad goal of this dissertation is therefore to provide empirical evidence on hunting patterns that have remained largely unnoticed by anthropologists to this point.

Two general hypotheses were fundamental to this research:

1. Following the logic of human behavioral ecology, individuals make decisions that broadly enhance their growth, survival, and reproductive opportunities, including parental investment in offspring. At varying degrees of consciousness, individuals consider the expected costs and benefits of their choices as they decide how to allocate their time and effort. For individuals, these costs and benefits vary according to both personal characteristics (age, sex, physical abilities, wealth, relatedness to others, etc.) and extrinsic variables such as seasonal weather changes, intermittent wage labor opportunities, and other circumstances. Because they face competing demands on their time, individuals generally strive for energetic efficiency in subsistence tasks (Smith 1979). When hunting, for example, individuals make choices that allow them to maximize the rate at which they acquire meat.

2. As an extension of the first hypothesis, the character and scope of the wildlife harvest reflect the choices made by individuals. Numerous variables factor into the decision to go hunting, including the availability and effectiveness of technologies, the agricultural calendar, dynamic nutritional needs, seasonal variation in the availability of substitutable resources (especially fish), and the opportunity costs of foregoing other activities, which vary over time. On hunting trips, prey choice decisions are consistent with those predicted by optimal foraging theory (Stephens and Krebs 1986). The actual composition of the harvest depends not only on the preferences and decisions of hunters but also the characteristics of each species, including its habitat preferences, anti-predator behavior, and population dynamics.

To test these hypotheses, I collected a variety of data that will be familiar to most human ecologists. The centerpiece of the research involved focal observations of hunters on their forays into the forest. Focal observational methods have become a standard part of research in human behavioral ecology, and this research complements other optimal foraging studies in the Neotropics (Hill and Hawkes 1983; Alvard 1993a). Although focal observations allow researchers to evaluate the costs and benefits of hunting decisions, I was also interested in the context in which those decisions take place. Accordingly, my research plan included several other avenues of data collection, all of which were designed to understand hunting as it fits into the overall economy. In order to develop a deeper understanding of hunting behavior, including opportunistic kills, I worked with indigenous research assistants to record all wildlife kills made by residents of the communities in which I worked. The assistants and I also recorded the acquisition of fish, which in many Neotropical societies contributes more protein to the diet than hunting (Hames 1989). To appreciate subtleties in the geographic distribution of kill sites, I initiated the mapping of individual fields with a GPS unit. In order to obtain data on time allocation, I conducted behavioral observations using instantaneous scan sampling techniques (Borgerhoff Mulder and Caro 1985). Daily food forms, originally intended as a means of cross-checking the work of the assistants, provided valuable insight into household diets and food-sharing habits. Genealogical work and censuses increased my appreciation of relationships between kin. Not all of the data collected during the study period play an equally prominent role in the analyses presented throughout this dissertation, but the whole process of data collection

(including participant observation, the hallmark of ethnographic fieldwork) enhanced my understanding of local livelihoods and culture in ways that provide important depth to my observations and conclusions.

This dissertation is based on approximately 13 months of fieldwork, from August 2004-September 2005. The project was based in Arang Dak, a community of about 170 people in 25 households (Figure 1.1). After some minor delays, I expanded the study into Suma Pipi, a community of about 70 individuals in 10 households located about 1 km downstream of Arang Dak. Both communities are located on the Lakus River, a tributary of the Coco River. Most individuals in Arang Dak describe themselves as Mayangna whereas most of those in Suma Pipi claim to be Miskito.¹ There is a sizeable percentage of both ethnicities in each community, however, and there has been considerable inter-marriage between the Miskito and the Mayangna. Although there are some notable differences between the two groups, both culturally and phenotypically, their subsistence practices are in many ways indistinguishable. In discussing these subsistence strategies, therefore, I usually do not make a distinction between the Mayangna and the Miskito.

Figure 1.1. A panoramic view of Arang Dak (Photo courtesy of Menuka Scetbon-Didi).



¹ In the literature, the Mayangna are most commonly referred to as “Sumu” or “Sumo” (Herlihy 1995). However, their preferred ethnonym is “Mayangna,” and that is the name that I use throughout this dissertation.

The Miskito have been the subject of past anthropological fieldwork, most notably by Helms (1971) and Nietschmann (1973). Although this project shares a quantitative focus with Nietschmann's work, the ecological setting for this study more closely resembles the site where Helms conducted her fieldwork. That is, while Nietschmann elegantly describes the subsistence adaptations of the Miskito on the Atlantic coast, this dissertation attempts to apply the same quantitative rigor to the Miskito living at a relatively montane, inland site. From her fieldwork along the Coco River, Helms (1971) provides an excellent overview of Miskito cultural ecology in a similarly montane setting, including many keen observations that remain true over thirty years later. Her work was primarily qualitative in character, however, and this dissertation provides some new quantitative perspectives on Miskito subsistence adaptations away from the coast. Compared to the Miskito, the Mayangna have received much less ethnographic attention, and in many respects they might be the least-studied indigenous society in Central America. This dissertation therefore represents a contribution to the literature on the Mayangna, although it should also be noted that there are still several important gaps in our ethnographic knowledge of this group.

The dissertation is organized as a monograph, with chapters that contribute to an overall picture of subsistence practices in Arang Dak and Suma Pipi. Following this introduction, Chapter 2 provides relevant background information on the Mayangna and Miskito and the Bosawas region in general. In that chapter, I also elaborate on the theoretical perspectives employed throughout the dissertation, and I review the ethnographic literature on hunting in the Neotropics. In Chapter 3, I approach hunting decisions from an optimal foraging perspective, and I compare the decision-making of rifle hunters and hunters with dogs. Chapter 3 also includes a lengthy ethnographic description of hunting, which provides important background to analyses throughout the dissertation. In Chapter 4, I examine the harvest of hunted game in relation to a number of variables, including hunting technologies, seasonality, and geography. I also evaluate the sustainability of the harvest and make some general recommendations for enhancing the long-term viability of hunting in the Lakus River watershed. Chapter 5 presents data on time allocation and fishing, especially as they relate to age and sex classes. In the final chapter, I discuss the noteworthy findings from this research and their broader significance.

Chapter 2

Theoretical and Ethnological Background

2.1 Introduction

This chapter provides background on a number of topics, including anthropological perspectives on the Mayangna and Miskito and a brief overview of the ecology and climate of the Bosawas region. I also describe some of the theoretical perspectives that shaped the goals and methodology of this project from its inception. In terms of theoretical background, I draw heavily from human behavioral ecology in general (Winterhalder and Smith 1992) and more specifically from inter-disciplinary work on optimal foraging theory (Stephens and Krebs 1986). I review one of the basic optimal foraging models, alternately known as the “diet breadth” or “prey choice” model (Charnov and Orians 1973), and I discuss its use in anthropological settings, including studies that have applied this model elsewhere in the Neotropics. Although the diet breadth model has proven generally robust in the analysis of decision-making by Neotropical hunters, it has not been used to model the prey choice decisions of hunters with dogs. I therefore review the available literature on hunting with dogs in the Neotropics, with special attention to the effectiveness of dogs in pursuits of the most common game species. Hunting dogs are just one of the many technologies available to hunters, however, and I therefore begin with a general overview of subsistence hunting in the Neotropics.

2.2 Anthropological research on hunting in the humid Neotropics

Anthropologists have long recognized the importance of hunting to Neotropical horticulturalist societies, but it was not until the 1970s that the presentation of quantitative data began to highlight similarities and differences in hunting strategies throughout Latin America. Early debates focused on dietary protein as a limiting factor in Neotropical diets (Gross 1975; Beckerman 1979; Spath 1981) and, by extension, the importance of securing adequate protein as the explanation for inter-tribal warfare (Harris 1974; Chagnon and Hames 1979), exchanges of meat for sexual access to females (Siskind 1973*b*; Vickers 1975), and the ubiquity of seemingly illogical food taboos against large mammalian prey (McDonald 1977; Ross 1978). To a lesser

extent, claims that tropical rain forests cannot support a population of mobile hunters and gatherers led anthropologists to reexamine the faunal resources available to Neotropical foragers (Bailey et. al 1989; Stearman 1991). In the last fifteen years, meanwhile, quantitative studies of Neotropical hunting have proliferated as biologists and anthropologists alike evaluate the conservation implications and long-term sustainability of wildlife harvests throughout the Americas (e.g. Vickers 1994; Alvard et al. 1997; Townsend 2000).

The resulting picture of Neotropical hunting strategies is one of occasionally dramatic variability, as societies adapt to new hunting technologies, influence from external markets, differences in the abundance and distribution of prey species, and available alternatives to subsistence hunting as a source of dietary protein. Then, too, cultural factors such as dietary taboos and ritualized hunting seem to defy functionalist explanations of cross-cultural hunting variability. Nevertheless, while acknowledging the extent to which hunting patterns may vary from one society to the next, it is still possible to identify some general trends that seem to hold true in many Neotropical settings.

Hunting is primarily a male activity, although there are indications that women sometimes kill animals independently (Jackson 1983:41; Stearman 1991:252; Townsend 2000:271). More often, it seems that women perform auxiliary tasks, such as caring for dogs, spotting game, retrieving arrows, and carrying killed animals (Romanoff 1983; Hill and Hawkes 1983; Brown 1984:549; Stearman 1991; Lu 1999:65). Data from Peru suggest that Matsigenka couples bring back more meat than men hunting alone (Romanoff 1983). Once an animal has been brought to the community or camp, women are often responsible for its preparation and distribution (Hill and Hawkes 1983; Lu 1999:65).

The size of the hunting party varies, but the modal number appears to be either one or two hunters (Carneiro 1974:124; Beckerman 1980; Yost and Kelley 1983:205; Jackson 1983:46; Alvard 1993b). When white-lipped peccary tracks are spotted, however, larger groups form to track the herd, and sightings of tapirs can have a similar effect (Carneiro 1974:124; Yost and Kelley 1983:205; Jackson 1983:46; Smith 2003b:111). Directed searches that specifically target these large ungulates are relatively rare, however, and most hunting trips can be characterized as general searches for whatever prey might be encountered that day (Yost and Kelley 1983; Smith 2005:511).

There is considerable variation in the length of hunting trips. Day hunts are common, with hunters leaving in the morning and returning in the late afternoon or early evening (Carneiro 1974:125; Hames 1980:47; Yost and Kelley 1983:204; Alvard 1993*b*). The frequency of multi-day expeditions seems to exhibit more cross-cultural variability, with some researchers reporting that multi-day hunts are rare (Balée 1985) while other reports describe longer expeditions with hunters sometimes sleeping in the forest in makeshift shelters (Carneiro 1974:126; Hames 1980:47; Yost and Kelley 1983:204; Alvard et al. 1997). In some cases, entire families leave the community and rely on a mix of provisions and acquired resources for several weeks at a time (Werner 1983). The willingness of the Waorani to leave on multi-day trips depends in part on the local school schedule, as spouses and offspring are expected companions on such expeditions (Lu 1999:62). Meanwhile, some societies have adopted a hunting and gathering strategy for at least part of the year, with groups like the Aché relying primarily on undomesticated resources while on extended treks through the rain forest (Hill and Hawkes 1983). By contrast, some hunters squeeze in brief morning or evening hunts when competing demands on their time do not permit full-day hunts (Hames 1980:47).

Hunters generally travel on well-established trails unless they are tracking or pursuing an animal (Hames 1980:39; Kaplan and Kopischke 1992:99), although some may opt to clear a new trail in little-used and presumably more abundant areas (Smith 2003*b*:112). Some hunters follow trails that maximize their exposure to a variety of biotopes (Hames 1980:39) while others sacrifice opportunities to explore multiple ecotones in exchange for an easier path along the ridgeline (Yost and Kelley 1983:204). Hunters from horticulturalist communities are “central place foragers” in the sense that they depart from and return to a fixed location, and physiological limits generally restrict hunters to a maximum radius of about 10 km from the communities on single-day hunts (Vickers 1980; Alvard et al. 1997:979). In some cases, however, motorboats allow hunters to reach distant zones much more quickly (Hames 1979*a*; Souza-Mazurek et al. 2000).

Hunters are often aware of specific locations where they are likely to encounter game, including salt licks, fruiting trees, and earthen burrows or tree trunks (Kaplan and Kopischke 1992:99; Orejuela 1992:75; Stearman 1991:254). Some species are particularly attracted to gardens, and Linares (1976) hypothesized based on the composition of faunal remains at archaeological sites that “garden-hunting” provided a convenient source of protein for pre-

Contact horticulturalists. The “garden-hunting” model has received intermittent attention in the last couple decades, with most researchers agreeing that Neotropical farmers at least occasionally benefit from opportunities to hunt crop-raiding species, such as agoutis, pacas, and collared peccaries (Greenberg 1992; Jorgenson 1993; Naughton-Treves 2002; Naughton-Treves et al. 2003; Smith 2005). “Garden-hunting” seems to require different techniques than those employed by forest-going hunters, as traps and ambush hunting appear to be the method of choice for killing crop-raiders (Carneiro 1974:128; Paolisso and Sackett 1985:186; Stearman 1990:381; Smith 2005:514). A number of species raid fields to eat manioc, the staple crop of many horticulturalist societies (Smith 2005:513). Because of their relatively large size, collared peccaries can be especially damaging manioc raiders, and some groups go to great lengths to protect their fields with fences and pit traps (Carneiro 1983:83-85). Ambush hunting may be particularly productive at night, when hunters wait with flashlights to illuminate animals as they enter the fields (Paolisso and Sackett 1985:186; Reed 1995:134). Flashlights are valuable in other contexts as well, and some hunters will wait by fruiting trees with flashlights and guns to target unsuspecting nocturnal foragers such as pacas, brocket deer, and tapirs (Smith 1976:457). In some locations, hunters will travel by boat at night, using their flashlights to illuminate the shore in search of tapirs and pacas (Vickers 1991:69; Alvard 1993b:83; Århem 1998:109). Ambush tactics often include vocal mimicry of desirable prey types, including both mammals and birds (Carneiro 1974:127; Brown 1984:548; Paolisso and Sackett 1985:183; Alvard and Kaplan 1991:84).

While flashlights and motors have introduced new alternatives to Neotropical hunters, no technology has had a more dramatic effect on hunting strategies than firearms. Forest peoples throughout Latin America have adopted guns, and numerous comparisons of shotguns and traditional technologies suggest that shotgun hunters enjoy superior return rates (Hames 1979a; Hill and Hawkes 1983; Yost and Kelley 1983; Alvard 1993b). It is therefore not surprising that forest dwellers generally prefer firearms over traditional weapons, although guns remain too expensive for many individuals (Hames 1979a:222; Yost and Kelley 1983:209). However, guns are often purchased secondhand and in poor condition, and the cost or unavailability of ammunition may preclude their use (Yost and Kelley 1983:209; Paolisso and Sackett 1985:188; Smith 2005:511). Moreover, there is considerable diversity in the types of guns used by Neotropical hunters, including rifles and both muzzle-loading and breech-loading shotguns

(Hames 1979a:223; Stearman 1990:381; Lu 1999:73). Each type of gun has its pros and cons. For example, Lu (1999:66) suggests that breech-loading shotguns are better for large animals while muzzle-loaders might be preferred for small mammals or birds. Elsewhere, Yuquí hunters in Bolivia prefer shotguns to rifles despite the fact that bullets are considerably cheaper than shotgun shells: “The shotgun, however, is a better all-around weapon and is more effective in killing smaller terrestrial game and the arboreal mammals. Since these animals now make up 88% of the Yuquí game inventory, the shift to shotguns was an appropriate response to changing game conditions” (Stearman 1990:381).

Even after adopting guns, many groups continue to use a wide assortment of traditional hunting technologies. Common weapons include blowguns and bows, which allow hunters to kill animals in the forest canopy (Carneiro 1974:124; Ross 1978:4; Hames 1979a; Yost and Kelley 1983; Paolisso and Sackett 1985:182; Stearman 1990:381; cf. Jett 1991). Many researchers have noted the diverse range of arrows used by individual hunters, and arrows are often designed to target a particular class of prey (Ruddle 1970; Carneiro 1974:124; Paolisso and Sackett 1985:182; Beckerman 1994b). The use of natural poisons on arrows or blowgun darts seems to vary between regions and societies (Carneiro 1974:124; Hames 1979a:225; Lu 1999:68). Spears may be used for terrestrial prey, although their absence in many ethnographic reports is conspicuous (Yost and Kelley 1983). To my knowledge, there are no widely-accepted theories that explain the distribution of different weapons throughout the Neotropics. While firearms are demonstrably superior to traditional technologies, comparisons of native technologies generally yield less insight into why some groups prefer, for example, bows over blowguns.

Hunting is often cited as one of the most enjoyable subsistence activities in the Neotropics (Carneiro 1974; Gregor 1977; Kensinger 1983; Paolisso and Sackett 1985; Smith 2005). The intensity of hunting trips seems to vary according to household needs, however. On the one hand, some ethnographers report that there is a specific word (usually translated “meat-hunger”) for the feelings of protein deprivation that accompany prolonged periods without meat or alternative sources of protein-rich food (Johnson 1982; Ross 1987). One might imagine that hunters experiencing meat-hunger might exert more effort and enjoy their venture less than their satiated counterparts. On the other hand, meat is a preferred food throughout the Neotropics, as it is in most societies (Good 1987). For some groups, no meal is considered truly complete

without meat, and Amahuaca men sometimes hunt even when there is still meat from a previous kill available for consumption (Carneiro 1974:123). The variable acuteness of nutritional needs is reflected in the Cashinahua tendency to distinguish serious hunting from “play” hunting (Kensinger 1995:38-40). While serious hunting demands a hunter’s concentration and considerable exertion, “play” hunting allows men to relax and perhaps escape an uncomfortable social situation in the community or household (Kensinger 1995:40). Hunting behavior analogous to play hunting appears to be relatively common throughout the Neotropics (Gregor 1977:218; Smith 2005:520).

Hunting is sometimes associated with religion and ritual, perhaps more so than any other subsistence task (Carneiro 1974:129; Smole 1976:180). For example, Aché children receive a name that corresponds to the animal prepared by their mothers during pregnancy, and Aché leaders have stressed that even endangered animals must be hunted occasionally for this ritual purpose (Hill and Padwe 2000:94). Among the Ka’apor, all men are ritually obliged to supply their wives with tortoise meat during periods of the pregnancy (Balée 1985:495). In some cases, rituals and magic are employed to enhance hunting success, as when the Yanoama conduct ceremonies and mock hunts to increase the likelihood of encountering preferred game animals on subsequent hunting trips (Smole 1976:180). Amahuaca hunting magic includes a number of seemingly bizarre rituals, such as the consumption of boa constrictor feces, allowing oneself to be stung by wasps, and rubbing toxic secretions from frogs into burns on the skin (Carneiro 1974:130-131). Among the Makuna, the shaman plays an important role in enhancing an individual’s hunting success (Århem 1976:38).

In contrast to the ritual acquisition of wildlife species, some societies formally taboo the hunting of certain animals. In many cases, these taboos are specific to a subset of the society, such as pregnant women, age classes, and clans, among others (Basso 1973*b*; Kracke 1981; Kensinger 1981). In other cases, the taboos and aversions apply more generally to the society as a whole (Basso 1973*a*; Kensinger 1981; Jackson 1983). In the Neotropical literature, explanations for these taboos and aversions have ranged from the ecological (McDonald 1977; Ross 1978) to the psychological (Kracke 1981). That this debate remains unresolved more generally in anthropology is evident in the recent persistence of similar arguments to explain taboos and aversions around the world (Aunger 1994; Colding and Folke 1997; Fessler and Navarrete 2003).

To get a sense of the extent to which taboos and aversions apply to certain animals, I compiled a cross-cultural sample of aversions in indigenous Neotropical societies (Table 2.1). My interest in this topic arose upon my observation that the Mayangna and Miskito do not pursue and consume several species that would appear to belong in the optimal diet breadth (see chapter 3). One tricky aspect in the compilation of this table is that there often are related species that share a common name. For example, there are at least nine species of howler monkeys (*Alouatta* spp.). I somewhat arbitrarily decided to focus on howler monkeys as a genus instead of examining each individual species, and I do likewise with capuchin monkeys, spider monkeys, naked-tailed armadillos, and tapirs. I also rely on common name distinctions for sloths and deer. This decision stems in part from the observation that, in places where there are multiple variants, the same rules and prohibitions generally apply to all such variants. For example, I encountered no societies that eat three-toed sloths but not two-toed sloths. In some cases, species other than those listed here are consumed or tabooed by societies, and this compilation is meant to provide a brief overview of aversions, not a comprehensive list. The sample includes many of the publications that have been featured in other cross-cultural samples (e.g. Vickers 1984) as well as other more recent articles with relevant data. The compilation includes data for the Piro (Alvard 1993*b*), the Buglé (Smith 2003*b*), the Yanomamo and Ye'Kwana (Hames 1979*a*; Hames and Vickers 1982); the Siona-Secoya (Vickers 1991); the Tukano (Jackson 1983), the Aché (Hill and Hawkes 1983; Hill and Padwe 2000), the Yuquí (Stearman 1991), the Amahuaca (Carneiro 1974), the Waorani (Yost and Kelley 1983; Lu 1999), and the Cashinahua (Kensinger 1995). In almost all cases, the authors confirmed the classification via email, and I am grateful for their input and suggestions.

Sometimes groups eat animals that are nominally taboo, and in other cases some members of a society uphold the taboo while others do not. At such times, relying on local cognitive frameworks for classification purposes is problematic. In terms of classification, I therefore focus primarily on the extent to which prey types are consumed, and this classification might be thought of in terms of percentages. Animals that are eaten by “virtually all” are generally consumed by at least 90% of the population, with the only exceptions perhaps pertaining to matters of personal taste, not widely-accepted cultural beliefs or taboos. By contrast, animals that are “not eaten” are consumed by no more than 5-10% of the population. For whatever reason, these animals are generally not viewed as fit for consumption, and the only

individuals to consume these types violate community norms. A third category, “eaten by only some members of the communities,” refers to ambiguous types for which there are no clear-cut cultural norms. The consumption of these types appears to be primarily a matter of personal preference. It is important to emphasize that the table includes only general aversions, not aversions or taboos that apply only to a subset of the society (e.g. pregnant and lactating women).

Among the interesting trends in this compilation is the observation that carnivores, especially felines, are often the subject of aversions and taboos. This trend also holds true for several groups not included in this sample, including the Sharanahua (Siskind 1973*a*), the Yanoama (Smole 1976), and the Cashinahua (Kensinger 1995). Those societies that exhibit no aversions toward carnivores, such as the Aché and the Yuquí, are generally unselective. By contrast, some species are rarely avoided by Neotropical hunters, including primates, peccaries, and the fossorial rodents, agoutis and pacas. Tapirs, capybaras, and deer are also pursued with regularity, although the latter in particular were formerly tabooed by many societies (cf. Ross 1978). Of the taxonomic groups in the table, the Xenarthra appear to exhibit the most variability. Except for the nine-banded armadillo, no other Xenarthran is consumed by more than half nor less than one quarter of the societies for which there are data (i.e. that type is present in the hunting zone and the preference is clear from the source). Particularly interesting is the observation that the Yanomamo consume anteater species (tamandua and giant anteaters) whereas the neighboring Ye’Kwana do not. Taste might be an important factor in the ambivalence toward Xenarthrans. Smole (1976:182) reports that tamandua flesh “has a strong odor and an acid taste” while the meat of both the two-toed and three-toed sloth “leaves something to be desired.” Taste is also cited as the reason for the Mayan reluctance to hunt armadillos, which have “undesirable fat nodules” (Jorgenson 2000:254). In many cases, though, taste is a somewhat questionable explanatory variable because few informants have actually sampled the meat of tabooed animals (Kensinger 1995:197). The development of food aversions and taboos remains a promising topic of inter-disciplinary research (Fessler and Navarre 2003).

Table 2.1. Aversions to wild game meat in a cross-cultural sample of indigenous Neotropical societies. See text for details.

Common name	Piro	Buglé	Yanomamo	Ye'Kwana	Siona-Secoya	Tukanoan	Aché	Yuquí	Amahuaca	Worani	Cashinahua
Jaguar	X	8	8	X	X ^c	X ^c	O	O	X	8 ^a	X
Puma	X	X	X	X	X ^c	X	O	O	X	X	X
Ocelot	X	-	O	X	X ^c	X	O	O	X	X	X
Jaguarundi	-	?	?	?	X	X	O	-	X	X	X
Tayra	X	X	?	?	X	X	O	O	X	X	X
Coati	O	O	O	O	O	8	O	O	O	O	O
Giant anteater	-	?	O	X	X	X	O	O	O	X	X
Tamandua	X	X	O	X	X	X	O	O	O	X ^c	O
Silky anteater	X	X	O	O	X	X	-	O	X	X	O
Sloths	X	8	O	O	X	8	-	O	X	X	X
Naked-tailed armadillo	-	X	-	-	X	?	O	-	?	X	X
Giant armadillo	-	-	O	X	X	?	-	O	X	X	X
Nine-banded armadillo	O	O	O	O	O	O	O	O	O	X	X
Woolly monkey	-	-	O	O	O	O	-	-	?	O	O
Howler monkey	O	8	O	O	O	O	O	O	O	O	O
Capuchin monkey	O	8	O	O	X ^c	O	O	O	O	O	O
Spider monkey	O	8	O	O	-	-	-	O	O	O	O
Agouti	O	O	O	O	O	O	O	O	O	O	O
Paca	O	O	O	O	O	O	O	O	O	O	O
Capybara	O	-	8	O	8	?	O	O	O	O	8 ^a
Collared peccary	O	O	O	O	O	O	O	O	O	O ^a	O
White-lipped peccary	O	O	O	O	O	O	O	O	O	O	O
Tapir	O	O	O	O	O	O	O	O	O	O ^a	O
Deer	O ^a	O	8	O	8 ^a	O	O	O	O	O ^a	O

X = not eaten, O = eaten by virtually all, - = not present, 8 = eaten by only some members of community

a = formerly taboo, now easing

c = not consumed, but put to some other use

? = not clear if the species is present or, if so, consumed

2.3 *Optimal foraging theory and the diet breadth model*

Much of the research presented in this dissertation is generally based on the tenets of human behavioral ecology (Winterhalder and Smith 2000). More specifically, hunting decisions by Mayangna and Miskito hunters are compared to predictions derived from optimal foraging theory (Stephens and Krebs 1986). Developed by evolutionary ecologists and based on Holling's disc equation (Charnov and Orians 1973), optimal foraging models have been used to examine the foraging habits of a wide variety of organisms (Sih and Christensen 2001). Models have become increasingly complex in recent decades as ecologists attempt to weigh the opportunity costs of time devoted to foraging, especially in relation to survival and reproduction (Mangel and Clark 1986).

Optimal foraging models assume that the forager's goal is to maximize the rate (R) at which they acquire a certain resource, usually energy. The rate depends on not only the energetic value of acquired resources (E) but also the time devoted to their acquisition. In the diet breadth model, there is a fundamental distinction between time devoted to a general search for prey (T_s) and time spent "handling" prey (T_h). Handling time can include several components, including periods of time spent pursuing, subduing, processing, or consuming prey. Searching for prey and handling prey are considered mutually exclusive activities; they cannot be done simultaneously. The forager's goal can therefore be represented in algebraic form by the equation:

$$R = \frac{E}{T_s + T_h}$$

In order to determine the optimal diet breadth, one must know the expected energetic returns from a given prey type. It is here important to make a distinction between prey "types" and prey "items." A prey item can be considered an individually harvested unit of plant or animal matter, such as an individual tapir or agouti, for example. A prey type, on the other hand, is a recognizable class of prey items, such as tapirs in general. In many cases, a prey type may be synonymous with the species as a whole. There are exceptions to this generalization, however, as when sexual dimorphism creates a distinct difference in return or encounter rates; in this case, males and females should be considered unique prey types (Smith 1991).

The expected energetic returns from a prey type depend on both its energetic value and the rate at which it is encountered (λ). During a given foraging bout in which the forager focuses on a particular prey type with average net energy e_1 and abundance λ_1 , the expected energetic reward can be represented by:

$$E = T_s(\lambda_1 e_1)$$

As noted above, the time spent foraging is the sum of the time spent searching for and handling prey. For a given prey type, the latter is the product of its encounter rate (λ_1) and the average handling time per encounter (h_1), such that the total time spent foraging is:

$$T = T_s + T_s(\lambda_1 h_1)$$

In expansion, the search times cancel out and the expected reward when focusing on prey type 1 is:

$$\frac{\lambda_1 e_1}{1 + \lambda_1 h_1}$$

When a second prey type is included the diet, the pertinent encounter rates, energetic rewards, and handling times are added as follows:

$$\frac{\lambda_1 e_1 + \lambda_2 e_2}{1 + \lambda_1 h_1 + \lambda_2 h_2}$$

If specializing on the first prey type yields higher energetic returns than pursuing both prey types upon encounter, then the optimal diet breadth model predicts that the forager should specialize on only that prey type. If, however, pursuing the second prey type increases overall energetic returns, it should also be included in the diet. Solving for the optimal diet breadth therefore requires consideration of each prey type's "profitability," as measured by its average net return per unit handling time (E/h). Prey types are then ranked according to this measure of profitability. The highest-ranked prey is always included in the optimal diet set. The second-ranked prey type will also be included if doing so increases the overall energetic returns per unit time. Likewise, additional prey types will be added until inclusion of a prey type *decreases* the overall returns per unit time, in which case the forager would do better by ignoring that prey type and continuing to search for higher-ranked prey items. It should be noted that the inclusion of additional prey types depends not on their own abundance (as reflected in their own encounter rate), but rather on the abundance of higher-ranked prey types. If the highest-ranked prey is readily available, the forager might do well to specialize. On the other hand, if higher-ranked

prey are scarce, more time will be spent searching and the decrease in return rate might promote inclusion of lower-ranked prey types.

It should be noted that the original optimal diet breadth model, as outlined here, hinges on a handful of crucial assumptions. Some, such as the exclusivity of search and handling, have already been noted. In addition, the model assumes that the forager has complete information about the profitability and abundance of each prey type and that the forager immediately and infallibly assigns prey items to the appropriate prey type upon encounter. Also, the model assumes foragers search for all prey types simultaneously and that prey items are encountered sequentially and in a Poisson process. These assumptions provide the justification for assigning search costs to the entire set of resources, not to individual prey items. Situations in which the search and encounter processes are not random should not be analyzed with the contingent diet breadth model. There are several variations of the original optimal foraging models that address different constraint assumptions (Stephens and Krebs 1986).

2.4.1 Anthropological applications of the diet breadth model in the Neotropics

Not long after the first optimal foraging theory (or OFT) research started to appear in the ecological literature, anthropologists began to consider possible ethnographic applications of the basic OFT models (Smith 1983). Anthropologists have used the optimal diet breadth model to analyze foraging decisions in a wide variety of environmental and social contexts, including studies with Australian aborigines (O'Connell and Hawkes 1981), the Cree in the Canadian boreal forest (Winterhalder 1981), the Semaq Beri of Malaysia (Kuchikura 1988), and the Canadian Inuit (Smith 1991). In all cases, the results generally conform to optimal foraging predictions (Kaplan and Hill 1992). The diet breadth model has also been applied fairly widely in Neotropical settings, and the model has thus far proven reasonably robust despite occasionally dramatic differences in the social organization, subsistence base, and hunting technologies of the respective study populations.

Among the first quantitative ethnographic tests of the diet breadth model was a study of Aché hunter-gatherers initiated by researchers at the University of Utah (Hawkes et al. 1982; Hill and Hawkes 1983; Hill et al. 1987). The Aché had only recently been contacted by non-indigenous authorities, and despite their resettlement at a Catholic mission, they continued to go

on extended treks into the forest (Hawkes et. al 1982). While they maintained fields at the mission, the Aché relied primarily on hunted and gathered resources while trekking. Although many Aché already possessed guns, Hill and Hawkes (1983) asked participants to hunt only with bows on some hunts, which allowed them to compare the respective efficiencies of the two weapons. Their results parallel those of Winterhalder (1981) by demonstrating that the optimal diet breadth can narrow when technological changes increase the profitability of highly-ranked prey. In this case, Aché shotgun hunters could do better by ignoring monkeys and small birds and continuing with a general search for prey while, on the other hand, these prey types were included in the optimal diet of their counterparts with bows (Hill and Hawkes 1983). Among the other interesting results from the Aché research was the observation that they (and especially the men) would sometimes bypass plant resources that would have boosted the energetic return rate, as measured strictly in calories (Hill 1988). The Aché focus was instead on foods that are high in protein and fat, particularly hunted game (Kaplan and Hill 1992).

The observation that Neotropical hunters prioritize the acquisition of wildlife resources rich in protein and fat justifies the extension of OFT to hunting in horticultural societies, for whom the energetic returns of cultivating bananas, plantains, and manioc invariably exceed the returns obtained from hunting and fishing (Hames 1989). Hames and Vickers (1982) applied the diet breadth model to three horticultural societies in Amazonia: the Siona-Secoya, the Ye'kwana, and the Yanomamö. While the data for this study were not collected for the explicit purpose of OFT analysis, Hames and Vickers (1982) contend that hunting decisions generally conform to predictions derived from the diet breadth model. Interestingly, they report that, unlike Aché prey choice, the optimal diet breadth did not appear to narrow with the replacement of bows by more efficient shotguns (Hames and Vickers 1982:373; cf. Hill and Hawkes 1983:166). However, their observation that Yanomamö hunters tend to bring back larger prey when hunting far from the community supports predictions of central place foraging models (Hames and Vickers 1982:364-367; cf. Schoener 1979; Orians and Pearson 1979). The prediction that the cost of travel to more profitable hunting zones will prompt hunters to accept lower-ranked prey near the community may explain the apparent depletion of wildlife around Neotropical villages (Vickers 1980; Vickers 1991).

The conservation of wildlife was the subject of Alvard's dissertation research with the Piro horticulturalists of Peru (1993*b*). At the time, there was considerable debate about the

potential of indigenous people to maintain the integrity of the rain forest environments in which they lived – a debate that continues more than a decade later (Redford 1991; Schwartzman et al. 2000; Redford and Sanderson 2000; Peres and Zimmerman 2001). Using the rate-maximizing assumptions of the diet breadth model as a null hypothesis, Alvard (1993a) demonstrated that Piro hunters select prey according to their OFT ranking, irrespective of their vulnerability to over-hunting (e.g. slow-breeding primates). Furthermore, Piro hunters do not deliberately refrain from taking adult female prey despite their importance to population replenishment (Alvard 1995a). A comparison of bow hunters and shotgun hunters in similar habitats confirms the conclusion of Hames (1979a) and Yost and Kelley (1983) that firearms generally allow for a higher return rate of wild game (Alvard and Kaplan 1991). However, Alvard (1994) demonstrated that shotguns have their limitations, as hunters were sometimes loath to expend their shells on low-ranking prey early in the hunt when there was still a chance of encountering higher-ranking prey. The Piro tendency to pursue low-ranking prey only as the hunt approaches its conclusion illustrates the tendency of the optimal diet breadth to expand as remaining foraging time decreases (Lucas 1983).

In conclusion, the diet breadth model has generally predicted correctly the suite of wildlife resources pursued by Neotropical hunters across a range of environmental and social settings. The aforementioned studies reiterate the importance of technology on prey choice decisions, and it is therefore interesting to note that no previous OFT study in the Neotropics has examined hunting dogs and .22-caliber rifles, the two most common hunting technologies in Bosawas.¹

2.4.2 *Hunting with dogs in the humid Neotropics*

Long an object of scientific interest, dogs continue to receive considerable interdisciplinary attention, and recent research reveals further evidence of the longtime symbiosis between dogs and people. The opinion that dogs represent the first domesticated animal receives support from genetic comparisons of mitochondrial DNA, which suggest that domestic dogs derive from East Asian wolves (Vilá et al. 1997; cf. Clutton-Brock 1977). The actual date of

¹ Hames (1979a) mentions that both the Ye'kwana and Yanomamö have hunting dogs, but their role in hunting is discussed only minimally.

domestication remains a subject of debate (Savolainen et al. 2002; Wayne and Vilá 2003), but archaeological evidence suggests a date of at least 12,000-14,000 years before present (Morey 2006). Given the length of their interaction with people, it is not surprising that dogs are particularly adept at interpreting human gestures and facial expressions. Experimental work indicates that, unlike chimpanzees, dogs can use cues such as pointing and the direction of a human gaze to identify and retrieve objects (Gácsi et al. 2004; Hare and Tomasello 2005). Humans have taken advantage of canine physical and social skills in many ways, including the use of dogs to pull sleds and travois, protect domiciles, and herd domestic animals (Schwartz 1997). Perhaps foremost among all their assignments, however, is the use of dogs for hunting.

The ethnographic literature is replete with references to the use of hunting dogs in an impressive variety of ecological settings. There appear to be few habitats in which dogs cannot be useful in hunting at least some of the available fauna. While an ethnological account of hunting dogs no doubt merits a monograph of its own, a handful of ethnographic examples will serve to make the general point of their near ubiquity. Among the locations in which researchers have reported hunting with dogs are New Guinea (Bulmer 1968), Taiwan (Fan et al. 1998), the Philippines (Estioko-Griffin 1985), Indonesia (Tenaza and Tilson 1985; Ellen 1999), India (Allchin 1966), Siberia (Levin and Popatov 1964), Kenya (Fitzgibbon et al. 1995), Botswana (Ikeya 1994), Zaire (Singer 1978), and Australia (Jones 1970; White 1972). If we consider archaeological and historical evidence as well, the geographic scope of subsistence hunting with dogs extends even farther, encompassing much of the industrial world where dogs are now used primarily for sport hunting, not subsistence hunting (Ohnuki-Tierney 1976; Anderson 1981; Fiedel 2005).

While the possession of dogs borders on universal, the ethnographic record includes a number of societies that kept no dogs. Kroeber (1942:6) noted that, in addition to his study area around the San Francisco Bay, dogs were also lacking in much of the South American lowlands.² Several ethnographers echo this observation by suggesting that dogs were not aboriginal at their study sites (Henry 1964[1941]:156; Wilbert 1972:96; Wagley 1977:60; Yost and Kelley 1983:205). High mortality rates might have slowed the rates at which indigenous societies acquired dogs, as Johnson (2003:196) reports that, despite good care, dogs brought into

² Schwartz (1997:40) concurs by noting that, although groups on the periphery of the Amazon had indigenous dogs before European contact, dogs were absent from the interior. In places where there were indigenous dogs, there was rapid interbreeding and replacement with European dogs after contact (Schwartz 1997:164).

Matsigenka communities frequently died of environmental hazards (cf. Fiorello et al. 2006:766). The Siriono lacked dogs in the 1940s, and Holmberg (1969:272-273) describes their reluctance to accept a donated dog, which did not distinguish itself in hunting and quickly became a nuisance in the community. It is therefore interesting to note that the Siriono employed hunting dogs fairly regularly during the 1990s (Townsend 2000). Similarly, Århem (1976:34) writes that the Makuna had been introduced to dogs, but their numbers were few and they were infrequently used for hunting. In a later publication, however, Århem (1998:109) implies that dogs later became the preferred technology for hunting peccaries. There seems to be a lag between the first introduction of dogs to a society and their widespread use in hunting.

In some Neotropical societies where they are kept as pets, ethnographers report that dogs are rarely used for hunting (Maybury-Lewis 1967:37; Nimuendajú 1967:95; Ruddle 1970:59). Alvard and Kaplan (1991:84) report that Piro shotgun hunters seldom bring their dogs on hunting trips, apparently because they scare off prey items before the hunters can shoot. In some cases, ethnographers question the general effectiveness of hunting dogs (Smole 1976:456; Wagley 1977:60). Nevertheless, dogs are sufficiently effective that the literature of the Central and South American lowlands includes many references to their use in hunting (Taylor 1951:58; Bennett 1962:41; Goldman 1963:57; Henry 1964[1941]:153-158; Yde 1965:120; Ruddle 1970:59; Harner 1972:58; Heinen 1972:139-140; Wilbert 1972:144-145; Carneiro 1974:127-128; Smith 1976:456; Smole 1976:179; Hames 1979a:222; Henley 1982:45; Hill 1983:85; Jackson 1983:41; Romanoff 1983:342-343; Yost and Kelley 1983:205; Brown 1984:552; Werner 1984:114; Murphy and Murphy 1985:89; Paolisso and Sackett 1985:177; Irvine 1987:108; Alvarsson 1988:179; Stearman 1990:381; Milton et al. 1991:98; Ojasti 1991:239; Vickers 1991:69; Kaplan and Kopischke 1992:99; Jorgenson 1993:66; Naranjo and Cruz 1998:120; Cunha and de Almeida 2000:15; Souza-Mazurek et al. 2000:593; Hill and Padwe 2000:87; McSweeney 2000:60; Picchi 2000:95; Townsend 2000:274; Lans et al. 2001; Orr et al. 2001:302; Henfrey 2002:100; Reyna-Hurtado 2002:68; Cormier 2003:115; Sirén et al. 2004; Altrichter 2005:356; Bonaudo et al. 2005:202; Minzenberg 2005:165; Smith 2005:511; Fiorello et al. 2006; Gurven et al. in press).

The sites at which there are reports of hunting with dogs are widely distributed throughout the Neotropics, and there appears to be few forested areas where dogs cannot be at least somewhat useful in hunting. Figure 2.1 depicts many of these sites (see Table 2.2 for

Figure 2.1. Neotropical forest locations at which there are reports of hunting with dogs.



Table 2.2. Key with references for Figure 2.1

Map number	Group	Source
1	Rural Mexicans	Naranjo and Cruz 1998
2	Rural Mexicans	Reyna-Hurtado 2002
3	Maya	Jorgenson 1993
4	Black Caribs	Taylor 1951
5	Tawahka	McSweeney 2000
6	Buglé	Smith 2005
7	Cuna	Bennett 1962
8	Irapa-Yukpa	Paolisso and Sackett 1985
9	Siona-Secoya	Vickers 1991
10	Waorani	Yost and Kelley 1983
11	Quichua	Sirén et al. 2004
12	Jívaro	Harner 1972
13	Aguaruna	Brown 1984
14	Matses	Romanoff 1983
15	Brazilian peasants	Minzenberg 2005
16	Brazilian rubber tappers	Cunha and de Almeida 2000
17	Amahuaca	Carneiro 1974
18	Machiguenga	Kaplan and Kopischke 1992
19	Tsimane	Gurven et al. In press
20	Sirionó	Townsend 2000
21	Yuquí	Stearman 1990
22	Izocéño	Fiorello et al. 2006
23	Mataco	Alvarsson 1988
24	Rural Argentinians	Altrichter 2005
25	Paraguayan peasants	Hill and Padwe 2000
26	Kaingáng	Henry 1964 [1941]
27	Bakairí	Picchi 2000
28	Mekranoti	Werner 1984
29	Parakana	Milton et al. 1991
30	Guajá	Cormier 2003
31	Brazilian colonists	Smith 1976
32	Mundurucú	Murphy and Murphy 1985
33	Waimiri Atroari	Souza-Mazurek et al. 2000
34	Waiwái	Yde 1965
35	Wapishana	Henfrey 2002
36	Afro-Trinidadian	Lans et al. 2001
37	Warao	Heinen 1972
38	Panare	Henley 1982
39	Makiritare (Yekwana)	Wilbert 1972
40	Yanoama	Smole 1976
41	Yanomamö	Hames 1979a
42	Wakuenai (Curripaco)	Hill 1983
43	Bara	Jackson 1983
44	Cubeo	Goldman 1963

sources). The literature review that uncovered these sources was not exhaustive, and there are undoubtedly other locations at which hunting dogs are used. Biases in this sample probably reflect my research interests, as many of the sources are quantitative studies by anthropologists. Almost all of the studies were published in English. I also did not include references to historical and archaeological evidence of hunting with dogs. Also, the extent of geographic information in the sources varied, and the accuracy of the plotted sites therefore varies accordingly.

While the ways in which Neotropical peoples employ hunting dogs are no doubt dictated in large part by differences in local ecology and prey abundance, there are enough reports to begin drawing a general picture of hunting with dogs in the Neotropics. Dogs are sometimes able to kill animals independently, including agoutis, armadillos, and the occasional deer (Heinen 1972:140; Smith 1976:456-458; Alvard and Kaplan 1991:86). Townsend (2000:274) reports that dogs killed about 6% of the animals in her sample. More often, however, the contribution of dogs entails bringing an animal to bay or trapping it in a hollow trunk or earthen burrow, where human hunters can then dispatch it (Carneiro 1974:127; Smith 1976:456; Jackson 1983:41; Paolisso and Sackett 1985:187; Irvine 1987:108). Thus, while some animals can be killed by hand (Heinen 1972:140), hunters almost invariably use other hunting technologies in tandem with their dogs. These technologies are generally identical to those employed by hunters without dogs, such as machetes, bows, harpoons, and guns (Smith 1976:456; Jackson 1983:41; Alvard and Kaplan 1991:86; Ojasti 1991:239).

The effectiveness of dogs depends on the anti-predator behavior of available species (Redford and Robinson 1987:661). Hunters with projectile weapons can attack prey that climb trees to escape dogs, such as coatis and predatory cats (Harner 1972:58; Jorgenson 1993:116). Many authors have noted that dogs are especially good for hunting agoutis, pacas, nine-banded armadillos, deer, and collared peccaries (Heinen 1972:140; Paolisso and Sackett 1985:184; Kaplan and Kopischke 1992:99; Lans et al. 2001). Dogs corral agoutis, pacas, and armadillos in burrows or trunks, at which point hunters will seal the exits to prevent escape and then dispatch the animal with machetes or other non-projectile weapons (Heinen 1972:140; Paolisso and Sackett 1985:187; Alvarsson 1988:284). Axes may be used to create an opening through which hunters can access the animal (Heinen 1972:140), and hunters sometimes smoke out otherwise inaccessible animals (Paolisso and Sackett 1985:187; Irvine 1987:108). Deer are sometimes killed when dogs chase the animals toward water, where hunters wait in dugout canoes to kill the

animal (Heinen 1972:140). Pacas may also be killed after being chased into the river by dogs (Yde 1965:125). In other locations, hunters train dogs to drive deer in their direction, where the hunters shoot the animals with shotguns (Smith 1976:456). Collared peccaries hide from pursuing dogs in trunks or holes, which allows hunters to catch up to the chase and dispatch the peccaries with a variety of technologies (Henry 1964[1941]:157; Smith 1976:456; Alvarsson 1988:284). Reportedly, hunters in the Argentine Chaco always use dogs when hunting collared peccaries (Altrichter 2005:356). The effectiveness of dogs in comparison to other technologies for hunting certain species is poignantly demonstrated by the case of the Waorani. Before they adopted hunting dogs, the Waorani actually tabooed deer, tapirs, and collared peccaries, reportedly because those animals were so difficult to kill with traditional Waorani technologies (Yost and Kelley 1983:206).

While the effectiveness of dogs in hunting collared peccaries is seldom disputed, their value in hunting white-lipped peccaries and tapirs is debatable. Although hunters can sometimes catch up and kill white-lipped peccaries when they turn to attack the dogs, this maneuver can easily prove fatal for the dogs (Smith 1976:456; Wagley 1977:62). Other groups report that dogs can ruin white-lipped peccary hunts by scaring off the herd (Wilbert 1972:42). Similarly, whereas Wilbert (1972:41) and Smith (1976:456) report that hunters can attack tapirs when they stop to combat the dogs in streams or other waterways, Kaplan and Kopischke (1992:99) report that Machiguenga hunters accuse dogs of scaring off the tapirs before they have a chance to shoot. By contrast, researchers approach unanimity in their opinion that dogs are a hindrance for hunting most birds and arboreal prey (Werner 1984:113; Kaplan and Kopischke 1992:99; Descola 1994:235). Lu (1999:129) reports that the success rate for hunters with dogs was lower than that of hunters without dogs, but the result was not statistically significant. The relative importance and effectiveness of dogs might vary seasonally. Buglé hunters report that dogs are less effective when the weather is rainy (Smith 2003*b*), and Kaplan and Kopischke (1992:99) report that Machiguenga hunters leave dogs behind when they concentrate on seasonally heavier monkeys in the wet season. When seasonal agricultural work precludes deliberate hunting trips, dogs can sometimes corral small game in the areas surrounding the fields (Smith 1976:456; Paolisso and Sackett 1985:186; Smith 2003*b*:115).

There are few reports of the modal number dogs used by individual hunters, but Smith (1976:456) reports that the use of 1-4 dogs is common for Brazilian colonists while

Machiguenga hunters generally embark with 1-3 dogs (Kaplan and Kopischke 1992:99). Townsend (1995:51-52) reports that Sirionó hunters typically bring 1-3 dogs. The dogs spread out upon entering the forest, and hunters and dogs communicate with calls and barks (Smith 1976:456; Kaplan and Kopischke 1992:99). The amount of training that hunting dogs receive seems highly variable (Heinen 1972:140; Smith 1976:456; Descola 1994; Lu 1999:75). For many groups, there seems to be a belief that hunting ability in dogs is an innate quality, and little attention is apparently given to their training (Heinen 1972:140; Smith 2003*b*:117). Others mention that successfully hunting some prey types requires special characteristics in the hunting dogs. Because deer flee long distances, for example, Trinidadians say that dogs must be swift and have good endurance to chase them (Lans et al. 2001). The exchange value of hunting dogs seems to depend largely on the size of the animals that they can effectively pursue, with dogs that can successfully track ungulates ranking higher than dogs that can detect and corral only smaller animals such as rodents and armadillos (Descola 1994:233; Howard 2001:255). Particularly adept hunting dogs with a demonstrated history of success can command a relatively high price when sold or bartered by their owners (Howard 2001:248-249; Smith 2003*b*:117).

Dogs are often injured on hunting trips, either cut by hunting technologies (e.g. machete) or bitten by prey animals such as peccaries and tapirs (Smith 1976:456; Werner 1984:115; Smith 2003*b*:111). Owners may attempt to treat injured dogs with traditional remedies or modern medicines (McSweeney 2000:66; Lans et al. 2001). Hunters also use a wide variety of techniques to improve the overall effectiveness of their dogs. These techniques include rubbing their hair or noses with plants or animal parts, magical incantations and sorcery, songs, and special foods (Kahn 1931:81-82; Yde 1965:120; Ruddle 1970:59; Smith 1976:456; Smole 1976:180; Jackson 1983:47; Brown 1984:551; Muñoz et al. 2000; Lans et al. 2001). Despite their apparent importance to hunting success, however, a number of researchers have reported that dogs are typically neglected and underfed (Smole 1976:180; Jackson 1983:41; Picchi 2000:95; cf. Yde 1965:119). In some settings, dogs appear to consume human excrement on a regular basis (Bergman 1980:152; Werner 1984:103). There are indications that talented hunting dogs receive better care than their less talented conspecifics (Im Thurn 1967[1883]:232; Heinen 1972:140; Crocker 1985:32; McSweeney 2000:66; Howard 2001:247). Reports of dogs being

eaten by human consumers are conspicuously absent in the ethnographic literature from the Neotropics (see Schwartz 1997 for reports of dogs being consumed elsewhere in the Americas).

2.5 The Mayangna and Miskito in ethnological perspective

The indigenous Mayangna and Miskito people of northeastern Nicaragua belong to the Macro-Chibchan language family, which includes Central American cultures such as the Kuna and Teribe of Panama, the Bribri and Maleku of Costa Rica, and the Rama of Nicaragua (Barrantes 1993). The full extent of the Chibchan language group extends into northern South America and includes cultures in Colombia and Venezuela (Layrisse et al. 1963; Craig and Hale 1992). Within Nicaragua, therefore, the indigenous Chibchan-speaking peoples of the Atlantic coast unsurprisingly show more affinity to South American groups than do the now extinct indigenous cultures of western Nicaragua, which were more closely tied to the great civilizations of Mesoamerica. Prior to the arrival of the Spanish in 1502, the Mayangna probably represented the largest group of Chibchan speakers in Nicaragua, with lands that reached from the vicinity of Lake Managua in the west to the Atlantic lowlands in the east (Stocks 1996). Recent linguistic studies suggest that the Mayangna were established in Nicaragua as long as 4,500 years ago, contradicting some theories that postulate a recent migration into the region (Constenla Umaña 1991).

Various typologies have been used to categorize Latin American tribal societies. Steward (1947), for example, employed a four-fold classification, dividing South American cultures into the Marginal tribes, the Tropical Forest tribes, the Circum-Caribbean tribes, and the Andean tribes. Within this broad classification system, Steward included the Mayangna and neighboring Central American groups in the Circum-Caribbean group, which is characterized by social stratification, chiefdom politics, intensive maize farming, and relatively high population densities (Steward 1947). Steward further contends that this socio-political complexity ebbed considerably in the wake of Spanish contact, and most Circum-Caribbean groups have essentially devolved into simpler cultures much like the Tropical Forest tribes. Subsequent research calls into question many of these conclusions, however, and Steward's model is generally considered too broad to account for variation at the regional level.

An alternative classificatory scheme emerges from archaeology, and the term “Intermediate Zone” was first used by Wolfgang Haberland in 1957 to distinguish much of lowland Central America from Mesoamerican cultures to the north and Andean cultures to the south (Haberland 1957). Geographically, the Intermediate Zone encompasses much of eastern Honduras and Nicaragua, down through Costa Rica and Panama and terminating in South America near the Maracaibo Basin. Unlike Steward, Willey (1984) contends that the political organization of societies in the Intermediate Zone was relatively simple. Willey describes small communities of maize and manioc agriculturalists with little social stratification, much like many extant indigenous communities in Central America. Despite the general popularity of the Intermediate Zone model, Cooke (1987) argues that it obscures the full extent of regional variation and that the area should not be considered a dark corridor between the cultural fluorescence of the Andes and Mesoamerica. Instead, Cooke contends that there was considerable regional variation and cultural diffusion in Pre-Columbian Central America. Within Nicaragua itself, however, there has been relatively little archaeological work to support Cooke’s model, perhaps stemming from intermittent political uncertainties in the region. Then, too, longstanding beliefs about the poor preservation of material remains in rain environments might account for the paucity of archaeological research in coastal Nicaragua.

On a regional scale, Mayangna and Miskito belong to the Misumalpan family, which also includes Ulwa and the now extinct Matagalpan language (Benedicto and Hale 2000). Mayangna itself included several regional dialects. Of the seven Mayangna dialects identified by Conzemius (1932), however, only three remain: Ulwa, Twahka, and Panamahka (Stocks 1996).³ Today, the Ulwa are predominantly located in the inland forests near Bluefields and Pearl Lagoon, while Twahka enclaves are mostly found in the rain forest regions of southern Honduras (Nietschmann 1969). The Mayangna who participated in this study are primarily descendants of the Panamahka, who have maintained their occupation of the Coco River’s main tributaries even as an expanding Miskito population has settled the Coco itself, mostly in the last two hundred years (TNC 1997; Carey 2000). Offen (in press) provides an excellent overview of the distribution of indigenous groups at the time of the Miskito expansion (Figure 2.2).

As with indigenous groups throughout the Americas, Nicaraguan Amerindians were decimated by infectious diseases such as measles and smallpox following European contact

³ For a broad review, see von Houwald (2003).

Figure 2.2. The distribution of indigenous groups in the Mosquitia at the time of the 18th century Miskito expansion (adapted from Offen in press)



(Newson 1982). A burgeoning slave trade compounded the rate of depopulation in the sixteenth century, with indigenous Nicaraguans primarily being sent to Spanish colonies in Peru and Panama (Newson 1982:272). In the remote rain forests of the Atlantic Coast, though, the Mayangna fared somewhat better than their contemporaries in western Nicaragua, where populations declined by as much as 97.5% (Newson 1982: 284). Buffered somewhat by the rough topography and dense vegetation of the Bosawas region, the Mayangna also benefited from the Spanish disinterest in the region. Especially fortuitous was the fact that gold deposits in the region were not discovered until 1890 (Parsons 1955*a*). Had the Spaniards been aware of these gold deposits, the Mayangna might have long ago succumbed to deliberate extermination or at least forceful relocation or enslavement (Carey 2000).

Although it is easy to attribute the cultural survival of the Mayangna to the remoteness of their homeland, Carey (2000) has recently argued that the Mayangna did much to maintain that remoteness. Carey cites ethnohistorical evidence of violent resistance to Spanish missionaries who penetrated Mayangna territory, and some missionaries died in the attacks. By the late 1700s, the Mayangna were also ambushing travelers and raiding Spanish settlements on the borders of their territory (Carey 2000:4). Despite their bellicosity, however, it is fairly clear that Carey downplays the extent to which the Mayangna suffered attacks from their Spanish neighbors to the west, who surely posed a constant threat to Mayangna autonomy and survival. However, throughout much of the colonial era, the threat of Spanish subjugation gradually gave way to the hazards posed by a new foe: the Miskito.

The predominance of the Miskito on Nicaragua's Atlantic Coast belies their humble origins. At the time of European contact, the Miskito were apparently a small group of somewhat marginalized coastal dwellers (Nietschmann 1973). This group probably spoke a Mayangna dialect, perhaps the now extinct Bawhika dialect (Helms 1971:18), and there is still considerable similarity between the Mayangna and Miskito languages. Whereas the Mayangna remained relatively isolated from European contact, however, the Miskito are a unique genetic amalgamation of shipwrecked African slaves, British buccaneers and merchants, Spanish colonials, missionaries, and more (Nietschmann 1973; Stocks 2003). This biological admixture is matched by the adoption of cultural and linguistic traits from these same sources, as evidenced by the presence of English words in the Miskito vocabulary and the importance of Christianity. Historically, the emergence of the Miskito as a regional power appears to stem from contacts

with English and French buccaneers, who provided them with guns in the seventeenth century (Helms 1971). A later alliance with the English empire buttressed their control of the Atlantic Coast, and the Miskito eventually advanced their settlements north to the Tinto River in Honduras and south to Pearl Lagoon in Nicaragua (Conzemius 1932; Nietschmann 1973).

The burgeoning power of the Miskito pushed the Mayangna farther inward, especially as the Miskito began to conduct slave raids of Mayangna settlements (Helms 1971). Insufficiently armed to combat the Miskito, many Mayangna groups retreated to the Bosawas region, where they settled along the headwaters of small tributaries (A. Stocks, pers. comm. 2003). Whether Mayangna resistance or Miskito disinterest in further expansion explains the prolonged isolation of these communities is an open question, but it is reasonably clear that the Miskito did not join the Mayangna in the Bosawas region until about 150 years ago (Stocks 1996). Evidence of trade between the two groups in the eighteenth and nineteenth centuries casts doubt on the depth of hostilities between the two groups (M.W. 1732; Bell 1862), but it is certain that Mayangna antagonism toward the Miskito stems from more than just the latter's current political superiority. Hostilities between the two ethnic groups have continued into the twentieth century, and many Mayangna informants report a general disdain for their Miskito neighbors.

Interestingly, even as the Miskito and the Mayangna began to settle in close proximity during the 1800s, the trend toward Miskito acculturation and Mayangna isolation persisted. This trend was particularly evident in the extent to which the indigenous groups embraced market integration and wage labor opportunities. Beginning in the middle of the nineteenth century, there was no shortage of opportunities to work for international rubber, timber, and banana companies. Indeed, Helms (1971) traces much of the current Miskito economic system to their participation in these wage labor jobs and their integration into the external market economy. On the other hand, Carey (1999) contends that Mayangna participation in these extractive industries was minimal, although his primary historical sources are somewhat limited. When they did engage in wage labor, Mayangna individuals apparently did it largely on a seasonal basis, seldom abandoning their dependence on subsistence farming, hunting, and fishing.

In the nineteenth century, foreign companies were joined on the Atlantic Coast by Moravian missionaries, who enjoyed a far more amicable reception than did their Spanish predecessors. Moravian mission work began primarily in coastal regions, but missionaries eventually reached the Bosawas region in the early 1900s (Heath 1915). Moravian churches

soon became widespread throughout the region, and the missionaries trained indigenous pastors. This pattern continues today in many indigenous villages, with Catholics joining the Moravians as the primary religious interests in the region. Stocks (1996) reports that the political importance of the church has declined somewhat in the wake of the Contra war, but this decline does not seem to be accompanied by a drop in membership.

The missionary accounts of the Moravians, together with earlier sources, comprise a relatively rich body of ethnohistorical insight into Mayangna culture. However, these sources often fail to address many uniquely anthropological concerns, and there is a pronounced shortage of quality ethnographic research on the Mayangna. Conzemius (1932) remains the primary ethnographic source, although it must be noted that this work is a general survey of all indigenous groups on Nicaragua's Atlantic coast. Although Conzemius provides a thorough look at the material culture, political organization, and subsistence practices of the region's indigenous inhabitants, his chronic failure to distinguish between the Rama, the Miskito, and the Mayangna severely undermines the usefulness of his monograph. One can reach only general conclusions about traditional Mayangna culture, which seems to share many traits with other Neotropical groups, including shamanistic religion, egalitarian political organization, sporadic inter-tribal warfare, polygynous marriage, and simple material culture.

2.6.1 The Post-Contra War Situation

The Bosawas Reserve was created by presidential decree in November 1991, shortly after President Violeta Chamorro took office following the long reign of Sandinista political leadership in Nicaragua (Kaimowitz et al. 2003). According to the decree, the reserve had a twofold purpose: to conserve wildlife in the reserve and to protect the natural resources and cultural heritage of the reserve's Mayangna and Miskito inhabitants. Despite the progressive rhetoric behind the creation of the reserve, however, it is fairly clear that the Chamorro administration had an underlying agenda for the Bosawas region. Following the demise of the Sandinista government, Nicaragua was filled with entrepreneurs seeking timber and mining concessions in the Bosawas region. Establishing the Bosawas Reserve allowed the Chamorro administration to retain a measure of control over the area (Stocks 2003).

Although the reserve was ostensibly intended to protect indigenous rights, the indigenous people themselves were not consulted prior to its creation (Stocks 1996). At the time, many of the Mayangna and Miskito inhabitants of the reserve had only recently begun to resettle in the Bosawas region. Much of the fighting in the Sandinista-Contra conflict occurred in the area, and many of the indigenous people had either fled to Honduras or had been shuttled off to refugee camps in western Nicaragua by the Sandinista government (Nietschmann 1989; Ortega 1991). The indigenous people returned home to find that their plantations had been destroyed, and landmines dotted the landscape in many areas.

Following the Contra War, the Nicaraguan government was also faced with the problem of resettling soldiers from both sides. To many politicians, the undeveloped forests of the Bosawas region, inhabited only by small groups of indigenous peoples, was the logical place to resettle soldiers and their families. Soon, newly created towns such as Ayapal on the southwestern edge of the reserve became staging areas for widespread colonization of lands within the reserve's boundaries (Stocks 1998). Many of the mestizo colonists lay claim to homesteads by clearing land for both agricultural fields and pastures, thereby promoting rapid deforestation and unsustainable land use (Stocks 1998). Many indigenous residents responded to these incursions by retreating into the northern part of the reserve, leaving behind a number of abandoned communities along the Bocay and Coco Rivers (Stocks 2003).

The Nature Conservancy (TNC) became aware of the reserve's conservation potential shortly after its creation. Recognizing that long-term conservation of the Bosawas rain forest largely depended upon an indigenous presence in the reserve, TNC initiated a project in 1993 to document indigenous land claims and stymie mestizo expansion into the reserve (Stocks et al. 2000). The process of mapping indigenous territories in the reserve has since been matched by efforts to document land claims elsewhere in Nicaragua (Dana 1998; Offen 2003; Stocks 2005). The land claims were viewed as a vital step in the process of securing legal land tenure to the traditional indigenous homelands in the reserve, and the result of the TNC project was a series of maps with local toponymy for each of the reserve's six indigenous territories (Stocks 2003).

TNC administrators recognized that the process of obtaining legal land title would be a long and arduous process, and it became clear that the documentation of indigenous land claims would serve little use if incursions by mestizo colonists continued to displace indigenous communities. When the indigenous territories requested assistance with the formation of a forest

guard corps, TNC therefore offered to provide technical and financial assistance (Stocks et al. 2000). Voluntary forest guards now patrol the boundaries of the reserve, preventing invasions of colonists and monitoring territorial norms of acceptable land use. Another facet of the TNC strategy focuses on strengthening local administrative institutions, and each territory now has a representative political body that both manages internal affairs and interacts with state officials and external non-governmental organizations⁴ (Stocks et al. 2000). Finally, in May 2005, after a protracted and occasionally contentious political battle, the efforts to secure land rights for the indigenous communities culminated in the presentation of land title to these indigenous associations (Stocks 2005).

2.6.2 *External interests in Arang Dak and Suma Pipi*

Bosawas remains an area of interest for conservationists, other NGO's, and religious organizations, and the remote location of Arang Dak and Suma Pipi did not prevent visits by various projects, including TNC, CEDAPRODE, the Nicaraguan Ministry of Health, and a visiting priest from the Department of Jinotega. While most of these visits were relatively brief in duration, the presence of two projects in particular merits special attention. First, the Saint Louis Zoo's *Proyecto Biodiversidad* was active in Kipla throughout the duration of my tenure. Until January, this involvement included data collection on household meat consumption and the patrolling of linear transects to determine animal densities in the territory.⁵ Employees of the Zoo's project included one man from both Arang Dak and Suma Pipi, who were appointed to collect data on hunted animals.⁶ A woman from Suma Pipi also visited all houses in both Arang Dak and Suma Pipi to distribute and review household records of meat consumption. Methodologically, these two aspects of the Zoo's project parallel components of my own study, and for approximately four months, there was occasionally considerable overlap between the two projects.⁷ Meanwhile, my wife worked for the Zoo as a conservation educator. Her work involved frequent travel throughout the territory, and she would occasionally enlist men from the

⁴ The indigenous association in Kipla Sait Tasbaika is generally known by its acronym, KUNASPAWA.

⁵ The work in the transects generally used methods described by Burnham et al. 1(980) and Buckland et al. (1993).

⁶ The assistant from Arang Dak eventually became an assistant for my project after completing his work with the Zoo.

⁷ This overlap was especially apparent when the Zoo's employee and my research assistant would simultaneously be on a hunter's porch, alternately asking the hunter questions about their expedition and prey.

village to transport her to various locales on the Lakus River. When not traveling, her stay in Arang Dak was not particularly disruptive to village life, as she did not employ anyone except for occasional help with translation.

The second project that deserves special mention is an ethno-ecological project coordinated by a former employee of the Saint Louis Zoo. Part of the UNESCO program, LINKS, this project recorded Mayangna knowledge about the fish and turtles in the reserve. Subsequent work will focus on mammals and plants, and preliminary work on the mammals began as I was completing my stay in Nicaragua. The LINKS project employs one regular employee, who coordinates interviews and occasional workshops in Arang Dak, including participants from other Mayangna communities and sometimes other territories. Other activities involved travel to Managua, and two or three indigenous men would sometimes accompany the indigenous coordinator of the project. Also working with the project was Menuka Scetbon-Didi, a student of anthropology from Université Jussieu in Paris. She lived in Arang Dak from February-May 2005, collecting data for a thesis. Her research involved considerable participant observation, and she regularly accompanied families as they fished, worked in their fields, panned for gold, collected household construction materials, etc.

2.7 Biophysical aspects of the Bosawas region

Arang Dak and Suma Pipi are located on the Lakus River, a tributary of the Coco River. Following Sioli (1967; 1984), anthropologists have traditionally divided Neotropical rivers into three categories: white, black, and clear (e.g. Beckerman 1994a). These rivers are distinguished by their sediment and acidity, with whitewater rivers characterized by the highest sediment loads and blackwater rivers by humic and fulvic acids that leach through the soil. The acidity in blackwater rivers is generally thought to undermine both fishing productivity and the agricultural quality of alluvial soils, and the blackwater rivers in Colombia have therefore been called “rivers of hunger”⁸ (Janzen 1974). To my knowledge, nobody has applied Sioli’s classification to the tributaries of the Coco, but it is reasonably safe to exclude blackwater as a possibility. Transparency is the distinguishing factor in Sioli’s scheme, and transparency on the Lakus varies

⁸ Gragson (1992a) disputes the former claim, citing comparable fishing yields per hour in whitewater and blackwater rivers.

seasonally, as it does for many Neotropical rivers (Richey et al. 1991). I therefore hesitate to dub the Lakus either a clearwater river or a whitewater river, but it is perhaps important to note that the sediment load does not include the relatively recent volcanic soils from the mountains to the west of the reserve, as does the Coco. In general, soil surveys in the region have been relatively rare, but soils in a neighboring watershed (the Patuca in Honduras) include mostly red latosols and lithosols in the uplands and marine alluvial soils along the watercourses⁹ (Cruz and Benitez 1994).

Suma Pipi and Arang Dak are located about 150 meters above sea level, and few of the surrounding hills exceed 300 meters in elevation. According to the Holdridge model of classifying life zones, most of the Lakus watershed can therefore be considered Basal Humid Tropical Forest (Bolton 1998). As elsewhere in Nicaragua, rainfall fluctuates throughout the year, and residents divide the year into two seasons, the dry “summer” and the rainy “winter.” The indigenous people typically claim that summer begins in late December or January, and winter begins in late May. The Saint Louis Zoo maintains a small weather station in Raiti, the capital of the territory, and I had planned to use these data to track short-term variations in rainfall and temperature. Unfortunately, repeated mechanical problems with the weather station prevented anything more than occasional bouts of accurate data collection. If 2004-2005 was a typical year, however, yearly rainfall probably reached 3,000 millimeters, with a pronounced peak in July. Hurricanes are relatively rare on the Caribbean coast of Nicaragua (Nietschmann 1973), but those that do strike the region can cause considerable damage, as did Hurricane Mitch in 1998 (Bolton 1998). April is generally the hottest month, with temperatures approaching 30° Celsius, although daily highs typically exceed 20° throughout the year.

The Bosawas Reserve is the largest conservation block in Nicaragua, and it occupies nearly seven percent of the national land area. Along with similar reserves in Honduras, namely the Platano River Biosphere Reserve, the Tawahka Asangni Biosphere Reserve, and the Patuca River National Park, the Bosawas Reserve represents the largest tract of broadleaf tropical forest north of Amazonia. This tract of rainforest is part of the virtually continuous belt of rain forest that runs from the Ecuadorian coast up to Belize and southern Mexico (House 1997). The Bosawas region has not been deforested to the extent that rain forests elsewhere in Central America have been (Heckadon-Moreno 1997), and remote sensing suggests that primary forest

⁹ Taylor’s (1963) general survey of Nicaragua suggests that brown latosols predominate in the Bosawas region.

continues to dominate the area despite agricultural clearing that followed the end of the Contra War in the early 1990's (Smith 2001). Additional remote sensing data indicate that indigenous territories display considerably less deforestation than neighboring mestizo areas (Stocks et al. unpublished manuscript).

Chapter 3

Optimal foraging perspectives on hunting in Bosawas

This chapter features tests of the hypothesis that the hunting decisions of Mayangna and Miskito hunters in Bosawas are consistent with predictions derived from optimal foraging theory. It begins with an ethnographic description of hunting in Bosawas. Special attention is paid to hunting with dogs, a topic that has not received extensive attention in the ethnographic literature. Hunting with dogs entails costs beyond those that factor into most optimal foraging analyses, as hunters must first devote time to catching up to their dogs before they can identify the prey type and decide whether or not to attack. I argue that these costs are best modeled with the recognition constraints model of Houston et al. (1980). Tests of the optimal prey choice model are presented for both hunters with dogs and hunters with rifles. In general, the results support the model, as all regularly pursued prey types increase the overall return rate. However, it appears that Mayangna and Miskito hunters choose not to pursue or consume some prey types that would be included in the optimal diet breadth. Possible explanations for these apparently suboptimal decisions are presented and evaluated. Finally, I evaluate the respective productivity of hunting with dogs, guns, or both dogs and guns. While all technologies yield a return rate that compares favorably to hunting returns throughout the Neotropics, the data suggest that the combination of the two technologies gives hunters the highest average return rate.

3.1.1 *Ethnographic literature on hunting in the Bosawas region*

Ethnohistorical and anthropological accounts of hunting in the Bosawas region are relatively rare.¹ The nineteenth century travel narratives of Bell (1862; 1989[1899]) provide some of the first glimpses into indigenous hunting practices, but already by this time firearms were becoming the preferred hunting technology despite the fact that bows remained their “most

¹ The Bosawas region and the coastal biotope described by Nietschmann (1972; 1973) differ to the point that they should be considered different hunting environments. While many prey types, technologies, and hunting techniques transcend the ecological differences, some of Nietschmann’s observations reflect the uniqueness of the coastal setting, which includes access to lagoons. The reserve also lacks the pine savannas that characterize much of the Atlantic coast (Parsons 1955b). Dunn (2004) recently conducted a short-term study of hunting at a site in eastern Honduras where hunters have access to both forested and savanna environments.

effective weapon” (1862:257). Conzemius (1932) reports that bows persisted as the primary hunting weapon into the twentieth century, and the indigenous Nicaraguans maintained a variety of arrows unique to hunting, fishing, or warfare. Herlihy (1995) writes that spears and blowguns were important aboriginal hunting weapons, but their absence in the early ethnographic accounts suggests that these technologies diminished in importance soon after contact with Europeans. Indigenous hunters apparently retained the use of bone whistles to lure agoutis, as both Conzemius (1932) and Helms (1971) report the use of this technique (cf. Harner 1972:59). Dogs receive a brief mention in Conzemius (1932), who notes that they were regularly used on hunting excursions. Conzemius (1932:78-79) reports that dogs are especially useful for hunting pacas and that Sumu hunters also used their hunting dogs to target deer. An earlier mention of dogs in the lowland areas near Bosawas comes from Belt (1911[1874]:159), who reports that indigenous traders traveled to mestizo towns in the mountains to barter for dogs.² In his 18th century account, M.W. (1732:297) also comments on the presence of dogs, noting that they are especially vulnerable to predation by jaguars (cf. Conzemius 1932:78). Together, these sources suggest that hunting dogs have been present in the Mosquitia for at least several centuries, which contrasts with societies for whom dogs are a relatively recent introduction³ (Hill and Hawkes 1983; Yost and Kelley 1983).

Despite some of the aforementioned differences, contemporary indigenous hunting strategies do not differ dramatically from those described in the early ethnographic literature. As in Conzemius (1932), hunting remains an almost exclusively male activity, often done

² The passage does not specifically indicate that the dogs were wanted for hunting, but it does suggest that the dogs were highly valued: “I could not ascertain what they wanted with the dogs, but both at this place and at Matagalpa I was told of the great value the Caribs put on them. Although the people of Olama expressed great surprise that the ‘Caritos,’ as they call the river Indians, should take so much trouble to obtain dogs, they had not had the curiosity to ask them what they wanted them for. Some people near the river have even commenced to rear dogs to supply the demand. The Caribs had a special liking for black ones, and did not value those of any other colour much. They would barter a gun or a large iron pot for a single dog, if was of the right colour” (Belt 1911[1874]).

³ The words that societies use for dogs might reveal clues about the length of their interactions with dogs (Carneiro unpublished manuscript). In some settings that lacked dogs before European contact, societies in need of a name for the animal borrowed European words for dogs, such as variations of the Spanish word, *perro* (e.g. Kloos 1971:59; Drummond 1977:852). Alternatively, some societies that encountered dogs in recent centuries sought parallels with familiar mammals, as when dogs were called by variations of the local word for “jaguar” (e.g. Holmberg 1969:272; Descola 1994). Schwartz (1997:40) suggests that, because they lack such obvious derivations, the indigenous words for dogs in the Orinoco River watershed and the Guiana Highlands are evidence of the pre-contact existence of dogs in these areas. Similarly, the Mayangna and Miskito words for dog are *sul* and *yul*, respectively. These words have no immediate resemblance to either the European words for dog or any of the indigenous names for large mammals in the reserve (see Appendix A). There is also a cognate (*sálu*) in Ulwa, a related Misumalpan language (Green 1999:249), which likewise suggests pre-Contact familiarity with dogs.

solitarily. The primary goal of hunting is to obtain meat for consumption, with the marketing of meat and skins (e.g. ocelot, jaguar) being less important to contemporary Mayangna than it has been to populations elsewhere in the Mosquitia (Stocks 1996; Merriam 1998; cf. Nietschmann 1973). Many of the species currently hunted in the Bosawas region are traditional targets, such as armadillo, agouti, iguana, tapir, paca, peccary, deer, etc.⁴ Finally, the continued importance of hunting is amply illustrated in the observations of a Moravian missionary:

It is also most interesting, even for a visitor unable to understand the language, to watch an Indian hunter describe his adventures in the forest. The usually stolid and unemotional Indian becomes most alert and vivid in his pantomimic descriptions of how he stalked his prey, what happened then and how he succeeded in getting it. He knows the names and the habits and the uses of everything that surrounds him: animals and plants, and is especially familiar with anything that can be found to quench his thirst and appease his hunger. (Mueller 1932:44)

In many ways, Mueller could have been describing the participants in my study.

3.1.2 *An Ethnographic description of hunting with guns in Bosawas*

The Mayangna and Miskito distinguish between hunting with guns and hunting with dogs. Other technological differences (the presence of axes, harpoons, lances, etc.) are secondary to this primary distinction. On those occasions when men hunt with both dogs and a rifle, they generally adhere to the strategies that are commonly employed by hunters with only dogs and hand technologies. In other words, to be considered a true rifle hunt, men must typically hunt without dogs. When hunting with dogs, guns may be used to target game animals, but an equally important purpose for some hunters is to protect their dogs from jaguar attacks. In terms of hunted game, the combination of rifles and dogs might be most effectively employed in pursuing tapirs: 8 of the 14 tapirs killed during the study period were located by dogs and subsequently wounded with rifles.⁵

Techniques used when hunting exclusively with guns resemble those described in previous ethnographic accounts of indigenous Neotropical hunters (Hames 1979a; Yost and Kelley 1983; Alvard 1993b). Whereas much of the anthropological literature focuses on shotgun

⁴ One exception to this generalization is frogs, which Conzemius (1932) notes are sometimes consumed by the Mayangna, but not the Miskito. In a detailed study of Mayangna herpetological knowledge, however, Malkin (1956) found no evidence for consumption of frogs. It is not known if this incongruity reflects an error in the earlier ethnography or a change in Mayangna subsistence.

⁵ In addition to the rifles, other weapons were sometimes used to complete the kill once the animal was largely immobile.

hunters, however, Mayangna and Miskito hunters have only .22 caliber rifles, many of them sporting the brand name Winchester.⁶ Bullets are purchased from local merchants, and the cost per bullet in 2005 was 2.5-3 cordobas. Bullets can sometimes be obtained from friends and family, although the lender is generally entitled to a share of whatever meat the hunter brings back. The same logic applies to borrowing rifles, as the owner expects to receive a portion of the hunter's harvest, perhaps as much as half. The quality of both the rifles and the bullets is rather dubious. Guns frequently misfire, and hunters often blame the bullets, especially when they have previously gotten wet. Others complain about the accuracy of their rifles, citing imperfections in the barrel of the gun.

Rifle hunters tend to follow established trails whenever possible, saying that the visibility is better and the noise of clearing new trails scares away animals. Trails may be either a loop through the forest or a straight path to a community in another watershed. In both cases, trails often parallel streams or follow ridgelines. Hilltops and streams are cited as the most likely places to encounter prey, and hunters sometimes opt to leave the trail in order to explore nearby summits or adjoining creeks. In addition to stopping for longer breaks on occasion, hunters periodically stop walking to listen for signs of prey presence. Mimicry of game animals seems somewhat rare, but hunters occasionally purse their lips and whistle in the hope that a group of spider monkeys will answer. One hunter also made a makeshift lure out of a used D-size battery case, with which he would sometimes attempt to lure agoutis while hiding in the buttress of a large tree.⁷

Birds are the most commonly encountered prey, and hunters pursue a wide variety of avian species. Most preferred are the three large species: tinamou, crested guan, and great curassow. Tinamous are most frequently pursued when they are encountered on the ground, and hunters sometimes stalk them for several minutes looking for a clear shot. Escapes are common, as the birds either sneak away or fly off before the hunter can shoot. Guans and curassows are usually spotted when perched in trees, but again, they often fly off before the hunter takes a shot. Male curassows are encountered most often in April, when their singing announces their presence to hunters. Some hunters specifically target great curassows at this time, although the

⁶ Foreign knockoffs are common in Nicaragua, and some of the guns were probably made by Central American companies illegally using the Winchester name.

⁷ The resulting sound was remotely similar to that of the noisemakers that are sometimes seen at New Year's parties in the United States.

dry leaf litter underfoot can make it somewhat difficult to stalk the birds stealthily. *Carpinteros* (woodpeckers) are also detected from the sounds they make, but they are sometimes considered too small to merit the wasted time and bullets of a pursuit.

Except for white-lipped peccary hunts, hunting parties seldom number more than two or three individuals, often including unarmed boys who go along to help transport prey or perform other errands. Most hunting trips can be characterized as general searches for prey, although hunters sometimes make a point of visiting marshy areas where tapirs are most frequently found. Tracking of prey seems generally rare, but hunters do attempt to track peccaries (both varieties) if they discover fresh prints and especially if they detect the animals' characteristic scent. Although hunters usually attempt to return home before nightfall, some rifle hunters report that they are willing to sleep in the forest if they encounter recent signs of white-lipped peccaries, as they will surely lose the trail if they do not resume tracking early in the morning.

When members of the community report opportunistic encounters with white-lipped peccary tracks, three to seven hunters form a group to track the herd. Tracking the group is fairly easy because peccaries create a swath of disturbed vegetation and partially-eaten food as they progress through the forest. Hunters are attentive to other signs as well, particularly smells and the clicking sounds made by peccary teeth. Hunters also watch for subtler signs, such as increased muddiness in a stream when the peccaries might be upstream. On these excursions, most hunters have rifles, but some are armed only with lances and machetes, which may be used not only to attack the animals but also to drive the herd back toward their companions with guns or perhaps to finish off an already wounded animal. Dogs play a limited role on white-lipped peccary hunts, but a dog was brought on one observed hunt. It was entrusted to a teenager, who kept it on a makeshift leash until hunters had encountered and encircled the peccaries. After the hunters opened fire, the peccaries began to flee, at which point the dog was released to scare the peccaries back toward the hunters.

With one notable exception, ambush hunting is not common in Bosawas, and I did not observe any platforms constructed to protect fields from agricultural pests. The only hunting that might truly be considered ambush hunting is the practice of awaiting paca at fruiting trees after dark. One man in particular specializes in hunting pacas this way, and he spends time during daylight hours looking for food remains that indicate recent visits by a nearby paca.

Accompanied by a younger brother-in-law, he later hides near the tree at night. If they hear

suspicious sounds, the brother-in-law illuminates the paca with a flashlight while the hunter aims and fires. This technique is effective primarily in January, when the breadfruit are falling, and I do not know of similar hunting at other times of the year.

During the dry season, men sometimes leave in the late afternoon to check on their bean fields upstream, then use flashlights to fish with bows or diving masks and *varilla* on the return journey. While upstream, men are particularly vigilant for crop predators that emerge at dusk to feed on the beans. Tapirs and red brocket deer are commonly cited as particularly troublesome pests, and one red brocket deer was killed by a man protecting his bean field. Although they are not eaten, northern raccoons are also killed when they are caught raiding bean fields. Other hunting by night is uncommon, as the indigenous do not often pole their boats along the river to catch animals coming to the water's edge.

3.1.3 An ethnographic description of hunting with dogs in Bosawas

Dogs are usually acquired at an early age, shortly after weaning. Fifty cordobas is the standard price as of this writing, but offspring of well-known hunting dogs sometimes sell for 100 cordobas. Older dogs are sometimes sold, and dogs with a good reputation for hunting can fetch up to 500 cordobas. Other dogs are given as gifts, and hunters often keep at least one or two puppies from their female dogs' litters. Owners sometimes attempt to breed their females with talented males, but managed breeding is not a priority. I am not an expert on dog breeds, but it appears that few dogs in the reserve are true to breed (Cheri Asa, personal communication, July 2003). Dogs generally eat whatever has been prepared for household consumption, but families sometimes buy milk for their puppies. The extent to which dogs are underfed varies considerably, as some dogs are obviously undernourished while others appear to be fed well. Good hunting dogs generally appear to receive better care than "house dogs." All dogs have names, and they are often named after forest animals. Dogs appear to receive few formal hunting lessons, as the preferred method is to bring a juvenile on a hunting trip with older dogs in the hope that it will learn to hunt by imitation.

The number of dogs on an expedition depends primarily on the number of good hunting dogs owned by the hunter. Not all dogs are considered hunting dogs, but if a hunter has three good dogs, for example, he usually chooses to hunt with all three. If, however, one of the dogs

has suffered a recent injury, a hunter might elect to leave it home and hunt only with his other dogs. Some dogs have a reputation for running off after larger animals, especially deer, and a hunter may choose to leave these dogs at home if he does not want to risk a lengthy search for a dog that runs off. The maximum number of dogs observed on a hunting trip was seven: four adults and three seven-month old pups. As with guns, dogs are sometimes borrowed, but this practice is generally restricted to close kin (e.g. borrowing a brother's dog), whereas guns are more freely shared with non-family members. When borrowing a dog, a hunter is again expected to give a share of the meat to the dog's owner.

Like rifle hunts, hunting trips with dogs may begin on foot or by boat. When traveling by boat, hunters might travel with only their hunting companions or, alternatively, other family members may go along to fish or work in the fields. In any case, hunting trails usually begin in an actively cultivated field or secondary forest. Dogs tend to remain close until the party reaches primary forest, when hunters begin to issue commands for the dogs to spread out and look for prey.⁸ Some hunters elect to remain on clearly defined trails until their dogs locate something, while others leave the trails early in the hunt and attempt to lead their dogs through denser vegetation. While their dogs search for signs of prey, hunters may continue walking, although they stop at regular intervals to listen for their dogs' barking. Especially if it sounds as if the dog has detected an animal's scent, the hunter might opt to remain in one place until the pursuit develops further. At these times, some hunters pull out a cigarette and light up, while I have seen others cut a sapling and whittle a new handle for their machete file (*lima*). Others simply wait patiently, hollering in high-pitched calls to elicit answering barks from the dogs. For listening purposes, hunters generally prefer hilltops, as it is easier there to hear barks from all directions.

Research suggests dog vocalizations vary according to context and that people can listen to a dog's barking and accurately classify the context that elicited the bark (Yin and McCowan 2004; Pongrácz et al. 2005). These discriminatory abilities are readily apparent on hunting trips with dogs, as a hunter can recognize from the barking when his dog is closing on its target. As an example, I was watching a man clear (*socular*) his dry season cornfield when his dog began barking near the river. The man listened for a second and said the dog had just detected the scent

⁸ The term "primary forest" does not imply that it is somehow "pristine" (cf. Denevan 1992a). Most areas visited on observations have seen considerable human use, including the extraction of timber for making boats, construction materials, and firewood.

of an armadillo, but that it had not yet located the animal's burrow. The dog continued to bark intermittently, but I was told that there was no need for us to investigate further until the barking became more frequent and higher-pitched. A few minutes later, I detected a noticeable change in the character of the vocalizations, and we honed in on the barking to find the dog nosing into the burrow where the hunter proceeded to kill the armadillo. On another occasion, I listened as a hunter explained to his brother-in-law the various interpretations of his dog's barking.

Because visibility in the forest was often poor, I was unable to observe closely the means by which dogs track and corral prey animals. While dogs can rely on vision to identify and pursue prey, they are particularly adapted to follow olfactory cues of prey presence. Experimental research indicates that dogs almost invariably follow tracks in the correct direction (i.e. in the same direction that the prey went) even when they have no prior knowledge of the animal's route (Steen and Wilsson 1990; Thesen et al. 1993; Wells and Hepper 2003). From occasional glimpses of pursuits in progress, I concur that olfaction plays the pivotal role in tracking by dogs, at least in this environment. On several occasions, I was waiting with hunters when an agouti scurried across our path, only to disappear again before a dog came along a few seconds later sniffing at the ground and generally tracking in the correct direction.

Once a dog begins barking convincingly, the hunter attempts to hone in on the dog's location. Catching up to the dogs is almost always at a faster pace than normal walking, and in many cases it involves a sprint through the forest. If the angle is favorable, hunters remain on well-established trails as long as possible, but they dart off into the underbrush if that is the quickest path to the dogs. Once off the trail, however, catching up to the dogs is particularly noisy, and it is sometimes difficult to hear additional barking. When they lose their bearings, hunters stop and call to the dogs, hoping to elicit a bark that will give them a better fix on the position. Haste is needed in part because some species (especially collared peccaries) are capable of fatally wounding the dogs. Even for smaller, less dangerous species, though, hunters try to arrive before the animal in question bolts from the burrow or trunk where it has been corralled by the dogs. High-speed charges through the forest are not without their risks, however, and I sometimes saw hunters trip and tumble over. None suffered serious injuries, though.

The importance of being able to hear the dogs is evident in hunters' behavior during a torrential rainstorm. As rain beats down on the broad leaves of the forest, the distance from

which they can hear the dogs shrinks dramatically, perhaps to less than 75-100 meters depending on the intensity of the rain. During heavy rains, hunters tend to remain standing in one spot, resignedly waiting for the precipitation to end. If the dogs have not yet returned, hunters may call for them to come back. If the dogs are present, though, hunters issue no commands to resume searching until the rain abates, and they seldom walk anywhere themselves unless they are returning toward the community. Despite the disadvantages of the rain, however, some informants claim that hunting with dogs is generally more productive in the rainy season, as dogs purportedly have a difficult time detecting scents in the dryness of summer.

As the study progressed, it became clear that hunters attempt to infer what type of prey the dogs might be tracking or pursuing. A number of variables are considered, including the speed of the chase, the intensity of the barking, the direction of the chase, and recent signs of prey presence. It soon became apparent, however, that their initial guesses are often incorrect. On one occasion, a hunter was picking up sticks as he caught up to the dogs, only to find them facing off with a giant anteater. He admitted afterward that he had assumed it would be a collared peccary, and the sticks would have been useful for sealing it off in a burrow or trunk. On another trip, a hunter heard his dogs barking and sprinted back to his boat, which he poled back and forth on the river for a few minutes before returning inland to find his dogs barking at a trunk where they had corralled an agouti. He said later that he was expecting a deer to come bursting out of the woods and into the river. Another time, a splash in a nearby stream convinced a hunter that his dogs had chased a paca into the water, and he searched the pool for several minutes before concluding that it must have been an agouti instead. Similarly, the discovery of fresh armadillo tracks convinced a hunter that his dogs must be after an armadillo when in fact he arrived to find a corralled agouti. In general, hunters seemed to err on the side of size. That is, when they were uncertain about the identity of a prey species, they would first react as though it were a larger animal, such as a deer or a paca instead of an agouti. Only after they ruled out the possibility of encountering a larger species would they attend to the specifics of killing smaller animals such as agoutis.

Dogs do not limit their search to preferred prey species, and hunters often lose considerable time when their dogs chase inedible prey or animals that cannot be killed with available technologies. For example, dogs chased and cornered northern tamanduas and giant anteaters, which are killed to protect the dogs from injury but are not subsequently consumed. A

greater grison was also killed in this manner on an unobserved hunt, although the hunter admitted that he had never seen such a creature before. Also, dogs often force coatis and tayras into trees, but hunters without rifles have no means to kill these animals. Coatis are not a preferred species, and only some of the hunters kill them for consumption; others sometimes elect to kill them to protect their cornfields. Similarly, while tayras are not consumed in Bosawas, hunters with rifles may pursue them to eliminate a threat to their chickens.⁹ Meanwhile, some dogs are even less discriminating, and in one case their owner honed in on their streamside location to find them barking furiously at a village boy who was fishing alone.

Such misadventures are more the exception than the norm, however, and hunters more frequently catch up to their dogs to discover that they have corralled an animal in an earthen burrow or a hollow trunk. When multiple dogs are present on a hunting trip, not all are necessarily present when a prey animal is discovered. A dog's intense barking usually attracts the attention of other dogs, though, and most adult dogs beat the hunter to the site (while juveniles are more likely to follow and arrive with the hunter). There are exceptions to this generalization, of course, especially when dogs are chasing separate animals (e.g. when they scatter a group of collared peccaries). Once at the burrow or trunk, dogs scratch and paw at the entrances in an attempt to reach the animal themselves, and they sometimes manage to kill armadillos or agoutis without the hunters' assistance.

The process of killing pacas, agoutis, and armadillos is similar. Hunters arrive and, after a quick evaluation of the site, begin grabbing or cutting available sticks, which they use to block exits from the burrow or trunk. Bunches of *suita* palm (*Asterogyne martrana*) leaves can also be used to plug holes in trunks that house agoutis. After the obvious holes are plugged, hunters assess the site further, perhaps walking the length of the trunk and clearing out the undergrowth with their machetes. Paca burrows have multiple exits, and hunters must ensure that all possible escape routes are sealed before they attempt to access the prey. Once everything is secure, hunters attempt to gain access to the animal by digging into an earthen burrow or cutting their way into a hollow trunk.

⁹ This was the stated reason for one hunter's attempt to shoot a tayra, although it should be noted that he soon gave up when he could not get a favorable shooting angle. Later questioning in the village revealed that nobody in the village lost a chicken to a tayra during my tenure in Bosawas, and opinions were divided about the extent to which tayras threaten domestic chickens and turkeys.

Especially in the case of trunks, there is often some uncertainty about the exact location of the animal. Once the first holes are cut, hunters tend to probe the trunk with the stalk of a nearby fern, from which they strip all fronds except a few at the tip of the probe. Hunters claim that the leaves serve as a noisemaker, which might scare an agouti into moving about and making revealing noises. Upon removing the probe, hunters examine the tip for indications that it made contact with the animal, particularly hairs that might have stuck to the stalk. Based on the results of these initial examinations, hunters may begin digging or cutting a hole in a new location. In some cases, hunters must cut as many as five holes in a trunk before they are able to prod the animal into a position to be stabbed.

Most heavy cutting is done with axes, although machetes can be used if an axe is not available. The flat of a machete blade is also used as a digging stick of sorts, although hunters sometimes fashion digging sticks at the site of an especially deep burrow. These latter implements are generally about 4-5 inches in diameter and approximately five feet in length. The end is sharpened with a machete and hunters then drive the tool into the ground, occasionally stopping to scoop out the loose earth with their hands. Machetes are also used to cut roots that impede progress.

Machetes are also used to kill most smaller prey, although there is some individual variation. Some hunters prefer to suffocate agoutis with sticks in order to minimize the bloodiness of the kill, as bloody clothes are often an unwanted consequence of kills with machetes. Also, when agoutis are cornered head first in a tight spot, hunters sometimes reach in and break their hind legs before pulling the animal back and strangling it with their hands. Other animals are not so easily accessible, and in order to retrieve the body hunters must sometimes cut or dig for several minutes after they have killed the animal. As for the body, some hunters bring sacks in which they transport animals. Others tie the legs together with nearby vines and then loop the vine over a shoulder to carry the animal home.

Most dogs remain active and excited while the hunter works, and their actions can be either helpful or a nuisance. After cutting a new hole, for example, a hunter might call his dog over for a quick sniff, counting on it to bark if the animal is near (Figure 3.1). Also, when taking

Figure 3.1. A hunter watches his dogs pursue an agouti that they have corralled in a burrow.
(Photo courtesy of Michael Aitkenhead)



a break from digging, hunters allow their dogs to jump in the hole and continue digging.¹⁰ After the hunter has widened the opening somewhat, dogs are sometimes able to squeeze into a burrow or trunk and bite or even kill the animal inside. Because of their smaller size, juvenile dogs are particularly able to squeeze into an agouti hole and deliver a potentially fatal bite. On the other hand, dogs are often underfoot, nosing into holes when hunters are ready to resume chopping. Some dogs are severely injured by machetes and axes when they choose to investigate holes at inopportune times. At other times, they pull at the sticks that plug the exits, and hunters must be vigilant to ensure that their dogs do not create a possible escape route for the trapped prey. Dogs also get themselves stuck in tight places, and hunters sometimes lose a little time pulling them out again. Dogs are also troublesome once the hunter has retrieved a dead animal, as they often tug and bite at the animal. Many hunters hold the dead animal above their heads while the dogs leap at the body until the excitement finally passes and the hunter can attend to tying it up. Other hunters let their dogs chew on the animal for a brief period before yanking it away and preparing it for transport.

Dogs are sometimes fed a piece of meat at the site of the kill, although this practice appears to depend on the size of the animal. Dogs are not fed agouti meat, for example, and cutting a piece of armadillo meat for the dogs also appears rare. Dogs are more likely to receive a sample of paca meat, as some hunters cut off the animal's footpads for the dogs (Figure 3.2). Collared peccary meat is also served to the dogs fairly regularly, and one hunter even attempted to feed a slice of peccary meat to his dog shortly after it had been bitten badly in the throat by the peccary. The hunter claimed that the meat of the attacker would be therapeutic for the injured dog. Also interesting was one occasion in which the hunter stuck his finger into the anus of a recently-killed paca and then wiped his finger on his dogs' noses, saying later that it would encourage them to find more pacas in the future.¹¹ It is important to note that some hunters did not attempt to reward or condition their dogs with meat or otherwise. It should also be noted, though, that dogs often have ample opportunities to lick or chew at the wounds of dead animals when hunters set the bodies down on the ground or in the boat.

¹⁰ For a brief review of canine digging behavior, see Jeske and Kuznar (2001).

¹¹ I wondered at first if this technique might have been invented on the spot for my sake, perhaps to elicit a certain reaction. When I questioned my assistants later, however, they agreed that they had heard of other hunters doing this on occasion. It is worth noting that pacas have eversible scent glands located just inside the anus, which may be used to mark territories (Collett 1981:562).

Figure 3.2. A hunter cuts a piece from a hunted paca's footpad to reward the dog responsible for locating the animal. (Photo courtesy of Menuka Scetbon-Didi)



To the untrained eye, most earthen burrows look much alike, and it is difficult to distinguish between those that house pacas, agoutis, or armadillos. Experienced hunters notice telltale signs, such as the type and quantity of natural debris at the mouth of the entrance. In general, hunters have a pretty good idea about what animal they can expect to find upon accessing the burrow. There remains at least some uncertainty, however, and hunters sometimes catch up to their dogs and dig for as long as an hour before concluding that the burrow is empty and that the dogs were mistaken. At such times, dogs are lucky if they escape a swift kick in the ribs as punishment for their error. The uncertainty sometimes works in the hunters' favor, though, as on one hunting trip when hunters were digging out an agouti only to discover a paca in the burrow as well. The hunters killed both the agouti and the paca, and they concluded in retrospect that the dog had chased the agouti into the sleeping paca's burrow. A similar sequence of events on an unobserved hunt also ended with a pair of kills, and informants suggest that it is not particularly unusual for hunters to benefit from an agouti's anti-predator behavior in this way.

Not all hiding places or burrows are equally favorable, and hunters sometimes arrive to find that their prey are safely ensconced in a particularly difficult spot. Examples include paca holes that delve too deeply into a bank or agoutis that climb up the hollow core of a standing tree. Burrows that lead under the buttresses of large trees are also somewhat problematic for hunters. On one occasion, a hunter quickly abandoned an agouti pursuit when he noticed that the trunk in which it was hiding also housed a number of vampire bats. Sometimes just the thickness and durability of a trunk is enough to dissuade hunters from continued pursuit. Pursuits in these difficult settings need not always turn out poorly, as evidenced by a couple hunters who closed off the exits to difficult trunks, then returned later to start a fire that killed the hiding agoutis via smoke inhalation.

When pursuing collared peccaries trapped in burrows or trunks, hunters might likewise opt to secure the animal inside and return later with different technologies. While it might be possible to kill these peccaries with machetes or sharpened sticks, rifles and lances are the preferred weapons. The decision to leave the site must be weighed against the possibility that the animal may escape, and I know of at least one situation in which the peccary successfully broke through the barricaded entrance to its burrow when the hunters in question decided to leave it there overnight and return the next day with a borrowed rifle. Lances are assembled at

the kill site as hunters leave the community with only the metal blades, which are notched in such a way that they can be attached with rope or vines to a wooden shaft. In practice, after securely plugging the peccary's hole with multiple sticks and logs, hunters look around the site for a favorable sapling to which they attach the blade. Then they remove just enough plugs to look inside for the peccary, and a couple well-aimed blows of the lance are usually sufficient to dispatch the animal. Killing a collared peccary with a rifle is a similar process, as hunters are careful to seal the peccary inside before they attempt to shoot the animal through a narrow opening.

Not all animals located and pursued by dogs are killed in burrows or trunks. Some collared peccaries turn and face off with the dogs on open terrain, allowing hunters to catch up and shoot the animal (or perhaps attack with a machete if a rifle is not available). Tapirs likewise face off with dogs on occasion, usually in the bed of a stream. Meanwhile, some animals become increasingly vulnerable to human hunters when dogs chase them into the river. Virtually all the indigenous residents of Bosawas become excellent boaters at an early age, and very few species gain an advantage when the pursuit moves to the river. Included on the rather lengthy list of animals killed in the river throughout the year are agoutis, pacas, tapirs, red brocket deer, white-tailed deer, and iguanas.

One hunter in particular specialized in hunting from his boat. He allowed his dog to roam the riverbanks while he waited in the boat with a companion. If the dog located an armadillo or paca burrow, this hunter would park the boat and ascend the bank to the site. By contrast, if the dog scared a deer or paca into the river, he was poised to make a successful attack. Of the two, deer are generally easier to kill, as hunters must only catch up to the animal and either strike it with a blade or hold it under the surface until it drowns. The paca, on the other hand, excels at submerging and hiding along the riverbank, and locating an underwater paca is generally tougher than killing it. Some hunters believe that taking a mouthful of water and spurling it onto the surface of the river will cause the paca to surface, but I saw no evidence to support the effectiveness of this technique. When searching for a paca in the river, hunters sharpen one end of their *palanca* (the pole with which they propel and steer the boat), which serves as a lance if they reencounter the paca in close proximity. An alternative is the *suksuk*, or harpoon, which hunters might keep in the boat if they anticipate the possibility of encountering

game in the river.¹² The harpoon features a barbed metal point, which is shoved into a narrow wooden shaft. The point detaches when jabbed into an animal's flesh, but it remains connected to the shaft with a narrow rope. While either a sharpened *palanca* or *suksuk* can inflict a severe first wound upon a swimming paca, it seems that hunters usually end up jumping into the water to finish the job with a machete.

Sometimes a hunter instructs his wife or other kin to remain in the boat watching for deer while he roams inland with the dogs. Deer tend to flee toward the river when pursued by dogs, and the only deer killed during the study period were either killed with rifles or killed in the Lakus River. Even when hunters do not have companions waiting in the river, deer that are chased into the river may be killed by other members of the community. In this case, the owner of the dogs is considered the rightful owner of the deer, but the expectation is that he will reward those who killed the animal with a large share of the meat, perhaps as much as a half. After losing track of the deer, meanwhile, the dogs usually make their way back to the hunter, who may remain unaware that a deer has been killed until he concludes the hunt.

While dogs are off seeking and pursuing prey, hunters with rifles remain watchful for opportunities to kill other animals. Encounters with large prey are somewhat rare, but game birds are encountered and pursued on a fairly regular basis. Dogs more often hinder than help these pursuits, particularly in the case of tinamous. Hunters pursue tinamous while they remain on the ground, but once they take wing, they usually fly too far away to merit further attention. Dogs interrupt tinamou pursuits when they see and charge after the birds, which take to the air before hunters can shoot. More often than not, however, tinamous are already flying off before hunters notice them, although it is unclear to what extent the birds are fleeing the hunters, the dogs, or a combination of the two. As for other birds, informants suggest that dogs can be useful for flushing great curassows, which tend to alight on nearby branches within range of the hunters' rifles. Finally, it is important to note that dogs can also scare away terrestrial mammalian prey. On multiple occasions, I saw dogs scare away agoutis as their owners were preparing to shoot, and it is easy to imagine the dogs preempting opportunities to shoot other species as well.

¹² In the indigenous languages, *suksuk* is also the name for the northern raccoon. The spelling for the harpoon is my own, and it may be that I was unable to detect aspirate sounds or differences in intonation that distinguish the word.

Some hunters bring slingshots on their forays into the forest, and they occasionally pursue birds that are generally too small to merit attention from rifle hunters. To a large extent, attempts to kill small songbirds are a form of entertainment for hunters while waiting for their dogs to locate prey. These “pursuits” are not necessarily restricted to slingshots, as I saw a hunter and his young companion throw small stones at some unsuspecting birds, and one hunter even tried to swat some passing birds out of the sky with his baseball hat. However, while their accuracy generally leaves much to be desired, slingshots can effectively kill some larger game. The list of animals killed with slingshots includes an agouti, a tinamou, parrot, and a toucan. Some of the smaller birds, such as quails and doves, are consumed after being killed with slingshots, while the especially diminutive species are most commonly left where they were killed.

Mayangna and Miskito hunters seem to manage the forest less than some indigenous groups (e.g. Posey 1985), at least while actively engaged in hunting. Little time is devoted to tending useful plants and trees discovered in the forest. The primary exception to this generalization is the care that some hunters show for young mahogany and cedar trees (*Carapa guianensis* and *Cedrela odorata*, respectively). In the reserve, these trees are considered perhaps the best timber for constructing boats, and they are also useful for house construction. Accordingly, hunters sometimes take a minute or two to clear away competing plants from the base of a promising young tree. Meanwhile, hunters occasionally encounter fully-grown cedars or mahogany trees (and other species), and they may cut into the wood to test its quality and readiness. If the tree is identified as a promising candidate for later construction, hunters may mark the path to its location by leaving distinctive marks in trees along the way.

Many hunters prefer to have a companion, and possible companions include almost any male in the community older than about nine or ten, including brothers, sons, nephews, cousins, or friends and other acquaintances. For school-age boys, class schedules can hinder their freedom to hunt on weekdays, although they sometimes go on shorter hunts before or after classes. Although two or more adult men may go hunting together on a general hunting trip (i.e. not a directed search for white-lipped peccaries), it is rare for two of the commonly-acknowledged “best” hunters in the community to hunt together.¹³ Regardless of a companion’s

¹³ As part of a comparative survey on hunting dogs, I asked a random sample of 39 community members in Arang Dak and Suma Pipi to name the best hunter. Four hunters received at least two votes (two others received one vote).

hunting competence, there are many potential advantages to hunting with a second person. While indigenous men can successfully pole upstream alone, for example, this task is noticeably easier with a bowman to help steer the boat. Similarly, hunters can usually find a way to carry a rifle, an axe, and a machete simultaneously, but the load is awkward and companions are typically entrusted with the axe when they are present. Likewise, companions may be responsible for carrying the game following a kill. When hunting with dogs, companions are often asked to verify the presence and direction of barking in the distance. If hunters hear no barking, they and their companions may temporarily split up and move in opposite directions, expanding the range of their earshot and increasing their chances of hearing remote barking. A companion might be the first to spot tracks, potential prey items, or possible threats, such as snakes. In the event of an emergency (e.g. snakebite), a companion can return to the community for help. When pursuing animals in burrows or trunks, companions can help plug exits and bring stalks with which to probe the hole. When trying to kill agoutis in hollow trunks, it is common for a companion to use a stalk or stick to drive the agouti to an opening where the hunter stands poised with his machete, ready to strike. Companions may restrain dogs while hunters are cutting into a trunk or retrieving bodies from a hole.

Most animals are killed on one-day excursions from the community, but sometimes hunters go on multi-day expeditions, or *giras*. Community members are virtually unanimous in their opinion that animals are more abundant upstream than they are within a few hours travel of the villages.¹⁴ These expeditions may last only a couple days or as long as 8-9 days, and they are particularly common in the weeks leading up to important holidays, such as Christmas and *Semana Santa*. Participation in a *gira* may include nearly any combination of male and female family members or unrelated companions. Women and girls often go along to cook and tend the campsites where parties set up alongside the river, although boys sometimes perform these tasks if no women are present. There is also considerable fishing on these expeditions, although the ratio of hunting to fishing depends largely on the season and the state of the river. While much of the fish and game may be consumed upstream, a large portion is salted and dried and brought

During my study, there was only one hunting trip in which two of those four hunted together, although each regularly hunted with other companions.

¹⁴ Community members are also quick to point out that animals were considerably more abundant around the villages when they first returned from the Honduran refugee camps in the early 1990's. Nietschmann (1990) noted that the absence of hunters during the Sandinista-Contra War represented a boon of sorts for animal populations, and hunters in the Lakus River watershed may have enjoyed unprecedented success in the early years of their resettlement in Nicaragua.

back to the community for later consumption. Fishing and hunting need not be the primary purpose of a multi-day trip, as community members sometimes travel well upstream to bring friends and families to the trailheads for paths to neighboring territories. While the majority of time on such trips might be devoted to travel, it is not unusual for participants to reserve at least one day just for hunting and fishing. Even on a *gira*, meanwhile, Sunday is considered a day of rest, and hunting and fishing are therefore rare, although there seems to be no prohibition on traveling (e.g. returning to the community from an upstream camp).

To some extent, the distinction between opportunistic and intentional hunting may seem somewhat artificial to the Mayangna and Miskito. On one hunt, for example, I initially thought that a hunter was being exceedingly thorough about creating a new trail through the forest, but I soon realized and later confirmed that this “trail” would actually be the boundary of a rice field that he began to clear soon afterward. Saturdays in particular are notable for their combination of hunting and non-hunting activities. Hunters may leave to hunt but then make a point of stopping by their fields on the way back to harvest enough bananas or manioc to last through the weekend. Many times, hunters remain open to the possibility of a kill even when engaged in other activities. When walking to his fields, for instance, a man might poke his machete into a burrow, looking to stir up the telltale bugs that signal the presence of an armadillo. Turtles and other prey may be pursued when encountered in the river by a fishing party. While traveling in the boat, some owners allow their dogs to roam the shore looking for prey, and travel is stopped if the dog finds something promising. A number of female iguanas are killed in this way every March when they come to the riverbank to lay eggs, as dogs have little trouble catching the egg-laden reptiles. Dogs also find game when community members are busy working in their fields, and work ceases temporarily while they pursue the animal. It should be noted, however, that farmers often leave their dogs at home when they are intent on finishing certain tasks, particularly clearing and planting fields.

Although I hesitate to use the word “taboo,” in some cases the Mayangna and Miskito in Bosawas consider mammalian species to be inedible. The strength of this belief varies between species, however. Giant anteaters, northern tamanduas, both sloth species, tayras, kinkajous, jaguars, ocelots, raccoons, and all species of rats, bats, and skunks are apparently considered inedible by all members of the community. By contrast, the willingness to consume the following species seems to vary across individuals and households: howler monkeys, white-

faced capuchins, coatis, and pumas. These latter species were consumed by at least some members of the community while refused by others.¹⁵ Aversions do not seem to correspond to cultural distinctions between the Mayangna and the Miskito, as I observed that individuals of both groups consumed or refused to consume howler monkeys, capuchin monkeys, and coatis.¹⁶ For a full list of large mammalian species (including scientific names) in the reserve, see Appendix 1.

¹⁵ The puma may have been eaten by only one adolescent male, as I was unable to verify if other family members partook of the meat. The boy claimed that he wanted to eat the puma because doing so would make him “strong” (*fuerte*).

¹⁶ I relied on self-identification to categorize individuals as either Miskito or Mayangna.

3.2.1 *Focal follow methods*

Randomization of focal subjects has proven difficult in past optimal foraging studies (e.g. Hill and Hawkes 1983; Alvard 1993a), but I attempted to randomize the sample as much as possible. My research assistants asked hunters every afternoon about their plans for the following day. From those hunters with plans to hunt, I drew one name at random to be the focal hunter. Sometimes hunters waited until morning to finalize their plans for the day, with plans often depending upon the weather or their attempts to coordinate activities with others in the village. On some mornings, hunters eventually opted to go hunting, and they sometimes invited me to go along. If I had not previously made arrangements to hunt with another man, I would accept such invitations, but it would have been considered rude to back out of an arrangement made the day before. Therefore, there are probably biases toward hunters who plan their work in advance and those who were more conscientious about inviting me.

At the beginning of the study, it became clear that most hunters would not take me along on their hunting trips without some additional compensation, and I therefore offered them fifteen Nicaraguan cordobas for each observation.¹⁷ This sum was designed to compensate hunters for the extra work of an observation (particularly the extended post-hunt interview) without motivating them to hunt when they would not otherwise do so. By comparison, the typical compensation for 6-7 hours of men's agricultural labor was fifty cordobas.¹⁸ Evidence that the promise of compensation did not inspire hunters to hunt when they would not normally do so is only anecdotal but nevertheless compelling. First, on five occasions, I was invited to go on a hunting trip, but prior plans prevented me from going. On each occasion, the respective hunters went hunting without me. Second, one hunter whom I had observed on eight previous trips told me in July 2005 that he no longer wanted to take me, saying that the 15 cordobas was not worth the extra effort. Of course, there is the possibility that other hunters felt likewise but continued to invite me in order to remain in my good graces more generally. I did not lend money or run errands for villagers when in Managua, but I made no secret of the fact that I planned to leave many of my supplies (e.g. machete, cookware, boots, etc.) behind when I had completed the

¹⁷ The exchange rate varied slightly throughout the year, but it was typically about 16.25 cordobas for each American dollar.

¹⁸ This labor generally involved clearing fields for later agricultural use. Women could earn slightly less, perhaps 20-30 cordobas, for a comparable amount of time spend planting or harvesting corn, rice, etc.

study. Although I did not foster the belief, perhaps hunters thought they might receive more gifts if they invited me to conduct observations. Then, too, perhaps some hunters were comforted by the fact that I carried an emergency medical kit with which I promised to treat their injuries or snakebites if the need arose. In general, however, these latter factors seemed to play a relatively inconsequential role in the hunters' willingness to invite me along.

On the hunting expeditions, I employed focal sampling methods, as described by Altmann (1974). In practice, this method entails continuous observation of a focal subject, recording all activities for the duration of the observation. To record data, I used a portable Psion Workabout computer equipped with The Observer 5.0 software by Noldus Information Technology. Computerized data collection is becoming increasingly common in anthropological research (Greene 2001; Gravlee 2002), and this particular combination of hardware and software was reviewed by Ice (2004). The Workabout computer proved to be an ideal platform for the behavioral software, as it endured the occasionally torrential downpours of the rain forest without problems (Koster 2006). The Workabout was ergonomically comfortable, and I designed the coding scheme so that the most common codes could be entered with only one hand, leaving my other hand free to collect GPS waypoints and navigate obstacles in the forest. That said, it is difficult to overemphasize the challenges of entering codes while scrambling up a muddy hill, and timing accuracy was sometimes compromised by 3-4 seconds while I worked to regain adequate footing. On other occasions, I initially entered an inaccurate code before realizing my mistake. Fortunately, The Observer allows users to enter written text throughout the course of the observation, and I was able to note such errors soon after they occurred. Editing of the data files after my return removed these coding errors prior to data analysis.

The coding scheme for the observations appears in Table 3.1. Most categories were defined before the first observation, and I followed Hill et al. (1985) for some of the codes.¹⁹ When designing the coding scheme, however, I deliberately left some codes unassigned, recognizing that there might be important behaviors that I had not anticipated. On the first three hunts, I recognized the importance of the "dog" codes: dog-listen, dog-catch up, and dog-gravitate. Fishing and house/camp were two additional codes that were not defined until after the study had begun. The first three observations were an opportunity to define the coding

¹⁹ It should be noted, however, that Hill et al. (1985) recorded data on multi-day treks through the forest, and many of their codes were not necessary for the day trips in my study.

Table 3.1. Coding scheme for hunters' activities

Code	Description
Boat	In boat traveling, preparing to travel, or disembarking
Walk	Walking through the forest or fields, especially when searching for game
Clear trail	Clearing vegetation, making bridges or makeshift staircases.
Wait-clear	Waiting for a companion to clear trail
Tracking	Pursuing signs of game (e.g. prints) without definite awareness of its location
Examine tracks	Scrutiny of tracks, food remains, excrement, etc.
Dog-listen	Stopped and listening for the barking of distant dogs
Dog-catch up	Trying to reach a dog's location, usually at a quicker pace than normal.
Dog-gravitate	Slowly moving in the direction of a dog's barking in order to hear better.
Pursuit	Actively attempting to stalk or kill an ambulatory animal in close proximity.
Pursuit-under	Attempting to kill an animal inside a burrow or trunk.
Field processing	Preparing a captured animal for transport.
Ambush hunting	Waiting silently for a chance to shoot prey, usually after calling to agoutis
Examine burrow	Investigating a burrow or hole for possible prey
Hunting technology	Sharpening machetes, loading guns, manufacture of makeshift spears, etc.
Recover technology	Walking to retrieve dropped technologies, usually dropped while catching up to the dogs.
Dog care	Active dog care, such as treating injuries or feeding
Wait for help	Waiting for a companion to offer assistance, especially when waiting for boats.
Help others	Offering assistance to a companion, usually not in the context of a pursuit.
Fish	Attempting to kill fish in either the river or streams
Watch others	Watching others attempt to acquire resources
Stop	Standing, not listening for dogs, often for route-planning or listening for prey
Rest	Seated and largely inattentive to the possibility of prey
Personal care	Washing, drinking, eating, defecating, urinating, adjusting clothes
Agriculture	Weeding, harvesting, planting, or clearing fields.
Gathering	Collecting non-game products from the forest, including firewood
Botanical tasks	Tending vegetation in the forest, especially by clearing away competing species.
Walk-acquired	Walking with non-game resources, including bananas, manioc, and firewood.
House/camp	Time spent at an upstream house or makeshift camp, often in a social situation.
Miscellaneous	A "catch-all" category for praying, looking for gold, looking for macaws to sell.
Me	Time when my presence clearly disrupts what the hunter would be doing.
Unknown	Time when the hunter is out of sight

scheme, eliminate ambiguity in distinguishing between codes, and familiarize myself with the computer and software. These initial observations are therefore not included in the data analyses presented in this chapter.

I was also able to attach modifiers to many of the behavioral state variables. For example, in the data file, I recorded not only the code for “Boat,” but also a modifier indicating whether the hunter was actively traveling, readying the boat for travel, stopped and listening for a dog, portaging, or actively pursuing a visible animal, among other possibilities. In some cases, modifier classes were added following my return to the United States, when I used text notes from the data file to add specific activities to the “Personal Care” code (e.g. washing, drinking, eating, etc.). The full list of possible modifiers is fairly extensive, and for space considerations I will not reproduce it here, especially given that many of the modifiers do not factor into the analyses presented here. However, the modifiers for “pursuit-under” merit some attention, as this coding scheme is crucial to one of the analyses presented later in this chapter (see Table 3.2).

Table 3.2. Modifiers to the “pursuit-under” code

Modifier	Description
Assessment	Examining site, looking for extent of burrow, clearing excessive vegetation
Plug	Plugging holes with sticks or vegetation to prevent the animal from escaping
Probe	Attempts to ascertain the exact location of the animal, often with pruned stalks.
Access	Digging into ground or cutting into trunk to gain access to the animal
Watch others	Passive observation of a companion’s efforts to pursue the animal
Wait-help	Waiting for a companion to bring a tool or perform another needed task
Look for second	After a kill, investigating the same burrow or trunk for another animal

In addition to the state variables outlined in Table 3.1, I also recorded important events, such as encounters with possible prey items, gunshots, individual axe and machete chops while hunters were cutting into burrows, stream crossings, calls and commands to dogs, and barks by remote dogs. This last category in particular was difficult to code while catching up to the dogs, as the noisiness of our travel through the forest often made it impossible to hear all the dogs’ barking. Also, I did not record the nearly continuous barking of dogs at the site of a pursuit (i.e. once the hunter had successfully caught up to the dog), as the activities of the hunter took priority over these barks.

While the activities of the focal hunter remained my primary focus, the software allowed me to record data on additional state variables. For example, I monitored rainfall with a dichotomous state variable: either it was raining or not raining, with no attempt to code for the intensity of the rainfall. A dichotomous variable also allowed me to monitor whether the hunter was traveling on a clearly defined trail or “bush-whacking” through denser vegetation. As we moved across the landscape, I also monitored the habitat type, following the broad classifications used by the indigenous people themselves: actively-cultivated field, secondary forest, and forest.²⁰ The transition between each stage of forest re-growth is typically not a specific point in time, however, and it took me some time to learn the subtle characteristics that distinguish these habitat types. Especially difficult was the distinction between active fields and secondary forest, as the Miskito and Mayangna resemble other Neotropical groups in their tendency to plant bananas and other fruiting trees after previous cultivation of more labor-intensive crops (Beckerman 1987). Only about four months into the project was I successful in coding habitat type reliably.

3.2.2 *Observer effects and representativeness of the sample*

Despite my oft-stated willingness and desire to observe a multi-day hunting expedition, hunters were reluctant to bring me along. As a result, I observed only daytrips originating in the communities or occasionally from an upstream residence. Informants suggest that hunting techniques on upstream expeditions do not differ dramatically from those employed closer to the community, but there are indications that hunters tend to hunt closer to the river when upstream. Accordingly, my data set might best be viewed as representative of only daylong hunting excursions originating in Suma Pipi and Arang Dak. When traveling by boat, data collection began when the boat departed and ended when it returned to the beach by the community. When traveling by foot, the boundary between the community and the surrounding forest served as the beginning and endpoint of behavioral observation.

One might expect that the presence of an anthropologist could alter the focal hunter’s return rate, perhaps by scaring off prey or by otherwise distracting the hunter. Compared to hunting with guns, however, return rates when hunting with dogs seem less likely to suffer from

²⁰ Secondary forest is generally called “*guamil*” or “*campo viejo*” in Bosawas.

the presence of an observer. I base this statement on the fact that dogs detect and corral most prey animals before the hunter arrives at the kill site. Nevertheless, to test for observer effects, I compared observed hunts to unobserved hunts. The methodology behind the data on unobserved hunts is detailed in Chapter 4. It is important to mention that, despite my frequent requests, hunters tended not to report unsuccessful hunts. In other words, if they returned home empty-handed, hunters sometimes failed to acknowledge the excursion when asked by the research assistant. This underreporting of unsuccessful hunting trips held true even when hunters killed animals that are considered inedible and left in the forest, such as the northern tamandua (*Tamandua mexicana*) and the greater grison (*Galictis vittata*).

The bias toward successful hunts makes it somewhat difficult to compare the overall return rates of unobserved and observed hunts. However, comparisons of only successful hunts might prove illustrative. A two-sample t-test indicates that there is no statistically significant difference between the return rates of successful observed hunts and successful unobserved hunts, as measured in kilograms of meat per hour ($t = .29$; $p = .77$; $df = 68$).

Perhaps a better indicator of possible observer effects can be found in the distribution of animals taken on observed and unobserved hunts, distinguished by species. I created a table of all the animals taken on all intentional hunting excursions, and a chi-square test revealed no significant difference in the respective distributions ($\chi^2 = 26.552$; $p = .148$; $df = 31$).

By presenting these results, I do not intend to imply that my presence had no discernible effects on the hunters' behavior. Approximately 0.3% of all observation time was "me" time – i.e. time when my presence clearly disrupted what the hunter would otherwise be doing. In practice, the most common disruption was straightforward conversation, when hunters would stop walking to ask me a question or explain something of interest. I did not initiate these conversations, and I made no effort to prolong the conversation, but I sensed that hunters sometimes felt I was too quiet and started discussions in order to restore a sense of normalcy to the excursion. On other occasions, hunters would interrupt their activities to attend to my perceived needs – once when I had a fairly bloody scrape on my hand and once when a hunter pulled his boat over and cut some leaves to serve as my umbrella during a torrential downpour. Meanwhile, one might imagine that my handheld computer and GPS would be objects of curiosity for the hunters. Somewhat surprisingly, only about five and a half minutes (about

0.03% of all observation time) were devoted to questions about these research tools (Koster 2006).

As the study progressed, I realized that my presence could also have subtler effects on hunters' behavior. For example, hunters sometimes wait in one place for several minutes while listening for the dogs. Despite my best efforts to remain immobile, I would sometimes shift my weight from one foot to another, especially when we were stopped on the slope of a hill. I noticed that such movements on my part seemed to prompt hunters to resume walking. Such observer effects are difficult to quantify, however.

On two occasions, my actions had a particularly obvious effect on a pursuit. First, when a paca plunged into a nearby stream, the focal hunter waded into the waist-deep water to search for the submerged animal. I remained on shore, and from my vantage point I soon saw the paca swimming away from the hunter underwater. The hunter noticed that my eyes were tracking across the water, and he followed my gaze to the fleeing paca, which he quickly dispatched with a swipe of his machete. On another occasion, an agouti was stealthily trotting through the forest when it entered our line of sight. The focal hunter began tracking the animal with his rifle, waiting for it to stop. As the barrel of the gun moved in my direction, I ducked out of the way, and the agouti responded to my motion by quickly darting into the forest. Because my actions altered the outcome of both pursuits, the handling times for these two animals have been excluded from the measures of profitability presented later in this chapter.

3.3.1 Results: Time allocation on intentional hunting trips

In all, I observed 61 intentional hunting trips. On fifty-four of those hunts, dogs were the principal hunting technology. For 21 of these 54 observations, hunters also brought rifles, which they used to varying degrees. As noted previously, the first three hunts helped to finalize the coding scheme and are not included in subsequent analysis. Of the remaining observations, I collected only minimal data on one of the hunts, as I was out of the community mapping the location of fields when my guide decided to conduct an impromptu hunt. Without my handheld computer, I collected primarily geographic data and basic information on search and pursuits times.

On the other seven observations, rifles were the focal hunter's principal technology, and the focal hunter brought no dogs. One of these seven observations was a directed search for white-lipped peccaries, as tracks had been discovered near the community and a couple of hunters organized a group to pursue them.²¹ The remaining six observations were general searches for prey, and the hunting techniques and use of guns are similar to those described elsewhere in the literature (e.g. Alvard 1993a). As such, codes were relatively unambiguous even in the initial observation, and none of the observations are excluded from data analysis.

I also witnessed two opportunistic kills: a paca killed in the river by the community and a nine-banded armadillo when I was accompanying a man as he prepared a new corn field. While these kills enhanced my understanding of hunting techniques, they are likewise not included in the data analysis.

3.3.2 *Guns versus dogs*

A comparison of time allocation on hunts readily reveals important differences between hunting with dogs and hunting with only rifles (Table 3.3).²² Rifle hunters spend more than twice as much time simply walking than do hunters with dogs. By contrast, hunters with dogs devote about 30% of their time to activities that are unique to that type of hunt: listening for their dogs, catching up to the dogs, gravitating in their direction, pursuing animals in trunks or burrows, and direct dog care.²³ That figure increases slightly when the specifics of boat-travel are considered. Whereas rifle hunters use their boats primarily for transportation, hunters with dogs more often incorporate boats into their quest for prey. Hunters with dogs spent 1.7% of all observation time just stopped and listening in their boats while their dogs searched for prey on

²¹ An ankle injury forced me to abandon this observation shortly before the hunters located the peccary group and killed several.

²² Later in this chapter, I use three categories to examine return rates for hunters with rifles, hunters with dogs, and hunters with both rifles and dogs. As noted in section 3.1.2, however, hunters with both rifles and guns generally follow the strategies and methods of hunters with only dogs, and I therefore lump both categories for this comparison of time allocation. Similar logic applies to the following optimal foraging discussion. Because rifles were rarely used during observations of hunters with both dogs and rifles, I examine all hunts with dogs as a single category.

²³ Hunting with rifles does not preclude the possibility of locating and pursuing animals in burrows. In all, five armadillos and one paca were killed when men poked their machetes into burrows and discovered their presence. On a hunt that is not included in the current analysis, I witnessed one armadillo killed in this manner. As seen in Table 3, rifle hunters spent a little time examining burrows, but given the small sample size, it is perhaps not surprising that they did not actually locate any prey while I was along.

Table 3.3. Time allocation by focal hunters on observed hunts. Figures are reported as percentages of total observation time. For observations in which dogs represent the primary hunting technology, the statistics are based on 50 observations. For those in which hunters used only rifles, the statistics are based on 6 observations.

Activity	Dogs	Guns	Activity	Dogs	Guns
Boat	21.5	6.1	Dog care	0.1	0
Walk	28	59.2	Wait for help	0.2	0.1
Clear trail	4.3	4.1	Help others ²⁴	0	0
Wait-clear	0	1	Fish	0.5	2.1
Tracking	0	0	Watch others	0.1	0.1
Examine tracks	0.5	1.4	Stop	1.6	6.8
Dog-listen	12.7	0	Rest	0.9	3.5
Dog-catch up	2.9	0	Personal care	1.2	4.7
Dog-gravitate	1.7	0	Agriculture	2.5	0.1
Pursuit	0.6	3.6	Gathering	0.7	0.5
Pursuit-under	12.7	0	Botanical tasks	0	0.3
Field processing	1.2	1.8	Walk-acquired	1.6	0.1
Ambush hunting	0	0.5	House/camp	1.9	1.5
Examine burrow	0.2	0.1	Miscellaneous	0.2	0.3
Hunting technology	1.3	0.9	Me	0.2	0.9
Recover technology	0.1	0	Unknown	0.4	0.3

²⁴ Note that this definition of helping is more restrictive than that employed by Hill (2002). If I were to use Hill's broader definition, then there would be at least some time helping others. For instance, as an example of cooperative behavior, Hill cites the announcement of a resource's location for others to pursue while ego continues to search (2002:114). In Bosawas, hunters would sometimes point out small birds for boys to pursue with slingshots while they conducted other activities (e.g. resting, walking, attending to hunting technology). On other occasions, it was difficult to ascertain if certain activities could truly be considered altruistic. For example, Hill cites clearing trail or making bridges for others to use as an example of altruistic behavior (2002:113). In my study, I sometimes felt that, when constructing makeshift steps in large trunks or steep slopes, hunters sometimes devoted more effort than the minimum needed for they themselves to traverse the obstacle (e.g. cutting steps appropriate for someone of shorter stature). Aside from the possibility that their intent was to make my path easier, it was difficult to discern how much their concern for their companions was affecting their efforts. In general, the Mayangna and Miskito are cooperative when hunting together, but given the smaller group sizes and the fact that much allegedly "altruistic" behavior is mutually beneficial, it should not be surprising that results here do not parallel Hill's work with the Aché.

shore. Additional time in the boat was spent honing in on the dogs' location (0.2% of all observation time) or pursuing prey that the dogs flushed into the river (0.8%). In sum, hunters spend 32.8% of all observation time listening for their dogs, moving in their direction, caring for their dogs, or pursuing and handling prey that their dogs have detected.

Many of the remaining discrepancies between the two different types of hunt can be explained as a product of the small sample size for rifle hunts. For instance, the statistics suggest that rifle hunters devote nearly four times as much time to personal care in large part because, while his companions continued to look for game, one hunter spent about an hour bathing and removing ticks that he had acquired from the red brocket deer that he was carrying. Similarly, more than 85% of fishing time by rifle hunters came on a single observation. More difficult to explain is the fact that rifle hunters appear to spend much less time in agricultural tasks and transporting non-game items (e.g. bananas and firewood). It could be that rifle hunters are more selective about which patches to exploit whereas hunters with dogs prioritize access to their fields at the end of the hunt.²⁵

3.4.1 *Optimal foraging analysis: Defining terms*

Before calculating the optimal diet breadth, an additional methodological note is needed. It is clear from Table 3.3 that hunters often engage in activities that are secondary to the assumed goal of maximizing their return rate of hunted meat. Foremost among these activities are agricultural tasks, including harvesting corn and bananas, weeding manioc, and planting sugarcane, among other activities. Time spent visiting at upstream residences, gathering firewood at the end of a hunting trip, and fishing are other activities that are not included in an active search for prey. In a seminal optimal foraging paper, Schoener (1971) distinguished between Type I and Type II foragers, and the distinction is useful in this case. As defined by Schoener, Type I foragers are opportunistic foragers, discovering food in the course of other activities (e.g. reproductive and anti-predator behavior). By contrast, Type II foragers are active

²⁵ While it is conceivable that hunters who are already carrying a rifle and a machete might find it difficult to transport non-game items, it is important to note that hunters with dogs also frequently have multiple technologies, including machetes, axes, or rifles. In no case did possession of these technologies seem to limit non-hunting activities. Geographically, most fields are located near the river, and much of the firewood is gathered within 100-200 meters of the river. On several occasions, hunters made several trips back and forth as they transported multiple loads of non-game items (e.g. bananas), and it is not difficult for hunters to leave their hunting technologies near the riverside while they devote time to agricultural tasks or the collection of firewood.

foragers in the sense that the acquisition of food resource is their primary goal. Anthropologists working in the Neotropics have noted that many individuals bring the technologies needed to make wildlife kills even when hunting is not their stated goal, and they will pursue preferred prey upon encounter (e.g. Beckerman 1983; Baksh 1995; Jorgenson 2000; Smith 2005). The Mayangna and Miskito likewise exhibited both Type I and Type II behavior, especially given that dogs sometimes locate prey even when hunters themselves are engaged in non-hunting activities. Methodologically, however, it is inaccurate to suggest that agricultural tasks and eating lunch at the family *champa* qualify as search time in an OFT sense. Upon returning to the United States, I therefore reviewed the data files and made a distinction between active search for prey and “opportunistic time” when hunters prioritized activities other than hunting. The parameters for the OFT analyses presented here are based on this narrower definition of search time to the exclusion of opportunistic time.

Pursuit times are defined as attempts to kill an animal once the hunter has conclusively ascertained the prey type and its exact location. For rifle hunters, the transition from search to pursuit is usually unambiguous. When hunting with dogs, however, there is sometimes considerable uncertainty. As noted, hunters frequently guess incorrectly what animal their dogs are pursuing in the distance. Even when they are reasonably confident that the dogs are chasing an agouti, for example, they cannot be sure where (or if) the dog will ultimately corral the animal, and they hone in on the dogs not knowing what the setting of the pursuit will be (see the notes on prey types below). In the foraging literature, perhaps the closest analogy to this uncertainty is the “recognition constraints” model described by Elner and Hughes (1978) and Houston et al. (1980). This model posits that some foragers can eventually distinguish between profitable and unprofitable prey types, but only after paying a cost of recognition time. Likewise, hunters must catch up to the dogs before they can make informed decisions about the profitability of further pursuit. That hunting with dogs imposes special costs is reinforced by the fact that hunters are often powerless to stop their dogs from pursuing animals until they can catch up to the chase themselves. In other words, while the hunter might not want to pursue an undesirable prey item, the dogs will usually continue the pursuit until the hunter arrives and leads them away from the site.²⁶ The implications of recognition costs on prey choice decisions are

²⁶ On multiple occasions, for example, dogs chased coatis into trees, and they remained on the ground looking up and barking at the animals until the hunter arrived to lead them away.

more fully elaborated later in this chapter. For the time being, it is important to note that the initial OFT analyses presented here focus on the hunter's decision to pursue or continue searching once he has successfully identified the prey type. When hunting with rifles, this identification typically equates to visual contact with possible prey. When hunting with dogs, by contrast, the transition from catching up with the dogs to pursuit (or abandonment) usually begins when hunters arrive at the site where dogs have corralled or cornered the prey item.

An additional clarification is needed in the definition of prey types. Martin (1983) criticized the prey choice model by arguing that an Eskimo would be unwise to ignore a beached whale simply because a swimming whale is not in the optimal diet breadth. Martin's mistake is his assumption that prey types must correspond with biological species. While distinguishing prey types by species might be a useful assumption in many cases, there are also several instances when it would be inappropriate to do so. For example, Alvard (1993a:381) reports that the "context" of agouti encounters was the determining factor in pursuit decisions by Piro hunters in Peru. When hunters caught agoutis unawares, they would pursue the animal. If, however, hunters noticed the agoutis only after they had begun fleeing into the forest, they would not pursue the rodents, for "pursuing a fleeing agouti into the forest would likely result only in frustration" (Alvard 1993a:381). In this case, it would be appropriate to define a fleeing agouti as a different prey type than one that remains unaware of the hunter's presence, as the expected profitability of pursuit differs dramatically.

The first clue that I should distinguish prey types beyond the species level was an agouti pursuit after the hunter's dog had flushed it into the river. It took the hunter and his younger brother only about three and a half minutes to track down the agouti, kill it, and haul it aboard. By contrast, pursuits of agoutis in burrows or trunks usually last about thirty minutes, and the outcome is far less certain – an agouti in a burrow stands a much better chance of escaping than a swimming conspecific.

In comparison to the agouti, a paca flushed into the river is a much more difficult animal to kill. Able to remain submerged for considerable lengths of time, the paca can swim from one side of the river to the other without being noticed by the hunter. If hunters lose track of the animal once it takes to the water, the prospects of a successful kill are rather bleak. By contrast, hunters seem to fare somewhat better when the paca attempts to escape in a stream. The animal is effectively limited to swimming in one dimension (i.e. upstream or downstream), and a quick

and conscientious hunter can lay branches across the stream in shallow sections above and below the point of submersion, preventing the paca from escaping the pool undetected. At that point, the hunter probes the banks of the stream, looking for the paca's hiding place. The success of the pursuit seems to depend largely on the depth of the water and whether or not the hunter saw exactly where the paca entered the water.

Finally, I make a distinction between earthen burrows and hollow trunks. Dogs might corral agoutis and pacas in either, although trunks seem to be the more likely destination for fleeing agoutis whereas pacas tend to stick to their earthen burrows.²⁷ Trunks and earthen burrows are similar in that hunters follow a common pattern of assessing the scene, plugging possible exits, digging or cutting to gain access to the animal, and probing to determine the animal's exact location in order to deliver a potentially fatal machete strike. There are important differences, however. First, the most obvious difference is that hunters must cut their way into trunks with machetes or axes, whereas they must dig into earthen burrows, usually with machetes or digging sticks but also with their hands. Second, on a related note, digging into an earthen burrow is perhaps a chancier affair, as there is the possibility that hunters will actually remove dirt in such a way that the animal inside can bolt past and escape. With trunks, as long as the size of the hole being cut does not exceed the size of the animal, hunters are reasonably assured that the only exit is via the holes that should have already been well plugged. Third, hunters can more easily see the full extent of a trunk, whereas it is more difficult to ascertain the depth and extent of an earthen burrow. Finally, it seems that dogs are more able to detect the sounds and smells of animals in trunks than in burrows, which then helps the hunter to pinpoint the location of the animal and (he hopes) dispatch it more quickly. Combined, these factors seemed to merit at least a preliminary examination of the respective differences between the different types of pursuit.

However, it is important to note that attempts to separate unique encounters into discrete prey types necessarily overlook much of the possible variation in encounter contexts. Hunters consider many factors when deciding whether or not to continue a pursuit. For example, while they have certain expectations about the profitability of pursuing agoutis in trunks, they are also attentive to the hardness of the wood and whether or not the trunk has already been accessed in a previous pursuit. Earthen burrows are likewise variable, as those that wend their way through

²⁷ The last of the most commonly killed animals, armadillos, are almost inevitably located in earthen burrows.

the root systems of large, buttressed trees appear to be more difficult than burrows without this added obstacle. Similarly, once a paca is flushed into the river, the clarity and depth of the water have obvious effects on the outcome of the pursuit.

3.4.2 *Optimal foraging analysis of hunting with dogs*

The observations used to estimate the profitability of each prey type are listed in Table 3.4. This table does not include animals that were encountered but not pursued, nor does it include episodes of chasing after the dogs that concluded without pursuit once the hunter had identified the prey item.²⁸ While most pursuits ended in a successful kill, I make a further distinction for unsuccessful kills. In this context, “escape” refers to situations in which the animal successfully fled the burrow or trunk where it had been corralled by the dogs. By contrast, “abandon” indicates that the hunter remained confident of the animal’s location, but he decided not to continue pursuit, usually because the hole was too deep or problematic to merit further pursuit. This distinction becomes slightly ambiguous only in the case of pacas that have fled into the river. In two cases, hunters searched the water for about an hour in an attempt to re-encounter the animal before giving up. Questioned later, they remained convinced that the pacas had not exited the water, but this assertion was difficult to confirm. Finally, there were some instances when hunters would arrive to find dogs excitedly yapping outside a burrow or trunk, only to discover after a period of probing and cutting or digging that the hole was in fact empty. I use the term “empty” to denote such situations. When questioned later, hunters often suggest that the dogs detected the scent of an animal that had been there recently but was no longer present. In the case of agoutis, hunters sometimes speculate that the dog had corralled the animal, but that it had slipped away unnoticed by the dogs. Because a recently-used burrow looks much like a currently-occupied, there is seldom any way of knowing beforehand that digging or cutting into the burrow is pointless.²⁹

²⁸ See Table 3.8 for cases of the latter.

²⁹ One could argue that these “pursuits” should not be assigned to individual prey types but rather be considered a general cost of hunting with dogs. My thinking in this case follows that of Hill and Hawkes (1983:147-148), who describe how Aché hunters sometimes seal exits to paca burrows and prepare for a kill before they visually confirm that the animal is actually inside. However, I conducted a separate OFT analysis in which I excluded these “empty” pursuits from the average handling cost of prey types, and the changes had no bearing on what prey types were included in the optimal diet breadth.

Table 3.4. Pursuit times and outcomes used to estimate the profitability of prey types. In this table, “Hunters” refers to the number of hunters working at a kill site, and “Dogs” likewise refers to the number present at the kill site. For space considerations, collared peccary is abbreviated as “C. peccary.” Weights are listed in kilograms.

Date	Hunters	Dogs	Species	Type	Handle time (min)	Outcome	Weight
10/2/04	2	1	Agouti	Earth	9.6	Empty	0
12/4/2004	1	1	Agouti	Earth	18.51	Abandon	0
12/28/2004	2	3	Agouti	Earth	106.13	Abandon	0
3/3/2005	2	1	Agouti	Earth	54.66	Kill	2.2
4/8/2005	1	2	Agouti	Earth	30.01	Kill	3.4
4/9/2005	2	2	Agouti	Earth	33.91	Kill	3.4
5/3/2005	1	2	Agouti	Earth	11.08	Abandon	0
5/14/2005	2	2	Agouti	Earth	22.08	Escape	0
7/2/2005	2	6	Agouti	Earth	43.55	Kill	2.3
7/2/2005	2	6	Agouti	Earth	27.28	Kill	3.4
7/26/2005	3	7	Agouti	Earth	27.77	Kill	3.3
4/23/2005	2	1	Agouti	River	3.52	Kill	4.6
9/24/2004	1	3	Agouti	Trunk	26.74	Kill	3.9
10/2/2004	2	1	Agouti	Trunk	49.92	Kill	3.6
10/2/2004	2	1	Agouti	Trunk	41.48	Kill	1.6
10/28/2004	1	4	Agouti	Trunk	18.17	Kill	3.8
11/10/2004	2	3	Agouti	Trunk	19.36	Kill	1.3
11/10/2004	2	3	Agouti	Trunk	11.78	Kill	2.5
11/10/2004	2	3	Agouti	Trunk	103.50	Kill	3.7
11/13/2004	1	1	Agouti	Trunk	95.69	Kill	2.8
11/13/2004	1	1	Agouti	Trunk	28.42	Escape	0
12/3/2004	2	3	Agouti	Trunk	20.42	Kill	2.1
12/9/2004	1	3	Agouti	Trunk	30.69	Kill	3.8
12/9/2004	1	3	Agouti	Trunk	33.59	Kill	2.5
12/28/2004	2	3	Agouti	Trunk	60.07	Kill	3.5
12/30/02	2	2	Agouti	Trunk	1.2	Empty	0
2/7/2005	1	3	Agouti	Trunk	18.32	Kill	3.3
3/9/2005	1	2	Agouti	Trunk	14.12	Kill	3.3
3/29/2005	1	1	Agouti	Trunk	51.73	Kill	3.8
4/8/2005	1	2	Agouti	Trunk	5.8	Empty	0
4/30/2005	2	2	Agouti	Trunk	18.55	Kill	2.9
4/30/2005	2	2	Agouti	Trunk	31.36	Kill	4.2
5/14/2005	1	2	Agouti	Trunk	11.18	Kill	3.9
5/14/2005	2	2	Agouti	Trunk	1.02	Abandon	0
6/11/2005	2	2	Agouti	Trunk	4.8	Empty	0
6/25/2005	2	2	Agouti	Trunk	27.67	Kill	2
7/2/2005	2	6	Agouti	Trunk	25.68	Kill	3.6
7/2/2005	2	6	Agouti	Trunk	3.96	Kill	2.7
7/2/2005	2	6	Agouti	Trunk	3.85	Escape	0
7/9/2005	2	4	Agouti	Trunk	49.53	Kill	4.2
7/9/2005	2	4	Agouti	Trunk	7.33	Kill	2.5
7/9/2005	2	4	Agouti	Trunk	2.7	Empty	0
7/23/2005	3	5	Agouti	Trunk	30.61	Kill	3.2
7/23/2005	3	5	Agouti	Trunk	26.1	Empty	0

Date	Hunters	Dogs	Species	Type	Handle time (min)	Outcome	Weight
7/27/2005	2	2	Agouti	Trunk	15.53	Kill	2.8
7/27/2005	2	2	Agouti	Trunk	18.50	Kill	3
7/30/2005	3	3	Agouti	Trunk	32.87	Kill	2.2
7/30/2005	3	3	Agouti	Trunk	12.45	Kill	1.5
8/12/2005	3	3	Agouti	Trunk	32.97	Escape	0
8/13/2005	1	1	Agouti	Trunk	16.87	Kill	3.7
10/2/2004	2	1	Armadillo	all	11.24	Kill	2.8
12/27/2004	2	1	Armadillo	all	13.79	Kill	5
12/28/2004	2	3	Armadillo	all	11.00	Kill	5.1
12/30/2004	2	2	Armadillo	all	10.29	Kill	5
2/23/2005	1	3	Armadillo	all	27.11	Kill	5.2
4/14/2005	1	2	Armadillo	all	69.76	Abandon	0
8/12/2005	3	3	Armadillo	all	43.66	Kill	5
8/13/2005	3	2	Armadillo	all	26.52	Kill	2.4
3/10/2005	2	1	Iguana	all	3.19	Kill	2.8
3/10/2005	2	1	Iguana	all	1.77	Escape	0
2/12/2005	2	1	Paca	Earth	28.87	Kill	8.5
2/23/2005	1	3	Paca	Earth	57.27	Kill	9.4
2/25/2005	1	1	Paca	Earth	77.61	Kill	6.9
3/3/2005	2	1	Paca	Earth	30.98	Kill	9.2
3/10/2005	2	1	Paca	Earth	7.23	Kill	5.7
3/10/2005	2	1	Paca	Earth	10	Empty	0
3/10/2005	2	1	Paca	Earth	5.8	Empty	0
4/2/2005	1	2	Paca	Earth	16.85	Escape	0
4/2/2005	1	2	Paca	Earth	3.30	Escape	0
4/23/2005	2	1	Paca	Earth	60.7	Empty	0
5/6/2005	2	1	Paca	Earth	39.5	Empty	0
5/7/2005	2	4	Paca	Earth	26.43	Kill	2.2
5/14/2005	2	2	Paca	Earth	18.92	Abandon	0
12/27/2004	2	1	Paca	River	57.79	Abandon	0
3/10/2005	2	1	Paca	River	72.23	Abandon	0
3/31/2005	3	1	Paca	River	2.10	Kill	9.8
9/24/2004	1	3	Paca	Stream	133.35	Kill	7.7
12/13/2004	1	2	Paca	Stream	57.25	Escape	0
2/7/2005	1	3	Paca	Stream	50.29	Kill	6.8
6/25/2005	2	2	Paca	Stream	6.7	Empty ³⁰	0
7/30/2005	3	3	Paca	Stream	34.58	Escape	0
12/30/2004	2	2	Paca	Trunk	6.58	Escape	0
2/25/2005	1	1	Paca	Trunk	24.13	Escape	0
8/22/2005	2	2	Paca	Trunk	52.12	Kill	9.9
8/27/2005	1	2	Paca	Trunk	11.0	Empty	0
10/4/2004	1	3	C. peccary	all	47.44	Kill	19
9/27/2004	1	4	C. peccary	all	28.91	Kill	19.5
7/26/2005	3	7	C. peccary	all	46.10	Kill	20.5

³⁰ In this situation, the hunter heard a splash and honed in on a stream, assuming it to be a paca. Although the dogs soon left the streambed, the hunter stayed and probed the stream banks until the discovery of agouti tracks convinced him that it was in fact an agouti, not a paca.

The figures in Table 3.4 were combined to give average profitability estimates for each prey type in terms of expected kilograms per unit of handling time, and the results were then used to calculate the optimal diet breadth for hunters with dogs (Table 3.5). The decision rule is expressed in the “Return” column, which indicates the expected rate of return (kcal/hour) if the hunter pursues that prey type along with the more profitable prey types. The results in Table 3.5 indicate that all regularly-pursued prey types increase the overall return rate for hunters with dogs. These results thus support the optimal diet breadth model, which predicts that hunters will not pursue prey types that lower the average return rate. In some cases, the expected increase in return rate upon including the next most profitable prey type is fairly small. Favorable encounters with iguanas and agoutis chased into the river are fairly rare, for example, which couples with these animals’ small size to boost the average return rate by only 18 calories per hour. By contrast, collared peccaries and agoutis in trunks increase the return rate more dramatically, the former because of their large size and the latter because of their high encounter rate.

Because I did not observe any tapir or deer pursuits, I can hazard only an educated guess about the expected profitability of these large ungulates. Encounters with tapirs are relatively rare – on approximately 245 unobserved hunting trips with dogs, there were reports of 15 tapir encounters, of which seven resulted in kills. Tapirs are the largest prey animals in the reserve, but their overall profitability is undermined somewhat by their high post-kill handling times. Unless they are killed near the river, tapirs must be butchered in the forest, as they are too heavy to carry back to the community in one piece. The guts and skin, which are not eaten locally, are usually left in the forest, but even without these low-utility parts there is often too much meat for two adult men to carry in one trip.³¹ In some cases, hunters returned to the village for assistance from friends and family in the butchering and transport of the meat. The total handling time in this case may last as long as 4-5 hours, but even a handling time of five hours for a 180 kg tapir yields a profitability estimate of 45,630 kcal/hour, which would place the tapir behind only river-bound agoutis as the most profitable prey items available to hunters in Bosawas.³² Given the

³¹ Metcalfe and Barlow (1992) have developed an OFT model that predicts the decision rule by which central place foragers would be expected to leave low-utility parts in the field.

³² Unsuccessful tapir pursuits would detract from this profitability estimate, but because the post-kill handling time is so long, even a 50% success rate would not make the tapir less profitable in comparison to other prey types. In other words, failed pursuits end quickly, allowing hunters to resume their search for other prey items.

Table 3.5. Calculation of the optimal diet breadth for hunters with dogs. Handling times have been converted to hours. The symbol “ λ ” indicates the encounter rate per hour of the respective prey types (i.e. not necessarily equivalent to species distinctions).

Species	Type	Average handling time (hr)	Average weight ³³	Average calories ³⁴	Profitability (kcal/hr)	λ	$\lambda \times \text{kcal}$	$\lambda \times \text{ht}$	Return (kcal/hr)	In optimal diet?
Agouti	River	0.06	4.60	5830.5	99,289.5	0.01	40.64	0.00	41	Yes
Collared Peccary	(All)	0.68	19.67	24927.5	36,643.6	0.02	521.30	0.01	554	Yes
Iguana	(All)	0.04	1.40	910.0	22,038.3	0.02	19.03	0.00	572	Yes
Armadillo	(All)	0.44	3.81	4832.3	10,871.5	0.05	235.80	0.02	787	Yes
Paca	Earth	0.49	3.22	4085.3	8,312.6	0.09	370.21	0.04	1097	Yes
Paca	Trunk	0.39	2.48	3137.1	8,020.5	0.03	87.47	0.01	1166	Yes
Agouti	Trunk	0.44	2.26	2865.2	6,503.2	0.26	758.98	0.12	1681	Yes
Paca	River	0.73	3.27	4140.5	5,640.9	0.02	86.59	0.02	1731	Yes
Paca	Stream	0.94	2.90	3675.8	3,907.9	0.04	153.74	0.04	1799	Yes
Agouti	Earth	0.58	1.64	2074.1	3,560.1	0.08	159.04	0.04	1859	Yes

³³ Note that the average weight is not the average weight of the species, but rather the average amount of meat that hunters can expect upon initiating a pursuit. Because unsuccessful pursuits are factored into the estimate, the average weights for the OFT model are typically less than the average weight of individual specimens.

³⁴ To obtain average caloric returns for each prey type after initiating a pursuit, I follow Hill and Hawkes (1983) and Alvard (1993a) in assuming that 65% of the harvested biomass is edible meat. All of the species in this table average 1,950 Kilocalories per kilogram of edible flesh except for the iguana, for which I use the Hill and Hawkes (1983) estimate of 1,000 Kilocalories per kilogram of snake flesh.

animal's large size and the opportunity for hunters to sell the meat for profit, it is not difficult to see why the tapir is perhaps the most coveted prey animal in the reserve.

Calculating estimates for the two species of deer is somewhat problematic. I witnessed two red brocket deer encounters on hunting trips, but in each case the hunters lacked rifles and could only watch as their dogs chased the deer into the distance. On two other hunting trips, brocket deer were killed when the dogs chased them into the river, where the animals were killed by others. On one of these occasions, a hunter could not figure out what animal his dogs were chasing, and he was pleasantly surprised at the end of the hunt to discover that his wife had killed the deer near the spot where she had been fishing. On another occasion, a hunter from Arang Dak speculated that his dogs were chasing a far-ranging deer, but he did not learn that residents of Suma Pipi had killed the animal when it fled into the river near the community (interestingly, because the residents also observed the hunter's dogs in pursuit of the deer, they sent a large share of the deer to the "owner" of the meat, but the messenger kept the meat for himself and nobody else informed the hunter of the kill). On unobserved hunting trips with dogs, two hunters with rifles were able to shoot juvenile red brocket deer that they saw when their dogs were roaming elsewhere. Hunters with rifles will ready their guns when they believe that their dogs might be pursuing deer in their direction, but I suspect that hitting a deer on the run at distances above 20-30 meters would be difficult for most of the hunters in Bosawas. As such, unless they are near their boats, hunters with dogs appear to stand little chance of successfully killing either of the two deer species in the reserve once the dogs take to the chase. Because of their large sizes, however, deer would probably be included in the optimal diet even if the probability of a kill were fairly small, assuming that average handling times did not last an inordinate amount of time (perhaps more than an hour).

3.4.3 The question of simultaneous search

The example of hunters with rifles pursuing deer while their dogs are elsewhere raises the question of what prey hunters should pursue independently of their dogs. Table 3.6 lists the prey items that hunters pursued when their dogs were looking for prey elsewhere. All of the prey types pursued by hunters with both rifles and dogs are also regularly pursued by rifle hunters on trips without dogs, so there is some indication that hunters are following similar prey choice

decision rules. However, some of the pursuits with other technologies, such as thrown projectiles, appeared to stand little chance of success and might initially be considered suboptimal decisions. While it might be possible to kill a quail with a thrown rock, for example, it is difficult to imagine that the average return of such pursuits would be more profitable than some alternatives. Yet, the fact that these pursuits, often conducted in a playful manner, do not hinder their dogs from continuing their search for prey suggests that these pursuits cannot be evaluated with the prey choice model, namely because search and pursuit are not mutually exclusive activities. In other words, hunters who throw rocks at birds suffer no opportunity costs. Given that hunters equipped only with machetes and axes rely on dogs to locate almost all of their successful kills, their activities while the dogs are searching are to some extent unimportant to the success of the hunt. Engaging in a nearly impossible pursuit is no more detrimental than rolling and lighting a cigarette, which is another common activity when the dogs are out searching for prey.

Table 3.6. Prey pursued by hunters when their dogs were elsewhere. The category “Technology” indicates the technology that hunters used in their attempts to kill the prey animal, not the full complement of technologies available to the hunter. An asterisk (*) next to some technologies indicated that hunters also had .22 caliber rifles, but they opted to pursue the prey item in question only with the listed technology. The number of attempts indicates the number of times hunters released projectiles of the respective technologies. For rifle pursuits, the number in parentheses indicates the number of bullets that misfired. On the April 14th pursuit, for example, the hunter’s first attempt misfired while the second bullet successfully fired just as the hunter’s dog returned and scared off the agouti.

Date	Species	Technology	Attempts	Handle time (minutes)	Outcome	Weight
4/14/2005	Agouti	Rifle	1 (1)	1.75	Dog scares it off	0
7/9/2005	Agouti	Rifle	0	0.16	Dog scares it off	0
9/24/2004	Black wood turtle	Hands	1	6.15	Capture	2.4
12/27/2004	Black wood turtle	Hands	0	2.90	Abandon	0
3/29/2005	Woodpecker	Rifle	1	1.28	Escape	0
7/9/2005	Woodpecker	Slingshot*	2	1.15	Escape	0
5/6/2005	Quail	Thrown rocks	2	2.00	Escape	0
7/2/2005	Quail	Slingshot*	0	1.09	Dog scares it off	0
7/9/2005	Quail	Slingshot*	0	1.80	Escape	0
7/23/2005	Quail	Baseball hat*		0.06	Escape	0
7/26/2005	Quail	Slingshot*	1	0.99	Escape	0
11/11/2004	Tinamou	Rifle	1	2.46	Kill	0.9
4/8/2005	Tinamou	Rifle	0	3.20	Escape	0
4/9/2005	Tinamou	Rifle	0	1.43	Escape	0
4/30/2005	Tinamou	Thrown stick	1	0.17	Escape	0
5/3/2005	Tinamou	Rifle	0	3.25	Dog scares it off	0
5/6/2005	<i>Pato de agua</i>	<i>Palanca</i> ³⁵	1	5.03	Escape	0
4/8/2005	Crested guan	Rifle	1	9.89	Kill	1.9
5/14/2005	Crested guan	Rifle	0	10.87	Escape	0
5/14/2005	Crested guan	Rifle	0	17.05	Escape	0
2/23/2005	Great curassow	Rifle	2 (1)	1.52	Abandon	0
4/30/2005	Bala (a turtle)	Hands		1.01	Escape	0

³⁵ The *palanca* is the wooden stick that Bosawas residents use to pole their boats.

3.4.4 *Additional costs of hunting with dogs*

Hunters are often unable to discern exactly what animal their dogs are chasing, and they are effectively powerless to prevent them from pursuing undesirable prey until they can catch up to the dogs themselves. In other cases, hunters hone in on a location at which their dogs have apparently corralled a prey item, only to discover after probing that the burrow or trunk is in fact empty. Nearly one-third of time spent catching up to the dogs ends without the hunters actually encountering the animal that the dogs had been chasing (279 minutes over the fifty observations in the above sample). These situations represent costs that are imposed when hunting with dogs but that are unique to the handling costs used in the optimal prey choice analysis above.

Table 3.7 lists episodes of catching up to the dogs that did not result in positive identification of a prey animal or an active attempt to pursue the animal (e.g. cutting into a trunk to verify the presence of an animal). In most cases, these episodes ended when the hunters could no longer hear the dogs barking or when the dogs returned into view. Although hunters did not directly see the animal, they often reached a conclusion about what it was based on the intensity of the dogs' barking and the speed and direction of the chase. After the hunt, I asked hunters to speculate on the identity of the pursued animal, and their speculations are likewise included in Table 3.7. Agoutis represent between 62-65% of the sample, which is not surprising given that they are the most frequently corralled prey animal. These results also indicate, however, that dogs often lose the trail of agoutis after they have been initially detected. By contrast, despite the fact that they are the second-most commonly killed animal, this sample suggests that nine-banded armadillos rarely escape being corralled once dogs detect their location to the extent that hunters are prompted to begin hunting. In other words, agoutis regularly escape dogs in "hot pursuit," but armadillos do not, perhaps because they are already taking refuge in their burrows when the dogs locate them.

Table 3.7. Episodes of catching up to the dogs that did not result in positive identification of the animal.

Date	Speculated prey animal	Time spent catching up (minutes)
10/28/2004	Agouti or red brocket deer	8.9
11/13/2004	Tapir	8.2
11/13/2004	Agouti	14.7
12/3/2004	Collared peccary	11.9
12/3/2004	Collared peccary	49.0
12/4/2004	Agouti	3.1
12/13/2004	Agouti	1.8
12/13/2004	Red brocket deer	19.2
1/14/2005	Unknown	13.3
2/23/2005	Unknown bird	0.8
3/9/2005	Agouti	3.6
3/9/2005	Agouti	6.9
4/8/2005	Agouti	0.9
4/8/2005	Agouti	5.6
4/9/2005	Agouti	5.9
5/3/2005	Collared peccary	5.7
5/3/2005	Agouti	4.0
5/14/2005	Agouti	2.2
5/14/2005	Agouti	3.3
6/25/2005	Agouti	2.7
6/28/2005	Agouti	5.5
6/28/2005	Agouti	3.3
7/23/2005	Agouti	2.5
7/30/2005	Agouti	15.0
7/30/2005	Agouti	3.3
8/13/2005	Unknown	3.8
8/22/2005	Agouti	3.6
8/22/2005	Red brocket deer	3.5
8/27/2005	Unknown	10.8

Another way in which dogs impose costs on hunting trips is by chasing after prey that hunters cannot kill or consider inedible. Table 3.8 lists all observed cases in which hunters caught up to their dogs to find that they had corralled or treed such an animal. Of the animals listed, only the coati is considered edible by at least some members of the community (see Appendix 1). On two occasions, hunters opted not to pursue a group of coatis despite having a rifle. On the third occasion, the hunter expressed a wish to shoot the coatis, but he did not have a rifle. Although it is not considered edible, one hunter twice attempted to kill tayras that had been treed by his dogs, citing the fact that they can injure dogs and eat community chickens. That same hunter simply led his dogs away from the site on a third occasion, though. Finally, the giant anteater and northern tamandua were killed by hunters to protect their dogs, then left at the kill site.

Table 3.8. Animals corralled or treed by dogs, but not considered edible or killable with available technologies.

Date	Species	Catching up time (min)	Handling time (min)	Outcome
12/3/2004	Coati	8.7	0.0	Not pursued
12/13/2004	Coati	11.4	0.0	Not pursued
8/13/2005	Coati	8.7	0.0	Not pursued
8/27/2005	Giant anteater	4.4	4.4	Killed, left at site
5/14/2005	Tamandua	0.0	4.2	Killed, left at site
12/28/2004	Tayra	7.1	0.0	Not pursued
5/3/2005	Tayra	8.4	13.5	Pursued, not killed
8/27/2005	Tayra	8.5	5.7	Pursued, not killed

These last cases are particularly interesting because the decision to leave the meat behind appears to violate predictions of the prey choice model. Both the giant anteater and northern tamandua are fairly large mammals: approximately 30 kg and 5.5 kg, respectively (Reid 1997). Assuming that the hunter had prepared the animal for transport, the handling time for the giant anteater would be about 12 minutes.³⁶ The resulting profitability would be 190,125 kcal/hour, easily outranking all other prey types in Table 3.5.³⁷ Likewise, assuming a total handling time of about eight minutes for the northern tamandua, the profitability of this prey type would be 52284.38 kcal/hour, placing it second on the ranking of prey types in Table 3.5.³⁸ Because of

³⁶ For this estimate, I used the average field processing times (7.5 minutes) for similarly-sized collared peccaries.

³⁷ This estimate assumes that 65% of the meat is edible and that there are 1950 kcal/kg of edible meat.

³⁸ This estimate was based on the same assumptions made for the above giant anteater calculation.

their rarity, pursuing and consuming these two species would not dramatically raise the average return rate of all hunting trips. In other words, even if hunters were to pursue and consume these species upon each encounter, the low encounter rate would prevent these prey types from contributing much meat long-term. On the other hand, hunters who do not pursue these prey types are foregoing opportunities to acquire sizeable quantities of meat. The failure to take these species thus violates the basic foraging rule that sufficiently profitable prey types should always be pursued upon encounter (Stephens and Krebs 1986:23).

In the discussion of hunting with rifles, I discuss the importance of taste, prestige, and nutrition in explaining the apparently suboptimal decision to bypass profitable prey items. For the time being, I will mention the claim by Bosawas residents that the meat of giant anteaters and northern tamanduas is distasteful and not fit for consumption. Even assuming that the hunters themselves will not eat the meat, one must wonder why they do not feed the meat to the dogs, which appeared quite ready and willing to consume the meat at the kill site. When I informally posed this question to hunters, the most common response was that they did not want their dogs to develop a “taste” for these animals, which might encourage the dogs to pursue them more fervently in the future. In the case of the giant anteater, the hunters also emphasized the dangers posed to the dogs by the animal’s sharp claws. Given that a good hunting dog sells for as much as 500 cordobas, the hunters’ concern is perhaps understandable.³⁹ On the other hand, they actively encourage their dogs to pursue collared peccaries, which can deliver fatal bites to pursuing dogs. The antipathy for anteater meat must therefore extend beyond concern for the dogs’ welfare.

3.4.5 “*Recognition constraints*” in optimal foraging models

The basic prey choice model assumes that foragers instantaneously identify their prey and that attack decisions are made immediately thereafter. The ecological literature includes a handful of cases where foragers must first devote some time to recognizing their prey. For example, shore crabs must lift mussels to ascertain their weight, which is an indicator of their profitability (Elner and Hughes 1978). Figure 3.3 graphically depicts the decision-making process when foragers must first recognize their prey. Unlike the basic prey choice model, in

³⁹ In 2004-2005, the typical pay for 6-7 hours of agricultural labor was 50 cordobas.

which ignored prey items carry no costs for foragers, the “recognition constraints” model imposes some unique costs on the forager. Because foragers must devote some time to recognizing prey types before they can decide whether to attack, they pay a recognition cost regardless of the subsequent attack decision.

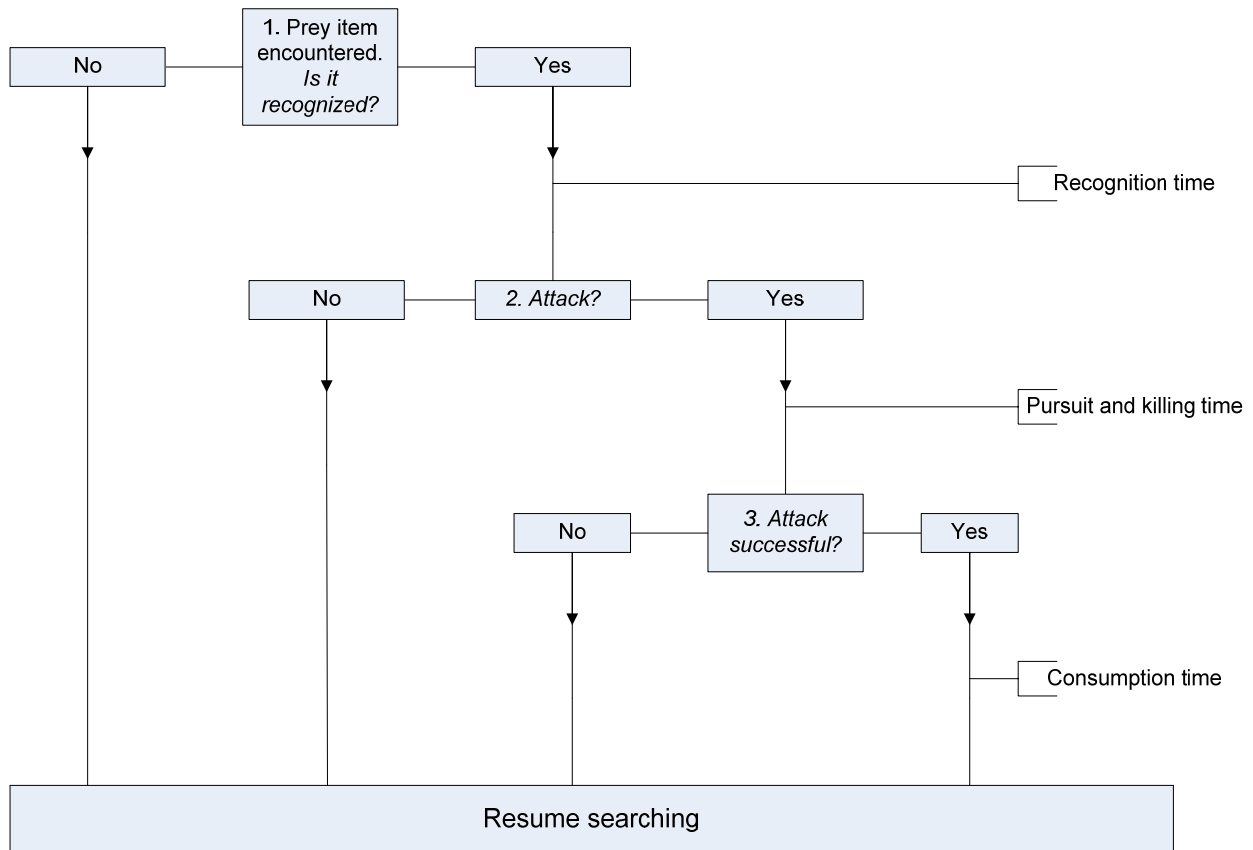
As part of their experimental work with great tits, Houston et al. (1980) developed a foraging model that incorporated recognition constraints. For a situation in which there are only two prey types, the decision rule for specializing on the most profitable prey type is given by the threshold:

$$\frac{\lambda_1 E_1}{1 + \lambda_1 (H_1 + R_1) + \lambda_2 R_2} > \frac{\lambda_1 E_1 + \lambda_2 E_2}{1 + \lambda_1 (H_1 + R_1) + \lambda_2 (H_2 + R_2)} \quad (1)$$

where λ = encounter rate, E = the average energetic value of the prey type, H = handling time for the prey type, and R = the time needed to discriminate between the two prey types. Note that when $R = 0$, the threshold simplifies to the basic diet breadth model.

The inclusion of recognition times has some interesting implications for prey choice decisions. While prey choice decisions in the basic model are predicated solely on the profitability and abundance of more profitable prey types, the abundance of the prey type in question becomes an important factor in the recognition constraints model. If the profitability and abundance of type 1 are held constant, then type 2 items may be attacked at high encounter rates and ignored at low encounter rates (Houston et al. 1980:170). Similarly, the length of the recognition time has an impact on prey choice decisions, as relatively high recognition times promote inclusion of otherwise unprofitable prey types (Stephens and Krebs 1986:65).

Figure 3.3. The hierarchical decision-making process of foragers that must first devote time to recognizing their prey. Once the forager identifies a possible prey item, it must devote some time to recognizing its prey type. Once the prey type has been recognized, the forager must decide whether to attack the prey. Assuming an attack is successful, the forager must also devote some time to its consumption (adapted from Figure 3.5 in Stephens and Krebs 1986:64).

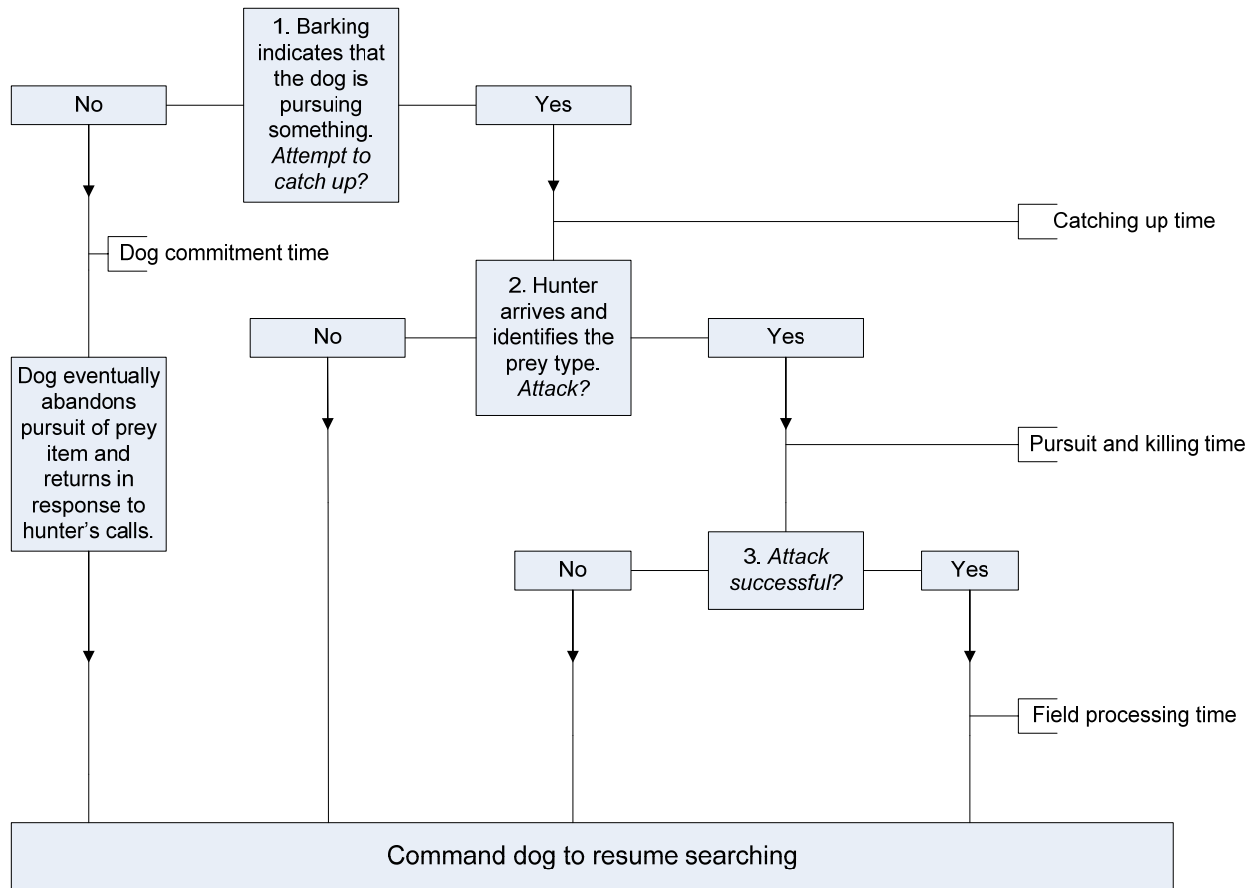


3.4.6 *A model of hunting with dogs in Neotropical rain forests*

The decision-making process of hunting with dogs (Figure 3.4) closely follows that of foragers which must first recognize their prey before making an attack decision. Dogs announce their pursuit of prey by barking intensely, but only after catching up to the dogs can hunters successfully identify the prey type. Even when hunters suspect that their dogs are pursuing a paca, for example, they cannot be sure where (or if) the paca will be corralled and, by extension, the expected profitability of continued pursuit. Catching up to the dogs often involves several minutes of arduous bushwhacking through the forest, but only by paying this cost can hunters discover if the prey animal has taken refuge in an easy-to-access trunk or an impossibly deep burrow. Perhaps more importantly, hunters are effectively powerless to stop their dogs from chasing unwanted prey items. While hunters issue commands to dogs in close proximity (e.g. “get in the boat” or “sniff this hole”), the Miskito and Mayangna apparently have no effective command for ordering their dogs to abandon a “hot” pursuit. Hunters generally resort to calling the dogs’ names when they want them to return, but dogs sometimes ignore these commands if they are intently pursuing another animal. In many cases, the best way to have the dogs resume a general search for prey is to catch up to them and then lead them away from the site where they have corralled an animal. On multiple occasions, hunters chose not to pursue animals corralled in unfavorably deep burrows and, once the dogs seemed to detect the hunters’ disinterest in the animal, they likewise abandoned the site without much coaxing on the part of the hunter. Until the hunter arrives, however, the dogs usually remain at the site, sniffing and pawing at the trapped animal, sometimes for lengthy periods of time.

The time that hunters spend catching up to the dogs is in many ways a proxy for the time that dogs spend pursuing a prey item to the exclusion of search for others. The relationship is not perfect, however. For one thing, hunters typically did not begin honing in until they were reasonably confident that the dog was close to corraling the animal. Dogs would sometimes circle the hunters for several minutes, barking sporadically as they followed the scent of an animal. Only after discovering the animal’s hiding place would the dogs begin barking convincingly, at which point the hunters would hone in on the location. In these cases, the time spent catching up underestimates the time that the dog was focused on that particular prey item.

Figure 3.4. The hierarchical decision-making process of hunting with dogs



Also, some hunters did not even attempt to give chase once their dogs began pursuing certain species, most notably red brocket deer and tayras. Both species can lead dogs on long and futile pursuits, and hunters seem resigned to a long wait once their dogs begin chasing these animals. On one occasion, a hunter watched his dog begin chasing a red brocket deer, then began walking back toward the community, calling out intermittently for the dog to come back. Other hunters, intent on continuing the hunt, ambled impatiently from hilltop to hilltop while calling for their dogs to return. Because data collection focused on the hunters' activities, catching up time in these cases is a poor indicator of the time dogs spend pursuing these prey types instead of conducting a general search. Nevertheless, this time that the dogs spend in pursuit of virtually un-killable prey represents an additional cost of hunting with dogs, which I call "dog commitment time" in Figure 3.4. To estimate this cost for applicable prey types, I count the time from the moment that the hunter realizes the dog is chasing the prey item until the dog returns to the hunter.

For analysis purposes, both dog commitment time and catching up time are similar costs, as in both cases the dogs are focused on a particular prey item to the exclusion of a general search for prey. Whether or not the hunter realizes what animal the dog is chasing, the important point is that hunters cannot begin pursuing the animal or resume a general search until they either catch up to the dogs or wait for the dogs to abandon the chase. To generate an estimate for the model, I therefore sum the average values of catching up time and dog commitment time. I also include the time that hunters spend attempting to kill unconsumed prey items. For example, I include the time needed to kill the giant anteater, as it was clear that the dogs would not resume searching for other prey until the hunter had dispatched the animal (cf. Hames 1991:181).

These costs can be incorporated into the basic diet breadth model as an additional constraint. The derivation here is an extension of the two-prey case examined by Houston et al. (1980). In a hunting environment with m prey types, of which n are included in the optimal diet breadth, prey types are added to the diet until:

$$\frac{\sum_{i=1}^n \lambda_i e_i}{1 + \sum_{i=1}^n \lambda_i h_i + \sum_{i=1}^m \lambda_i d_i} > \frac{e_{n+1}}{h_{n+1}} \quad (2)$$

where:

λ_i = encounter rate with prey type i

e_i = average expected net energy gain after encounter with prey type i

h_i = pursuit, killing, and field processing time after encounter with prey item of type i

d_i = Catching up time or dog commitment time after encounter with prey item of type i ⁴⁰

Whereas in the basic diet breadth model, foragers incur no costs for relatively unprofitable prey types not included in the optimal diet, hunters with dogs may pay costs for all prey types encountered by their dogs. When hunting dogs encounter an undesirable or unprofitable prey type such as a tayra, they pursue it against their owner's wishes. The time lost to these fruitless chases is an inevitable cost of hunting with dogs, at least in situations where hunters lack the means to prevent these chases. While hunters are effectively powerless to stop the dogs from chasing unwanted prey items, they regain a measure of control upon catching up to the dogs and identifying the prey type. At that time, they weigh the expected benefits of initiating a pursuit against the opportunities available from resuming a general search for prey, as in the basic prey choice model. Because dog-related costs detract from the profitability of continued search, hunters may be inclined to pursue prey that would not be included in the optimal diet if there were no dog-related costs.

3.4.7 *Optimal foraging analysis of the expanded model*

The parameters used to calculate the optimal diet breadth when hunting with dogs are listed in Table 3.9. As noted previously, all regularly pursued prey types are already in the optimal diet independent of dog-related costs (cf. Table 3.5). However, dog-related costs reduce the average return rate by about 8% from 1,859 calories/hour to 1,712 calories/hour. In other words, average hunting returns would increase by almost 150 calories/hour if not for catching up time and dog commitment time. While all pursued prey types in this setting would have been included in the optimal diet breadth even before factoring in these added costs, there are many conceivable settings in which these costs could promote the inclusion of otherwise suboptimal

⁴⁰ I use a d instead of an r to emphasize that these are dog-related costs, not strictly recognition costs, as treated by Houston et al. (1980).

prey types. For example, if higher-ranked prey types such as collared peccaries and nine-banded armadillos were encountered more frequently than they are around Arang Dak and Suma Pipi, then the projected return rate of focusing only on highly-ranked prey types could serve to exclude lower-ranked prey types. Increases in the profitability of higher-ranked prey types could likewise promote the exclusion of lower-ranked prey such as agoutis, much as Hill and Hawkes (1983) noted the exclusion of capuchin monkeys for Aché shotgun hunters. Finally, if the profitability of lower-ranked prey types declined to the point that they fell out of the optimal diet breadth, the costs associated with catching up and recognition could be sufficient to bring them back in. I consider an ethno-archaeological example in section 3.4.8.

Table 3.9. Parameters used to calculate the optimal diet breadth when hunting with dogs, including dog-related costs.

Species	Type	λ	d (hr)	h (hr)	e (Kcal)	Profitability (Kcal/hr)	Return	In optimal diet?
Agouti	River	0.005	0.000	0.059	5830.5	99289.5	24	Yes
Collared Peccary	(All)	0.021	0.073	0.680	24927.5	33111.4	490	Yes
Iguana	(All)	0.021	0.000	0.041	910.0	22038.3	506	Yes
Armadillo	(All)	0.049	0.073	0.444	4832.3	10871.5	703	Yes
Paca	Earth	0.091	0.077	0.491	4085.3	8312.6	989	Yes
Paca	Trunk	0.028	0.135	0.391	3137.1	8020.5	1,053	Yes
Agouti	Trunk	0.265	0.129	0.441	2865.2	6503.2	1,537	Yes
Paca	River	0.021	0.145	0.734	4140.5	5640.9	1,585	Yes
Paca	Stream	0.042	0.168	0.941	3675.8	3907.9	1,651	Yes
Agouti	Earth	0.077	0.094	0.583	2074.1	3560.1	1,712	Yes
Red brocket deer	(All)	0.014	0.633	0.000	0.0	0.0	~	Not pursued
Tayra	(All)	0.014	0.696	0.000	0.0	0.0	~	Not pursued
Coati	(All)	0.014	0.160	0.000	0.0	0.0	~	Not pursued
Giant anteater	(All)	0.005	0.146	0.000	0.0	0.0	~	Not pursued
Tamandua	(All)	0.005	0.070	0.000	0.0	0.0	~	Not pursued
Missing	(All)	0.133	0.118	0.000	0.0	0.0	~	Not pursued

3.4.8 *Hunting with dogs but without steel tools in the pre-contact Neotropics*

While steel machetes and axes are indispensable technologies for virtually all Neotropical societies, their widespread adoption in the Americas was a relatively recent phenomenon. Before contacts with European explorers enabled the eventual distribution of steel tools, indigenous American societies relied on less efficient stone axes for many subsistence tasks. While most anthropological studies of stone tools have concentrated on their implications for swidden agriculture in the prehistoric Neotropics (Carneiro 1979*a*; Carneiro 1979*b*; Denevan 1992*b*), the regular use of steel axes and machetes by indigenous Nicaraguan hunters raises questions about the extent to which hunting without these steel tools might have differed from modern strategies. Holding all other parameters in the above OFT analysis constant (especially encounter rates), would the changes in prey type profitability when working with stone tools alter the optimal diet breadth and, by extension, would the additional costs of hunting with dogs become a determining factor in prey choice decisions?

It is important first to mention that indigenous Central American societies have kept dogs throughout much of their history in the region. Archaeologists report that dogs were present as early as 7,000 B.P. and that they would have allowed early indigenous hunters to capitalize on predator-naïve forest animals (Cooke and Ranere 1989:308-309; Cooke and Ranere 1992:51). Interestingly, while Linares (1976) does not mention the presence of hunting dogs at the Cerro Brujo site in Panama, she notes the absence of arboreal prey such as monkeys, sloths, and coatis in the faunal remains, which suggests that the hunters there lacked either blowguns or bows with which to target animals in the forest canopy. Although I am not especially familiar with the literature, the preponderance of agoutis, pacas, and armadillos in the sample leads me to speculate that the hunters at the Cerro Brujo site may have hunted primarily with a combination of dogs and hand weapons much like those employed in Bosawas. It is important to note that dogs of European ancestry have generally replaced the pre-Colombian breeds of the Americas (Schwartz 1997; Leonard et al. 2002). For current purposes, I assume that the hunting skills of the pre-Colombian breeds are comparable to those of the dogs that I observed in Nicaragua. This question merits further study, however.

There has been considerable experimental work on the comparative efficiencies of stone and steel axes. Although experimental methodologies varied widely between the studies, most

results agree that steel axes are between 3 to 10 times faster than stone axes (Townsend 1969; Saraydar and Shimada 1971; Carneiro 1979a; Mathieu and Meyer 1997). In practice, a number of factors can affect the effectiveness of axes, including the sharpness and shape of the blade, the hardness of the wood, the physical strength and skills of users, and technique (Mathieu and Meyer 1997). Given that choosing a single figure would arbitrarily overlook many of these factors, I opted to recalculate the estimates twice using both efficiency comparisons from both the low end and high end of the spectrum (3 and 10 times faster, respectively).

To recalculate the profitability estimates, I examined the time that hunters spent accessing animals in trunks (“pursuit-under: access” in the coding scheme). While machetes are sometimes used in the process of probing for animals or plugging escape holes, I doubt that machetes dramatically increase the efficiency of these tasks, and I therefore did not re-examine these aspects of pursuit-under. Similarly, while machetes are used as digging sticks when pursuing animals in earthen burrows, I suspect that traditional wooden tools are comparable to machetes in terms of digging efficiency, and I did not recalculate the profitability of pursuing animals in burrows. Accordingly, the only prey types for which I generated new estimates were agoutis and pacas in trunks. I calculated the estimates by multiplying the average times spent accessing the animal with steel tools by either the appropriate conversion (3 or 10), then adding that figure to the other facets of handling the prey (probing, field processing, clearing and assessment, etc.) to create new average handling times for the two prey types. I excluded dog-related costs from these analyses, as the first question is to assess the suite of optimal resources in the absence of time lost to dog commitment time and catching up time. These costs would serve to lower the average return rate, as noted in section 3.4.7.

Tables 3.10 and 3.11 depict the results of these analyses. While the overall return rate declines in both cases, the respective decreases in profitability are not enough to exclude either agoutis or pacas in trunks from the optimal diet breadth. Furthermore, the rank order of profitability changes only slightly when stone tools are assumed to be three times less efficient than steel tools, as pacas in rivers become a more profitable prey type than both pacas and agoutis in trunks. Not surprisingly, adjusting the figures by a factor of ten has a more visible effect on the profitability of the agoutis and pacas in trunks. As seen in Table 3.11, the added cost of working with stone tools would drop the two prey types to the bottom of the rankings (albeit still in the optimal diet breadth).

While all prey types remain in the optimal diet breadth even before factoring in dog-related costs, it is conceivable that the relative decline in the profitability of agoutis and pacas in trunks might have affected the hunting tactics of prehistoric hunters with dogs. While foraging theory predicts that these prey types would have been taken upon encounter, hunters would have done well to maximize encounters with more profitable prey types (Hill et al. 1987:20). In particular, cooperative hunting near the rivers might have yielded higher return rates than solo excursions into the forest, especially if prehistoric hunters in Nicaragua were as competent as their contemporary counterparts at managing boats. Using dogs to drive animals toward companions in the river might have been a particularly effective strategy given the relative ease of killing some species in the river, and Wilbert (1972:144) reports the effective use of this technique by the Makiritare. Looking at the geographic distribution of kill sites (see Chapter 4), all red brocket deer and nearly half the tapirs first located and chased by dogs were killed in the river, and without highly-developed projectile weapons, it was probably not possible to kill these animals in any other way. Even when dogs failed to drive prey items into the river, exploiting the river's edge probably would have increased encounters with armadillos and earthen paca burrows, both of which would have been more profitable than pursuits of holed-up agoutis in the forest. In many ways, then, prehistoric hunters in the Bosawas region might have benefited from focusing on the river and gallery forest as the primary locus of their hunting activities, especially given the technological limitations faced by pre-Contact Neotropical peoples.

It is important to reiterate, however, that these exploratory calculations do not predict the exclusion of agoutis and pacas in trunks. On average, it appears that hunters without steel tools would still have increased their overall return rate by pursuing these prey types upon encounter. The added costs of hunting with dogs further increases the likelihood that hunters would have pursued these prey types. When hunting with dogs, agoutis are by far the most frequently-encountered prey type, and hunters surely would have realized that, upon ignoring a corralled agouti and commanding the dogs to resume searching, chances were high that the next prey item corralled by the dogs would be just another agouti. Given the abundance of agoutis and the costs of catching up to the dogs, it is unlikely that prehistoric hunters would have ignored agoutis once they had been corralled by the dogs. Furthermore, it is possible that the regular use of alternative technologies would have allowed hunters to dispatch animals trapped in trunks more quickly than the average times predicted by the calculations in Tables 3.10 and 3.11. In particular,

Table 3.10. Optimal diet breadth analysis assuming the use of stone tools is three times less efficient than steel tools.

Species	Type	Average handling time (hr)	Average weight	Average calories	Profitability (kcal/hr)	λ	$\lambda \times \text{kcal}$	$\lambda \times \text{ht}$	Return (kcal/hr)	In optimal diet?
Agouti	River	0.06	4.6	5831	99,289	0.01	40.64	0.00	41	Yes
Collared Peccary	(All)	0.68	19.7	24928	36,644	0.02	521.30	0.01	554	Yes
Iguana	(All)	0.04	1.4	910	22,038	0.02	19.03	0.00	572	Yes
Armadillo	(All)	0.44	3.8	4832	10,871	0.05	235.80	0.02	787	Yes
Paca	Earth	0.49	3.2	4085	8,313	0.09	370.21	0.04	1,097	Yes
Paca	River	0.73	3.3	4141	5,641	0.02	86.59	0.02	1,161	Yes
Paca	Trunk	0.57	2.5	3137	5,517	0.03	87.47	0.02	1,223	Yes
Agouti	Trunk	0.69	2.3	2865	4,127	0.26	758.98	0.18	1,635	Yes
Paca	Stream	0.94	2.9	3676	3,908	0.04	153.74	0.04	1,702	Yes
Agouti	Earth	0.58	1.6	2074	3,560	0.08	159.04	0.04	1,762	Yes

Table 3.11. Optimal diet breadth analysis assuming the use of stone tools is ten times less efficient than steel tools.

Species	Type	Average handling time (hr)	Average weight	Average calories	Profitability (kcal/hr)	λ	$\lambda \times \text{kcal}$	$\lambda \times \text{ht}$	Return (kcal/hr)	In optimal diet?
Agouti	River	0.06	4.6	5831	99,289	0.01	40.64	0.00	41	Yes
Collared Peccary	(All)	0.68	19.7	24928	36,644	0.02	521.30	0.01	554	Yes
Iguana	(All)	0.04	1.4	910	22,038	0.02	19.03	0.00	572	Yes
Armadillo	(All)	0.44	3.8	4832	10,871	0.05	235.80	0.02	787	Yes
Paca	Earth	0.49	3.2	4085	8,313	0.09	370.21	0.04	1,097	Yes
Paca	River	0.73	3.3	4141	5,641	0.02	86.59	0.02	1,161	Yes
Paca	Stream	0.94	2.9	3676	3,908	0.04	153.74	0.04	1,256	Yes
Agouti	Earth	0.58	1.6	2074	3,560	0.08	159.04	0.04	1,343	Yes
Paca	Trunk	1.19	2.5	3137	2,636	0.03	87.47	0.03	1,378	Yes
Agouti	Trunk	1.58	2.3	2865	1,810	0.26	758.98	0.42	1,489	Yes

smoking out the animals, while fairly rare in the reserve today, might have been a more common practice in the absence of steel tools. In conclusion, there is little reason to believe that the relative abundance of pacas and agoutis in archaeological faunal assemblages would differ significantly from the frequency of kills in this sample. Agoutis, pacas, and armadillos are the most commonly killed animals when hunting with dogs, and this generalization probably holds true in prehistoric settings as well.

3.5.1 *Concluding thoughts on the costs of hunting with dogs in the Neotropics*

Hunters with dogs incur additional costs associated with catching up to their dogs and identifying the prey type. Unlike hunters with firearms, bows, or blowguns, hunters with dogs cannot simply ignore unprofitable prey items and continue a general search for prey. While dogs primarily chase prey types that allow hunters to improve their return rate, they sometimes chase animals that are not considered edible (e.g. anteaters) or animals that cannot be killed without projectile weapons (e.g. coatis). Furthermore, dogs sometimes corral otherwise profitable prey items in locations that are largely inaccessible to the hunter, such as deep earthen burrows. Before they can identify the prey type and ascertain the expected profitability of initiating a pursuit, hunters must first pay the cost of catching up to their dogs. I have argued that this cost can best be modeled with the “recognition constraints” model of Houston et al. (1980), with the sum of dog commitment time and catching up time serving as the additional constraint in the model. Because this cost must be paid whether or not hunters choose to initiate a pursuit, this model can have interesting effects on prey choice decisions.⁴¹ Prey types that initially appear unprofitable may be pursued because the cost of rejecting them is large enough to make rejection disadvantageous.

While all regularly pursued prey types by hunters in Bosawas are included in the optimal diet breadth independent of the additional cost of catching up time, there are a number of situations in which dogs might pursue prey types that would not be included. As an example, I considered the effect that stone tools would have on the decision rule for agoutis and pacas in trunks. While the reduction in profitability did not affect the inclusion of these prey types in the

⁴¹ By lowering the return rate, these added costs also increase the time that hunters should continue to pursue an individual prey item before abandoning the pursuit, a threshold known as the “optimal pursuit time” (Anholt et al. 1987).

optimal diet, the fact that they dropped to the bottom of the ranking in one analysis is a reminder that technological differences can affect the relative profitability of prey types. Anthropological OFT research has repeatedly shown that technological improvements which improve the encounter rates and profitability of higher-ranked prey types can lead to a narrowing of the optimal diet breadth (Winterhalder 1981; Hill and Hawkes 1983). This lesson is particularly instructive in the Neotropics, where the adoption of firearms and motorboats is becoming increasingly pervasive (Stearman 2000). Even if these changes increase the efficiency with which hunters encounter and harvest more profitable prey types, such as the large ungulates, the greater abundance of smaller prey types like agoutis and the cost of catching up to the dogs every time they give chase to these prey types could lead hunters to pursue them even if they are not otherwise in the optimal diet breadth.

Observational data suggest that catching up times for prey types in the sample range from about 4-10 minutes while dog commitment times for deer and tayra average close to 30-40 minutes. These figures are probably good estimates for similar species elsewhere in the Neotropics, as the anti-predator behavior of the respective species seems to be the primary factor in the values of these dog-related costs. That said, it is conceivable that environmental differences could lead to increases in the length of catching up times in particular. While hunters in Bosawas seldom experienced much difficulty in reaching the dogs, Neotropical forests are characterized by a patchwork of biotopes that includes highland primary forest, seasonal floodland forest, swampy areas, and anthropogenic forests (Hames 1980:37-38; Hill and Hawkes 1983:143-144). Hunters in Bosawas generally avoid young secondary forest and the seasonal floodplains, as the thick and tangled vegetation is difficult to penetrate with only a machete. In areas where such growth predominates, the difficulty of navigating through such biotopes could increase the time needed to catch up to the dogs, thereby affecting not only prey choice decisions but also the value of hunting with dogs in the first place. While hunting technologies and the suite of available prey types remain central to any OFT analysis, human ecologists should not overlook variability in the time lost to dog-related costs as an important factor in the foraging decisions of hunters with dogs in the Neotropics.

3.6.1 *An optimal foraging analysis of hunting with rifles in the Bosawas Reserve*

Compared to hunting with dogs, calculating the optimal diet breadth for rifle hunters was a little trickier, primarily because I observed only six hunting trips by rifle hunters. While those observations provided valuable insight into the strategies employed by rifle hunters, the sample sizes of pursuits and encounters were inadequate to estimate the parameters of the prey choice model. To augment the data on encounter rates, I therefore added data from unobserved hunting trips with rifles (see Chapter 4 for a complete description of the methodology). However, the limitations of informant recall methods are well understood (Bernard et al. 1984), and post-trip interviews almost certainly underestimate the actual encounter rate with smaller, sporadically pursued prey items. My experience with rifle hunters suggests that they seldom forget to report animals weighing more than one kilogram (even when the prey item was not pursued) but that smaller prey items are more likely to be unreported. Table 3.12 lists all reported encounters by rifle hunters on 49 hunting trips, including the six hunting trips that I observed. The trips included in this sample are all day trips originating in the community, as it was difficult to estimate the amount of time devoted to active hunting on multi-day *giras*. On day trips, too, hunters would sometimes spend time in other activities, especially agricultural tasks. To obtain more accurate data on time spent hunting, assistants therefore asked hunters to estimate how much time they spent actively hunting. In many cases, hunters reported that they did nothing but hunt, but sometimes briefer hunting trips of 1-2 hours followed a longer amount of time spent working on other tasks.

While I observed pursuits of many of the species that rifle hunters regularly pursue, there are a number of species for which I have to rely on other sources to hazard estimates of handling time. Fortunately, there are two good OFT studies in Neotropical settings that list estimates for shotgun pursuits of common prey types (Hill and Hawkes 1983; Alvard 1993a), and I use the average handling times from these studies as a guide for estimating handling times in Bosawas. It should be noted, however, that the species in Nicaragua are not always identical to those in Peru or Bolivia. For example, while both species share the same generic name, Alvard's (1993a) study included the red howler monkey (*Alouatta seniculus*) while the mantled howler (*Alouatta palliata*) is the only species of howler monkey present in Bosawas. Similar variation is noted for capuchin and spider monkeys, and the estimate of Hill and Hawkes (1983:149) for armadillos

Table 3.12. Encounters and pursuits by rifle hunters on 49 hunting trips (including 6 observed hunting trips).

Species	Scientific name	Encounters	Pursuits	% pursued	Pursuits that led to kills	Kills	Harvest (kg)
White-lipped peccary	<i>Tayassu pecari</i>	2	2	100	2	9	239.7
Baird's tapir	<i>Tapirus bairdii</i>	1	1	100	1	1	160.0
Collared peccary	<i>Tayassu tajacu</i>	4	4	100	3	3	68.2
Red brocket deer	<i>Mazama americana</i>	3	3	100	3	3	47.8
Crested guan	<i>Penelope purpurescens</i>	22	21	95	18	21	40.1
Great tinamou	<i>Tinamus major</i>	47	40	85	28	29	29.1
Puma	<i>Puma concolor</i>	1	1	100	1	1	24.0
Great curassow	<i>Crax rubra</i>	6	6	100	4	6	15.7
Agouti	<i>Dasyprocta punctata</i>	9	6	67	6	6	15.1
Armadillo	<i>Dasyus novemcinctus</i>	2	2	100	2	2	8.0
Howler monkey	<i>Alouatta palliata</i>	9	1	11	1	1	6.6
Spider monkey	<i>Ateles geoffroyi</i>	1	1	100	1	1	6.4
Capuchin monkey	<i>Cebus capucinus</i>	6	2	33	2	2	6.0
Coati	<i>Nasua narica</i>	1	1	100	1	1	3.6
Parrots	<i>Amazona spp.</i>	5	4	80	4	4	2.2
Little tinamou	<i>Crypturellus soui</i>	10	9	90	5	5	1.7
Tiger-heron	<i>Tigrisuma mexicanum</i>	1	1	100	1	1	1.3
Plain chachalaca	<i>Ortalis vetula</i>	5	3	60	2	5	1.1
Woodpecker	<i>Dryocopus lineatus</i>	4	4	100	3	3	0.8
Toucan	<i>Ramphastos sulfuratus</i>	2	1	50	1	1	0.6
Picon	<i>Ramphastos swainsonii</i>	3	1	33	1	1	0.6
Doves	<i>Geotrygon spp.</i>	4	3	75	3	3	0.6
Variegated squirrel	<i>Sciurus variegatoides</i>	3	0	0	0	0	0.0
Iguana	<i>Iguana iguana</i>	1	1	100	0	0	0.0
Tawny-faced quail	<i>Rhynchortyx cinctus</i>	8	3	38	0	0	0.0
Ocelot	<i>Leopardus pardalis</i>	1	1	100	1	1	0.0
Tayra	<i>Eira barbara</i>	1	0	0	0	0	0.0
Oropendola	<i>Psarocolius wagleri</i>	5	1	20	0	0	0.0

seems to be based on pursuits of four distinct species. The decision to use these estimates overlooks possible variation in the anti-predator behavior of the separate species, which could in turn affect average pursuit times. However, Alvard's (1993a) description of the methods used to hunt red howler monkeys, for example, are similar to those cited by Nicaraguan informants as characteristic of mantled howlers. Given the similarities between these related species and the absence of more precise estimates, the data from these studies provide a worthwhile (albeit rough) estimate of the pursuit times for the species present in Bosawas.

Table 3.13 presents the results of the optimal diet breadth analysis, which indicates that virtually all pursued species raise the overall return rate and should be included in the optimal diet.⁴² The only exception to this generalization is the little tinamou, the lowest-ranked species in Table 3.13. While the data suggest that rifle hunters should ignore little tinamous, I hesitate to attach too much weight to these findings for a couple reasons. First, I directly observed six of the nine pursuits of little tinamous used in this sample, and four of those pursuits were unsuccessful, thereby lowering the estimate of its profitability. Because there is almost certainly a reporting bias toward successful pursuits, other higher-ranked species probably would appear less profitable if I had observed a similarly high percentage of pursuits of these species, which would in turn make little tinamous more profitable in comparison. Second, little tinamous would have been included in the optimal diet breadth if I had excluded from the sample one hunting trip in which the hunters killed a number of white-lipped peccaries. Because most rifle hunters on day trips do not venture into hunting zones where they might expect to encounter white-lipped peccary herds, they probably adjust their expectations accordingly and pursue less profitable prey types like little tinamous, which would raise their overall return rate in the absence of white-lipped peccary encounters.

⁴² I exclude pumas and tayras from the analysis because, while the one puma in the sample was consumed by the adolescent who shot it, these two carnivorous species are not considered edible by the majority of hunters in the study. Given that the prey choice decision rule hinges on the opportunity costs of foregoing possible encounters with more profitable prey, the fact that most hunters would not even recognize these animals as a possible prey type convinces me not to include them in the analysis.

Table 3.13. Calculation of the optimal diet breadth for rifle hunters

Rank	Species	Avg. handling time (hr) ⁴³	Avg. weight (kg)	E(Kcal)	Profitability (kcal/hr)	λ	Return (kcal/hr)	In optimal diet?
1	White-lipped peccary	0.51	119.85	233708	458250	0.01	1960	Yes
2	Agouti	0.04	2.52	4914	122850	0.04	2142	Yes
3	Baird's tapir	3	160.00	312000	104000	0.00	3405	Yes
4	Collared peccary	0.37	17.05	33248	89858	0.02	3931	Yes
5	Red brocket deer	0.39	15.93	13047	33453	0.01	4072	Yes
6	White-nosed coati	0.22	3.60	7020	31909	0.00	4097	Yes
7	Nine-banded armadillo	0.27	4.00	7800	28889	0.01	4152	Yes
8	Howler monkey	0.42	6.60	8580	20429	0.04	4399	Yes
9	Bare-throated tiger-heron	0.08	1.30	1612	20150	0.00	4404	Yes
10	Great tinamou	0.05	0.73	905	18104	0.20	4532	Yes
11	Keel-billed toucan	0.05	0.60	744	14880	0.01	4536	Yes
12	Chestnut-mandibled toucan	0.05	0.60	744	14880	0.01	4542	Yes
13	Spider monkey	0.59	6.40	8320	14102	0.00	4565	Yes
14	Parrots	0.05	0.55	682	13640	0.02	4573	Yes
15	Great curassow	0.26	2.62	3249	12495	0.03	4622	Yes
16	Crested guan	0.21	1.91	2368	11278	0.09	4741	Yes
17	Capuchin monkey	0.38	3.00	3900	10263	0.03	4789	Yes
18	Plain chachalaca	0.05	0.37	459	9176	0.02	4793	Yes
19	Lineated woodpecker	0.05	0.20	248	4960	0.02	4794	Yes
20	Doves	0.05	0.20	248	4960	0.02	4794	Yes
21	Little tinamou	0.05	0.19	236	4712	0.04	4499	No

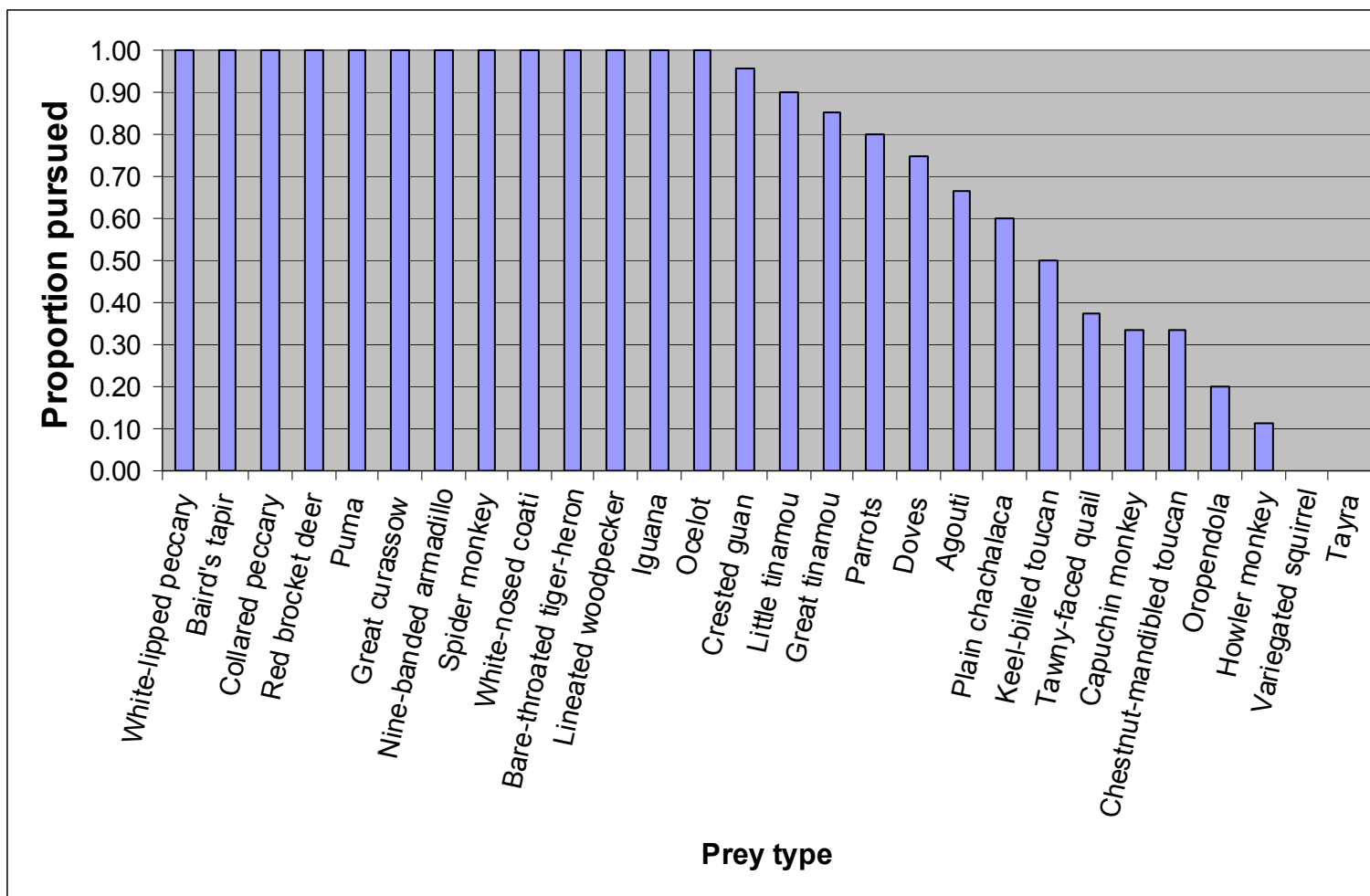
⁴³ Estimates of handling times for collared peccaries, howler monkeys, capuchin monkey, and spider monkeys come from Alvard (1993a:371). Estimates of coatis, white-lipped peccaries, and armadillos come from Hill and Hawkes (1983:167). I use Alvard's (1993a:371) estimate of 0.04 hours for agouti pursuits, which is almost equal to the one agouti pursuit that I observed by a rifle hunter (about two minutes). My estimates for red brocket deer are significantly higher than estimates for deer in both Alvard (1993a) and Hill and Hawkes (1983). In the case of Alvard (1993a), I suspect that pursuit times are low in large part because so few of the pursuits are successful (only about 8% of deer pursuits result in a kill). The majority of handling time for the observed red brocket deer kill involved post-kill preparations for transport, whereas the kill itself took less than two minutes. Because hunters in Bosawas reported no unsuccessful red brocket deer pursuits, I opted to use the data from this observed kill as an estimate of handling time. Following the discussion in section 3.4.2, I use an estimate of 3 hours for tapir pursuits, most of which seems to be devoted to post-kill processing at the kill site. Finally, both Hill and Hawkes (1983) and Alvard (1993a) give average figures for game birds as a whole, not by individual species. In my experience, hunters are willing to stalk the larger game birds (e.g. curassows and guans) for a longer amount of time than smaller birds. I therefore use data from my own observations to estimate handling times for bird species, relying on Alvard's average only for the tiger-heron, a larger bird whose anti-predator behavior is not well-documented.

While all regularly-pursued prey types are included in the optimal diet breadth, my results parallel those of Alvard (1993a) in that hunters sometimes elect not to pursue some of these prey types upon encounter. This inconsistency in pursuit decisions represents a violation of the basic prey choice model's zero-one rule, which predicts that prey types in the optimal diet will always be pursued upon encounter while those outside the optimal diet will always be ignored (Stephens and Krebs 1986:23). In the foraging literature, a tendency to pursue a prey type only intermittently is called a "partial preference" (Krebs and McCleery 1984). While partial preferences might be construed as an attempt to conserve a prey species that is vulnerable to local extinction, Alvard (1993a) demonstrated that observed partial preferences among the Piro typically have an explanation that accords well with predictions derived from optimal foraging theory. For example, Piro hunters seldom pursue an agouti if it has already spotted them and begun its flight into the forest⁴⁴ (Alvard 1993a:381). Also, following predictions described by Lucas (1983), Piro shotgun hunters are more likely to pursue game birds as they near the conclusion of the hunt, reflecting the declining probability of encountering a more profitable prey item in the time remaining. This consideration is especially important for shotgun hunters who might be reluctant to waste their only shells on small prey items early in the hunt (Alvard 1993a:380).

Figure 3.5 shows the proportion of encounters with each prey type that subsequently led to pursuits by rifle hunters in Arang Dak and Suma Pipi. As predicted by OFT, most of the highest-ranked prey types are always pursued upon encounter. While Mayangna and Miskito hunters exhibit partial preference for some prey types, most of these deviations from the zero-one rule can be explained from an OFT perspective. For example, the three agoutis that were not pursued had already begun their escape when first noticed by the hunters, much like the encounter variability in Peru described by Alvard. The context of encounters with game birds also affected pursuit decisions, as the only guan that was not pursued had already begun fleeing when the hunter noticed it. Similarly, three of the un-pursued tinamous had begun their flight before being detected. The remaining four bypassed tinamous were ignored by hunters who were actively tracking or pursuing peccaries (see Hill et al. 1987 for a discussion of opportunity costs and OFT predictions when hunters are tracking).

⁴⁴ Alvard does not describe the different contexts of agouti encounters in term of prey types, but it is reasonably clear that agoutis caught unawares should be considered a different prey type than those that have already begun scurrying off into the forest.

Figure 3.5. Proportion of pursuits upon encounter. As an example, all great curassows were pursued upon encounter while only 50% of the toucans were pursued. Table 3.12 lists the number of encounters on which this chart is based.



Reasons given for the decision not to pursue smaller game birds varied, with the smallness of the prey item being a particularly common explanation. It is not surprising that rifle hunters should be particularly attentive to the size of prey items. While small prey types might raise the overall return rate, the cost of the bullets needed to kill that prey item increases the cost of its pursuit above just the time lost in the pursuit in the pursuit. As a comparison, bullets cost about 2.5 or 3 cordobas apiece during the study period, while a pound of hunted game meat sold for either 5 or 6 cordobas. Given the choice, hunters would be better off saving their bullets if the expected payoff of pursuing a prey item is less than what they could purchase with the cost of the bullet. While hunters sometimes pursue prey types that average about half a pound in size (e.g. the lineated woodpecker), my impression is that these pursuits have as much to do with target practice as they do the acquisition of meat for consumption.

3.6.2 *Partial preferences for capuchin and howler monkeys*

While most partial preferences in Bosawas are explainable from an OFT perspective, the irregularity with which hunters pursue howler monkeys and capuchin monkeys is more difficult to explain. Only two out of the six encounters with capuchin monkeys led to pursuits while hunters pursued only one of the nine howler monkeys that they encountered. In almost all cases, the reason given for the decision not to pursue these species was that they are considered inedible (“*no es comestible*”). While the meat from the almost exclusively frugivorous spider monkey is considered particularly tasty by Bosawas residents, the meat of capuchin and howler monkeys is much less coveted. These two species are not taboo in any strict definition of the word, however, and the fact that they are sometimes pursued and consumed indicates that the Miskito and Mayangna recognize these primate species as a potentially exploitable resource. An interesting question, then, is why Miskito and Mayangna hunters often ignore these two prey types, which are both included in the optimal diet breadth and regularly pursued by indigenous groups elsewhere in the Neotropics.

I first want to evaluate the possibility that technological differences between the hunters in Bosawas and the groups from which I derived OFT parameters might explain why howler monkeys and capuchin monkeys are frequently ignored by the Miskito and Mayangna. Particularly noteworthy is the observation that the Aché and Piro used shotguns, not rifles (Hill

and Hawkes 1983:153; Alvard 1993a:360). The respective merits of rifles and shotguns, both breech-loaders and muzzle-loaders, have received some attention in the Neotropical hunting literature. Lu (1999:66) lists the advantages and disadvantages of rifles and shotguns as they are used by the Huaorani in Ecuador. While muzzle-loading shotguns differ from breech-loading guns in their stopping power for large animals, the spraying pattern of both types means that shotgun hunters need not be particularly adept marksmen to wound a prey item fatally. Rifles, by comparison, require better aim on the part of the hunter. The difference between shotguns and rifles is apparent in the technological preferences of Yuquí hunters. Although rifle ammunition is considerably cheaper than shotgun shells, Yuquí hunters prefer the shotgun because it is a “better all-around weapon” and “more effective in killing smaller terrestrial game and the arboreal animals” (Stearman 1990:381).

When evaluating the importance of accuracy in pursuits with guns, the size of the animal is undoubtedly a factor but perhaps less important than its anti-predator behavior. The predicted inclusion of capuchin and howler monkeys in the optimal diet breadth is predicated on the assumption that their behavior does not make them especially difficult for rifle hunters to kill in comparison to shotgun hunters elsewhere. Both Hill and Hawkes (1983) and Alvard (1993b) have commented on the evasive tactics of capuchin and howler monkeys under predation. Hill and Hawkes note that pursuits of capuchins last “quite some time” because they hide well in tall trees:

They move rapidly and erratically and lay low to the branches, making a difficult target. They are never shot on the move. The hunter waits until they sit still in a spot which is not blocked by branches. Considerable maneuvering is required in order to get one good shot. (1983:151)

Alvard notes that howler monkeys likewise hide in tall trees but that males in particular “would often peer over the edge to observe the hunters below, allowing the hunters to shoot them in the head” (1993b:101). In both cases, then, howler and capuchin monkeys exhibit anti-predator behavior that could conceivably make those prey types more difficult for rifle hunters to hit than some of the avian prey items that they regularly pursue. It should be noted, however, that both studies emphasize the patience needed to wait for a favorable shooting angle, not the difficulty in actually shooting the animal once hunters get a good look at it.

While rifles presumably require better aim than shotguns, there is little evidence to suggest that the need for better accuracy is the primary factor that discourages rifle hunters in

Bosawas from pursuing howler and capuchin monkeys. At no point did Mayangna and Miskito hunters give any indication that these primate species are more difficult to hit than other prey types. When asked if capuchin and howler monkeys are difficult targets, informants responded that they are no different than spider monkeys, which are almost invariably pursued upon encounter by rifle hunters in Bosawas.⁴⁵ The number of shots needed to kill capuchin and howler monkeys supports the hunters' assertion. Of the three capuchin monkeys killed during the study period, all were killed with the hunter's first shot. Hunters were not quite as successful with howler monkeys, as three of the five in the sample were killed with a single bullet while the remaining two howler monkeys required a second attempt.⁴⁶ These success rates are actually better than observed success rates of shots at smaller avian prey items. In terms of meat per bullet, monkeys are a better option than the game birds that hunters regularly pursue. While it is possible that hunters opted to pursue only when capuchin and howler monkey encounters lent themselves to successful shots, there is little evidence to suggest that, compared to their shotgun-bearing counterparts elsewhere, rifle hunters in Bosawas would be less likely to pursue these primate species because of hypothesized differences in the required accuracy of the two weapons.

Should capuchin and howler monkeys therefore be included in the optimal diet breadth? In the case of capuchins, the evidence is somewhat equivocal. As seen in Table 3.13, they are one of the lowest-ranked prey types, only a little ahead of the lowest-ranked prey types in the calculations. Optimal foraging studies elsewhere in the Neotropics cast further doubt on the relative profitability of capuchin monkeys. While Alvard (1993a) found that capuchin monkeys are included in the optimal diet breadth, they were the lowest-ranked species in his sample and Piro hunters exhibited a partial preference for this prey type. By contrast, Hill and Hawkes (1983) report that capuchin monkeys increase the return rate of bow hunters but not shotgun

⁴⁵ To my knowledge, the only encounter with a group of spider monkeys that did not elicit a pursuit by a rifle-bearing hunter was not on a hunting trip but rather a voyage upstream to bring volunteers from the TNC *guardabosque* program to a work site in the conservation zone. The hunter later said that he did not attempt to capitalize on this opportunistic encounter because he was in enough of a hurry that he could not take the time needed to get a good shooting angle on the spider monkeys. On the same trip, however, he killed five game birds, reportedly because these pursuits required only minimal time. Interestingly, this same hunter also encountered a group of capuchins and a group of howler monkeys, neither of which led to a pursuit. For the capuchins, a species that he had killed and consumed less than a month earlier, the hunter again cited the absence of time to maneuver for a shot. For the howler monkeys, on the other hand, he explained that he and his family do not eat meat from this species.

⁴⁶ One of those killed with a single bullet remained on its perch even after it had died and the hunter had to shoot three additional bullets to knock it to the ground.

hunters. There may be an element of seasonality in pursuit decisions about capuchins, as Alvard (1993b:103) notes that they are pursued less frequently in the dry season, when seasonal weight loss makes them lighter than during the rainy season. In sum, in the absence of additional empirical data, it is not possible to conclude that capuchin monkeys definitely belong in the optimal diet breadth for rifle hunters in Bosawas. Much could depend on the context of the encounter, as hunters might benefit from pursuing easily-targeted capuchins but ignoring those capuchins that appear especially difficult to kill.

The case for the inclusion of howler monkeys in the optimal diet breadth is much less ambiguous. Because of their larger size, they outrank all game birds in the sample, just as they did in Alvard's (1993a) study with the Piro. However, whereas the Piro almost always pursued howler monkeys upon encounter, Mayangna and Miskito rifle hunters pursued only one of the nine howlers that they encountered. I witnessed two of these encounters, and in both cases the hunters in question gave the monkeys only a passing glance, making no discernible effort to assess the difficulty of a pursuit. In subsequent interviews, both hunters reiterated that, while some people kill and consume howler monkeys, they and their families do not. Hunters on unobserved hunting trips cited the same reason for their decision not to pursue howler monkeys that they encountered, and at no point did informants claim that howlers are hard to kill or not worth the effort because of seasonal fluctuations in weight. In the absence of contravening evidence, I therefore conclude that howler monkeys should be included in the optimal diet breadth and that hunters who do not pursue them are using a criterion other than their OFT profitability as a basis for their decision.

3.7.1 Explaining suboptimal decisions by Mayangna and Miskito hunters

Both hunters with dogs and rifle hunters fail to consume prey types that would raise their overall return rate of hunted game: giant anteaters and northern tamanduas for hunters with dogs and howler monkeys and possibly capuchin monkeys for hunters with rifles. It is noteworthy that these unconsumed species are relatively vulnerable to local depletion and extinction, as they generally reproduce less prodigiously than more commonly consumed prey species such as the peccaries and caviomorph rodents (Robinson and Redford 1986a). All of the aforementioned species are listed as threatened or endangered species by the Convention on International Trade

in Endangered Species of Wild Fauna and Flora (CITES). Accordingly, these seemingly suboptimal foraging decisions merit examination as possible examples of conservationist behavior by the Mayangna and Miskito. I will review the evidence for conservation, and I will also examine alternative hypotheses, focusing in particular on the importance of taste and social esteem to hunting decisions.

3.7.2 Revisiting the “Ecologically Noble Savage” hypothesis

In an effort to protect Latin America’s remaining tropical rain forests, some conservationists advocated the “biosphere” approach, which posits that a protected natural area surrounded by zones of sustainable human use is perhaps the best option for long-term forest conservation (Oldfield 1987). Rather than expelling forest inhabitants from their traditional homelands, the biosphere approach encourages them to continue their traditionally low-impact subsistence practices in the buffer zones around the core area. With their longstanding reputation for conservation, indigenous societies were viewed as the ideal stewards of protected areas in the Neotropics, especially given the concurrent efforts by indigenous societies (often with the assistance of international NGO’s) to secure legal land title to their traditional lands (Redford and Mansour 1996). The stereotype that indigenous peoples maintain a harmonious balance with their natural surroundings was dubbed “the ecologically noble savage” in a poignant essay by Redford (1991).

Alvard (1993a) used optimal foraging theory to test the hypothesis that indigenous people are natural conservationists and, more specifically, that they sacrifice short-term gains for the long-term preservation of the resource base. Optimal foraging theory is a valuable null hypothesis for such a test, as OFT models predict that hunters will favor short-term optimization of hunting returns, not conservation (Winterhalder and Smith 2000:56). Alvard (1993a) convincingly demonstrated that Piro prey choice decisions conform to predictions of the optimal diet breadth model despite the fact that several of the regularly-pursued prey types are especially vulnerable to localized depletion and extinction. Alvard calls special attention to the willingness of Piro hunters to target howler and spider monkeys: “The observation that no restraint was shown killing the large primate species is the strongest evidence contrary to the conservation hypothesis” (1993a:376).

Following Alvard's reasoning, does the Mayangna and Miskito ambivalence toward howler monkeys therefore reflect a conservationist ethic? While the reluctance to pursue howler monkeys is admittedly perplexing from an OFT perspective, I hesitate to conclude that conservationist motives provide the best explanation for this tendency. Perhaps the most important question to answer is why Mayangna and Miskito hunters who bypass howler monkeys do not show similar restraint upon encountering spider monkeys, which actually breed more slowly than howlers (Robinson and Redford 1986*a*). While it is possible to speculate that howler monkeys therefore represent a better fallback resource, one that could be conserved in anticipation of future shortages, at no point during the study period did native informants cite either conservation or risk as important factors in their prey choice decisions. While I did not systematically investigate food preferences, numerous informal discussions with Mayangna and Miskito informants suggest that the predilection to pursue spider monkeys but ignore howler monkeys stems from one important factor: taste. Along with pacas and tapirs, spider monkeys are widely considered one of the best-tasting prey types, and similar preferences for the frugivorous species are common throughout the Neotropics (Robinson and Redford 1994*b*:304). Howler monkeys, by contrast, generally rank below the rodents, nine-banded armadillos, and all the game birds and ungulates.⁴⁷ If howler monkeys tasted better, it appears that Mayangna and Miskito would pursue them as earnestly as they pursue other species.⁴⁸

The poor taste of anteaters also probably explains the refusal of hunters to consume these species. In the case of giant anteaters and northern tamanduas, the conservationist hypothesis is even less convincing, primarily because hunters with dogs kill these prey types upon encounter to protect the dogs and hasten the resumption of a general search for prey. The image of hunters unceremoniously abandoning anteaters in the forest after a kill contrasts sharply with popular stereotypes of Native Americans using virtually the entire carcass for a broad variety of needs

⁴⁷ The preference for spider monkeys over howler monkeys has parallels elsewhere in the literature (Lizzaralde 2002:91; Shepard 2002:106). For example, Johnson (2003:57) reports that the Matsigenka (a.k.a. the Machiguenga) highly value spider monkeys but dislike howler monkeys: "But the Matsigenka of Shimaá complain that (howler monkey) meat has an unpalatable smell and can cause indigestion. The male also has a reputation of being a shaman. Many people, but by no means all, refuse to eat its flesh." Howler monkeys are often the subject of food taboos, perhaps more so than any other primate genus in the Neotropics (Cormier 2006).

⁴⁸ One possible explanation for the aversion to howler monkeys came to light in a workshop between the Saint Louis Zoo and the Kipla territorial association. An older informant reported that a yellow fever epidemic spread among the reserve's primate populations. Although one might hypothesize that a general aversion to howler monkeys developed at that time, the informant reported that this epidemic also affected the spider monkey population. It therefore remains unclear why the aversion would apply only to howler monkeys and not the similarly-sized spider monkeys.

(cf. Krech 1999). While few informants have actually sampled anteater meat, the consensus opinion is that the meat does not taste good (“*La carne . . . no es muy buena.*”). Unlike some groups in Central America, the Mayangna and Miskito do not even feed anteater meat to the dogs (cf. Reid 1997:55).

The example of anteaters thus broaches the question of food taboos. Unlike howler and capuchin monkeys, giant anteaters and northern tamanduas are apparently never eaten by the Mayangna and Miskito. Other mammalian species that are not eaten in Bosawas include jaguars, ocelots, sloths, kinkajous, greater grisons, and opossums. While I did not observe any pursuits of these rarely-encountered species, some of these species are rather large and would probably be included in the optimal diet breadth if they were to be pursued. Many of these species are also relatively susceptible to overhunting, and some might contend that such aversions represent conservationist behavior (Ross 1978). On this point, I generally agree with Nietschmann (1978), who pointed out that it makes little sense to conserve a resource that is never used. However, an important caveat is that hunters might indirectly benefit from avoiding certain species. In recent decades, it has become clear that animals are vital to Neotropical forest regeneration, especially by contributing to seed dispersal (Bodmer 1991; Brewer and Rejmanek 1999). It is theoretically plausible that Mayangna and Miskito hunters refrain from pursuing certain species in order to promote the long-term integrity of the forest, thus exchanging a short-term sacrifice for a long-term benefit. However, while indigenous peoples are renowned for their ethno-ecological knowledge (Berlin and Berlin 1983; Hames 1987; Hill and Tykvarangi 1996), the Miskito and Mayangna did not cite ecological interactions as a factor in their prey choice decisions. More research is needed on Mayangna and Miskito ethno-ecological knowledge, but the current evidence suggests that their hunting decisions do not reflect a desire to conserve Neotropical flora and fauna. For those prey choice decisions that violate predictions of OFT, taste seems to be the overriding factor, not conservation.

Although Miskito and Mayangna prey choice decisions generally do not reflect conservationist intentions, I want to emphasize that these results do not imply that they are incapable of conservation. There are a number of ways in which hunters can exhibit conservationist behavior that also adheres to OFT predictions, most notably by spending less time hunting or by avoiding habitats that are particularly important to the reproduction and survival of wildlife populations (Hames 1987). Meanwhile, the willingness of Kipla’s territorial

association to host the Saint Louis Zoo's project and accept wildlife management recommendations is a testament to their willingness to adopt conservationist practices. It should also be emphasized that habitat loss has a much more detrimental effect on Neotropical wildlife than subsistence hunting (Redford 1992). Remote sensing imagery of the Bosawas region indicates that the indigenous territories are significantly less deforested than neighboring mestizo areas, even after adjusting for differences in population (Stocks et al. unpublished manuscript). Although their prey choice decisions do not appear to be affected by conservationist motives, it is possible that the entire suite of Mayangna and Miskito subsistence adaptations is much less detrimental to Neotropical wildlife than many of the alternatives used by groups elsewhere in the region.

3.7.3 The adequacy of the diet and the importance of taste to prey choice decisions

The question of taste has not received much attention in the anthropological literature on optimal foraging theory. One of the exceptions is Hill et al. (1987), who note that the Ache ranking of favorite foods does not correspond to the profitability of those foods in the OFT analysis. However, the authors convincingly argue that ethnographers should not expect congruence between food preferences and resource profitability: "Taste preferences (i.e. which resources an informant would most like to eat) are a function of the food value of the resource and ignore costs of acquisition and processing. Thus, while most Americans, for example, may prefer the taste of lobster to that of rice, it is not necessarily the resource that they would most often choose to buy given the cost" (Hill et al. 1987:19). By this logic, a supremely delectable prey item might be ignored because of high acquisition costs. In Bosawas, however, species like howler monkeys and anteaters are ignored despite the fact that the cost of their acquisition is actually lower than preferred prey types. The first important question when examining the costs and benefits of such decisions is whether, from a nutritional perspective, the Mayangna and Miskito can afford to make choices based on taste.

The diets of Neotropical peoples exhibit considerable variability, mediated in large part by the quality of the environments in which they live. While staple crops such as bananas and manioc can be cultivated even in nutrient-poor soils and suboptimal climatic conditions, these environmental factors can make the acquisition of sufficient dietary protein and fat somewhat

problematic (Beckerman 1993). In areas where the available biomass of fish and game is insufficient for basic dietary needs, some groups have relied on resources such as insects, snails, and worms to complement whatever fish and game they manage to acquire (Beckerman 1979; Dufour 1987).

The observation that the Mayangna and Miskito do not rely on such resources is the first clue that their diets already provide sufficient dietary protein. While there is some evidence that Mayangna groups have eaten frogs in the past (Conzemius 1932; cf. Malkin 1956), native informants regarded me with incredulity when I suggested that resources like frogs, worms, and insects can be nutritious. The ease with which I was able to capture frogs outside my hut suggests that, from an OFT perspective, the Mayangna and Miskito are ignoring a potentially useful source of protein. To some extent, the ambivalence shown toward species like howler monkeys, sloths, and anteaters represents merely a more conspicuous example of the tendency to ignore potentially profitable resources – a tendency made even more conspicuous by the fact that so many other Neotropical groups consume these species with no apparent qualms.

Quantitative data also suggest that the residents of Arang Dak and Suma Pipi are consuming adequate levels of dietary protein. “Adequate” is obviously a relative term, but Robinson and Bennett (2000:24) cite USDA statistics that recommend 50 grams of protein per day for a 70-kilogram individual.⁴⁹ Given that meat contains about 20% protein, 0.28 kilograms of meat per day would be sufficient to meet this requirement, and data in Table 3.14 suggest that Neotropical peoples come close to matching this estimate.

Table 3.14. Per capita consumption of wild meat of selected Neotropical societies (adapted from Robinson and Bennett 2000:24)

Society	Location	Per capita consumption of meat (kg/consumer/day)	Source
Yanomamö	Venezuela-Brazil	0.25 (+ 0.13 fish)	Chagnon and Hames 1979
Machiguenga	Peru	0.23	Alvard 1993 <i>b</i>
Piro	Peru	0.23	Alvard 1993 <i>b</i>
Waorani ⁵⁰	Ecuador	0.28	Yost and Kelley 1983

⁴⁹ By contrast, an FAO/WHO document (1973) recommends a range of 37 to 62 grams depending on the quality of the protein.

⁵⁰ It appears that Robinson and Bennett may have miscalculated the Waorani estimates. Yost and Kelley (1983:214) base their estimate of 0.28 kg/day on the assumption that 70% of the harvested biomass is edible meat whereas Robinson and Bennett (2000:24) cite 65% as the estimate for their comparison. If that latter figure is applied to the Waorani data, their per capita consumption drops slightly to 0.267. Estimates of 70% edible meat are common in the literature, however (Townsend 2000:276).

The residents of Arang Dak do not match these other Neotropical groups in their consumption of hunted game, but they have the added advantage of relying on meat from domestic animals to augment harvested fish and game. In total, the residents of Arang Dak average about 0.16 kg of meat per consumer per day (Table 3.15). While this intake of meat might provide sufficient dietary protein in itself, residents also consume three grains: beans, rice, and corn. In addition to the 32 grams of daily dietary protein that they acquire from the aforementioned meat, I estimate that residents also obtain an additional 9 grams/day from the consumption of these grains.⁵¹ Together, these sources provide 41 grams of daily protein per consumer. Assuming they need 50 grams per day, the remaining need could be satisfied by eggs, milk, and protein in other cultivated foods (e.g. palm fruits), as well as a wide variety of products from the local store, including powdered milk, oatmeal, and corn flour. I suspect, however, that most consumers do not actually need 50 grams per day, as much of the protein comes from high-quality sources (i.e. meat) and few individuals weigh 70 kilograms or more. Indirect evidence of the adequacy of available dietary protein comes from the observation that communities like Raiti on the Coco River (about 9 km from Arang Dak) consume much less hunted game than Arang Dak (Williams-Guillen et al. 2004). Despite eating less than 15% of the meat consumed by residents of Arang Dak, indigenous communities on the Coco appear to compensate by increasing their consumption of grains. Although they are somewhat isolated from the market traffic on the Coco River, residents of Arang Dak would normally have little trouble finding alternative sources of dietary protein if they were to curtail their reliance on hunted game.⁵² Although purchasing rice and corn flour from neighboring communities incurs its own costs, that alternative is available for hunters who are reluctant to consume howler monkeys, for example. While hunted game is far from a luxury, the supply of alternative protein sources is usually

⁵¹ The estimate is based on data from household food forms and admittedly imprecise. I recorded daily consumption of grains at the household level for 6 months (3/1/05-8/31/05). Estimates of amounts were given by the cooks, usually women. Probably because much of the rice and beans are purchased from the local store (where amounts are weighed), cooks generally give fairly accurate estimates of how food was prepared. I converted these reported amounts to kilograms (the pound is the standard measure in the reserve), which yielded daily averages of 0.4 kg of rice, 0.41 kg of beans, and 0.07 kg of corn per household. The average household included 6.32 consumers, defined as individuals at least 3 ½ years old. I used USDA laboratory data to estimate the protein content of the respective grains, with rice provided 0.03 kg of protein/kg rice while both beans and corn provide 0.09 kg of protein per kilogram.

⁵² I say “normally” because the cultivation of grains, especially rice, is rife with uncertainty. In 2005, an outbreak of rats destroyed most of the rice fields in the region, especially downstream in the Waspam area, which made it difficult to acquire rice even from external markets. At the time of my departure from the field, international organizations including the United Nations were investigating the situation to determine how much external assistance would be needed (BBC news reports, September 8, 2005; September 12, 2005).

Table 3.15. Per capita consumption of meat from domestic animals and wild fish and game for residents of Arang Dak.⁵³

Source	Kilograms harvested	Edible portion	kg/consumer/day ⁵⁴
Hunted game	7553.41	4909.72	0.09
Fish	2347.69	1878.15	0.03
Beef	-	950.00	0.02
Pork	1923.00	1249.95	0.02
Poultry	393.50	255.78	0.004
Total			0.16

⁵³ The data are based on the following assumptions. For hunted game, I assume that 65% of the harvested biomass is edible meat (following Hill and Hawkes 1983). For fish, I assume that 80% of the harvested biomass is edible (following estimates from Chagnon and Hames 1979). Because it was not possible to weigh all harvested fish by residents of Arang Dak (particularly when residents consumed fish upstream before returning to the community), I had to estimate how much the harvest of fish exceeds the measured harvest of 1878.15 kg. Cross-checking of a random sample of harvests indicates that the unweighed harvest of fish is about 20% of the total harvest (i.e. my assistants recorded 80% of the fish biomass captured by residents of Arang Dak). I therefore multiplied the recorded figures to get an estimate of how much fish residents actually caught. Although some fish and game are sold to residents of neighboring communities, residents of Arang Dak also purchase meat from these communities, particularly when they pass by the community after trips upstream on the Lakus River. Unlike Alvard (1993b), I therefore make no allowances for the possibility that the sale of game reduces what is available for consumption in Arang Dak.

Two bulls were killed during the study period, and because the butchers borrowed my scales when distributing the meat, I was able to record the amount of edible meat from each. Hence there was no need to make any additional calculations to identify the amount of edible meat obtained from the animals.

Estimates of pork and poultry come from the household food forms (see Chapter 4 for a description of the methodology). In all, 55 pigs were killed by residents of Arang Dak during the study period (1 calendar year), of which 31 were adults. While pigs were not routinely weighed, adult pigs generally weighed about 45 kg while juveniles averaged about 22 kg when they were killed, yielding an estimate of 1,923 kg of pig biomass. I again assume that 65% of that biomass is edible.

I used a similar method to estimate the amount of poultry consumed in Arang Dak. The food forms indicate that 193 chickens, 19 turkeys, and 23 ducks were consumed during the study period. Adult chickens and ducks weigh 2 kg while adult turkeys weigh 3 kg. The juveniles that are consumed average about half that figure (1 kg for chickens and ducks, 1.5 kg for turkeys). Juveniles constitute 40% of the domestic fowl that are killed for consumption. I again assume that 65% of the biomass is edible meat.

I reiterate that only figures from Arang Dak were used for this estimate, as I wanted to examine the full duration of the study period (9/1/04-8/31/05) in order to account for seasonal differences. As a point of comparison, however, the per consumer harvest of hunted meat in Suma Pipi was 0.03 kg/consumer/day, which is based on a sample of 59 consumers over 260 days.

⁵⁴ Following Alvard (1995b), I define consumers as individuals older than 3.5 years of age.

sufficient to permit at least some selectivity on the part of the hunters.

Given that food preferences are a cultural universal (Brown 1991), it should perhaps be unsurprising that the strength of those preferences occasionally supersedes the OFT ranking of a resource, particularly when alternative resources provide adequate nutrition. As noted, the question of taste has not received much attention from optimal foraging researchers, presumably because it is not clear how to use differences in taste to recalibrate the profitability of prey types. Food preferences exhibit considerable variability not only between cultures but also between individuals in the same society or community. Differences in the consumption of giant anteaters are a poignant reminder that food preferences defy easy cross-cultural generalization. While they are not consumed in Bosawas, giant anteaters are eaten by the Sirionó of Bolivia despite the observation that the nutritional adequacy of their diet would not suffer by ignoring this species (Townsend 2000:276). It is therefore difficult to conclude that the Mayangna and Miskito ignore giant anteaters only because they already consume adequate dietary protein. Similarly difficult is the fact that taste preferences differ between individuals. Some residents of Arang Dak and Suma Pipi are willing to eat coatis, pumas, and howler monkeys while others do not consume these species. Such preferences can have an obvious impact on prey choice decisions, and the ideal would be to alter optimal foraging models in ways that account for these differences.

3.7.4 The role of uncalculated social costs in suboptimal foraging decisions

Human behavioral ecologists have increasingly turned to considerations of prestige and social esteem as possible factors driving suboptimal foraging decisions. Much of the recent literature draws on costly signaling theory, which is an outgrowth of Zahavi's handicap principal (Zahavi 1975). Costly signaling theory posits that the costs incurred by a suboptimal forager can be recouped if the cost is outweighed by the benefits of broadcasting information about the quality of the signaler (Bleige Bird et al. 2001). Turtle hunting among the Meriam of Australia's Torres Strait provides a useful example (Smith and Bleige Bird 2000). Turtle hunting requires considerable exertion and agility, and it is financially costly for hunters, as they must provide their own gasoline for the boats. The benefits do not directly offset the costs, as the turtle meat is distributed at a communal feast with no immediate expectation of reciprocity for the hunters. Accordingly, Smith and Bleige Bird (2000) conclude that successful turtle hunters reap social

benefits from the signal that the feast broadcasts to observers. However, it should be noted that defining a currency to measure these social benefits for modeling purposes remains somewhat elusive in costly signaling research.⁵⁵ While it is reasonably clear that prestige and social esteem could entail both increased survivorship and reproductive opportunities, obtaining the data to measure the full extent of these fitness benefits in a quantitative model can be difficult for relatively short-term ethnographic projects (Sosis 2000).

The reluctance of Miskito and Mayangna to pursue and consume apparently profitable prey items does not meet the criteria of costly signaling theory,⁵⁶ but I borrow the theory's emphasis on social esteem as a means to explain suboptimal foraging decisions. In this case, however, the decision-making process is reversed. Unlike turtle hunting, in which hunters pursue an unprofitable resource in order to gain social benefits, I suggest that Miskito and Mayangna hunters avoid profitable prey types partly to avoid paying social costs. In terms of reputations, it might be preferable to return home empty-handed than to be known as a hunter who must pursue widely-disliked game to provide for his family. Anthropologists have long recognized the relationship between food preferences and social class (Messer 1984), and there is little doubt that the consumption of undesirable foods can tarnish reputations and social esteem. Anecdotal evidence in support of this hypothesis was apparent on those few occasions when hunters brought home howler monkeys. When I arrived with my assistants to complete the questionnaire, families somewhat sheepishly presented the bodies for examination, as though they were embarrassed that the anthropologist had caught them with howler monkey meat. Whether the social costs of consuming howler monkeys and other unappealing prey types actually outweigh the opportunity costs of not pursuing them is an open question. Unfortunately, I lack both a modeling framework and sufficient data to present quantitative evidence for this hypothesis, but the question of wild game aversions in Bosawas remains a promising topic for future research, particularly given the evidence that many of the species that are not consumed would be included in the optimal diet breadth.

⁵⁵ For the sake of comparison, the currency in OFT models is traditionally defined as energy, with the assumption that foragers attempt to maximize the rate at which they acquire energy while foraging.

⁵⁶ To be considered "costly," signal traits must be "(1) differentially costly or beneficial in ways that are (2) honestly linked to signaler quality, and (3) designed to effectively broadcast the signal" (Bleige Bird et al. 2001:9).

3.7.5 *Concluding thoughts on suboptimal foraging decisions in Bosawas*

The observation that hunters regularly bypass profitable prey types does not negate the heuristic value of the diet breadth model, but it does demonstrate the need for researchers to be sensitive to factors other than OFT rankings as important factors in prey choice decisions. The results of this study provide mixed support for the explanatory power of the diet breadth model. On the one hand, all regularly pursued prey types increase the average rate of return, as predicted by the model. On the other hand, hunters exhibit partial preferences for some profitable prey types such as howler monkeys that would increase their overall return rate. Furthermore, some prey types such as giant anteaters are left in the woods even after hunters have killed them to protect their dogs. Such decisions can be difficult to explain from an optimal foraging perspective, which assumes that hunters attempt to maximize the rate at which they acquire meat. The lesson from Bosawas is that different meats can vary in their value depending not only on inherent qualities (i.e. taste) but also their cultural significance. Foods have a symbolic meaning independent of their nutritional characteristics, and it would be naïve to assume that the symbolic importance of a prey species has no bearing on a hunter's willingness to pursue it. To date, anthropological OFT research has not satisfactorily addressed the ways in which taste and social costs or benefits can affect human foraging decisions. With its focus on the social benefits of conspicuously unprofitable resources, costly signaling theory begins to integrate the social value of a resource and its profitability from an OFT perspective. The research presented here furthers the discussion by demonstrating that the social costs of a resource may be a motivating factor in seemingly illogical foraging decisions, particularly when those costs are reinforced by powerful sensory inputs such as taste. In addition to further consideration of human nutritional needs and the sensory qualities of individual resources, resolution of this question probably requires additional attention to the psychosocial processes by which people develop food preferences and aversions (cf. Fessler and Navarrete 2003).

3.8.1 *A comparison of hunting with dogs and rifles*

Some of the first quantitative data on Neotropical hunting were applied to questions of technological efficiency, particularly in the comparison of firearms to traditional technologies. Hames (1979a) and Hill and Hawkes (1983) demonstrated that shotguns are more efficient than bows while Yost and Kelley (1983) show that shotguns are more efficient than blowguns, albeit less efficient than spears⁵⁷ (with efficiency measured in kilograms of un-butchered meat per hour of hunting time). Subsequent work further supports the conclusion that shotguns are more efficient than bows (Alvard 1995b), which helps to explain why firearms quickly became the weapon of choice for Neotropical peoples.

While comparisons of traditional technologies and shotguns repeatedly demonstrate the superiority of the latter, there are few estimates in the literature of return rates when hunting with dogs. While some groups continue to use traditional technologies largely because firearms are restricted in protected areas (Alvard and Kaplan 1991) or because they are unavailable or prohibitively expensive (Yost and Kelley 1983:209), the possibility remains that comparable return rates with traditional technologies disincline Neotropical hunters from investing in guns. The following analysis compares hunting with dogs and guns, the two principal technologies used by hunters in the Bosawas Reserve.

3.8.2 *Comparative methods*

To obtain an adequate sample, the following data include both observed and unobserved hunts during the study period.⁵⁸ The methodology for acquiring data on unobserved hunts is outlined in depth in Chapter 4, but I note here that assistants completed questionnaires following unobserved hunts. Questionnaires included a number of questions on hunting trips, including data on participants, technologies, means of transportation, hours of departure and return, routes followed on the hunt, time devoted to activities other than hunting, items other than hunted game

⁵⁷ Yost and Kelley (1983:216) explain that the figures for spears are deceptive, as spears are brought primarily on group hunts for white-lipped peccaries after tracks have previously been spotted. Furthermore, the classification of hunting excursions as spear hunts, blowgun hunts, or shotgun hunts is not mutually exclusive. If hunters brought both a spear and a shotgun, for example, that hunting trip would be counted twice, with the harvest data and time expenditure counted for both categories.

⁵⁸ As noted elsewhere, the study period lasted from 9/1/04-8/31/05 in Arang Dak and 12/15/01-8/31/05 in Suma Pipi.

brought back to the community, encounters with potential prey items, and kills. For this analysis, I focused only on day trips, as it proved too difficult for hunters to estimate the time devoted to various activities when on multi-day expeditions upstream. Also excluded from this analysis were several nocturnal trips by one hunter to ambush pacas as they foraged at fruiting trees near the community.

I defined three categories of hunts based on the technologies: hunts with dogs, hunts with rifles, and hunts with a combination of the two. I retained the “dog and gun” category for all hunts in which both technologies were present even though the rifles were not fired at all on 61% of these hunts. Other hunting technologies were sometimes present, including axes, lances, slingshots, and machetes (all hunting parties had at least one machete, and only younger hunting companions tended to go without one on occasion).

Estimates of hunting productivity are based on hours spent hunting, not the total time spent away from the community, as it seemed inaccurate to categorize as hunting time activities such as fishing, cutting and weeding bananas, eating breakfast at an upstream *champa*, and clearing fields. In my experience, most studies use the hour of departure and return to the community as the measure of hunting time. I am not sure if the Mayangna and Miskito are unique in their tendency to combine hunting with other activities while on excursions from the community, but my experience with the hunters in Bosawas suggests that the time devoted to secondary tasks is not insubstantial and merits exclusion from the analysis. For the sake of cross-cultural comparison, however, I will later append figures for harvest yields per time spent away from the community.

To calculate an average hunting yield, it is obviously important to include unsuccessful hunting trips. A perceived reporting bias against unsuccessful hunts will come as no surprise to most scholars of subsistence hunting (cf. Redford and Robinson 1990). Because I employed indigenous research assistants, who could presumably share the hunters’ reluctance to report unsuccessful hunting trips, I was especially concerned about the possibility that these trips were not being recorded. To look for signs of reporting bias, I subdivided hunting trips into two additional categories: those that took place when I was conducting time allocation research and those that did not.⁵⁹ As detailed in Chapter 5, I conducted time allocation research for one week

⁵⁹ I sometimes assisted with data collection on days other than time allocation days, especially when training a new assistant.

a month from about 5:30 A.M. until at least 6:00 P.M. (sometimes longer if community members had yet to return to the community). On those days, I was generally aware of what all community members were doing, and I am reasonably confident that I rarely failed to note unsuccessful hunting trips. Comparisons of these hunts with hunts on non-time allocation days can reveal biases in the data.

3.8.3 Results: Reporting biases

Table 3.16 includes the results of this analysis. Before addressing the specific differences in hunting returns, I first examine the question of reporting bias. For all three categories, the hunting yields are higher on non-time allocation days. However, at least in the case of hunting trips by rifle hunters, I hesitate to attribute this difference to a reporting bias. First, the percentage of unsuccessful hunts is actually lower on time allocation days (7% vs. 11% on non-time allocation days). Second, the opportunity for very large kills on a single hunt can skew the average hunting yields. In the sample of rifle hunting trips on non-time allocation days, over 68% of the biomass was harvested on only three of the thirty-five expeditions. In other words, because hunters on those trips successfully killed tapirs and white-lipped peccaries, these three hunting trips account for more than two-thirds of the harvest. When I subtract the data from these three trips from the sample, the average hunting yield of the remaining hunting trips (0.57 kg/manhour) is very close to the average for time allocation days. The entire sample of rifle hunting trips therefore appears to be a good representation of hunting with guns in the reserve.

Table 3.16. Mean hunting returns by hunting technology. “TA” refers to data collected on time allocation days and “non-TA” similarly refers to non-time allocation days.

Technology	Manhours	kg/triphour of hunting time			kg/manhour of hunting time ⁶⁰			Percentage (%) of unsuccessful hunting trips		Average length of hunt (hrs)	
		TA	Non-TA	All	TA	Non-TA	All	TA	Non-TA	TA	Non-TA
Dog	1150.9	1.47	1.95	1.84	0.91	1.08	1.04	14 (5/35)	12 (13/107)	4.38	4.65
Gun	496.8	1.06	3.49	2.78	0.55	1.62	1.33	7 (1/14)	11 (4/35)	4.96	4.80
Dog and gun	786.1	2.40	4.41	3.75	1.57	2.79	2.39	16 (5/32)	9 (6/65)	5.19	5.17
					Total		1.54				

⁶⁰ If the figures are based not only on the time that hunters spent hunting but also the entire time spent away from the community (measured from the hour of departure to the hour of return), the results change accordingly – Dogs: 0.75 kg/manhour; Guns: 0.96 kg/manhour; Dogs and guns: 1.85 kg/manhour.

The possibility of a reporting bias on the remaining two categories is a little less straightforward. For hunting with dogs and with dogs and guns, the average return on time allocation days is lower than on non-time allocation days. Unlike rifle hunting, though, the percentage of unsuccessful trips is higher on time allocation days, perhaps indicating that unsuccessful trips were underreported on non-time allocation days. However, while the sample sizes are small, a chi-square test revealed no significant differences in the percentage of unsuccessful trips on time allocation days compared to non-time allocation days for either trips with only dogs ($\chi^2 = .109$; $df = 1$; $p = .74$) or with both dogs and guns ($\chi^2 = .872$; $df = 1$; $p = .35$). As with rifle hunts, a few large kills can skew the averages. For example, only one tapir was killed on hunting trips with just dogs, and it happened to occur on a non-time allocation day. Had it occurred on a time allocation day, the average return rate on time allocation days would actually exceed the rate for non-time allocation days.⁶¹ Similarly, only one of the thirty-two hunting trips with both dogs and guns on time allocation days resulted in a tapir kill while almost 8% of the trips on non-time allocation days included tapir kills. If those percentages were reversed, the respective averages would level out considerably. Because tapir kills are presumably unrelated to my pre-established fieldwork schedule, I tentatively conclude that allowing the assistants to work independently did not result in a reporting bias for any of the three types of hunting trips. However, I am reasonably sure that at least some unsuccessful hunts went unreported, particularly shorter excursions that were combined with other activities (e.g. taking a turn through the forest before stopping to collect firewood). The percentage of unreported hunts probably did not differ much among the three categories; hence the data are still useful for comparing the respective technologies. For cross-cultural comparisons, though, I suspect that the actual return rates are perhaps 10% lower than the figures reported here.

3.8.4 *Hunting yields by technology*

Once again, the respective return rates seem to demonstrate the superiority of firearms to traditional technologies, as rifles provide a better average return than dogs. The most interesting result from this analysis, however, is that the combination of the two technologies yields a higher

⁶¹ The figures would yield an average of 1.55 kg/manhour on time allocation days and 0.9 kg/manhour on non-time allocation days.

return rate than either technology by itself. Hunting with both dogs and guns is 80% more productive than hunting with rifles alone and 130% more productive than hunting with just dogs, as measured in kg/manhour. While anthropologists generally view firearms as a replacement for traditional hunting tools, this analysis illustrates that firearms can actually complement some traditional technologies to provide even more favorable returns. This result thus provides a compelling explanation for the persistence of hunting dogs even in locales with ready access to firearms and ammunition. These data also refute the opinion that dogs do more harm than good by chasing off prey before hunters are able to shoot.

Given the aforementioned observation that the rifles are used on less than 40% of the hunting trips with the two technologies, what best accounts for the superiority in hunting yields of this combination? While hunters certainly benefit from the opportunity to target prey items encountered when the dogs are elsewhere, the combination of dogs and guns dominates for one primary reason: tapirs. Of the eight tapirs killed on daylong hunting trips from the communities, six were first detected by dogs and then killed by hunters with rifles (often in combination with other technologies when bullets failed to down the animal immediately). Tapirs comprise almost 60% of the biomass harvested on hunting trips with dogs and guns. By comparison, only one tapir was killed on hunting trips with just dogs, which occurred when the dogs chased the animal into the river, where a group in a passing boat was able to kill it with machetes. That hunter was fortunate, as two other tapir encounters by hunters with only dogs ended with the animals bolting into the forest while the hunters could only watch. Hunters with rifles can kill tapirs, but they encounter tapirs less often than hunters with dogs. The combination of dogs and guns works because dogs boost the encounter rate while the rifles provide the means with which to kill the prey. While dogs sometimes chase off tapirs before the hunters can shoot, the increased encounter rate appears more than sufficient to offset the situations in which the encounter does not lead to a favorable shooting angle.

Interestingly, when I exclude those hunting trips on which hunters killed tapirs, the return rate of hunting with rifles (1.032 kg/manhour) is marginally better than hunting with both rifles and dogs (1.027 kg/manhour).⁶² The disproportionate effect of tapir kills on return rates is

⁶² The revised sample excludes one trip on which a tapir was killed by a rifle hunter, one trip on which a tapir was killed by a hunter with dogs, and six trips on which tapirs were killed by hunters with both dogs and guns (including one excursion on which a hunter with dogs and a rifle killed both a tapir and a collared peccary). For the sake of comparison, the return rate of hunters with dogs in the revised sample is 0.901 kg/manhour.

similarly evident in a statistical test of the return rate data from the full sample. By reducing return rate data from each hunting trip in the sample into ranks, a nonparametric Kruskal-Wallis test minimizes the skew introduced by tapir kills. The Kruskal-Wallis test is not significant ($K = 3.201$; $p = 0.202$), and this result suggests that no technology or combination of technologies consistently outperforms the others. Although hunting with dogs and rifles seems to increase the frequency of tapir kills, most trips result in far more modest returns. Because hunters with only rifles or dogs can also harvest large prey, including the occasional tapir and especially the peccaries, the returns of hunters with these technologies often surpass those of hunters with both rifles and dogs.

On hunting trips with both guns and dogs, rifles occasionally prove advantageous for targeting other prey animals that are pursued by the dogs. For example, while collared peccaries more frequently flee into a burrow or trunk when chased by dogs, they sometimes turn and face off in open air, at which point a trailing hunter might be able to take a shot. Such pursuits contribute to the higher return rate of the dog and gun combination, as do pursuits of prey items such as game birds and deer when the dogs are elsewhere. That said, perhaps the main benefit of bringing a gun is defense of the dogs from predators, especially jaguars. Three jaguars were killed during the study period, all shot by the same hunter after they had attacked his dogs in the forest.⁶³ Of course, most jaguar attacks on the dogs occur when they are not in the hunter's immediate vicinity, but having a rifle affords hunters at least a moderately better chance of protecting their dogs. Rifles may also be used to shoot other threats to the dogs, including pumas, ocelots, and giant anteaters. Hunters with a limited supply of bullets sometimes choose not to shoot an otherwise desirable prey item because they want to retain sufficient bullets to protect the dogs. For hunters who are intent on protecting their highly valued dogs, rifles become an almost indispensable technology. Thus, while the benefits of combining dogs and guns are evident in the superior return rates, the advantage of bringing a gun when hunting with dogs exceeds the difference in hunting yields.

Given the choice between hunting with only guns or only dogs, the data suggest that the former is the better option. It is important to recall, however, that more than 60% of the biomass harvested by rifle hunters was provided by three very successful hunting trips. If trips with tapir

⁶³ Another jaguar was killed in August 2004, shortly before the study period began. This jaguar died in a trap about 100 meters west of Arang Dak. Several men constructed the trap following nocturnal jaguar attacks on pigs in the community.

or white-lipped peccary kills are eliminated from both datasets, hunting with dogs is actually 60% more productive than hunting with rifles (0.9 kg/manhour vs. 0.56 kg/manhour, respectively). To some extent, the decision to hunt with one technology instead of another depends on the importance that individual hunters attach to opportunities for the occasional bonanza of large prey. A number of other factors are likewise important, including the cost of the respective technologies and the preferences of individual hunters. It is noteworthy that hunters who own both dogs and rifles sometimes hunt with only guns, but they rarely leave their rifles at home when hunting with the dogs. Interestingly, while rifles are regularly borrowed from others by hunters with dogs, hunters who own rifles seldom ask to borrow another's dogs for a hunting trip.

3.8.5 The pros and cons of dogs and guns

Beyond differences in hunting productivity, what are the advantages and disadvantages of each technology? Table 3.17 summarizes some of the differences between dogs and guns, which are examined in more depth in the text below. While I did not examine this issue with a formal survey, these opinions combine both emic and etic perspectives, as I weighed informal conversations with hunters against my own observations. I suspect that there would be some debate amongst my informants about the respective merits of each technology and the relative importance of the criteria in this discussion. By making these comparisons, I do not intend to reach definitive conclusions about which technology is categorically "better" but rather to highlight some of the factors that affect decisions about hunting technologies in Bosawas.

- Initial expense

Rifles are almost invariably more expensive than dogs. Even a secondhand rifle can cost a hunter at least 2,400 cordobas while a new rifle might cost twice that amount when purchased from merchants outside of the reserve. Hunters who do not possess guns are virtually unanimous in their desire to own one, but they remain too expensive for many Bosawas residents. By contrast, the highest price paid for any of the dogs in the study was 400 cordobas, and I have not heard of a dog ever selling for more than 500 cordobas. Puppies can be purchased for much less, usually 50-100 cordobas depending on ancestry and age at the time of purchase.

Table 3.17. Pros and cons of dogs and cons for factors other than differences in hunting yields. For each issue, the “X” indicates which technology is more advantageous. The “~” symbol indicates that neither technology is especially advantageous for the issue in question.

Issue	Dogs	Rifles
Initial expense	X	
Maintenance costs		X
Cost of use	X	
Reliability of use	~	~
Risk of loss		X
Learning curve	X	
Intangibles	~	~

- Maintenance costs

While rifles are initially more expensive than dogs, the routine maintenance costs of dogs are higher. Whereas rifles can be stored without expense, dogs must be fed daily. Although “cheap” carbohydrate-heavy foods like bananas and manioc can supply much of the dogs’ energetic needs, they also require protein and fat in their diet. If it is available, families with puppies often purchase milk at a standard price of 2 cordobas per gallon. Dogs are also fed fish, game, and grains, including grains purchased from the store. Given that most dogs do not become proficient hunters until they are at least a year old, the acquisition of puppies represents a sizeable investment that may not pay off for quite some time, if ever. It should be noted that the quality of care varies dramatically. Those dogs that do not hunt well generally appear underfed, and they sometimes resort to attacks on unsuspecting chickens as a way to stave off their hunger. Malnourishment also appears to contribute to the dogs’ susceptibility to illness.

- Cost of use

While the maintenance costs of dogs are substantial, it costs little more than some extra calories to take them on a hunt. By comparison, each bullet costs 2.5-3 cordobas, a cost that is magnified by the fact that many of the bullets misfire. I estimate that, on average, hunters must pay at least 4 cordobas for each bullet that they successfully shoot at a prey item.

- Reliability of use

Ammunition is occasionally in short supply at local stores, which can render rifle hunters powerless unless they manage to find bullets to borrow from others. Dogs are not always reliable, either. Injuries and pregnancies can hinder the availability of dogs for hunting. Dogs that routinely run off can be frustrating for hunters, as they often return too tired to be of much service on a hunting trip.

- Risk of loss

Unless they are stolen, rifles are seldom lost. A hunter with a rifle can be reasonably confident that he will have indefinite use of the gun. Dogs represent a riskier investment, as mortality rates are fairly high. Of the forty-one adult dogs in the communities at the start of my study, twenty had died by the conclusion (49%). The cause of death for those twenty fatalities includes four that succumbed to illnesses, four that died from snakebites, one killed by a jaguar, and one that died when it stumbled into a trap that was constructed to catch a jaguar which had been attacking community pigs. The remaining ten dogs were lost in the woods, presumably

victims of either snakebites or jaguars. The oldest dog in the community was eight years old, and the next oldest was six years old.

- Learning curve for effective use

Informants are reticent when asked which technology is more difficult to use, and they are insistent that hunting with either technology requires comparable skills and knowledge. Although the specific strategies vary according to technology, route selection and methods for dispatching prey are equally important to hunts with dogs or rifles. While I generally agree with these assessments, my impression is that hunting with dogs is easier to learn vicariously. Juvenile boys accompany both types of hunts, but on hunts with dogs they actively assist with plugging exit holes and pushing the prey down the trunk toward the waiting hunter. The only activity that seems reserved for the hunter is the actual stabbing of the animal, a skill that seems to require less direct experience than shooting a rifle accurately.

- Indirect benefits / Intangibles

Owners of rifles can benefit from their guns by lending them to other hunters. The community's guns enjoy considerable demand when a hunting party is preparing to follow white-lipped peccaries, and the owner of the rifle is entitled to as much as a half of any animals killed with the gun. Aside from additional meat, rifles can serve as a status symbol in ways that dogs cannot.

Besides their role as a hunting accessory, dogs in Bosawas are also pets, and they provide the same combination of affection and entertainment that makes them popular as pets even in places where their skills as hunters are not needed. They also provide a measure of protection for houses, as their presence discourages burglars when their owners are not at home.

3.8.6 A cross-cultural perspective on hunting returns in Bosawas

Combining the results from all the day hunts gives an average of 1.54 kilograms of undressed meat per manhour of hunting time (Table 3.16). Even assuming that the actual figure is perhaps 10% lower (because of the underreporting bias noted earlier), this return rate compares favorably to figures reported for groups elsewhere in the Neotropics (Table 3.18). While these data encompass a broad range of ecological settings and hunting technologies, the comparison suggests that Mayangna and Miskito hunters enjoy a relatively high return rate. In

fact, the observed rate of 2.39 kg/manhour for hunters with both dogs and guns is one of the higher return rates reported by ethnographers working with Neotropical peoples. Beyond this initial impression, it is also interesting to make preliminary comparisons of hunting technologies, especially traditional technologies. Although ecological differences preclude rigorous tests of hunting returns between the dogs and other traditional technologies, it is interesting to note that the return rate of Miskito and Mayangna hunters with only dogs and hand weapons exceeds the reported return rate of bow hunters elsewhere. For instance, among the societies listed in the table, the Barí, the Yanomamo, and the Machiguenga hunt primarily with bows, and the observed return rate of 1.04 kg/manhour for Miskito and Mayangna hunters with dogs surpasses the return rates of these three bow-hunting groups (0.14 kg/manhour, 0.45 kg/manhour, and 0.10 kg/manhour, respectively). Also, while the Aché data reflect both shotgun and bow hunts, Hill and Hawkes (1983:164) report that Aché bow hunters averaged 0.53 kg/manhour, which is again below the return rate for hunters with dogs in Bosawas. In general, one might tentatively conclude that hunting with dogs is typically more productive than hunting with bows. Although preferences for a given technology reflect not only their productivity but also the costs of their construction and/or maintenance, these figures could potentially be useful for attempts to explain the distribution of different hunting technologies in the Pre-Columbian Neotropics.

Table 3.18. Mean hunting returns of Neotropical societies. Adapted from Beckerman (1994a) with minor modifications.

Society	Kilograms/Manhour	Source
Pumé	0.81	Gragson 1989
Bari	0.14	Beckerman 1994a
Shipibo	1.60	Bergman 1980
Borono	0.31	Werner et al. 1979 ⁶⁴
Xavante	0.62	Werner et al. 1979
Mekranoti	1.06	Werner et al. 1979
Kanela	0.17	Werner et al. 1979
Waorani ⁶⁵	2.43	Yost and Kelley 1983
Aché	0.66	Hill and Hawkes 1983
Bakairi	0.24	Picchi 1982
Makú	1.52	Milton 1984
Ye'kuana	1.60	Hames 1979a
Yanomamo	0.45	Hames 1979a
Siona-Secoya	3.20	Vickers 1988
Piro ⁶⁶	1.27	Alvard 1995b
Machiguenga	0.10	Alvard 1995b
Mayangna / Miskito	1.54	This chapter

⁶⁴ The figures for the Bororo, Xavante, Mekranoti, and Kanela are higher in this table than in the corresponding table in Beckerman (1994a) because I note that Werner et al. (1979) report productivity in terms of dressed meat per hour whereas the rate of un-butchered meat per hunter-hour appears to be the norm for the remainder of the studies. I therefore divided figures from Werner et al. (1979:307) by 0.65, the estimated amount of edible meat in a carcass, to obtain new estimates for comparable return rates in these societies.

⁶⁵ Lu (1999:84) gives a lower estimate for hunting productivity by the Waorani (1 kg/manhour). By contrast, Mena V. et al. (2000:73) give a similarly high return rate (2.8 kg/manhour) in another study with the Waorani.

⁶⁶ This average for the Piro includes only the figures for shotgun hunts. Alvard (1995b) also includes the average for bow hunts: 0.38 kg/Manhour.

3.9.1 *Conclusion*

This chapter evaluated the extent to which decisions of Mayangna and Miskito conform to predictions derived from optimal foraging theory. In general, prey choice decisions by hunters in Bosawas support the diet breadth model, as all regularly pursued prey types increase the overall return rate. However, some species are routinely ignored by hunters, and I argue that their poor taste and associated social costs provide a better explanation than conservationist intentions for these apparently suboptimal decisions. Hunting with dogs imposes additional costs, which can be modeled by incorporating the cost of catching up to the dogs as an addition to the basic prey model (Houston et al. 1980). While all prey types pursued by hunters with dogs are already included in the optimal diet breadth, these additional costs can promote the inclusion of low-ranking prey types that would otherwise not be included in the optimal diet breadth. Additional analyses evaluated the possibility that working with stone tools might make prey types that seek refuge in hollow trunks sufficiently unprofitable to drop out of the optimal diet breadth. While the reduction in profitability was not enough to make pursuits of these prey types suboptimal, changes in the profitability ranking are a poignant reminder that results of this study are not transferable to other settings without consideration of the complementary technologies used by hunters with dogs. In general, researchers seeking to explain prey choice decisions by hunters with dogs must consider not only technology and the suite of possible prey types but also the extent to which the ecological setting might affect the costs of catching up to the dogs. A comparison of hunting with dogs and rifles indicates that the latter are more efficient in terms of meat acquired per unit time. However, hunters who use both rifles and dogs enjoy the highest return rate, largely because of their success in hunting tapirs. With or without rifles, hunters with dogs enjoy return rates that compare favorably to rates reported for other Neotropical peoples, which helps to explain the widespread distribution of hunting dogs throughout the region.

Chapter 4

Characterizing the harvest: Technology, geography, and sustainability

In this chapter, I use hunting data from the full study period to characterize the harvest and assess the impact that Mayangna and Miskito hunters have on the wildlife populations in the Lakus River watershed. While conducting focal observations of intentional hunting trips, I noticed several trends that differ somewhat from the conventional view of Neotropical hunting. While many animals are killed on intentional hunting trips, many others are killed opportunistically in the course of other activities. To examine the full effect of hunting on local fauna, it is important to document the complete harvest. With the help of indigenous research assistants, I recorded all wildlife kills by community members in Suma Pipi and Arang Dak. These data were used to conduct a number of analyses that amplify the ethnographic description of hunting in Bosawas. Throughout the chapter, I touch on the conservation implications of the analysis.

This chapter opens with a description of the methodology that I used to gather the harvest data. After summarizing the composition of the harvest, I examine the effects of technology and seasonality on the hunting of individual species. Next, comparisons with cross-cultural data reveal the extent to which the harvest in Arang Dak and Suma Pipi differs from the hunting harvests of groups elsewhere in the Neotropics. After describing the ways in which the hunting zone is characterized by a mixture of anthropogenic and relatively undisturbed habitats, I examine spatial patterns in the distribution of kill sites. The geographic data also provide parameters that are needed for an assessment of hunting sustainability. I review sustainability models in general, and I describe the production model that is used to assess sustainability in this study. After discussing the results of this assessment, I conclude with some general observations and recommendations to improve the long-term survival of endangered wildlife populations in the reserve.

4.1.1 *Methods: The harvest data*

I employed indigenous research assistants to monitor the community for incoming fish and game resources. Assistants in Arang Dak were provided with two Pesola spring scales (10 kg and 50 kg, respectively) while the assistant in Suma Pipi worked with a Berkley digital fish scale (50 kg). Assistants were also given clipboards with the needed data sheets. Because of its larger size, three employees shared assistantship duties in Arang Dak, each working every third day. On the designated work day, employees would remain in the community during all daylight hours, ready to weigh incoming wildlife and fill out questionnaires. There was only one assistant in Suma Pipi, who was required to be present in the community from dawn until 7:30 A.M. and from 4:00 until darkness (when most of the resources were brought into the community). During the interim period, a woman in the community (the assistant's spouse) weighed any incoming fish and game, noting also the type and number of fish and the age and sex of hunted game. Upon returning to the community, the assistant from Suma Pipi would then add these data to the form and complete the interview with the hunter or fisher in question. Assistants were paid sixty cordobas per day. For their participation in this component of the project, households received thirty-two cordobas per month.

Both the fishing and hunting questionnaires included data on the hour of departure and return to the community, the names of participants, the technologies brought by each participant, the names of dogs brought along, other resources brought back to the community (e.g. bananas, firewood), the means of transportation (i.e. on foot or by boat), activities other than fishing and hunting undertaken by the participants, and a sketch map of the outing. Fish were weighed by species, not individually (e.g. if five *tuba* were present, the number of specimens would be noted and all weighed together). Hunting forms also included questions on encounters with possible prey items (including those that were not pursued), with specific questions pertaining to the number of animals encountered, what the hunter was doing at the time of encounter, what the animal was doing at the time of encounter, whether the animal was pursued (and if not, why), how many shots were fired (if applicable), why the pursuit was abandoned (if applicable), and how the hunter first realized the presence of the animal. If dogs detected the animal, hunters were asked which dog received credit for the encounter. Questions added to the form after the study had been started included a query about animal tracks spotted during the hunting trip. For

animals that were killed, the assistants also recorded the sex, weight, and the technologies used to kill the prey item. If the animal had been killed in a burrow or trunk, the assistants noted the type (e.g. earthen or the species of tree). Assistants also noted the age of the animals, although these data were based on their judgment. To minimize ambiguity, it would have been preferable to examine dental patterns (Alvard 1995a:795), but a preexisting arrangement between the community and the Saint Louis Zoo's project made the collection of prey mandibles somewhat problematic.

Assistants were trained to work independently, but I also helped with a number of forms, especially on days when I was simultaneously collecting time allocation data. In total, I helped with 39% of the hunting forms and about 22% of the fishing forms.¹ Except with a few participants who spoke reasonably fluent Spanish, the assistants' help with translation was vital to data collection. On days when the assistants in Arang Dak worked independently, I reviewed data sheets at the end of the day to look for errors or omissions. Data sheets from Suma Pipi were reviewed only once per week, as the smaller number of forms made this time frame feasible. Direct observations of hunting and fishing trips provided an opportunity to evaluate the thoroughness of the assistants' work. After an observed hunting trip, for example, I would allow assistants to complete a form as though it had been an unobserved trip. Comparisons of these data sheets with the data from my own observations suggested that assistants accurately recorded data and that discrepancies generally stemmed from inaccurate data provided by the hunters. Hunters appeared especially prone to underreporting smaller prey items, particularly when the animals in question were not pursued. Sometimes hunters likewise failed to report seemingly unimportant non-wildlife resources brought back to the community, such as a small bunch of fruits or sticks meant for use around the house. Reported times of departure were generally accurate to within 30 minutes, aided in part by the regular schedule kept by the local schools (bells chimed at the appropriate hour). Many participants also used wristwatches, as did the assistants.

Community members occasionally returned home after dark with fish or game, and they were hesitant to seek out the assistants to complete a form. To minimize data lost in such situations, each household was provided a clipboard and a weekly food form. This methodology was adapted from Merriam (1998), who discovered that interviews with female heads of

¹ By another measure, I helped collect the data on 450 of the 1090 animals in the sample.

household (i.e. those responsible for food preparation) were an effective method of accounting for wildlife harvests in a neighboring territory. At the beginning of each workday, assistants would visit each household to help fill out the form.² In general, the female head of household was interviewed, although sometimes an older daughter or son supplied the data. For each day of the week, the form listed all regular sources of animal protein: hunted game, fish, beef, pork, poultry, eggs, and milk. If one of the items had been consumed, assistants would record the type (e.g. species of fish), amount, how it was acquired (i.e. through the efforts of a household member or as a gift or purchase), the price (if applicable), and the original owner (in the case of gifts and purchases). These food forms were collected weekly and cross-checked against the forms I had for hunting and fishing trips. If fish or game on the food forms lacked a corresponding data sheet, the assistants would visit the household in question to collect the data. As it was not possible at such times to collect the weight of the fish or game, I used either averages of already-weighed specimens (preferably) or published estimates to calculate the harvested biomass.

Data collection in Arang Dak began on August 15th, 2004, but I report here only the harvest from September 1st, 2004 to August 31st, 2005. Both the assistants and the households needed the first two and a half weeks to become familiar with the research methodology, and I therefore opted to eliminate from the dataset the data from that period. For Suma Pipi, data are presented from December 15th, 2004 to August 31st, 2005. The start of data collection in Suma Pipi was delayed by a series of administrative complications following a death in the community and the resignation of the original research assistant. Data were collected for about a week in November 2004, but those data are likewise excluded from this analysis. Once the methodology was well-understood, data collection was reasonably straightforward, and I was generally impressed with the participation of community members. That said, there was an obvious bias in the reporting of small fish and game, especially initially. At community meetings, I impressed upon participants the importance of presenting even relatively diminutive specimens to the

² The original research plan called for households to fill out the forms independently, with a weekly revision of the forms by myself and the assistants. However, cross-checking in the first two weeks of the study revealed that many families were somewhat languid about completing the forms on a daily basis. In other cases, the absence of literate household members made completion of the forms unfeasible without assistance. Accordingly, the research methodology was changed to enhance data collection. While assistants completely took over data entry for some households, the forms remained in the house and some of the more enthusiastic participants continued to enter the data themselves, in which case the assistant would review the forms in the morning to confirm their accuracy and completeness.

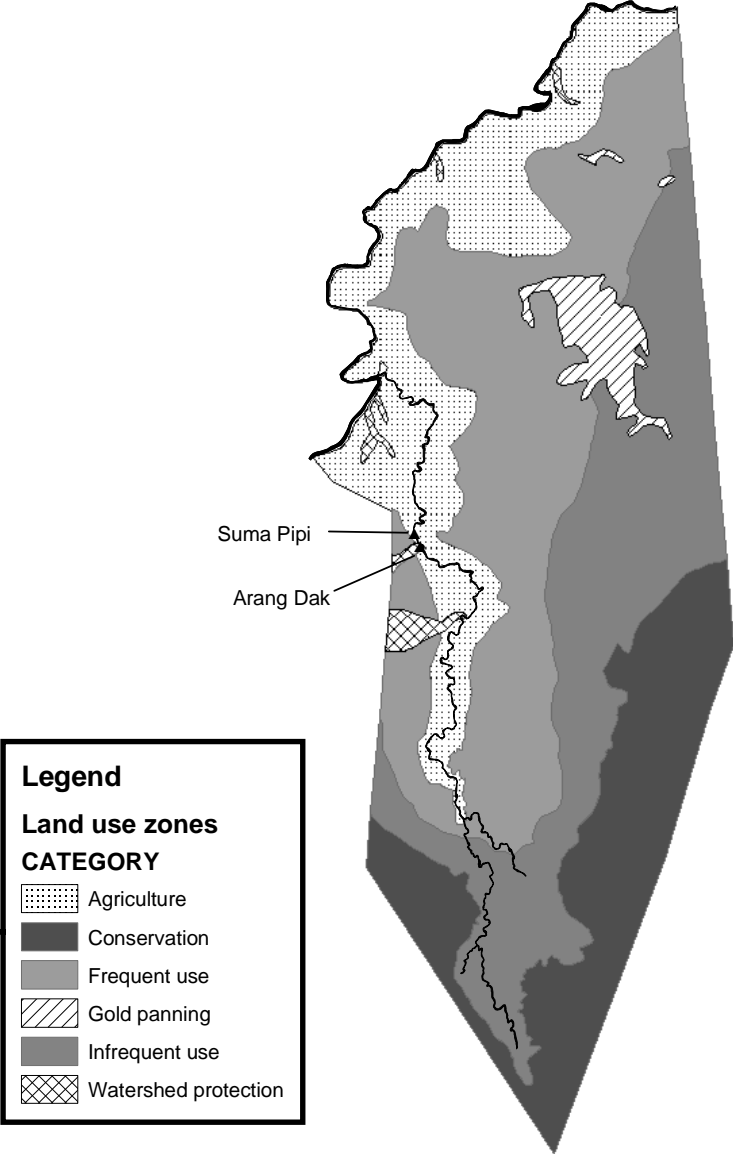
assistants, and I attempted to increase the reporting of such small harvests by giving pencils or sweets to children in the community when they alerted the assistants to the presence of fish or game.

Despite my attempts to document all fish and game kills by community members, some biases remain. As noted, there is a bias against small harvests, as is common in such research (Redford and Robinson 1990). Also, despite my emphasis on reporting even unsuccessful hunting trips, I suspect that hunters sometimes returned home empty-handed but told the assistants that they had done only other subsistence work (i.e. not hunting) while away from the community. Finally, it proved difficult to record all animals killed by community members when they traveled to other communities and territories. For example, some community members worked as wage laborers on a road construction project in Mayangna Sauni As for extended periods of time. The trailhead to this neighboring territory is well upstream on the Lakus River, and the trip takes at least two days. While it was usually possible to ask participants in the study what they had killed on the return journey from Mayangna Sauni As, it was not possible to document kills made by travelers leaving Arang Dak and Suma Pipi. The dataset thus underestimates the number of animals killed in the headwaters of the Lakus. To a lesser extent, the dataset probably underestimates kills made on the trails to communities along the Coco River (esp. Raiti and Walakitang) and the Umbra River. In addition, residents of Suma Pipi in particular tended to make occasional multi-day gold prospecting trips to the headwaters of nearby streams, and I suspect that at least a few animals killed on these trips went unreported.

4.1.2 Methods: Sketch mapping and GIS

The mapping of kill sites by residents of Arang Dak and Suma Pipi benefited greatly from previous geographic work in the reserve conducted by Dr. Anthony Stocks. An anthropologist at Idaho State University, Stocks worked with The Nature Conservancy (TNC) in the mid-1990s to begin the process of securing legal land title for the indigenous communities in the Bosawas area (Stocks 1996). As part of that process, Stocks worked with indigenous assistants to create maps that combined features from spatially accurate 1:50,000 topographic maps with indigenous toponymy and additional watercourses not included in the topographic maps (Stocks 2003). These maps also delineate land use zones for subsistence and economic

Figure 4.1. The indigenous territory, Kipla Sait Tasbaika, with land use zones



activities that, while not strictly enforced during the study period, provide an organizational framework for the discussion of territorial norms and ecological management (see Figure 4.1). Copies of these maps are kept by the TNC office in Managua, and the maps have recently been converted into a GIS format by Stocks and colleagues at Idaho State.

While the maps created by Stocks provided valuable points of reference for the areas around Arang Dak and Suma Pipi, it became apparent soon after my arrival that the mapping of kill sites would be enhanced by identifying additional landmarks. Accordingly, borrowing a method used by Smith (2003a), I convened a community mapping session with at least one adult from each household. Provided a large piece of blank white paper, participants worked with one of my research assistants to draw locally important landmarks and features complete with indigenous toponymy. Participants began by drawing the Lakus River and its tributaries, which was not surprising given that the indigenous residents tend to talk about different areas within the reserve by referring to the nearest stream. They also included the most heavily used trails, focusing in particular on the trails that parallel the river.³ Individual fields were then added to the map, with attention given not only to actively-cultivated fields but also to the *guamiles* (abandoned fields of varying ages). Finally, participants in the community added to the map a few other landmarks, including an abandoned gold mine and the source of the water system that provides the community with fresh stream water.

While this hand-drawn map provided a trove of valuable landmarks, it was not to scale. Although participants clearly attempted to depict accurate spatial relationships between landmarks on the map, I resolved to create a spatially accurate GIS dataset based on the map from the community mapping session. With a Global Positioning System (GPS) unit, I therefore began the task of documenting the coordinates of features on the map. With local guides, I walked trails and collected GPS points along the way, paying special attention to stream crossings, treefalls, and fields that would be particularly valuable as references for mapping the kill sites. I also brought the GPS on hunting observations, which allowed me to identify common routes used by hunters. When it became apparent how much of the hunting occurs in the agricultural zone, I also resolved to map individual fields. While it would have been ideal to

³ Almost all residents maintain a trail that begins at a *muelle* (i.e. port) along the river, leads up through their fields and *guamiles* (abandoned fields and secondary forest), and extends into the mature forest behind their fields. These trails are used especially for cutting firewood and occasionally for gathering *suita* and other forest products. Because they tend to peter out shortly after reaching the forest, I did not insist that they be included on the community map.

map both the active fields and the fallows, the task of circumnavigating an overgrown and thorny fallow rendered the mapping of the abandoned fields impractical. Because farmers tend to clear new fields close to their older fields (and in fact many of the manioc fields are cleared from 3-6 year old fallows), I concluded that mapping actively cultivated fields would provide a sufficiently detailed look at the general areas in which individual households worked. I trained one of my assistants in the use of GPS, and I assigned him the task of mapping all the fields cleared by residents of Arang Dak and Suma Pipi during the study period. In practice, there are two growing seasons in the reserve, one in the rainy season and one in the dry season. The mapping of fields with GPS began in January at the start of the dry season and concluded in late July with the fields planted in May and June (the beginning of the rainy season). Cross-checking indicates that this assistant mapped the fields much as I would have done, and the differences between our coordinates seemed to stem from the inherent inaccuracy of the GPS unit itself.

The mapping of individual kill sites followed a method developed by Smith (2003a). After weighing and completing a questionnaire on incoming game, my assistants used a blank piece of paper to draw sketch maps of the routes followed by hunters and the locations of kill sites and also encounters with potential prey items.⁴ Hunters were asked to describe the location of a site, after which the assistants would ask clarifying questions to pinpoint the exact location. Both the assistants and the hunters shared a body of geographic knowledge, with which they were able to describe locations without resorting to actual maps. The sketch maps initially lacked sufficient detail, but the assistants soon learned to appreciate the level of detail needed to plot the kill sites accurately. Because residents are familiar with the metric system as a way to measure fields, hunters sometimes described locations in quantitative terms. As an example, the description of a kill site might be related to an assistant by saying, "I had just crossed Arang Dak. Was on the cow trail when the dogs led me to an agouti burrow about 200 meters off to the right." The assistants would then draw the appropriate features on the sketch maps, including the distance estimates. As the study progressed, I began to share this body of knowledge and could sometimes complete maps without help from my assistants. Hunters with whom I conducted observations also began to relate the location of kill sites to the routes we had followed on previous hunting trips.

⁴ In many cases, the location of the encounter and the kill site were identical. In some cases, though, animals were encountered in one location but killed in another, as when deer took to the river upon being chased by dogs. For these situations, the plotting of encounters proved to be a valuable tool for interpreting the context of the pursuit.

Some kill sites were much easier to map than others. All kills in the river were straightforward, for example, and kills made along mapped trails were also fairly easy to plot. By contrast, hunting trips that ended up far from the Lakus River proved more difficult to map, as there were no nearby fields or trails to use as points of reference. Cross-checking of 80 kill sites suggests that I was able to plot sites with an average error of 358 meters. All of these sites were located no more than 6.5 kilometers from Arang Dak, though, and I suspect that the plotting of farther kill sites is less accurate. This decline in accuracy would be especially likely for white-lipped peccaries killed inland from the river.

Upon returning to the United States, I created a database of kill sites in ArcView 8.3 by ESRI. I began by converting the GPS points that I had collected in the field into shapefiles of fields, trails, and other useful landmarks. I then superimposed these files atop GIS data of rivers and streams, the land use zones, and topographic data provided by Idaho State. Finally, I used the sketch maps drawn by the assistants to create a point shapefile of kill sites.

4.2 Characterizing the harvest

The documented kills by residents of Arang Dak and Suma Pipi are listed in tables 4.1 and 4.2, respectively. Note that these lists include animals that were killed but not consumed (e.g. jaguar, greater grison, caiman), and readers should refer to Appendix 1 as a guide to which mammals are considered inedible. In total, at least 44 species were taken and possibly more, as it was sometimes difficult to distinguish beyond the generic level. The list includes 20 mammalian species, at least 19 species of birds, and 5 reptilian species. Both in terms of numbers and biomass, mammals dominate the combined sample, as they comprise 74% of the animals killed in the sample and 95% of the total biomass. The top eight contributors of consumed meat were mammals,⁵ and six of those species (tapir, agouti, white-lipped peccary, paca, collared peccary, and armadillo) together comprise 82% of the biomass in the overall harvest. This primary reliance on mammals is typical of lowland Neotropical peoples (Beckerman and Sussenbach 1983).

⁵ If consumed, jaguars and giant anteaters would likewise outrank the avian and reptilian species.

Table 4.1. Animals killed by residents of Arang Dak, 9/1/04-8/31/05. Numbers in parentheses indicate the number of specimens on which the percentages are calculated.

Scientific name	Species	Number	Biomass (kg)	% male	% adult
<i>Tapirus bairdii</i>	Baird's tapir	13	2338.0	77 (13)	100 (13)
<i>Dasyprocta punctata</i>	Agouti	350	1031.1	34 (345)	70 (347)
<i>Agouti paca</i>	Paca	116	856.8	49 (110)	77 (112)
<i>Tayassu tajacu</i>	Collared peccary	39	768.2	56 (36)	81 (37)
<i>Tayassu pecari</i>	White-lipped peccary	20	744.9	44 (18)	85 (20)
<i>Dasyus novemcinctus</i>	Nine-banded armadillo	160	655.5	50 (157)	58 (159)
<i>Mazama americana</i>	Red brocket deer	15	215.8	20 (15)	73 (15)
<i>Panthera onca</i>	Jaguar	3	194.0	50 (2)	100 (3)
<i>Myrmecophaga tridactyla</i>	Giant anteater	4	160.0	0 (4)	100 (4)
<i>Iguana iguana</i>	Iguana	55	127.9	32 (53)	74 (53)
<i>Ateles geoffroyi</i>	Spider monkey	11	76.2	55 (11)	91 (11)
<i>Penelope purpurescens</i>	Crested guan	34	64.9	34 (32)	82 (33)
<i>Puma concolor</i>	Puma	2	59.5	50 (2)	100 (2)
<i>Crax rubra</i>	Great curassow	18	51.4	56 (18)	89 (18)
<i>Odocoileus virginianus</i>	White-tailed deer	1	49.0	?	100 (1)
<i>Tinamus major</i>	Great tinamou	48	45.1	24 (42)	84 (45)
<i>Alouatta palliata</i>	Howler monkey	5	35.0	100 (5)	100 (5)
<i>Leopardus pardalis</i>	Ocelot	2	30.0	100 (1)	100 (1)
<i>Trachemys scripta</i>	Slider turtle	15	29.2	-	-
<i>Nasua narica</i>	Coati	8	24.4	33 (6)	88 (8)
<i>Rhinoclemmys funerea</i>	Black wood turtle	10	23.1	-	-
<i>Tamandua mexicana</i>	Northern tamandua	2	12.0	100 (1)	100 (1)
?	Unidentified turtle	7	10.5	?	?
<i>Procyon lotor</i>	Northern raccoon	1	9.2	100 (1)	100 (1)
<i>Cebus capucinus</i>	Capuchin monkey	3	7.8	100 (3)	67 (3)
<i>Kinosternon leucostomum</i>	White-lipped mud turtle	15	7.6	-	-
<i>Amazona</i> spp.	Parrots	7	3.8	71 (7)	100 (7)
<i>Ramphastos sulfuratus</i>	Keel-billed toucan	6	3.4	100 (5)	100 (5)
<i>Ramphastos swainsonii</i>	Chestnut-mandibled toucan	6	3.0	100 (6)	100 (6)
<i>Galictis vittata</i>	Greater grison	1	3.0	100 (1)	100 (1)
<i>Ara</i> spp.	Macaws	1	3.0	100 (1)	100 (1)
<i>Rhynchortyx cinctus</i>	Tawny-faced quail	7	2.5	100 (5)	100 (7)
<i>Crypturellus soui</i>	Little tinamou	7	2.2	43 (7)	86 (7)
<i>Ortalis vetula</i>	Plain chachalaca	7	2.0	43 (7)	100 (7)
<i>Geotrygon</i> spp.	Doves	7	1.7	?	100 (6)
<i>Sciurus variegatoides</i>	Variegated squirrel	5	1.4	75 (4)	60 (5)
<i>Tigrisuma mexicanum</i>	Bare-throated tiger-heron	1	1.3	100 (1)	100 (1)
<i>Cochlearius cochlearius</i>	Boat-billed heron	2	1.1	100 (2)	50 (2)
?	<i>Pato de monte</i>	1	0.9	100 (1)	0 (1)
<i>Dryocopus lineatus</i>	Lineated woodpecker	3	0.8	100 (1)	100 (1)
<i>Crypturellus boucardi</i>	Slaty-breasted tinamou	1	0.5	0 (1)	100 (1)
?	Unidentified bird	1	0.3	100 (1)	100 (1)
?	Unidentified bird	1	0.1	?	?
	Total	1021	7658.1		

Table 4.2. Animals killed by residents of Suma Pipi, 12/15/04-8/31/05. Numbers in parentheses indicate the number of specimens on which the percentages are calculated.

Scientific name	Species	Number	Biomass (kg)	% male (n)	% adult (n)
<i>Tayassu pecari</i>	White-lipped peccary	9	218.0	33 (9)	44 (9)
<i>Tapirus bairdii</i>	Baird's tapir	1	166.5	0 (1)	100 (1)
<i>Odocoileus virginianus</i>	White-tailed deer	2	98.0	50 (2)	100 (2)
<i>Agouti paca</i>	Paca	7	44.2	57 (7)	43 (7)
<i>Mazama americana</i>	Red brocket deer	3	42.5	33 (3)	67 (3)
<i>Dasyprocta punctata</i>	Agouti	13	32.0	42 (12)	38 (13)
<i>Tayassu tajacu</i>	Collared peccary	1	24.0	100 (1)	100 (1)
<i>Ateles geoffroyi</i>	Spider monkey	3	20.5	100 (1)	100 (3)
<i>Dasypus novemcinctus</i>	Nine-banded armadillo	3	15.9	100 (3)	100 (3)
<i>Caiman crocodilus</i>	Caiman ⁶	1	15.5	?	?
<i>Crax rubra</i>	Great curassow	6	15.4	67 (6)	83 (5)
<i>Penelope purpurescens</i>	Crested guan	5	8.3	20 (5)	100 (5)
<i>Iguana iguana</i>	Iguana	2	4.2	0 (2)	50 (2)
<i>Tinamus major</i>	Great tinamou	3	3.2	33 (3)	100 (3)
<i>Amazona</i> spp.	Parrots	3	2.9	67 (3)	100 (3)
?	Unidentified turtle	2	1.9	?	?
<i>Ara</i> spp.	Macaws	1	1.0	?	?
<i>Crypturellus soui</i>	Little tinamou	1	0.6	100 (1)	100 (1)
<i>Ramphastos swainsonii</i>	Chestnut-mandibled toucan	1	0.5	100 (1)	100 (1)
<i>Geotrygon</i> spp.	Doves	2	0.4	50 (2)	100 (2)
	Total	69	715.5		

⁶ The meat of this caiman was not consumed. The hunter indicated that he might someday attempt to sell the skin in his native Honduras.

Of the 1,090 animals, 41% (representing 36% of the biomass) were acquired opportunistically in the course of activities other than hunting. About 34% of the animals killed and 33% of the biomass were acquired on Saturday (figures 4.2 and 4.3), which reflects the consensus wish to have meat following the Sunday mass. The Mayangna and Miskito are relatively strict about observing the Sabbath, and very little hunting occurs on Sunday (cf. Nietschmann 1973:176). Traveling is permitted, however, and all but one of the seven animals killed on Sunday followed opportunistic encounters with pacas or iguanas while traveling (the last was the sample's northern raccoon, which was taken late Sunday night by a farmer protecting his bean field from predation). Approximately 53% of the animals were killed on excursions in which members of the party also brought back bananas, manioc, or firewood (although the hunters themselves were not always responsible for their acquisition). Women killed eleven animals, including 7 white-lipped mud turtles (usually while fishing), two iguanas, and two red brocket deer that had been chased into the river by dogs.⁷ Women also participated in several other kills by helping to pole boats in pursuit of animals in the river or by contributing to the cooperative harvesting of turtles using nets.

Figure 4.2. Number of animals taken by day of the week

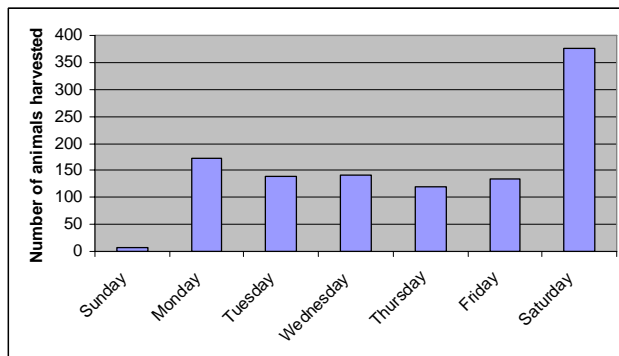
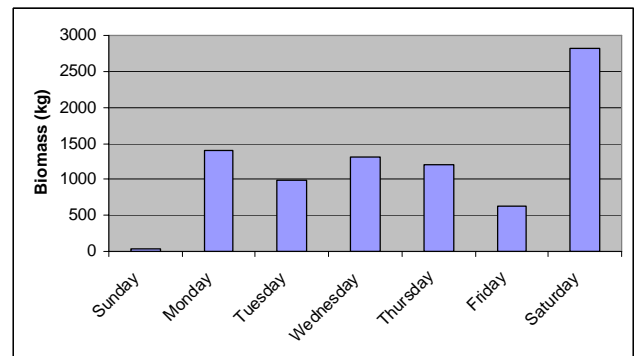


Figure 4.3. Biomass harvested by day of the week



⁷ An additional kill was recorded for a woman out with her dog, which independently located and killed a nine-banded armadillo. The woman arrived to find the dog gnawing at the already-dead animal.

To measure the full impact of human hunting on prey populations, data on animals that were injured but not killed are important (Redford and Robinson 1990). Collecting data on injured animals was somewhat challenging because of the reporting biases noted earlier. Nevertheless, informants reported that they wounded several animals with rifles over the course of the study, including two tapirs, two collared peccaries, two white-lipped peccaries, one red brocket deer, one spider monkey, and two great tinamous. The extent of the injuries is not known, however, and it is therefore difficult to estimate the probability of surviving the wounds. In one case, hunters left the following day to track an injured tapir but reported no further signs of the animal. There is some indirect evidence that dogs were independently able to kill and consume smaller game, such as armadillos and agoutis, but it was not possible to confirm this.

Included in the tables are data on age and sex classes harvested by hunters in Arang Dak and Suma Pipi. These data build on work by Alvard (1995a), who found little evidence that Piro hunters selectively target age and sex types that minimize the impact on the long-term sustainability of prey populations, with adult females being particularly important to population replenishment. However, detailed examination of this hypothesis suffers from a lack of extensive data on the age and sex structures of Neotropical prey populations (Robinson and Redford 1994b; Leeuwenberg and Robinson 2000:380-381). The data presented here will therefore become more useful once the demographic structures of prey populations are better known, particularly with regard to the ways in which age and sex classes differ between hunted and unhunted areas (Robinson and Bodmer 1999).

In the interim, it is interesting to examine preliminarily some of the noteworthy age and sex-related characteristics of the harvest in Arang Dak and Suma Pipi. Many of the species for which there are adequate sample sizes (e.g. armadillo, paca) do not deviate substantially from a 100:100 sex ratio, which in the absence of contravening data represents the default estimate (Bodmer and Robinson 2005:312). Among the notable exceptions are agoutis, iguanas, tapirs, and red brocket deer. A biased harvest ratio for iguanas is not unexpected given the vulnerability of females during the egg-laying season, and the ratio of males to females is 5:33 during March and April and 12:5 during all other months. More unusual is the biased harvest of female agoutis, which differs significantly from a 100:100 sex ratio ($\chi^2 = 36.302$; $df=1$; $p < 0.001$). A female-biased agouti harvest was also reported by Jorgenson (2000) for hunters in Quintana Roo, Mexico, but the departure from an even sex ratio was not statistically significant. By contrast,

Souza-Mazurek et al. (2000) report a male-based agouti harvest in Brazil, and it remains difficult to determine the extent to which sex ratios of harvests are mediated by hunting technologies and differences in prey populations. Given that 96% of the agoutis in the combined sample were first detected by dogs, it may be that dogs are particularly adept at locating and corralling females (and their offspring in some cases), although a test of this hypothesis requires additional evidence on the actual sex ratio of the prey population.

Harvests of red brocket deer in the Neotropics likewise exhibit some variability, as Alvard (1995a:799) reports a female-biased sex ratio in the Piro harvest while Branan and Marchinton (1987:346) report a sex ratio that more closely approximates equivalence. The harvest in Arang Dak and Suma Pipi is also biased toward females, and the sample is significantly different from a 100:100 ratio ($\chi^2 = 5.556$; $df = 1$; $p = 0.02$). This bias seems to transcend differences in hunting technology, as 75% of the red brocket deer first detected by dogs ($n = 8$) were female while 80% of the deer first detected by the hunters were female ($n = 10$). It appears that some other trait makes female deer more likely to be killed than males. The opposite holds true for tapirs, as males constitute 71% of the combined sample. Unlike red brocket deer, however, this result is not statistically significant at the 0.05 level ($\chi^2 = 2.571$; $df = 1$; $p = 0.11$). If this ratio held constant with additional kills, it could potentially represent a harvesting bias that promotes conservation of one of the more easily overhunted species in the reserve. It does not appear that the Mayangna and Miskito are intentionally attempting to conserve this species, however, as all tapirs were pursued upon encounter during the study period.

In general, hunting with dogs may effectively preclude selectivity on the part of the hunters. Especially in the case of animals trapped in burrows or trunks, hunters initially have little inkling of their prey's age and sex. Even if hunters with dogs were inclined to focus only on males, the costs of doing so might be prohibitive given that they invest considerable pursuit time before they can successfully identify the sex of the animal. On observed hunts, no hunter cited the age or sex of an animal as a reason to abandon a pursuit, and I tentatively conclude that the harvest reflects the proportion of age and sex classes in the prey population (particularly as they are represented in the hunting zone) combined with their susceptibility to being detected and corralled by dogs. As noted, the absence of sound data on the distribution of age and sex classes in prey species precludes a rigorous test of this hypothesis.

4.3 *Harvest data by technology*

In comparing the harvests of Suma Pipi and Arang Dak, it is noteworthy that the former seems more oriented toward rifle hunting instead of hunting with dogs. All of the specimens in the four species that contribute the most biomass to the Suma Pipi (i.e. white-lipped peccary, tapir, white-tailed deer, and red brocket deer) were killed without the assistance of dogs. The lone collared peccary in the Suma Pipi sample was also killed by a rifle hunter without dogs, which means that dogs assisted in none of the large ungulate kills by residents of Suma Pipi. Closer examination reveals that all of the ungulates except for one red brocket deer in the Suma Pipi were killed with the same rifle, which was shared by two brothers. The people in Suma Pipi are not averse to using hunting dogs, but the study period appears to have occurred at a time when there were few serviceable dogs in the community. Two dogs that were responsible for locating all three of the armadillos and almost half of the thirteen agoutis in the Suma Pipi harvest died in February 2005, after which the dogs' owner killed no other mammalian prey during the remainder of the study period. Other than those two dogs, only one other dog in the community was credited with detecting and corralling prey items (agoutis and pacas primarily). The owner of the aforementioned rifle also purchased a reputed hunting dog from a nearby community in November 2004, but the dog was returned to the seller soon thereafter when it failed to demonstrate any hunting prowess. In such a small community, such circumstances can have a disproportionate effect on harvest data, and I hesitate to conclude that hunting tactics and technology preferences in Suma Pipi differ considerably from those in Arang Dak. In general, many of the households in Suma Pipi do not hunt much, but the same can be said of several households in Arang Dak (figure 4.4).

Figure 4.4. Household harvest of consumed meat per day. Households from Arang Dak begin with the prefix “AD” while those from Suma Pipi begin with “SP.” Using kilograms per day accounts for the different amount of time that each community participated in the study.

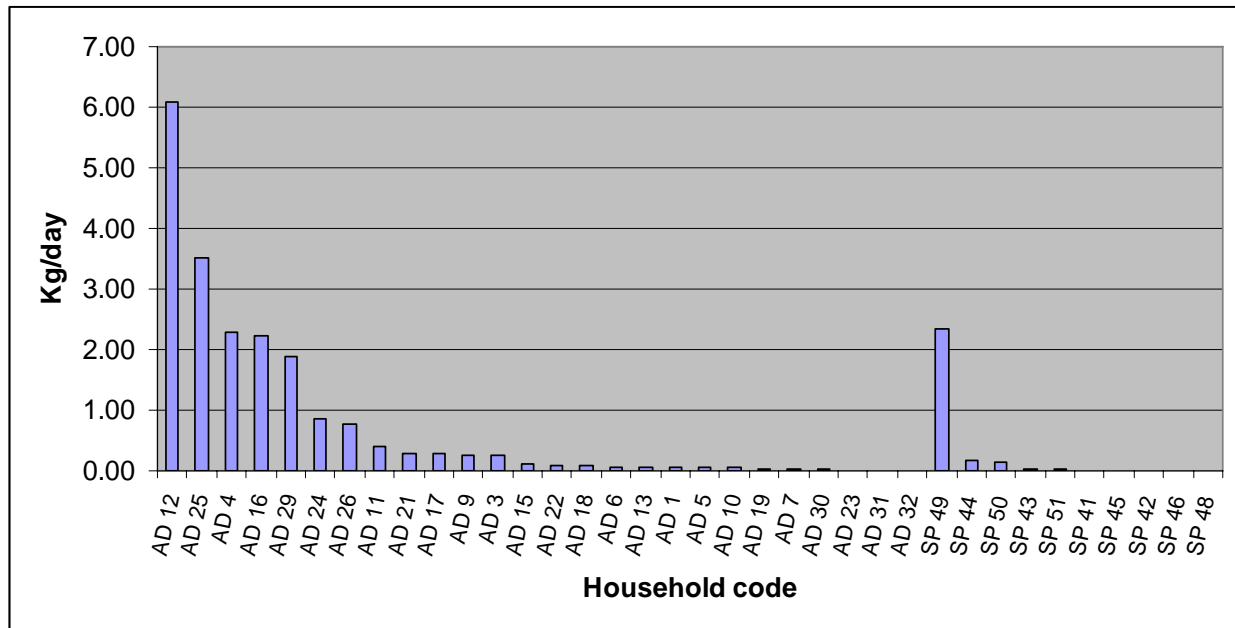


Table 4.3 details the technologies used to kill or capture all species in the combined harvest. The categories do not necessarily reflect the full suite of technologies available to the hunters at the time, only the technologies needed to detect and dispatch the animal. For example, while hunters with dogs also had rifles in many cases, the guns were seldom used for agouti kills, and the kills were therefore classified as “dog” kills. By contrast, the “dog and gun” category signifies that both technologies were instrumental in the kill. The “gun” category indicates that the animal was detected without the assistance of dogs and that rifles were the primary technology used for the kill. It is possible to make a gun kill even when hunting with dogs, as when hunters encounter and kill red brocket deer while their dogs are elsewhere. Finally, the “other” category applies to kills made without either guns or dogs, usually by hunters using machetes, slingshots, lances, or their bare hands. Two iguanas were excluded from the sample because it was not possible to identify the technologies used during the kills.

Table 4.3. Harvest of prey species by technology See text for details.

Species	Gun and dog	Dog	Gun	Other	Total
Agouti	4	345	11	3	363
Nine-banded armadillo	1	152	1	9	163
Paca	0	114	7	2	123
Iguana	0	30	11	14	55
Great tinamou	0	3	47	1	51
Collared peccary	17	19	3	1	40
Crested guan	0	0	39	0	39
White-lipped peccary	0	0	27	2	29
Great curassow	0	0	24	0	24
Red brocket deer	1	7	9	1	18
White-lipped mud turtle	0	0	0	15	15
Slider turtle	0	0	0	15	15
Baird's tapir	9	2	2	1	14
Spider monkey	0	0	14	0	14
Black wood turtle	0	1	0	9	10
Parrots	0	0	9	1	10
Doves	0	0	5	4	9
Unspecified turtles	0	0	0	9	9
Coati	6	0	2	0	8
Little tinamou	0	0	6	2	8
Chestnut-mandibled toucan	0	0	7	0	7
Plain chachalaca	0	0	7	0	7
Tawny-faced quail	0	0	7	0	7
Keel-billed toucan	0	0	5	1	6
Howler monkey	0	0	5	0	5
Variegated squirrel	0	0	4	1	5
Giant anteater	1	3	0	0	4
White-tailed deer	0	1	2	0	3
White-faced capuchin	0	0	3	0	3
Lineated woodpecker	0	0	3	0	3
Jaguar	2	1	0	0	3
Ocelot	1	0	1	0	2
Puma	0	0	2	0	2
Northern tamandua	0	2	0	0	2
Macaws	0	0	2	0	2
Boat-billed heron	0	0	1	1	2
Caiman	0	0	1	0	1
Northern raccoon	0	0	1	0	1
Greater grison	0	1	0	0	1
Unidentified bird	0	0	0	1	1
Slaty-breasted tinamou	0	0	1	0	1
Unidentified bird	0	0	1	0	1
Bare-throated tiger-heron	0	0	1	0	1
<i>Pato de monte</i>	0	0	1	0	1
Totals	42	681	272	93	1088

The data in Table 4.3 provide compelling evidence that kills of individual species are closely associated with certain technologies. Not surprisingly, rifles are the weapon of choice when targeting birds and arboreal prey (especially primates). Rifles were also the primary weapon used to kill white-lipped peccaries.⁸ By comparison, the three most commonly-killed species (agoutis, armadillos, and pacas) are almost overwhelmingly killed with dogs and hand technologies (e.g. machete). In total, dogs contributed to 85% of the kills of mammalian prey. Meanwhile, almost all turtles were captured with technologies other than dogs and guns. On the other hand, more than half of the iguanas were taken with dogs and hand technologies. The low number of kills for some species prevents a chi-square test of the entire distribution, but a sample separated by taxonomic class reveals a statistically significant deviation from random ($\chi^2 = 920.3$; $df = 6$; $p < 0.0001$; see table 4.4). Except when pursuing iguanas, it is clear that dogs are of minimal importance to pursuits of birds and reptiles.⁹

Table 4.4. Distribution of kills by technology and taxonomic class

	Gun and dog	Dog	Gun	Other
Mammals	42	647	94	20
Birds	0	3	166	11
Reptiles	0	31	12	62

Within the mammalian class, further generalizations can be made. As noted, dogs assume primary importance in the hunting of agoutis, pacas, and armadillos while primates and white-lipped peccaries remain the province of rifle hunters. The two species of deer are roughly divided between kills made with the assistance of dogs and those without. Collared peccaries likewise defy easy classification, as almost equal numbers were made with dogs and the combination of dogs and guns. It should be noted, however, that more than 75% (13 of 17) of the collared peccaries that were killed with dogs and guns had been corralled in burrows or trunks and probably could have been killed with technologies other than guns (hunters use guns in these circumstances to save themselves the trouble of fashioning a lance). Rifles appear to be more instrumental in kills of tapirs, one of the three species (along with coatis and jaguars) for

⁸ The two white-lipped peccaries in the “other” category were juveniles captured by hand shortly after their mother had been killed with a rifle.

⁹ Two of the three birds in the “dog” category were juvenile tinamous killed by a dog after their mother had fled from a hunter approaching with a rifle. The third was an older tinamou caught unawares by a pouncing dog.

which kills made with both guns and dogs comprise more than half of the sample.¹⁰ Compared with collared peccaries, tapirs more frequently turn and face off with the dogs in open air (including streambeds), which creates opportunities for hunters with rifles to shoot at the animals. The effectiveness of using both dogs and guns in the hunting of tapirs has been described elsewhere in this dissertation, and the data presented here reinforce this point.

The observation that hunted species are closely associated with certain technologies has interesting implications for conservationist agendas in the Neotropics. It has long been noted that shotguns allow hunters to increase the efficiency with which they target mammalian species that are especially susceptible to localized depletion, such as tapirs, white-lipped peccaries, and primates (Redford and Robinson 1987). The data from this study indicate that rifles are likewise effective in the hunting of these species, and the influx of additional rifles into the reserve could increase the pressure on these vulnerable populations. By contrast, hunting dogs are especially effective in pursuits of four species (agoutis, armadillos, pacas, and collared peccaries) that can withstand a relatively high amount of hunting pressure and that seem to thrive in the patchwork of habitats in the agricultural zone (Jorgenson 2000; Smith 2005). Compared with rifle hunting, hunting with dogs therefore appears to align more closely with conservationist recommendations for sustainable hunting in the Neotropics. An important caveat to this generalization is that the combination of dogs and guns seems particularly detrimental to one of the reserve's more endangered species: tapirs. Dogs by themselves represent a relatively benign hunting technology, but in combination with modern firearms they constitute a more potent threat to the tapir population. Dogs also lead to the killing of some rare species that would otherwise be ignored by hunters, including giant anteaters, northern tamanduas, and greater grison.

4.4 Seasonality in the harvest

Researchers in the Neotropics have reported seasonal variation in the species composition of wildlife harvests (Yost and Kelley 1983:218; Hill et al. 1984; Souza-Mazurek et al. 2000:586). There are a number of reasons why the harvest of a species could vary over time, including migratory, subsistence, and breeding patterns of the species in question along with

¹⁰ The classification is a little deceptive in the case of jaguars, as the felines are the ones that typically seek out and pursue the dogs (as opposed to the opposite). Two of the jaguars were killed when a hunter with a rifle came to his dogs' defense.

changes in hunting tactics, patch choice, time devoted to hunting, and the availability of other prey. Table 4.5 includes month-to-month data on the number of specimens taken by hunters in Arang Dak, the community for which I have a full year of data. The table focuses on regularly-consumed species that contributed more than 100 kg of undressed biomass to the harvest in Arang Dak. The table also includes cumulative figures on the number of animals harvested in the dry season (January-May) and rainy season (June-December). Table 4.6 presents results of chi-square analysis that tests whether species are disproportionately harvested in either the dry season or rainy season.

The most striking result from this analysis is the inordinate number of iguanas harvested in March. As noted earlier, egg-bearing females are especially easy to harvest with dogs when they come to the river's edge in March. Iguanas contribute more to the diet in March than they do in all other months combined. The other particularly noteworthy result is the absence of temporal variation in the harvesting of collared peccaries. Whereas white-lipped peccaries are killed in less than half of the months in the sample, at least one collared peccary was killed in every month. These data thus support the general observation that collared peccaries are a "reliable" source of game while the white-lipped peccary is in some sense "unreliable" (Vickers 1984:372). Despite their unpredictability in comparison to collared peccaries, though, white-lipped peccaries contribute a comparable amount of meat (as seen in Table 4.1).

In general, the data in Table 4.5 correspond to similar data on harvests in a neighboring territory, Mayangna Sauni Bu (Gros et al. 2004). For example, these data from the Saint Louis Zoo's *Proyecto Biodiversidad* also show a decline in the harvest of armadillos in March, April, and May. The harvest of collared peccaries likewise exhibits a fairly constant temporal distribution in Mayangna Sauni Bu. The main difference between the datasets is the harvest of pacas during the dry season. The Zoo's data indicate that fewer pacas were harvested in March and April than in any other month while my study shows that the harvest of pacas actually peaks

Table 4.5. Monthly harvest of the eight species that contributed more than 100 kg of biomass to the harvest in Arang Dak (September 1, 2004 - August 31, 2005). Species that were not consumed (jaguar, giant anteater) are not included in the table. Species are listed in rank order of biomass contributed to the diet, although the figures refer only to the number of harvested specimens. The final two columns are cumulative totals for the dry season (January-May) and the rainy season (June-December). Numbers in parentheses for armadillos indicate the number of animals that weighed more than 2 kilograms. Armadillos weighing 2 kg or less were typically killed in groups of three or four along with their mother.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Dry	Rainy
Tapir	0	3	2	0	3	1	1	1	0	0	0	2	8	5
Agouti	21	24	14	19	37	50	62	31	20	21	31	20	115	235
Paca	9	19	22	9	6	6	9	6	7	7	5	11	65	51
Collared peccary	6	2	3	4	3	2	1	4	3	4	5	2	18	21
White-lipped peccary	5	0	3	4	0	0	0	0	0	6	0	2	12	8
Armadillo	10	17	8	2	5	8	25 (14)	30 (19)	15 (13)	15 (14)	7	18 (17)	42	118 (77)
Red brocket deer	1	2	2	3	1	1	0	0	0	1	2	2	9	6
Iguana	1	1	33	4	9	0	1	1	4	0	0	1	48	7

Table 4.6. Comparison of dry season and rainy season harvests. Expected values for dry season and rainy season harvests were calculated by multiplying the total number of animals harvested by the number of months in the season divided by twelve, the number of months in the year. For example, the null hypothesis assumes that 41.67% of the 13 tapirs in the sample would be taken in the five-month dry season while 58.33% would be taken in the seven-month rainy season. The chi-square analysis tests deviations from this distribution. The category “season” denotes species that are disproportionately harvested in either the rainy season or the dry season, assuming $p < 0.05$. The test of armadillos includes only specimens that weigh more than 2 kg (cf. Table 4.5).

Species	Dry	Rainy	Dry expected	Rainy expected	Chi-square	p	Season
Tapir	8	5	5.4	7.6	2.141	0.14	
Agouti	115	235	145.8	204.2	11.152	< 0.01	Rainy
Paca	65	51	48.3	67.7	9.894	< 0.01	Dry
Collared peccary	18	21	16.25	22.75	0.323	0.57	
White-lipped peccary	12	8	8.3	11.7	2.819	0.09	
Armadillo	42	77	49.6	69.4	1.997	0.16	
Red brocket deer	9	6	6.3	8.8	2.074	0.15	
Iguana	48	7	22.9	32.1	47.138	< 0.0001	Dry

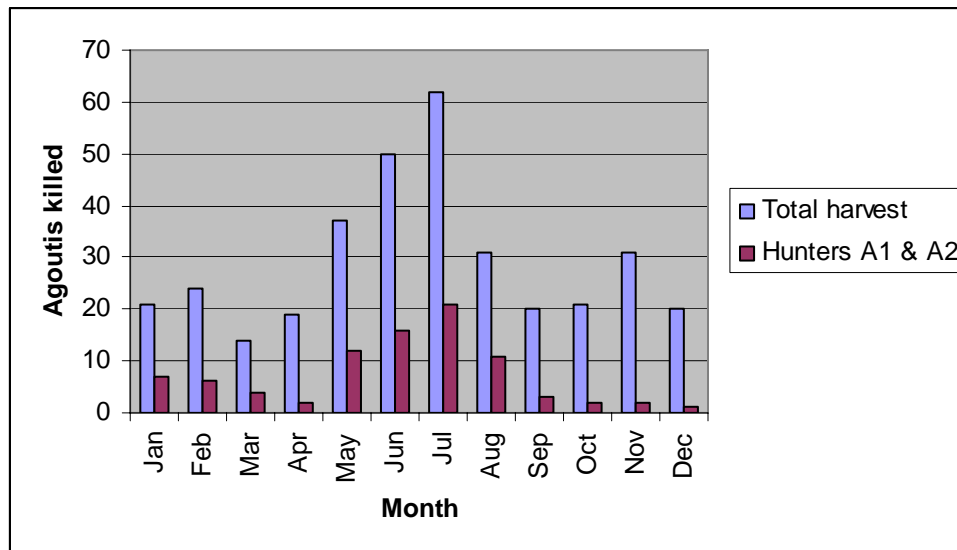
in March. There appears to be no immediate explanation for this discrepancy, although methodological differences could be a factor. Nine of the twenty-two pacas from March in my study were killed upstream of Arang Dak by hunters on multi-day *giras* or when working on fields far from the community – two settings that were particularly challenging for data collection in the zoo’s project (Orlando Dixon, personal communication, October 2004). The elevated harvest of pacas in the dry season corresponds to a much higher encounter rate of pacas on observed hunts with dogs: 0.22 paca encounters/hour during the dry season ($n = 63.6$ hours) versus 0.06 encounters/hour during the rainy season ($n = 79.9$ hours). Also noteworthy is the fact that just two dogs were credited with locating sixteen of the twenty-two (72%) pacas harvested in March. These same two dogs also assisted in the capture of almost half (48%) of the 33 iguanas captured in March. Given that iguanas and pacas can be found in close proximity at that time (with paca burrows being especially common in the gallery forest near the river), it may be that their owners found it especially advantageous to deploy these dogs in this particular biotope, thereby resulting in elevated harvests of both species. In general, these two dogs seemed unusually good at finding game near the river while their owners remained waiting in the boat, and communities without comparable dogs might harvest fewer pacas at this time of year.

Along with iguanas and pacas, agoutis were one of the three species to exhibit significant seasonality (Table 4.6). Unlike the other two species, though, agoutis are disproportionately harvested in the rainy season. Encounter rates again correspond to the increased harvest of agoutis at this time, as hunters with dogs on observed hunts encountered this species at a rate of 0.22 agoutis/hour during the dry season ($n = 63.6$ hours) compared to 0.43 agoutis/hour during the rainy season ($n = 79.9$ hours). It may be that agoutis are more easily detected by dogs in the rainy season, thus contributing to the disproportionate harvest. A number of other factors are no doubt important as well, however, and a look at the monthly breakdown of agouti kills by the eight most prolific families in Arang Dak provides further insight into the seasonal variation of the harvest (Table 4.7). For example, hunter H acquired a new hunting dog in late May, 2005, which provided him a fairly consistent supply of agoutis until the end of the study in August. By contrast, the dog shared by hunters F1 and F2 was killed by a jaguar in mid-April, and their only kill for the remainder of the study was an opportunistic kill of an agouti caught swimming in the river. Also interesting is the way in which the agouti kills of hunters A1 and A2 impact the overall harvest (Figure 4.5). Together, these two hunters account for almost 25% of the agoutis

Table 4.7. Monthly harvest of agoutis by family in Arang Dak. Cases in which two adult hunters from the same household share the use of hunting dogs are denoted with numerical suffixes (e.g. hunter A1 and A2 from household AD 29). Together these eight families killed 91% ($n = 320$) of the 350 agoutis taken by residents of Arang Dak during the study period (September 1, 2004 – August 31, 2005).

Household code	Hunter ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
AD 29	Hunters A1 & A2	7	6	4	2	12	16	21	11	3	2	2	1	87
AD 12	Hunter B	1	1	0	7	10	6	7	3	4	8	7	7	61
AD 4	Hunters C1 & C2	3	3	4	6	5	7	9	0	3	0	1	2	43
AD 25	Hunter D	1	3	0	2	3	6	5	8	2	3	1	1	35
AD 16	Hunter E	0	1	1	1	4	7	10	2	2	2	2	0	32
AD 11	Hunters F1 & F2	4	5	4	1	0	0	1	0	3	3	7	2	30
AD 24	Hunters G1 & G2	4	3	0	0	0	0	0	0	2	2	2	4	17
AD 17	Hunter H	0	0	0	0	1	3	7	4	0	0	0	0	15
Total		21	24	14	19	37	50	62	31	20	21	31	20	350

Figure 4.5. Comparison of the monthly agouti harvest in Arang Dak and the agouti kills made by two hunters (a father and son) from Family A. Note that the total harvest includes the kills made by these two hunters, and the figures for hunters A1 and A2 can therefore be interpreted as a percentage of the total harvest.



killed by residents of Arang Dak. That percentage jumps to 33% of the agouti kills made from May-August, a period when their juvenile dogs began to demonstrate the ability to locate and corral agoutis. The family also acquired an additional hunting dog in June, which contributed to their agouti kills (in addition to creating a need for more meat, which was accentuated at the time by the failing rice crop). By contrast, this family recorded only 11% of the agouti kills in April, a month in which the elder of the two hunters spends much of his time working as a hired laborer by clearing fields with his chainsaw. Even without the kills made by this family, however, the agouti harvest still exhibits a peak in June and July and a significantly disproportionate harvest in the rainy season ($\chi^2 = 10.252$; $p < 0.01$; $df = 1$). While there may be a legitimate increase in the availability or vulnerability of agoutis during the rainy season, factors such as hunters' time allocation to subsistence tasks (including hunting) and the acquisition and development of hunting dogs cannot be overlooked as possible sources of variation in the seasonal harvest of agoutis.

4.5 Cross-cultural perspectives on the harvest of mammals in Arang Dak and Suma Pipi

In recent decades, there have been several quantitative reviews of Neotropical hunting harvests, particularly with respect to the composition of mammalian game in the harvest (Beckerman and Sussenbach 1983; Vickers 1984; Redford and Robinson 1987; Jerozolinski and Peres 2003). Each review adopts a unique approach to the topic, but there is considerable agreement on the important factors affecting the composition of the harvest. The authors are generally unanimous in their opinion that hunting technologies, the age of settlements, food taboos, the availability of other sources of dietary fat and protein, and differences in the composition and density of available fauna can affect the proportions of mammalian species in the harvest. The reviews also agree that Neotropical groups typically exhibit preferences for large-bodied prey species, as predicted by optimal foraging theory (Jerozolinski and Peres 2003:420). To gauge how the harvest in Suma Pipi and Arang Dak conforms to general trends observed elsewhere in the Neotropics, I compare harvest data from this study to cross-cultural data collected by Vickers (1984) and Redford and Robinson (1987). It should be noted that the data used in both reviews come from settings that differ dramatically in the factors noted above

(e.g. technologies, taboos, animal abundance, etc.) and that such cross-cultural reviews necessarily mask much of the variability in the sample.

Vickers's review examines the extent to which different types of game species are important to harvests, both numerically and in terms of biomass. His review deviates from a strict taxonomic categorization of important prey species in the Neotropics by combining rodents and lagomorphs while distinguishing between deer and peccaries (both Artiodactyla). Vickers also distinguishes between indigenous and mestizo societies, although he also provides aggregate data for all societies in the sample. For this comparison, I retain this distinction while noting that the mestizo societies in the sample generally consume fewer carnivores and primates than their indigenous counterparts. From my own data I include only animals that were consumed, thus excluding most of the carnivores and some of the edentates killed during the study period. Quantitative harvest data are converted into rank order.

Table 4.8 presents results of the comparison. In some ways the harvest in Arang Dak and Suma Pipi differs little from the cross-cultural sample. Both in terms of numbers taken and biomass, the respective importance of tapirs and carnivores is reasonably consistent, with the former being a large contributor to the overall biomass while the latter ranks last in both the cross-cultural sample and the harvest in Arang Dak and Suma Pipi. Among the noteworthy differences are the relative importance of rodents and lagomorphs and the relative unimportance of primates and peccaries in the Arang Dak and Suma Pipi harvest. Rodents and lagomorphs outrank all other categories in terms of numbers and trail only tapirs in terms of biomass contributed to the diet. In both cases, they rank two spots higher than the average from the cross-cultural sample. I have previously called attention to the integral role of hunting dogs in the elevated harvest of pacas and agoutis in Bosawas, so it is interesting to note that dogs appear relatively unimportant to the other two societies in the cross-cultural sample for which harvests of rodents and lagomorphs exceed the average rank: the Bari and the Ye'kwana. The Bari lacked dogs altogether (Beckerman 1980) while dogs seemed to be a hindrance for Ye'kwana hunters (Raymond Hames, personal communication, May 2004). Many of the rodents in the Ye'kwana sample are pacas taken at night with shotguns (Hames 1979a:239).

Primates appear to be more important to other societies than they are to the Mayangna and Miskito. In Arang Dak and Suma Pipi, primates outrank only carnivores in terms of edible biomass while they trail only peccaries and tapirs in the cross-cultural sample. To some extent,

Table 4.8. The rank order of mammalian game in Arang Dak and Suma Pipi compared to a cross-cultural sample of eight indigenous Neotropical groups compiled by Vickers (1984)

Prey type	Number consumed	Rank (this study)	Cross-cultural rank	Consumed biomass	Rank (this study)	Cross-cultural rank
Tapir	14	6	6	2504.5	1	2
Rodents and lagomorphs	491	1	3	1965.51	2	4
Peccaries	69	3	1	1755.1	3	1
Edentates	163	2	4	671.4	4	5
Deer	21	5	7	405.3	5	6
Primates	22	4	2	139.5	6	3
Carnivores	8	7	5	44.8	7	7

this difference can be explained by the availability of primate prey. Bosawas lacks primate genera that are important to hunters elsewhere in the Neotropics, particularly woolly monkeys, which were the most frequently killed animal in the Waorani sample (Yost and Kelley 1983:210). However, with three primate species, Bosawas possesses more primate diversity than the hunting zones of the Aché, which has both capuchin monkeys and howler monkeys but lacks spider monkeys. Nevertheless, primates outrank all other categories of prey species in the Aché sample (Vickers 1984:371), suggesting that the unimportance of primates in the Mayangna and Miskito harvest cannot be attributed only to a lack of species diversity. Aversions to the meat of capuchin monkeys and howler monkeys, the absence of suitable habitat in the immediate vicinity of the communities, and the relative lack of hunting technologies suited for arboreal prey probably contribute to the unimportance of primates in Arang Dak and Suma Pipi.

In the cross-cultural sample, peccaries rank first both in terms of numbers and harvested biomass. By contrast, they rank third in Arang Dak and Suma Pipi, and the relative unimportance (for lack of a better word) appears to stem from the low ratio of white-lipped peccaries to collared peccaries in the harvest. In Arang Dak and Suma Pipi, white-lipped peccaries contribute 55% of the peccary biomass while the lowest percentage for any society (the Siona-Secoya) in the Vickers sample is 58.7% (1984:373). The average ratio for the eight indigenous societies in the sample is 77.35% white-lipped peccary meat to 22.65% collared peccary meat.¹¹ In other words, the average society in the Vickers sample appears to harvest three times as much white-lipped peccary meat as collared peccary meat. As with primates, the relative unimportance of white-lipped peccaries in Suma Pipi and Arang Dak could stem from a number of factors, including the absence of appropriate habitat near the communities, generally lower densities when compared to forests elsewhere, and the availability of preferable alternatives. As noted in Chapter 3, the per hour return rates of Mayangna and Miskito hunters are higher than most in the Neotropics, and their success on shorter day hunts near the community perhaps obviates the need for lengthier expeditions into the forest in search of white-lipped peccaries.

A comparison with data presented by Redford and Robinson (1987) provides further insight into the harvest of mammals by hunters in Arang Dak and Suma Pipi. Redford and

¹¹ A mistake in the percentages for the Ye'kwana data in Table VI (Vickers 1984) leads to a mistake in the overall average. The figure of 22.65% represents what appears to be the correct percentage after recalculating the numbers.

Robinson compile data from a number of Neotropical settings, including many of those used in the Vickers (1984) sample.¹² For each prey species, Redford and Robinson present data in terms of the number of animals killed per consumer-year. While they also present aggregate data on hunting by mestizo colonists, I again focus on the sample of indigenous societies. Redford and Robinson (1987:651) include sixteen indigenous societies, and I added to the dataset two subsequent studies that use the index of animals per consumer-year advocated by Redford and Robinson (Alvard 1993b:172; Souza-Mazurek et al. 2000:586). There are other datasets that could provide comparable data (e.g. Townsend 2000), but I include only those studies that specifically report data in terms of animals per consumer-year.¹³ Consumers are again defined as individuals who are at least three and a half years old (cf. Alvard 1995b). Although community membership fluctuated throughout the year, there were on average 158 consumers in Arang Dak and 59 in Suma Pipi.

Results of the comparison are presented in Table 4.9. Although the harvests of species in Arang Dak are generally within the range of variation reported elsewhere, most species were harvested at a rate lower than the Neotropical average. The only exceptions to this generalization are the two most commonly killed animals in the Arang Dak and Suma Pipi sample: agoutis and nine-banded armadillos. Agoutis are harvested at almost three times the Neotropical average (although they are still within the range of variation given by Redford and Robinson). By contrast, the harvest rate of nine-banded armadillos is closer to the Neotropical average (only 20% higher). All other species are harvested at a rate lower than average, and the difference is especially pronounced for primates. The harvest rates of spider monkeys in Arang Dak and Suma Pipi are only 12% of the Neotropical average while howler monkeys and capuchins are barely 5% of the average. In other words, the average consumer elsewhere in the Neotropics eats almost twenty times more howler and capuchin meat than does a typical consumer in Arang Dak or Suma Pipi. Given the oft-mentioned importance of hunting with dogs in Bosawas, it is noteworthy that the magnitude of difference appears less pronounced for those prey species that are more easily hunted with dogs. For example, pacas are harvested in Arang Dak at 75% of the Neotropical average – still lower than average but much less so than primates.

¹² Shortly before submitting this thesis, it came to my attention that Peres (2000b) has published updated averages.

¹³ There may be additional studies that use the suggested index. I did not conduct an exhaustive literature review and I include data from Alvard (1993b) and Souza-Mazurek (2000 et al.) to enhance the scope of the sample, not to imply that there are not other suitable datasets already in the literature.

Table 4.9. Comparison of the harvest rates (number of animals taken per consumer-year) of common mammalian prey to a cross-cultural sample of Neotropical societies compiled by Redford and Robinson (1987:Table 6), with additional data from the Piro of Peru (Alvard 1993b) and the Waimiri Atroari of Brazil (Souza-Mazurek et al. 2000).¹⁴

Common name	Scientific name	Range (including colonists) ¹⁵	Cross-cultural sample	Number in sample	Piro	Waimiri Atroari	Neotropical average	Arang Dak Suma Pipi Combined	Arang Dak	Suma Pipi ¹⁶
Squirrel	Sciurids	.007-6.00	2.057	5	0.26	?	1.758	0.025	0.032	0
White-lipped peccary	<i>Tayassu pecari</i>	.166-4.070	0.923	11	?	0.664	0.901	0.145	0.127	0.214
Paca	<i>Agouti paca</i>	.009-4.392	0.915	10	0.37	0.264	0.815	0.615	0.734	0.167
Nine-banded armadillo	<i>Dasyus novemcinctus</i>	.030-4.117	0.793	8	0.19	0.200	0.673	0.815	1.013	0.071
Collared peccary	<i>Tayassu tajacu</i>	.013-3.765	0.652	13	0.18	1.432	0.673	0.200	0.247	0.024
Agouti	<i>Dasyprocta</i> and <i>Myoprocta</i>	.007-4.006	0.639	15	0.60	0.348	0.620	1.815	2.215	0.309
Howler monkey	<i>Alouatta</i> spp.	.003-1.514	0.505	10	0.51	0.390	0.496	0.025	0.032	0.000
Spider monkey	<i>Ateles</i> spp.	.035-1.766	0.492	8	0.34	1.700	0.598	0.070	0.070	0.071
Capuchin monkey	<i>Cebus</i> spp.	.001-1.300	0.334	7	0.05	?	0.299	0.015	0.019	0
Tamandua ¹⁷	<i>Tamandua</i> spp.	.014-.740	0.183	6	0.00	0.008	0.138	0.010	0.013	0
Brocket deer	<i>Mazama</i> spp.	.016-1.486	0.175	7	0.41	0.112	0.194	0.090	0.095	0.071
Sloth	<i>Bradypus tridactylus</i>	.009-.243	0.077	5	0.00	?	0.064	0.000	0	0
Tapir	<i>Tapirus</i> spp.	.009-.122	0.049	9	0.18	0.520	0.104	0.070	0.082	0.024

¹⁴ A new estimate for the Neotropical average was calculated by adding the Piro and Waimiri Atroari data to the weighted averages from the Redford and Robinson cross-cultural sample. For each species, the number of studies in the Redford and Robinson sample varied, and the recalculations were based on the total number of studies in the expanded sample. For example, there were eight studies with paca data in the Redford and Robinson sample. The Piro and Waimiri Atroari data represent the ninth and tenth data point in the sample, so the recalculated average is based on these ten societies. Question marks indicate the absence of data in the additional studies, and averages were recalculated accordingly. For example, Alvard (1995b) reports that white-lipped peccaries are apparently absent from the Piro hunting zone (they were not encountered by Piro hunters). Therefore, only the Waimiri data are added to the sample, giving a total of 12 societies on which the average is based. I include zero values for sloths and tamanduas in Alvard's study because they were encountered but not pursued, much like sloths in Bosawas. In the Waimiri Atroari study, the presence or absence of squirrels, white capuchins, and sloths was not immediately apparent.

¹⁵ In addition to the sixteen indigenous societies included in their cross-cultural sample, Redford and Robinson (1987:Table 4) present the range of variation for all 22 communities in the sample, including six colonist societies.

¹⁶ The figures for Suma Pipi are likewise presented in terms of the animals taken per year. Per year estimates were calculated by dividing the observed harvest by the number of days that the community participated in the study (260) divided by 365. The estimate for the combined Arang Dak and Suma Pipi sample is based only on the 260 days that the latter participated, not the projected estimate for the year.

¹⁷ In the Arang Dak and Suma Pipi data, the figures for tamandua here reflect the number of animals killed, not the number consumed.

Tapirs, brocket deer, and collared peccaries are likewise closer to the average than are primates and white-lipped peccaries.

Together, these two comparisons with cross-cultural data provide a richer perspective on the hunting patterns in Arang Dak and Suma Pipi. The heavy reliance on agoutis, pacas, and armadillos in these communities is somewhat unusual. By contrast, the harvest of primates and white-lipped peccaries appears to be lower than normal, both in terms of absolute numbers harvested and as a proportion of the overall harvest. Much of the deviation from the typical Neotropical pattern appears to stem from technological differences, as most of the societies in the cross-cultural samples do not rely on hunting dogs to the extent that the Mayangna and Miskito do. Except for agoutis and armadillos, prey species around Arang Dak and Suma Pipi receive less hunting pressure per consumer than they do elsewhere in the Neotropics, but this difference is less pronounced for species that can be hunted with dogs (e.g. collared peccaries, tapirs, brocket deer). These latter species therefore comprise a larger percentage of the harvest in Arang Dak and Suma Pipi while species usually taken with firearms or other projectile technologies are proportionately more important to other groups.

4.6.1 Indigenous agriculture and the hunting landscape

Before examining the distribution of kill sites, the available habitats in the hunting zone merit some attention. While much of the Lakus River watershed remains forested, I focus primarily on the anthropogenic habitats created by agricultural labor. These anthropogenic habitats deserve special attention for several reasons. First, much of the hunting occurs in close proximity to the fields (and sometimes directly in the fields themselves). Second, many hunters combine hunting outings with agricultural tasks, and the timing of those tasks can dictate the areas in which they choose to hunt. Third, species differ dramatically in the extent to which they can exploit anthropogenic habitats. Some species such as armadillos and collared peccaries thrive in agricultural areas while others such as spider monkeys and white-lipped peccaries need primarily undisturbed forest (Linares 1976; Jorgenson 1995; Reid 1997). While studies in other disciplines have specifically examined the importance of these anthropogenic habitats in the overall hunting landscape (Escamilla et al. 2000; Daily et al. 2003; Smith 2005), anthropological investigations have given less attention to the effect that the heterogeneity of habitats has on

hunting patterns. For example, Hames (1991) and Alvard (1994) conclude from quantitative data that hunting contributes to localized depletion of prey species near human communities. While hunting is undoubtedly an important factor (perhaps the most important factor), it is hard to overlook the fact that the areas nearest the communities are generally characterized by a patchwork of agricultural and forested habitats. Because each of these habitats can attract and support a different suite of prey species, it is important to elaborate on the extent to which anthropogenic habitats characterize the hunting zone.

With his dissertation research on the ethnobotany of the Honduran Tawahka, House (1997) provides perhaps the most thorough examination of agricultural practices in the Mosquitia. In the interest of space, I omit some important details here, but this comparatively brief description provides a general overview of farming in Suma Pipi and Arang Dak. While I owe much of my background knowledge on agriculture in the Mosquitia to House (1997), Dodds (1998), and Stocks (1998), I also spent considerable time asking indigenous farmers about their perspectives on farming, with special attention given to the timing and geographic scope of agricultural activities. This investigation concluded with a formal questionnaire administered to twenty-one randomly selected male heads of household. The questionnaire focused on grain fields (beans, rice, corn) during the study period and the year before, with questions pertaining to site selection, inter-cropping, production, and agricultural succession.

There are essentially two growing seasons in Bosawas, one in the rainy season and one in the dry season. Beans and corn are the principal dry season crops, as residents take advantage of the low water to plant these grains on the exposed riverbank and alluvial floodplain. Fields are usually cleared from natural riverside vegetation or stands of bamboo, not primary forest. These dry season fields are not burned prior to planting, and beans and corn are allowed to grow from beneath the chopped up vegetation. Beans and corn are occasionally planted in the same field, either intermixed or in separate parcels. Clearing of the fields is primarily done by the owner of the field and his family, but 38% of respondents reported hiring non-family members to help clear a dry season field at some point in the previous two years. Planting beans requires little labor, as the seeds can be quickly thrown atop the soil. Planting corn is a more intensive process, and about half of the corn fields are planted with the help of hired laborers, often women. Both crops are harvested by family members as they ripen, a process that requires little outside assistance. There is some flexibility in the timing of the cultivation, as fields can be cleared and

planted as early as mid-December and as late as February. As noted by Helms (1971:132), the early arrival of heavy rains in late April or May can ruin bean crops that have not yet been harvested. Prolonged rainy weather in December and January can also dissuade farmers from planting beans and corn.

Farmers tend to clear dry season fields near their fields from the previous season. In some cases, farmers have a handful of parcels in close proximity, and they rotate bean and corn crops between these parcels. Suitable locations for new fields can sometimes be found only several miles away from the community, and families often relocate to an upstream *champa* for a few days to clear and plant fields and then to harvest the crop a couple months later. At that time, having nearby banana or plantain fields is advantageous, and farmers will often plant bananas after harvesting the beans and corn. The bananas will then be ready for consumption the following season when they arrive to plant a new field nearby. Some residents also maintain larger plantain and banana groves near their *champas*. These groves are exploited throughout the year, and some families visit these groves almost every Saturday to harvest several large *racimos* of bananas for use throughout the following week.

Shortly after planting beans and dry season corn, farmers turn their attention to clearing fields for the coming rainy season. Rice, a rainy season corn crop, and manioc are particularly important crops planted at the onset of the rainy season in May or June. Manioc is almost invariably planted in a *guamil*, a fallow field varying in age from 2-10 years since its most recent use. The *guamiles* require less labor to clear and burn, and manioc productivity suffers little from planting in a cleared fallow. By contrast, farmers in Arang Dak and Suma Pipi suggest that rice and corn thrive only in upland plots cleared from primary forest (cf. Dodds 1998:94). The selection of a promising site is of considerable importance, and residents can rattle off a fairly lengthy list of trees that are associated with good soils. Clearing these forest plots requires at least several days of labor, as farmers first clear out the underbrush with machetes and then fell the large trees with axes. For larger fields, hired laborers are often employed to help with this process, and especially ambitious farmers may hire the owner of the only chainsaw in the community to assist with the largest trees. Fields are burned sometime between March and May, depending on the whims and planting schedule of the owner, although there is often concern that heavy rains will arrive prematurely. In 2004, almost one-fourth of the households in the

community opted not to plant rice when the rains arrived before they were able to burn the field (they instead planted bananas).

Planting rice is a fairly laborious process, and large groups are formed to accomplish the chore in a matter of hours. Planting rice is the one agricultural task in which reciprocal labor (*biri biri* in Mayangna) remains very important, and the same work group can end up planting several fields together over consecutive days. Interestingly, the owner of the field is generally expected to provide lunch for the workers, and those farmers who are also regular hunters may deliberately look for game the day before a scheduled planting. In comparison, planting corn and manioc does not need to be timed so strictly, and this task is usually accomplished by small family groups and the occasional hired laborer. Multiple crops may be planted in the same field, including combinations of rice, corn, manioc, cocoyam, bananas or plantains, and sugarcane, but intermixing the crops is fairly rare except for the occasional planting of bananas in rice patches. Weeding of all fields is generally done by the owner or his offspring, but large groups are again formed in September and October to harvest the rice. Following the harvest of corn and rice, many farmers elect to plant bananas or plantains in the field. In July-August 2005, several farmers decided to plant manioc or bananas in their rice fields after the outbreak of rats decimated the crop before it could be harvested.

Technically, the Mayangna and Miskito enjoy usufruct rights to the land. That is, farmers can lay claim to a piece of forest only by clearing and cultivating it (as opposed to pre-established claims to the land). In practice, however, farmers prefer to clear new fields near their previous plots, and as a result there are clusters of fields in various stages of cultivation and regrowth, all belonging to the same farmer. Some minor disputes arise when one farmer believes that another is infringing on a forest patch near his fields – parcels that he himself plans to use someday. The river is an important landmark for some residents, and they lay informal claim to forest lands behind their current fields (i.e. areas farther inland from the river). Such concerns are becoming increasingly acute in the wake of the titling process for the indigenous territories, as some residents are convinced that the division of the territory into individually-owned parcels (or *fincas*) is an inevitable outgrowth of the process. Regardless of matters pertaining to legal ownership, however, residents advocate the practice of locating new fields near already-established holdings, not only for convenience but also because theft of crops is a chronic problem. If fields remain clustered and isolated from those of other households, then owners can

safely incriminate others who are spotted emerging from that area with crops. While these preferences and trends do not prevent farmers from beginning new fields in a previously unexploited area, almost all fields cleared during the study period were close to other parcels already cultivated by the same individual.

In total, residents of Arang Dak and Suma Pipi cleared 37.46 hectares of land for cultivation during the rainy season (i.e. this figure does not include land cleared for bean and corn crops in the dry season). Of this figure, between 20-27 hectares were cleared from primary forest.¹⁸ The fact that almost all of the land cleared from primary forest is located in the agricultural zone on the TNC territorial map attests to the patchy nature of the agricultural zone. In other words, there is still considerable forest in the agricultural zone. A breakdown of land use by crop reveals the emphasis on planting rice in plots cleared from primary forest (Table 4.10). For fields in which rice was planted (either alone or in combination with other crops), at least two-thirds of the land was cleared from primary forest. By contrast, 90% of the land cleared for manioc fields without an accompanying grain crop (i.e. rice or corn) came from a *guamil*.

While most hunting occurs in the primary forest, these fields and fallows are defining features of the hunting landscape. Some patches of forest exploited by hunters are close to fields, and the species they target are known crop-raiders that might be partaking of ripening grains or the ever-attractive manioc fields. By contrast, other species exhibit less tolerance of the patchy mix of forests, fields, and fallows in the agricultural zone, and hunters can be reasonably confident that they will not find these forest-dwelling species near the fields. Also, the agricultural calendar may affect the geographic distribution of kill sites at different times of the year. For example, hunters who relocate to an upstream *champa* during bean-planting season unsurprisingly hunt in nearby patches of forest when time allows. Even when staying in the community, hunters often choose routes that allow them to visit their fields at some point during the excursion, if only to pick up some bananas or manioc. These factors can have a noticeable effect on the geographic scope of hunting efforts around Suma Pipi and Arang Dak, and it is therefore important to account for the location of agricultural fields when examining the spatial distribution of kill sites around the communities.

¹⁸ Some fields were cleared from a fallow and a nearby patch of forest. Given the methodology, it was not possible to determine the exact percentages of *guamil* and forest in these fields.

Table 4.10. Land cleared for agricultural use, separated by crop or combinations of crops. In this table, the category “Number” refers to the number of fields with that particular crop or combination of crops. For each category of crop(s), the amount of land cleared from forest, *guamil* (fallow), or a combination of forest and *guamil* (i.e. mixed) is listed, as measured in hectares.

Crop(s)	Number	Forest	<i>Guamil</i>	Mixed	Total
Rice	6	1.00	0.87	0	1.87
Rice and manioc	4	0	1.64	0	1.64
Rice and bananas or sugarcane	4	1.43	0.58	0	2.01
Rice and corn	4	2.96	0	0	2.96
Rice, corn, and manioc or bananas	9	7.80	1.64	1.69	11.13
Corn	7	0.10	0.65	3.01	3.76
Corn and manioc	8	2.83	2.07	2.20	7.09
Corn and bananas or sugarcane	6	2.13	0.07	0.49	2.68
Bananas	5	0.72	0.15	0	0.86
Manioc	17	0.30	2.53	0	2.82
Manioc and bananas or sugarcane	3	0	0.28	0	0.28
Cocoyam	1	0.22	0	0	0.22
Unplanted	1	0.14	0	0	0.14
Total	75	19.61	10.48	7.375	37.46

4.6.2 *The geographic distribution of the harvest*

Like most Neotropical peoples, the Mayangna and Miskito are central place foragers in the sense that hunters depart from their communities to acquire game, which they then bring back to the community for cooking and consumption (Orians and Pearson 1979). Because transport costs near the community are relatively low, central place hunters can do better by hunting in nearby zones unless the benefits of distant patches outweigh the costs of traveling there. It is therefore not surprising that most kill sites are clustered around the communities within a radius of about 7-8 kilometers (Figure 4.6). Beyond that distance, most kill sites are located along the Lakus River or its main tributary, Mura Tingni. The river is likewise important closer to the communities, and 21% of the total biomass harvested by residents of Suma Pipi and Arang Dak comes from animals that were either swimming or standing in the shallows of the Lakus or Mura Tingni (including half of the 14 tapirs killed during the study period). An additional 13% of the biomass was acquired within 100 meters of the Lakus or Mura Tingni, including many pacas and armadillos killed in burrows along the riverbanks. In total, 28% of the animals killed during the study period were killed either in the river itself or within 100 meters of the water's edge.¹⁹

The land use zones on the TNC maps designed by Anthony Stocks in collaboration with the indigenous communities closely correspond to the observed distribution of kills, as almost 90% of the animals (representing 86% of the biomass) were taken in the agricultural zone or the hunting and plant collection zone (Table 4.11). By contrast, the infrequent hunting and conservation zones received much less hunting pressure, and most of the kills in these zones are located along the major rivers. A relatively high number of kills were made in Miskito Indian Tasbaika Kum, the indigenous territory located to the west of Kipla Sait Tasbaika. Of these kills, all but two were made in hunting or gold-panning areas located about three kilometers west of Arang Dak – a part of the reserve that is used by residents of both territories.

¹⁹ While such summary statistics are certainly prone to error given the imprecision of the sketch mapping methodology, I should note that kills made near the river were among the easiest to map, as assistants found it easy to ask informants to estimate how far they were from the water. That said, there were many other kills just outside the 100 meter buffer that might in reality have been within 100 meters.

Figure 4.6. Geographic distribution of kill sites

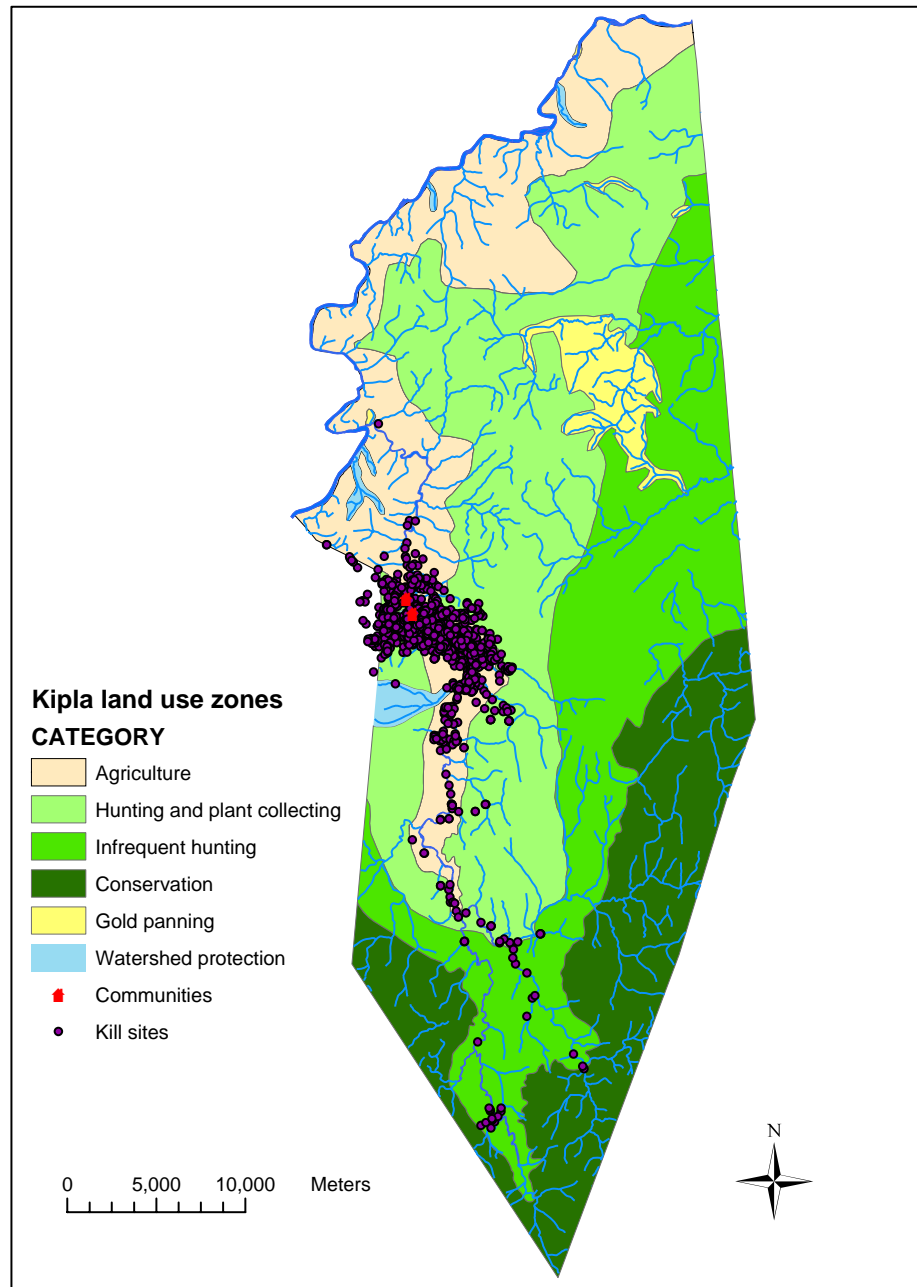
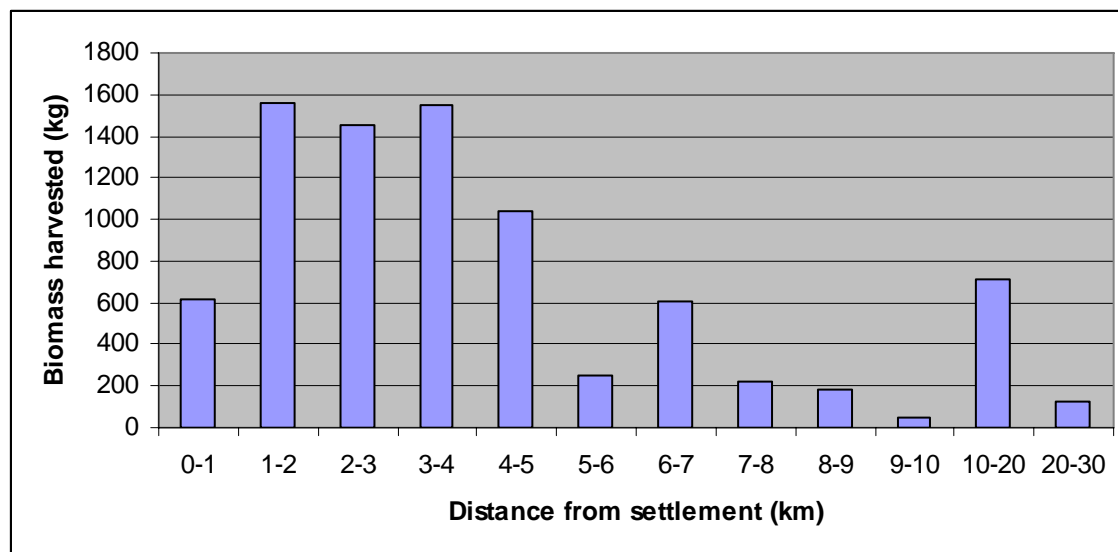


Table 4.11. Harvest by land use zone on the TNC maps

Land use zone	Number	Biomass (kg)
Agriculture	780	5195.0
Hunting and plant collecting	192	2020.5
Watershed protection	51	343.4
Infrequent hunting	28	316.5
Conservation	1	5.3
Gold-panning areas	0	0.0
Kills in Miskito Indian Tasbaika Kum	38	487.1
Total	1090	8367.8

Figure 4.7. Harvested biomass by distance from the hunter's community of origin. Note that not all intervals are equal in size, as distances beyond 10 kilometers are merged in the interest of space.



The clustering of kill sites around the communities is reflected in the amount of biomass harvested in distance intervals radiating outward from the villages (Figure 4.7). Almost 75% of the biomass is harvested within five kilometers of the hunters' home community, with a pronounced peak from 1-4 kilometers. This is also the range in which the most frequently harvested mammals are killed (Table 4.12). On average, agoutis, pacas, armadillos, red brocket deer, and collared peccaries are taken between 2-4 kilometers from the community. Many of the tapirs are taken in this range as well (the average distance for tapirs is skewed by one kill made about 19 kilometers from Arang Dak). Of the seven species that contribute the most biomass to the harvest in Arang Dak and Suma Pipi, only white-lipped peccaries are killed on average more than five kilometers from the communities.

There are a few other patterns in Table 4.12. While the three largest and most frequently killed game birds (great tinamous, crested guans, and curassows) are generally killed several kilometers from the community, most of the smaller bird species are taken less from less than two kilometers away on average. This pattern may reflect the observed tendency for hunters with guns to take smaller, less preferred game on their way back to the community after failing to find preferable prey earlier in the outing (Alvard 1994). Interestingly, this same pattern seems to characterize kills of howler monkeys and capuchin monkeys. Although the sample sizes are small, both of these primate species are killed on average less than two kilometers from the community, and almost all were taken later in the outing by men who were returning home. Given the general distaste for the meat of these two species, it is not particularly unusual that hunters treat them much like a low-ranked prey type despite their relatively large size.

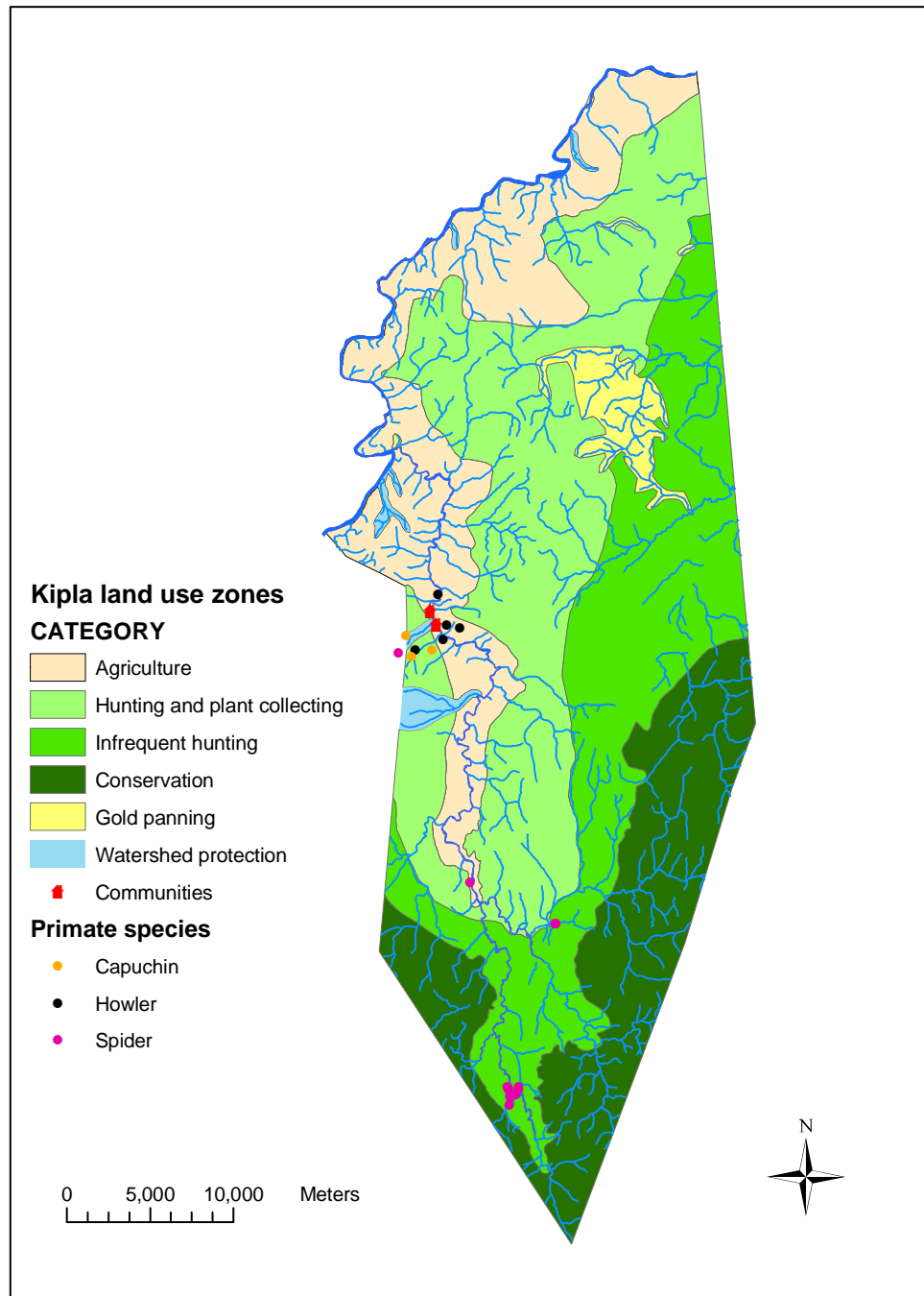
By contrast, the third primate species in the reserve is killed farther from the community than any other prey species (Figure 4.8). Spider monkeys are killed almost 24 kilometers from the community on average, and only one was taken less than five kilometers from Arang Dak and Suma Pipi. Nine of the fourteen spider monkeys taken during the study period were killed in an area of about 1 km². Eight of these nine were taken on a single upstream *gira* while the last was killed by a man from Arang Dak working on the territorial border with TNC staff.²⁰ The absence of suitable habitat closer to the communities may explain the large distance at which spider monkeys are killed, as Smith (2005:517) uses the distribution of kill sites in Panama to

²⁰ This man indicated that other spider monkeys were killed by members of the TNC work group, but these animals were taken by members of other communities and are therefore not included in this analysis.

Table 4.12. Average distance from kill sites to the hunter's community of origin, by species

Class	Species	Number	Distance (km)
Mammals	Variegated squirrel	5	0.974
	Howler monkey	5	1.360
	Northern tamandua	2	1.428
	Capuchin monkey	3	1.920
	Red brocket deer	18	2.134
	Coati	8	2.410
	Northern raccoon	1	2.605
	Agouti	363	2.947
	Puma	2	3.259
	Ocelot	2	3.416
	Collared peccary	40	3.452
	Nine-banded armadillo	163	3.484
	Paca	123	3.612
	Giant anteater	4	3.810
	Greater grison	1	3.942
	Jaguar	3	3.997
	Baird's tapir	14	4.697
	White-tailed deer	3	6.987
	White-lipped peccary	29	7.228
	Spider monkey	14	23.854
Reptiles	Caiman	1	1.126
	White-lipped mud turtle	15	4.296
	Iguana	57	4.543
	Unidentified turtles	9	4.724
	Slider turtle	15	6.411
	Black wood turtle	10	7.716
Birds	Plain chachalaca	7	1.165
	Slaty-breasted tinamou	1	1.205
	Lineated woodpecker	3	1.315
	Keel-billed toucan	6	1.371
	Doves	9	1.411
	Pico cuchara	2	1.471
	Macaws	2	1.736
	Parrots	10	1.867
	Bare-throated tiger-heron	1	1.956
	Chestnut-madibled toucan	7	2.340
	Little tinamou	8	2.562
	Great tinamou	51	4.052
	Tawny-faced quail	7	4.218
	Crested guan	39	5.579
	Great curassow	24	10.313

Figure 4.8. Geographic distribution of primate kills



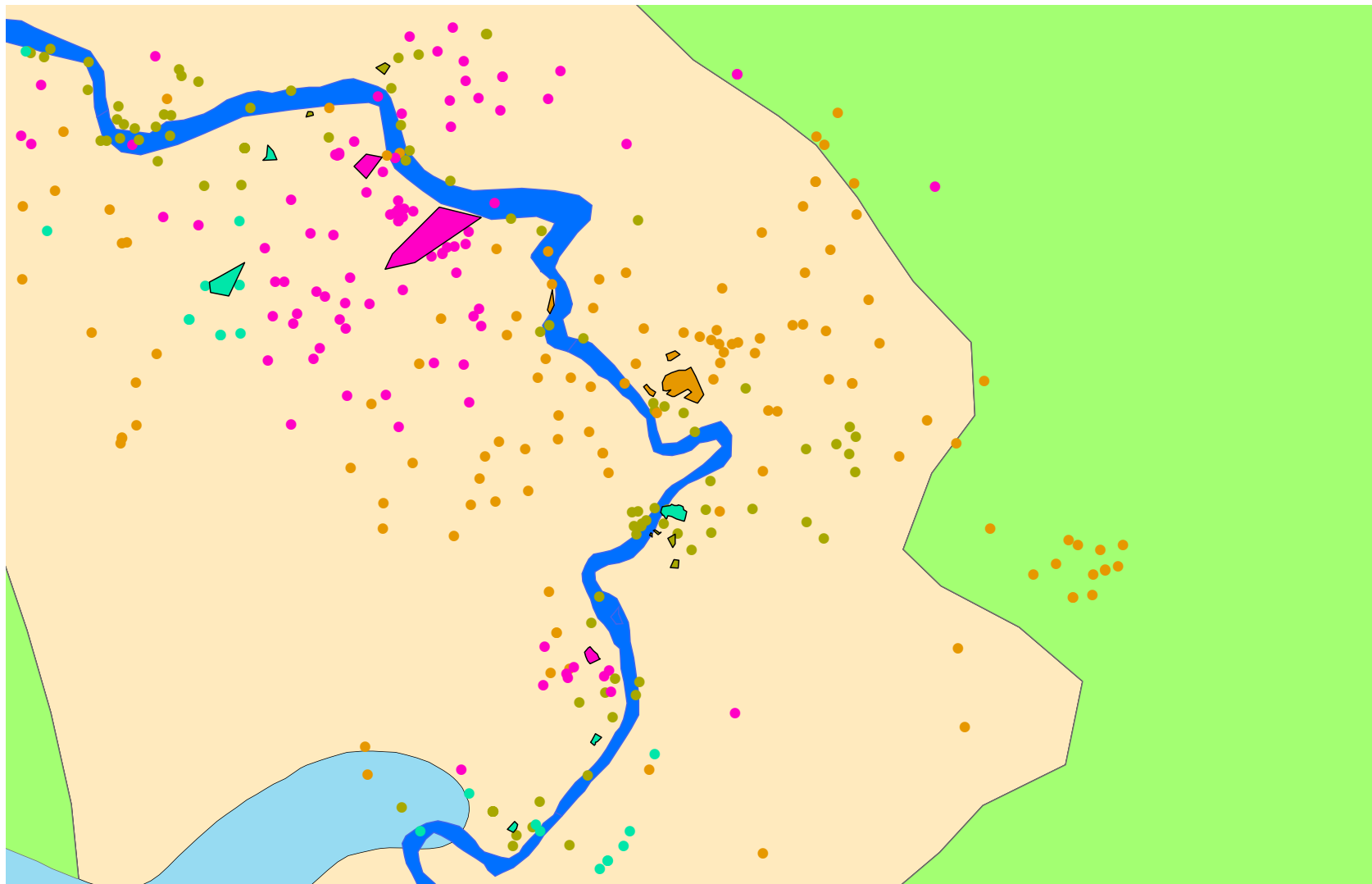
categorize spider monkeys as “deep forest game.” Smith likewise categorizes capuchin monkeys and howler monkeys as deep forest game whereas these two species are taken fairly close to agricultural areas around Arang Dak and Suma Pipi – all howler monkeys and capuchin monkeys killed during the study period were taken within one kilometer of a newly cultivated field. Even if spider monkeys exhibit less tolerance for patchy habitats, it is surprising that more specimens are not taken in the forested areas closer to the communities.²¹ On hunting trips in the frequent hunting zone, rifle hunters look closely for spider monkeys and attempt to lure groups with whistles. Although hunters report that spider monkeys could once be found in these areas, encounters were rare during the study period and it appears that the distribution of kills reflects the relative absence of this species near Arang Dak and Suma Pipi. Over-hunting of spider monkeys thus becomes a possible explanatory variable for their absence near the communities, as does general anti-predator behavior (i.e. avoiding areas that see regular human use).

Another interesting pattern was the extent to which individual hunters’ kill sites are clustered around their fields (Figure 4.9). While there is overlap in the individual distributions, there is noticeable clustering in all cases. This pattern reflects the tendency to combine hunting with other subsistence tasks, particularly agricultural activities. “Garden hunting” may also be partially responsible for the clustering around fields, as hunters combine their quest for game with the protection of their fields from crop-raiding species such as agoutis, pacas, and collared peccaries (Linares 1976). Assuming hunting return rates are roughly equivalent between nearby patches, there is little reason for hunters not to hunt near their fields, which reduces transport time to harvest crops and may help boost agricultural productivity by eliminating pests. Also, because boats are limited and other family members can work in the fields while the hunter searches for game, household members often travel together by boat to locations near the fields.

In general, the geographic distribution of kills supports prevailing thoughts on the spatial dimensions of Neotropical hunting. Kill sites are clustered around the communities (and kills of smaller prey types are particularly close), as predicted by central place foraging theory. Species

²¹ Reid (1997:40) comments that spider monkeys can survive in un hunted secondary forest.

Figure 4.9. Geographic distribution of four hunters' kills in relation to their fields. Kills (circles) made by hunters share a color with their fields (polygons).



that thrive in patchy habitats are commonly taken near agricultural areas surrounding the communities and along the river while species such as spider monkeys and white-lipped peccaries are harvested almost exclusively in forested areas farther from the villages. A new observation that has few parallels elsewhere in the Neotropical literature includes the tendency for kill sites to be disproportionately clustered around hunters' fields. Also interesting is the observation that howler monkeys and capuchin monkeys are harvested very close to the community while spider monkeys are killed farther from the community on average than any other prey species. If the distribution of kill sites reflects the densities of prey populations and, by extension, serves as evidence of game depletion, then one might conclude that the local spider monkey population is depleted while capuchin monkey and howler monkey populations exhibit no such depletion. This finding would be particularly interesting in light of the observation that hunters regularly bypass opportunities to pursue capuchin monkeys and howler monkeys, citing their poor taste (see Chapter 3). It could be that the hunters' disinterest in these species helps to explain their persistence in zones near the community while hunting preferences for spider monkeys contribute to their scarcity around Arang Dak and Suma Pipi. However, without additional data on the extent to which habitat differences affect primate population densities, it is difficult to reach anything but tentative conclusions on this matter.

4.7 The sustainability of subsistence hunting in the Neotropics

In the past two decades, the sustainability of hunting in tropical forests has been the subject of increased attention from conservation scientists (Robinson and Redford 1994*b*; Robinson and Bodmer 1999; Robinson and Bennett 2004). Wildlife management is increasingly important as the swift colonization of forested areas by groups with access to highly effective hunting technologies presents a threat to tropical biodiversity (Redford and Robinson 1987; Stearman 1990; Lopes and Ferrari 2000). Increased population growth and market involvement also put new demands on wildlife harvests by previously isolated indigenous groups (Stearman 2000). Concerns about the loss of biodiversity are especially pronounced in Africa and Asia, where habitat loss has combined with high hunting pressure to create a crisis situation (Milner-Gulland et al. 2003; Robinson and Bennett 2004). Many of these same factors are present in Latin America, however, and conservationists often discuss the best way to protect Neotropical

biodiversity. Scientists debate whether uninhabited nature preserves represent the best option or whether human residents with low-impact subsistence practices are the ideal stewards for the surrounding forests (Redford and Sanderson 2000; Schwartzman et al. 2000; Naughton-Treves et al. 2005). Restricting wildlife harvests by hunters located either within or outside of park boundaries is often difficult, however, as rural peoples frequently lack dietary substitutes for wild game (Bennett 2002; Milner-Gulland et al. 2003; Robinson and Bennett 2004). Given the poverty in many tropical nations, Balmford and Whitten (2003) contend that the costs of Neotropical conservation should be borne by industrialized countries in temperate climates, not by impoverished and marginalized groups dwelling in the forest with few economic alternatives.

While these general debates remain unresolved, conservation biologists have devoted considerable attention to evaluating the sustainability of wildlife harvests at the local level. Robinson and Redford (1994*b*) review the ways in which researchers have measured sustainability in Neotropical forests. These evaluations include comparisons of population densities between hunted and unhunted areas, with the assumption being that lower densities in hunted areas provide evidence of the extent to which prey populations are depleted. Because reduction of population density below carrying capacity can promote increased reproduction and juvenile survival, however, this measure actually yields little information on sustainability (Robinson and Redford 1994*b*:250). Longitudinal studies of changes in population density provide stronger evidence of effects caused by hunting, although population stochasticity can complicate assessments. Another measure proposed by Vickers (1991) is hunting yields, as measured in kills per man-hour of hunting time. While hunting yields between separate communities can provide some insight into the population composition of the surrounding method (e.g. Smith 1976), this method is more effective when examining hunting yield changes over time, as in Vickers's decade-long study (1991). Researchers using this measure of sustainability must account for possible demographic, economic, and technological changes in the hunting community, as these variables could have a decided effect on the motivations and capabilities of the hunters (Robinson and Redford 1994*b*:251). Another index of hunting sustainability is the age structure of the harvest, as juveniles generally make up a larger percentage of kills in heavily hunted populations (see section 4.2). Without additional data on the demographic characteristics of unhunted populations, the diagnostic power of this method is somewhat limited (Robinson and Redford 1994*b*:253).

The conservation literature also includes theoretical models that can be used to assess hunting sustainability. Two commonly-used models are the harvest model developed by Bodmer (1994) and the production model of Robinson and Redford (1991).²² Bodmer's harvest model requires data on densities and birth rates for prey populations to calculate production (number of individuals produced/km²). Actual harvests can then be compared to annual production, with the assumption that hunters can harvest 60% of the production for very short-lived species (those for which the age of last reproduction is less than 5 years), 40% of the production for short-lived species (those for which the age of last reproduction is between 5 and 10 years), and 20% of the production for long-lived species (those for which the age of last reproduction is greater than 10 years). Acquiring accurate data on population densities and the reproductive status of harvested females (used to estimate birth rates) is often beyond the scope of many projects, however, and Bodmer's harvest model has therefore been used less often than the production model of Robinson and Redford (1991).

Like Bodmer's model, the production model of Robinson and Redford (1991) incorporates estimates of population growth and population density. The difference is that Robinson and Redford (1991) use published estimates to create a more general model for use throughout the Neotropics. In a previous publication (Robinson and Redford 1986a), they compile from the literature the reproductive parameters needed to calculate the intrinsic rate of natural increase (r_{\max}) for thirty-nine mammalian species using Cole's equation (1954). They then generate estimates of annual production by combining these growth rate estimates with predicted density estimates derived from their review of density calculations by Neotropical biologists (Robinson and Redford 1986b). As in Bodmer's harvest model, Robinson and Redford (1991) assume that hunters can harvest 60% of the production for very short-lived species, 40% of the production of short-lived species, and 20% of the production of long-lived species. Harvests above that figure would almost certainly not be sustainable.

Although widely applicable, the Robinson and Redford production model is not without its weaknesses, many of which were noted by the authors themselves (1991). First, the model assumes that reproductive estimates drawn from captive individuals and predicted density estimates are characteristic of wildlife populations throughout the Neotropics (Robinson and

²² Both of these models involve a number of steps and assumptions, and they will therefore not be reproduced in their entirety.

Redford 1994b:255). Although the figures derived from these compiled datasets allow for a widely applicable model, the possibility remains that the characteristics of populations in a specific setting might differ substantially from the general estimate. Second, the model assumes that there is a predictable relationship between population density, production, and potential harvest. While density-dependent reproductive variation seems to be a general characteristic of tropical mammals, this relationship has not been conclusively demonstrated for most Neotropical species (Robinson and Redford 1991:425; Robinson and Bodmer 1999:5). Third, Cole's equation assumes no mortality in the population, which may be a dubious assumption in many settings (Slade et al. 1998; Milner-Gulland and Akçakaya 2001:689). Using r_{\max} instead of actual population growth rates might also lead to an overestimate of production (Milner-Gulland and Akçakaya 2001:687).

Recognizing the limitations of their model, Robinson and Redford (1994b:255) emphasize that the production model can be used only to evaluate whether an observed harvest is not sustainable. By contrast, harvest values below the predicted maximum sustainable yield (MSY) do not demonstrate that the harvest is definitely sustainable. Mortality in the population, lower than average population densities, or low birth rates could entail a MSY less than that predicted by the model. Robinson and Redford (1991:428) therefore encourage researchers to treat with caution any harvest that approaches the MSY. While the model may overestimate potential production in many cases, Peres (2000a:47) also points out that the model could also underestimate production if local densities exceed the averages drawn from the literature review. While the production model provides a worthwhile preliminary evaluation of hunting sustainability, researchers must therefore consider other evidence before reaching strong conclusions about the harvest of certain species.

4.8.1 *The sustainability of the harvest in Arang Dak and Suma Pipi*

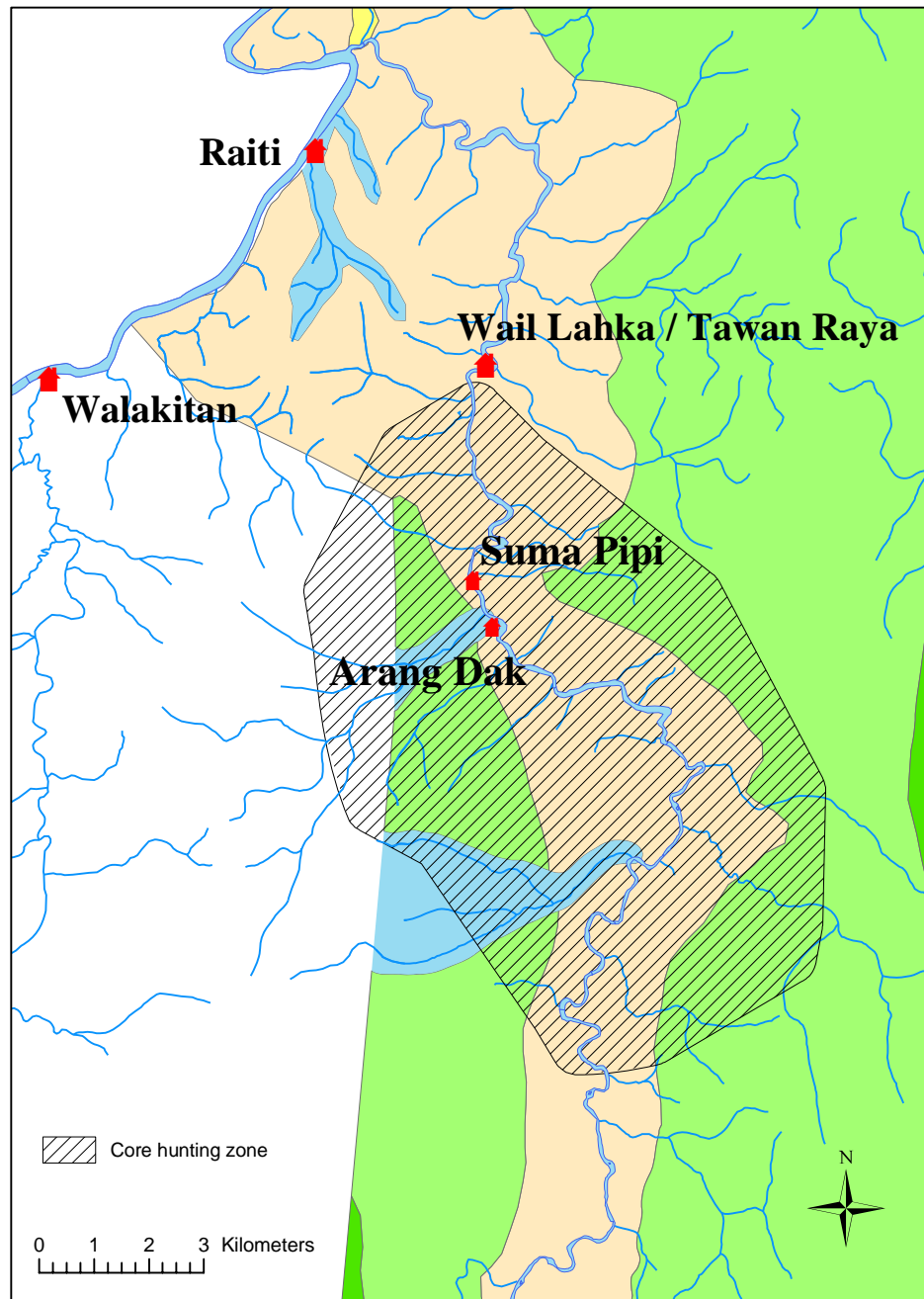
The Robinson and Redford (1991) production model presents the maximum sustainable yield (MSY) in terms of how many animals or how much biomass can be harvested per square kilometer). Therefore, in addition to the number and weight of animals harvested, the size of the hunting zone is also central to sustainability calculations. Alvard et al. (1997:979) calculated the size of the hunting zone around a Peruvian community by noting that Piro hunters ranged no

farther than 10 km from the community on daylong hunting trips, which was used to estimate a circular catchment area of 314 km² radiating outward from the community. The upper limit of 10 km is similar to that reported for other Neotropical groups, although there are exceptions for societies that embark on multi-day expeditions (Novaro et al. 2000:714). Vickers (1991:57-58) notes that the Siona-Secoya hunting zone around Shushufindi included a core zone that received the vast majority of hunting pressure while outlying areas received only intermittent or seasonal pressure.

To estimate the size of the hunting zone, I created a polygon in ArcGIS that encompassed all kills made by hunters on daylong hunting trips from Arang Dak or Suma Pipi. I then buffered this polygon an additional 500 meters to account for possible inaccuracies in the sketch mapping process. The result is an oblong polygon with an area of 77.6 km² (Figure 4.10). The shape of the core hunting zone seems to be dictated in large part by the course of the Lakus River, as the longest transverse across the zone has endpoints very near the river. That the zone extends farther south than north (in relation to the communities) is not too surprising given that most residents of Arang Dak in particular cultivate fields upstream of the community. There is no doubt some overlap with the hunting zones of neighboring communities, especially Wail Lahka and Tawan Raya, which are located just at the northern edge of the hunting zone for Arang Dak and Suma Pipi. Some families from the larger communities of Raiti and Walakitang have fields near the northwestern edge of the hunting zone, and they might also take animals from the hunting zone on occasion. According to the Saint Louis Zoo's *Proyecto Biodiversidad* data, though, these other communities generally hunt fewer animals than Arang Dak (Williams-Guillen et al. 2006). In general, it appears that residents of Arang Dak and Suma Pipi make most of the kills in the hunting zone, but the possible impact of these external pressures should not be overlooked when assessing sustainability. It is also worth mentioning that some families from Raiti maintain *fincas* several miles upstream of Arang Dak. While it is difficult to estimate the full extent of their hunting success, one family in particular often seemed to have wild game (including multiple ungulates) when passing through Arang Dak on their way to the Coco River.

Given that Suma Pipi participated in the study for less than a year, I estimated their annual harvest by projecting the observed harvest over an additional three and a half months. This method assumes that a household is equally likely to kill a particular species at all times of the year. This assumption may be unreasonable for some species, especially iguanas, which are

Figure 4.10. The core hunting zone around Arang Dak and Suma Pipi



harvested primarily in the dry season. Residents of Suma Pipi harvested only two iguanas during the study period, however, and it is not unreasonable to assume that they may have killed a third before entering the study period. I also make no allowances for white-lipped peccaries and tapirs although I am almost positive that none of these animals were killed by hunters in Suma Pipi in the three and a half months before they entered the study – the gifting and selling of meat to residents of Arang Dak would have alerted me had these large animals been killed at that time.

An additional methodological note is needed on the MSY estimates for white-faced capuchin monkeys and Baird's tapir, neither of which was included in the original model by Robinson and Redford (1991). Calculating an estimate for the capuchins was not problematic, as Robinson and Redford had included all the needed parameters in previous publications (1986a; 1986b). While they had published density estimates for Baird's tapir (1986b), their companion piece on reproductive parameters did not include the needed data for Baird's tapir (*Tapirus bairdii*), but only for South America's lowland tapir (*Tapirus terrestris*). Similarly, subsequent literature on hunting sustainability in Central America appears to lack MSY estimates for Baird's tapir using Robinson and Redford's methodology. I therefore resolved to calculate an estimate based on available data.

There has not been much literature published on Baird's tapir reproduction. Brown et al. (1994) provide some of the only data available on captive Baird's tapirs. Fortunately, these data suggest that the reproductive characteristics of Baird's tapir differ little from those of the lowland tapir. For the lowland tapir, Robinson and Redford (1986a) list 3.7 and 23.5 as the ages of first and last reproduction and 0.38 as the annual birth rate of female offspring. These figures differ little from estimates drawn from observations of captive Baird's tapir²³ (Janine Brown, personal communication, June 23, 2006). The maximum finite rate of natural increase (λ_{\max} in the Robinson and Redford model) would therefore be identical for the two species: 1.22.

Whereas calculations of annual production were reasonably straightforward, calculating the average density was a little more difficult. On the one hand, there are several estimates of Baird's tapir densities in relatively undisturbed habitats (compiled in Brooks et al. 1997). On the other hand, many of these estimates come from the oft-studied Barro Colorado Island in Panama's canal zone, which might not be the best analog for forests elsewhere in Central

²³ The female tapir featured in Brown et al. (1994) recently gave birth at the Miami Zoo as a 22-year-old. Baird's tapirs might bear offspring at ages beyond the 23.5 years cited by Robinson and Redford (1986a) for lowland tapirs. By using this estimate, I might be slightly underestimating the potential production of this species.

America (Glanz 1990). The remaining estimates of Baird's tapir densities come from Mexico, Belize, and Costa Rica, but these estimates vary widely, sometimes even at the same study site (Table 4.13). The highest estimate ($1.6/\text{km}^2$) is thirty-two times greater than the lowest estimate ($0.05/\text{km}^2$), and the maximum sustainable yield estimate varies by a similar factor depending on which estimate is used.²⁴ Given this variation, I elected to deviate from the methodology used by Robinson and Redford (1991). Because the harvest of tapirs in Arang Dak and Suma Pipi was so high, I wanted to determine whether the harvest would be unsustainable even under optimum conditions. Therefore, instead of using an average of density estimates, I used only the highest reported estimate in the literature. Using the density estimate of 1.6 tapirs/ km^2 provided by Foerster (2002) yielded a maximum sustainable harvest of 0.042 individuals/ km^2 . To calculate the maximum amount of biomass that can be harvested, one must multiply this latter figure by the average body mass of the species. I used the average of 300 kg cited by Robinson and Redford (1986b) despite the fact that the two specimens I was able to weigh during the study period (one adult male and one adult female) both had a body mass less than 200 kg. Using the larger estimate increases the maximum sustainable harvest estimate and, by extension, provides very strong evidence that the harvest is not sustainable if it exceeds this liberal estimate. In other words, the MSY estimate of 12.67 kg/ km^2 represents the highest possible sustainable harvest given the data in the literature. Because the average density and body mass of most tapir populations in Central America are probably lower than the figures used to generate this MSY estimate, observed harvests below this figure might also be unsustainable.

²⁴ Interestingly, the study site that yielded the highest estimate of 1.6 individuals per square kilometer is characterized by a high percentage of secondary forest – almost half of the area in the tapirs' home ranges (Foerster and Vaughan 2002). Other studies have reported higher-than-expected presence of tapirs in secondary forest (Naranjo 1995; Reyna-Hurtado and Tanner 2005), and it might be that Baird's tapirs exhibit unusually high densities in anthropogenic habitats.

Table 4.13. Reported densities of Baird's tapir elsewhere in Central America²⁵

Location	Density estimate (individuals / km ²)	Source
Corcovado National Park, Costa Rica	1.6	Foerster 2002
Corcovado National Park, Costa Rica	0.6	Naranjo 1995
Chiquibul, Belize	0.05-0.16	Fragoso 1991
Santa Rosa, Costa Rica	0.15-0.24	Williams 1984
Lacandon Forest, Mexico	0.24	Naranjo and Bodmer 2002

²⁵ Robinson and Redford (1986*b*) also list an average density of 0.5 individuals per square kilometer. However, they do not list the two sources used to calculate this average.

4.8.2 Sustainability assessment

As seen in Table 4.14, the hunters in Arang Dak and Suma Pipi appeared to harvest spider monkeys, pacas, and tapirs at rates above the maximum sustainable yield estimates given by Robinson and Redford (1991). Hunters harvested 1.35 kg/km² of spider monkey meat whereas the model predicts that harvests above 1.22 kg/km² are not sustainable. Similarly, the observed paca harvest of 11.84 kg/km² exceeds the maximum yield of 10.78 kg/km² given by the model. The tapir harvest is patently unsustainable even given the generous assumptions noted above, as the observed harvest is more than twice the maximum sustainable yield. While the model cannot demonstrate that harvests of other species are definitely sustainable, only agoutis and white-lipped peccaries were harvested at more than half the maximum sustainable yield. Despite being the second most commonly killed prey species, nine-banded armadillos were harvested at only 47% of the maximum sustainable yield.

Of the three species that appear to be harvested unsustainably, pacas are perhaps the most surprising. This rodent species receives relatively little attention in the sustainability literature, as it is considered less susceptible to over-hunting than primates and tapirs (Bodmer et al. 1997). Studies elsewhere have generally found little evidence for unsustainable harvests of pacas (e.g. Townsend 2000). Informal observations around Arang Dak likewise suggest that this species exhibits few signs of localized depletion around the community. Several adult pacas were killed within sight of the community, and my assistants often observed paca tracks on the trails radiating outward from Arang Dak. Given this evidence, it appears that the sustainability assessment for this species merits further attention. I generally do not believe that pacas are harvested above sustainable limits, and consideration of additional data suggests that the Robinson and Redford estimate might be too low for this particular setting.

The first important observation is that numerous pacas were harvested outside the core hunting zone. Because pacas can often be found near the river, hunters with dogs on multi-day expeditions regularly encounter and kill this species as they travel upstream. About 7% of the harvested biomass of pacas was taken outside the core hunting zone. Accordingly, adjustments of the annual harvest data suggest that hunters in Arang Dak and Suma Pipi harvest pacas at 10.89 kg/km² in the core zone. This figure still exceeds the MSY estimate from Robinson and Redford (1991), but just barely. Also, it may be that the density estimates used by Robinson

Table 4.14. Sustainability of harvest for mammalian prey

Species	Projected harvest (kg)	Annual harvest (kg/km²)	Maximum sustainable yield (kg/km²)²⁶	Definitely not sustainable?
Howler monkey	35.00	0.45	2.52	No
Spider monkey	104.98	1.35	1.22	Yes
Capuchin monkey	7.8	0.10	0.25	No
Armadillo	677.82	8.73	18.40	No
Agouti	1076.01	13.86	25.54	No
Paca	910.67	11.84	10.78	Yes
White-lipped peccary	1050.94	13.54	23.70	No
Collared peccary	801.89	10.33	42.22	No
Red brocket deer	275.46	3.55	17.49	No
Baird's tapir	2571.7	33.13	12.67	Yes

²⁶ From Robinson and Redford (1991), with the exception of capuchin monkeys and tapirs. Estimates of MSY for capuchin monkeys were derived from average density values, body mass figures, and reproductive parameters from Robinson and Redford (1986a; 1986b). The value listed here for Baird's tapir is based on estimates in the literature that would yield the highest possible MSY. Specifically, I used the highest reported density of tapirs (1.6 individuals per square kilometer). I also used the upper ceiling of tapir body mass (300 kg) despite the fact that the weights of harvested tapirs were generally closer to 200 kg. I use these values to emphasize that the harvest in Arang Dak and Suma Pipi would not be sustainable even under the best imaginable conditions (see the text for details). By no means should this MSY estimate be used to assess sustainability elsewhere in the Neotropics without considering these details, as harvests below the 12.67 kg/km² used here might also be manifestly unsustainable.

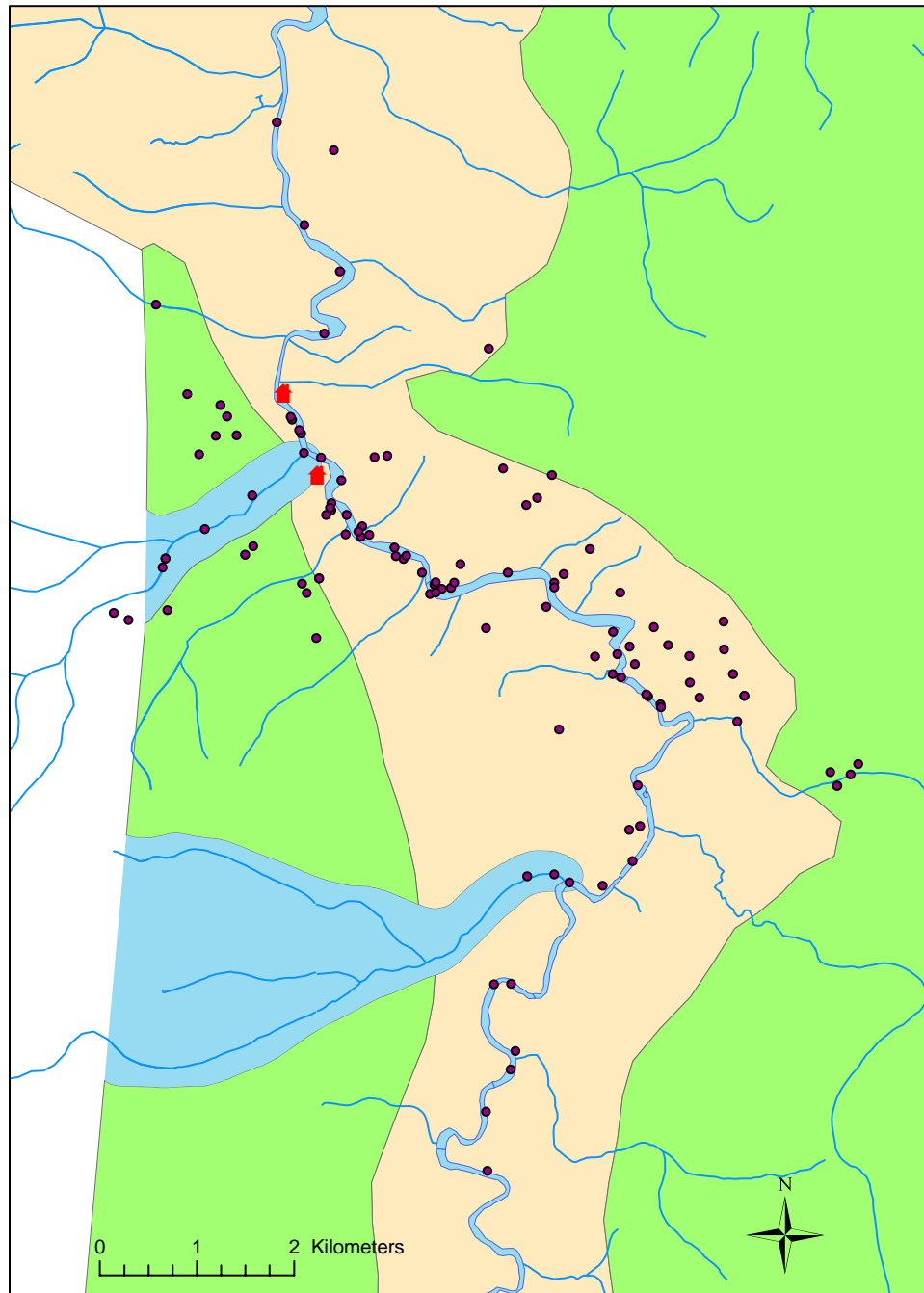
and Redford (1991) do not adequately reflect the extent to which pacas can adapt to agricultural areas. Most of the estimates used in their production model are drawn from census work in relatively undisturbed forest habitats, generally far removed from agricultural landscapes. However, pacas are notorious crop-raiders (Linares 1976), and they might proliferate beyond expected values when living in close proximity to fields.²⁷ Reid notes that pacas are “surprisingly common in small strips of riparian forest in agricultural zones” (1997:245; cf. Hill and Padwe 2000:98). The geographic distribution of paca kill sites generally echoes Reid’s comment, as over half of the pacas were killed within 100 meters of the river or in the river itself – areas that can be considered gallery forest for the most part (Figure 4.11). In the absence of hunting pressure, the expected density of pacas in the agricultural zone would appear to be substantially higher than the density estimates used by Robinson and Redford (1991).

Robinson and Redford’s assumption that hunters can harvest only 20% of production might also be too conservative for this species. While pacas live longer than many other Neotropical rodents, they reproduce more quickly than most of the other species in the long-lived category, most notably tapirs and the primates (Robinson and Redford 1991). It may be that hunters could sustainably harvest about 40% of production, as the model assumes for agoutis, which are only moderately more prolific. Under that assumption, the maximum sustainable yield estimate for pacas would double from 10.78 to 21.56 kg/km², in which case the observed harvest would not exceed sustainable limits. Given their abundance around the communities and relatively fast reproductive rate (compared to primates), it seems premature to conclude that the harvest of pacas is unsustainable. These data also suggest that the MSY estimate for pacas in the Robinson and Redford production model (1991) might need an adjustment to account for the ease with which this species seems to adapt to patchy anthropogenic landscapes.

While there are several factors countering the conclusion that the harvest of pacas is not sustainable, a related set of factors supports the observation that the harvest of spider monkeys exceeds the maximum sustainable yield. Unlike pacas, spider monkeys exhibit little tolerance of

²⁷ In fact, even in relatively isolated forest settings, pacas appear to be more common than the density estimate used by Robinson and Redford (1991). For the production model, the authors typically rely on predicted values that are based on empirically-based relationships between body size, diet, and population density (see Robinson and Redford 1986*b*). However, Robinson and Redford (1986*b*) also report that eight empirical studies yield an average paca density (27.51 individuals/km²) that is substantially higher than the predicted value (11.49 individuals/km²). Subsequent research also suggests that paca densities are higher than this predicted value, as Beck-King et al. (1999) use transect methods to give an estimate of 67-70 individuals/km² at their research site in Costa Rica. This site, however, was largely devoid of feline predators, which might be the primary source of depletion at other sites.

Figure 4.11. Locations of paca kills in the core hunting zone



anthropogenic habitats, and they generally require large tracts of undisturbed forest (Reid 1997:180). Those habitat preferences are perhaps the primary reason that spider monkeys are rarely encountered within a few kilometers of the communities. As noted above, almost all spider monkeys were killed well upstream of Arang Dak and Suma Pipi, and only one of the fourteen specimens killed during the study period was taken in the core hunting zone. Similarly, Alvard et al. (1997) report that, while the observed harvest rate of spider monkeys was slightly above the MSY, these primates are rarely encountered near a Piro community in Peru. The authors interpret this rarity as evidence of localized depletion, and this conclusion might hold true for Arang Dak and Suma Pipi as well. If all spider monkeys had been killed in the core hunting zone, this harvest would have been unsustainable and would probably lead to localized extirpation. This unsustainable harvest level would be accentuated by the likelihood that, even in the absence of hunting pressure, the density of this species would probably be less than expected in the core hunting zone, which includes considerable anthropogenic habitat unsuitable for spider monkey populations. Nine of the fourteen spider monkeys killed during the study period were taken in an area of less than 1 square kilometer in the headwaters of Mura Tingni. Eight of these were taken within the span of a few days on a single multi-day *gira*. While the spider monkey population in the territory could probably withstand occasional harvesting by hunters on expeditions, the sudden intensity of this hunting pressure in a single group of monkeys is cause for concern.

4.8.3 *Tapirs and source-sink hunting*

A number of studies have reported unsustainable harvests of lowland tapirs (*Tapirus terrestris*) in diverse Neotropical sites (Alvard et al. 1997; Hill and Padwe 2000; Townsend 2000). The settings for these studies were not new settlements, however, and in some cases the harvest of tapirs had not slackened considerably after decades of hunting. To explain why tapirs had not been locally extirpated, Novaro et al. (2000) emphasize the importance of large unhunted areas adjacent to the core hunting zones. Described as a “source-sink” situation, these *de facto* game reserves can serve as a “source” area to compensate for the “sink” in the hunted areas (Pulliam 1988). Source-sink models have received considerable theoretical attention (e.g. Joshi and Gadgil 1991; McCullough 1996; Sirén et al. 2004), but the applicability of these models to

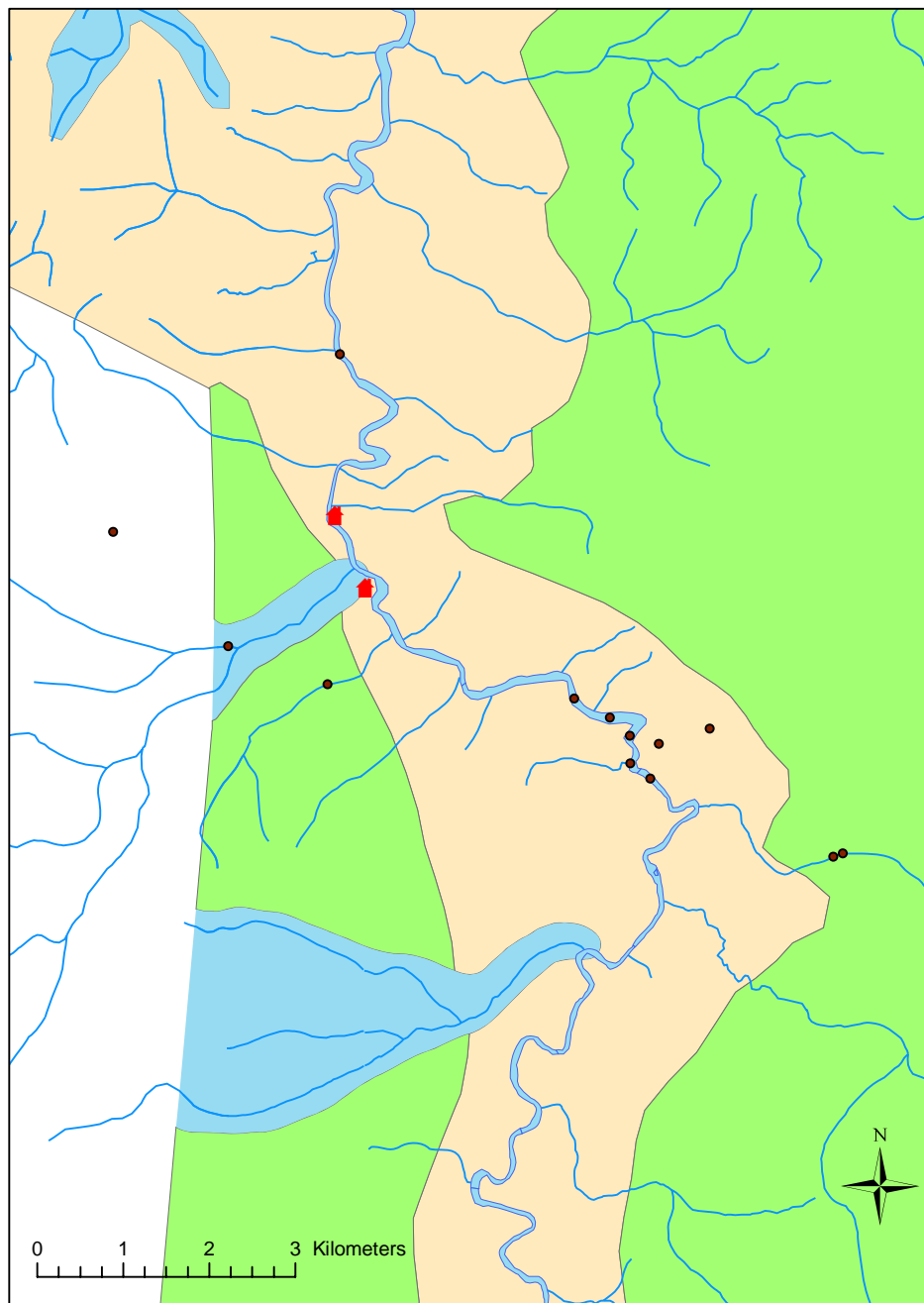
the design and implementation of Neotropical game reserves has been hampered by the absence of empirical data on density-dependent dispersal rates (Novaro et al. 2000). While dispersal rates of tapirs remain largely unknown, preliminary evidence suggests that they exhibit high mobility (Salas and Kim 2002). Given their low reproductive rate and attractiveness to hunters, the survival of tapir species in the Neotropics might depend in large part on the formalization of unhunted refugia (Novaro et al. 2000).

Similar dynamics appear to characterize the harvest of Baird's tapirs around Suma Pipi and Arang Dak. Most of the tapirs taken during the study period were killed within just a few kilometers of the communities (Figure 4.12). As noted above, the harvest of tapirs was emphatically unsustainable, even given the generous assumptions used to generate the MSY estimate for this species. Because tapirs have been the focus of similar hunting pressure since residents of Suma Pipi and Arang Dak returned from Honduran refugee camps in 1991, it appears that this unsustainable harvest is offset by the continued immigration of tapirs into the hunting zone. Rearranging the parameters of the production model indicates that the projected harvest of 2,571.7 kg might be sustainable only if the hunting zone were at least 203 km² (as compared to the hunting zone of 77.6 km² that I used to assess sustainability). In practice, the size of the unhunted area might need to be much larger than the 125.4 km² suggested by this preliminary calculation, as densities in Bosawas could be less than 1.6 individuals/km² used in the MSY estimate. For the time being, the conservation and infrequent use zones that were delineated in the TNC mapping project might serve as an effective refuge, as their combined size exceeds 500 km². To design an effective management plan, though, more research is needed on the actual densities of tapirs in the Lakus River watershed as well as general information on the dispersal rates of this species.

4.8.4 *Discussion of hunting sustainability*

On the one hand, the prospect of long-term conservation in the Lakus River watershed appears reasonably promising. Much of the hunting is done with dogs and simple hand technologies, which are particularly effective in the hunting of species that are relatively immune to over-hunting, such as agoutis, pacas, armadillos, and collared peccaries. While hunted meat is an important source of dietary protein, residents of Arang Dak and Suma Pipi have other options

Figure 4.12. Location of tapir kills in the core hunting zone (13 of the 14 tapirs killed during the study period).



for meeting their nutritional needs, including fish, grains, and domestic animals, particularly pigs. These alternatives might explain why the harvest of many prey species is lower in Arang Dak and Suma Pipi than it is elsewhere in the Neotropics. Another reason for optimism is the size of the unhunted areas upstream of the communities. Much of the territory receives minimal hunting pressure, and these areas could serve as an important refuge for prey populations. Given that hunting returns near the communities compare favorably to return rates elsewhere in the Neotropics, the hunters in Arang Dak and Suma Pipi appear to have little reason to make repeated forays into the conservation and infrequent use zones.

On the other hand, there is still cause for concern about the future of wildlife populations in the Lakus River watershed. While the most commonly hunted species show little evidence of overhunting, other prey populations do not show equal robustness. Spider monkeys exhibit signs of localized depletion, as they are generally found only far from the community. By contrast, while tapirs are often encountered near Arang Dak and Suma Pipi, the extent to which the harvest of this species exceeds the MSY indicates that the continued presence of tapirs depends on the existence and integrity of unhunted areas to serve as a refuge and breeding ground. Thus far, the residents of Kipla Sait Tasbaika have had little reason to exploit these areas, but that situation could change quickly if the population continues to grow. The indigenous territories lack the in-migration that explains the explosive population growth in mestizo areas, but the indigenous communities are nonetheless growing rapidly, as Stocks (1998) cites a rate of 3.5% annual growth. At almost 5%, the growth rate in Arang Dak over the yearlong study period actually exceeded that figure. To feed that growing population, the concern is that more primary forest will be converted to agricultural land. Community leaders are convinced that new communities will someday form upstream of Arang Dak, perhaps founded by younger members of Arang Dak and Suma Pipi. New communities and agricultural expansion would not only reduce primary forest habitat, but they might also increase hunting pressure in areas that were previously hunted only sporadically. Hunters often kill prey near their fields, and the geographic distribution of future wildlife harvests will probably mirror the distribution of cultivated fields. Agricultural expansion is problematic for conservationists because many species (e.g. white-lipped peccaries) require relatively large tracts of undisturbed primary forest. While recent work suggests that many wildlife species can persist in anthropogenic habitats (Daily et al. 2003), such habitats are typically bereft of the flagship species that inhabit healthy Neotropical forests.

More generally, concerns about the effect of indigenous population growth on tropical biodiversity are not restricted to Bosawas. While the link between population growth and either deforestation or unsustainable hunting seems to be reasonably intuitive, McSweeney (2005) points out that need not automatically lead to the degradation of resources. On the contrary, McSweeney argues that growing indigenous populations are sometimes better able to create productive alliances with conservationist organizations and defend the integrity of the (often undefined) borders around their homelands. To some extent, McSweeney's comments offer sound counsel to conservationist agendas in Bosawas, but it is important to remember that not all territories in the reserve are equally susceptible to conflicts of interest with colonists. While a burgeoning population might be advantageous in areas that abut zones of increasing settlement by colonists (as in Mayangna Sauni Bu, a territory to the southwest of Kipla Sait Tasbaika), the Lakus River watershed is sufficiently isolated that colonist settlements in the area do not appear imminent. With the recent acquisition of legal land title by the indigenous territories, the Miskito and Mayangna leaders are in a position to make far-reaching decisions about the future of settlement throughout the reserve. Given that the headwaters of the Lakus River to a large extent represent the core of the reserve, I encourage both the indigenous leadership and outside organizations to monitor with caution the long-term development of settlements upstream of Arang Dak.

4.9 Conclusions

In some ways, hunting in the Bosawas Reserve differs little from ethnographic accounts of hunting by indigenous peoples elsewhere in the Neotropics. Adult men are responsible for most of the harvest, and the strategies used to hunt some of the preferred targets (e.g. white-lipped peccaries) are similar to those employed elsewhere. Mammalian kills contribute most of the edible biomass in the harvest of hunted game, and most kills are made within a few kilometers of the community. Beyond these similarities, though, there are also some notable differences. The Mayangna and Miskito appear to rely more heavily on hunting dogs than many Neotropical peoples, and the emphasis on dogs seems to be the primary factor in the high harvest rates of agoutis and armadillos. Dogs are especially adept at locating and corralling some common crop-raiding species, including pacas, agoutis, collared peccaries, and armadillos. It is therefore not surprising that many of the kill sites are located in the agricultural zone. “Garden hunting” is a widely-cited characteristic of Neotropical wildlife harvests, but previous research has not emphasized the extent to which the use of dogs promotes hunting near anthropogenic habitats. More specifically, individual Mayangna and Miskito hunters harvest a disproportionate number of animals close to their respective fields, a trend that has likewise received little attention in the Neotropical hunting literature.

Table 4.15 summarizes some of the more noteworthy results of the analysis in this chapter. While the Mayanga and Miskito hunt and consume a wide variety of species, the residents of Arang Dak and Suma Pipi generally harvest most prey species at rates below the average for indigenous societies elsewhere in the Neotropics. With a few exceptions, these low harvest rates are matched by the absence of conclusive evidence for unsustainable hunting. While most of the hunting takes place close to the communities, the harvests of only three species exhibit clear evidence of unsustainability. Of these species, only spider monkeys are rarely encountered in the core hunting zone. The persistence of pacas in the hunting zone might reflect their ability to flourish in anthropogenic habitats, a characteristic that is not addressed in most sustainability models. By contrast, tapirs are over-harvested in the core hunting zone, and in-migration from unhunted areas might be the main reason that the species can still be found in the core hunting zone. Maintaining the integrity of these conservation zones might be the key to

Table 4.15. Overview of important Chapter 4 results

- While the Mayangna and Miskito harvest a wide variety of mammalian, reptilian, and avian prey, only a few species contribute most of the edible biomass. A few species are not consumed but are killed to protect crops or domestic animals (including hunting dogs).
- Kill of some species are closely associated with certain technologies. Birds and arboreal prey are almost invariably taken with rifles, but most of the regularly harvested mammals are killed with only dogs and simple hand technologies (especially machetes and axes). Either alone or in combination with hunting dogs, rifles are relatively more important in pursuits of the large ungulates.
- Other than iguanas, which are overwhelmingly harvested in the dry season, the only two species for which the harvests exhibit significant seasonality are agoutis and pacas. Agoutis are disproportionately harvested in the rainy season while pacas are disproportionately taken in the dry season. The agricultural calendar and the acquisition and development of hunting dogs might explain some of the seasonality, but more research is needed on the extent to which dogs can detect and corral these species at different times of the year.
- Compared to other indigenous societies in the Neotropics, the residents of Arang Dak and Suma Pipi generally consume fewer animals per consumer. The only exceptions to this generalization are agoutis and armadillos, which are the two most commonly harvested prey species. Rodents and tapirs are relatively more important to the Miskito and Mayangna than they are to other indigenous societies; peccaries and primates are relatively less important.
- The Mayangna and Miskito acquire most of their hunted game within five kilometers of their communities. Many of the kills are made in the agricultural zone and, more specifically, close to the respective hunter's fields. This trend reflects the way in which the Mayangna and Miskito incorporate hunting into their daily routine, as men in particular often combine hunting with other subsistence and economic activities.
- An assessment of hunting sustainability provides evidence that three of the ten examined species are harvested unsustainably: pacas, spider monkeys, and tapirs. The result for pacas is somewhat anomalous, as this rodent species is generally considered relatively impervious to overhunting. More research is needed to determine whether paca densities in anthropogenic areas exceed estimates derived from studies in undisturbed forest.
- Tapirs are harvested at unsustainable rates in the core hunting zone, and in-migration from unharvested refugia might be the primary reason that they have not been locally extirpated. Wildlife management plans for Bosawas must consider the importance of such source areas to the long-term survival of this species and for wildlife populations in general.

the long-term survival of tapirs and other wildlife species. Attention to the spatial dynamics of hunting and the movement of prey populations will become increasingly important if continued population growth leads to the founding of new communities in previously uninhabited areas.

In part because of their isolation from market forces, their continued reliance on traditional technologies, and the large tracts of undisturbed forest upstream of their communities, the Mayangna and Miskito in the Lakus River watershed have not witnessed the widespread depletion of wildlife populations that characterizes some forests elsewhere in the Neotropics. The pace of economic and demographic change is often swift, however, and the reserve's unhunted areas are not immune to the threats posed by technological improvements, increased market involvement, and continued expansion of the agricultural frontier. The long-term conservation of wildlife populations in the reserve therefore depends in large part on management decisions that take into consideration the reproductive characteristics and habitat preferences of prey species while simultaneously remaining sensitive to the needs of the human population.

Chapter 5

Time allocation and fishing across the lifespan

Human behavioral ecologists have increasingly focused on age-specific foraging abilities and time allocation because of the relevance of these activities for understanding the unique characteristics of human life history evolution. This chapter contributes to the debate by examining time allocation and fishing with respect to age and sex classes in Arang Dak. Significant differences in the sexual division of labor are not unexpected, but it was interesting to note that the time devoted to certain activities also seems to change with age. I examine these differences in light of a recent hypothesis that, in order to maximize overall production, a household should assign chores according to the physical and cognitive abilities of its members. I then examine age and sex-related differences in the use of the many fishing technologies employed by the Mayangna and Miskito. The fishing data generally follow the time allocation data, with individuals apparently devoting themselves to the activities and fishing techniques that maximize production given their abilities. I discuss the ways in which these results contribute to the debate on age-specific foraging, and I highlight promising avenues for future research.

5.1 Theoretical background

Recent debates in human behavioral ecology have focused on the distinctive life history traits of humans (Winterhalder and Smith 2000). In recent years, attention has shifted from the long postmenopausal life spans of women (Blurton Jones et al. 1997; Hawkes et al. 1998) to the prolonged period of juvenile dependence. Much of the debate has been inspired by the “embodied capital” hypothesis introduced by Kaplan et al. (2000), in which the authors contend that long childhoods allow humans needed time to master difficult foraging tasks that will boost their long-term fitness. Although children consume more than they produce for the first 15-20 years, the foraging surpluses that they enjoy as mature adults allow them in turn to invest in their children. The authors point out that, in comparison to chimpanzees and other non-human primates, humans rely more heavily on high-quality, difficult-to-acquire foods. Examples of difficult foraging tasks include hunting and also “extractive foraging,” which involves food resources that are not easily accessible and ready for consumption like the collected resources on

which chimpanzees specialize (Kaplan et al. 2000:167). In support of this model, Walker et al. (2002) and Gurven et al. (in press) provide evidence that hunting returns peak several years after hunters reach maximum strength and size, which implies that hunting requires refined cognitive skills, not just physical abilities.

Opponents of the embodied capital hypothesis contend that foraging success is constrained primarily by physical limitations, not cognitive limitations (Bleige Bird and Bird 2002). In support of this view, Bird and Bleige Bird (2002) present results of a study in Australia in which foraging returns did not vary with age for activities that require high learned skill but low strength while there *were* significant age trends for foraging tasks that require fewer cognitive skills but high strength. Similarly, Blurton Jones and Marlowe (2002) report that Hadza children who live in boarding schools are not significantly worse at foraging tasks than Hadza children living in traditional communities, thereby suggesting that at least some extractive tasks require little training or cognitive development. These researchers argue that the prolonged period of juvenile dependence is not necessarily adaptive in itself but rather reflective of the unusually long human life span. This opinion is supported by Alvarez (2000), who shows that the life history characteristics of humans do not differ dramatically from those of other primates after accounting for the longer overall life span.

While this debate remains unresolved, several researchers have used these models to generate predictions about age-specific time allocation to subsistence tasks (e.g. Bock 2002). The optimal allocation of time to separate activities is concisely described by Hames (1992), who points out that time devoted to an activity carries opportunity costs of not engaging in other fitness-enhancing activities. Humans must balance time devoted to a number of tasks, often divided broadly into either reproductive or somatic (i.e. growth and maintenance) effort (Hames 1992:204). In practice, these activities can include the acquisition of food and water, the construction of dwellings and extractive technologies, food preparation, social activities, courtship, and childcare, among others. Although each of these activities can carry fitness benefits, the value of these activities is characterized by diminishing returns. As people spend increasing time in one activity, the opportunity costs of foregoing other activities also rise, thus making it more valuable to switch to another activity (Smith 1987). For example, after securing a few animals, a hunter might do better to forego continued hunting in order to return home and share the meat with his mates and offspring (thus engaging in parental care and mating effort

while simultaneously reducing his risk of snakebites, falling limbs, etc.). For those familiar with optimal foraging theory, the decision rule for this switch parallels Charnov's (1976) marginal value theorem, which is used to assess patch choice decisions.

The importance of attention to opportunity costs is central to Tucker's (unpublished manuscript) critique of the aforementioned debate about the relative significance of strength and skill as factors in age-specific time allocation to subsistence tasks. In response to data on lower return rates for juveniles, Tucker argues that children have less motivation than adults to harvest resources at high rates because they have fewer competing demands on their time and, by extension, fewer opportunity costs. Although Mikea children harvest tubers at a rate below that of adult foragers, Tucker and Young (2005:168) question whether foraging efficiency is their primary goal, and they cite an observed "food fight" in which several kilograms of tubers were wasted as evidence that Mikea children view foraging as an extension of play. As long as parents are producing adequate surpluses for household consumption, children have little motivation to harvest food resources efficiently.

There are thus three possible explanations of low foraging returns by human children: (1) limited size and strength, (2) insufficient mastery of needed cognitive skills, and (3) limited motivation. Although researchers continue to debate the relative importance of these factors to age-specific return rates, they are generally unanimous that prime-aged adults enjoy higher return rates than either children or the elderly (although the variation depends in large part on the cognitive and physical demands of the particular foraging task). To the extent that household members have a common interest in household production, this observation can be used to generate some qualitative predictions about time allocation to work activities by household members. In particular, smaller and less-skilled household members will disproportionately handle chores that require little skill or strength while the opposite applies to stronger and higher-skilled household members (Bock 2002; Gurven and Kaplan 2006). Also, because cognitive skills and task-specific knowledge may decline less rapidly than physical strength, older individuals might be expected to devote a disproportionate amount of time to high-skill but low-strength activities (Gurven and Kaplan 2006). Among the Piro and Machiguenga, for example, Gurven and Kaplan (2006) report that elderly men appear to devote less time to hunting while increasing their attention to high-skill, low-strength activities such as agriculture and tool manufacture.

Although I do not take a side in the debate about life history evolution, I use these predictions as an explanatory framework for the age-specific time allocation patterns that I observed in Nicaragua. Without arguing in support of a particular life history model, I examine the extent to which time allocation to various activities matches predictions of the competing models. In particular, the work of Gurven and Kaplan (2006) was especially influential, in large part because of the similarities between the Mayangna and Miskito and the populations highlighted in their work, the Machiguenga and the Piro of Peru. Like the residents of Bosawas, the Machiguenga and the Piro are Neotropical horticulturalists who rely on swidden agriculture for much of their food while supplementing their diet by fishing and hunting.

5.2 An overview of time allocation in Arang Dak and Suma Pipi

For Mayangna and Miskito men, time allocation to subsistence tasks is largely governed by the agricultural calendar. As noted in the previous chapter, the dry season is an especially busy time for the indigenous farmers because they must clear and burn fields for planting in May or June while simultaneously caring for and harvesting their bean crop. Although agricultural labor peaks in the dry season, there is work to be done throughout the year. After planting rice and manioc at the start of the rainy season, farmers try to weed their fields at least two or three times before the crops mature a few months later. In September and October, the harvest of rice usually takes several days, and farmers with particularly large fields often need to employ non-family members to help with this task. Unlike rice, manioc and bananas are harvested as they are needed, usually every few days. Women sometimes do this task, but men and adolescent boys harvest most of the manioc and bananas. Most crops are intended for household consumption, but a few men plant cash crops such as coffee and tobacco. Others tend coconut and cacao trees, the fruits of which can occasionally be sold or traded to others in the community.

When not occupied with farming, indigenous men pursue a variety of tasks. Earning money is often a priority, as the Mayangna and Miskito are integrated into the market economy. There are small shops in the villages along the Lakus River and larger stores in the communities on the Coco River, such as Walakitang and Raiti. Families in Arang Dak and Suma Pipi visit these establishments to purchase what they call “the necessities” (*las necesidades*), including

soap, packaged coffee, sugar, powdered milk, machetes, hammocks, flashlights, batteries, clothing, and candles. When rats decimated the rice crop in June and July of 2005, residents of Arang Dak also increased their purchases of foodstuffs imported from mestizo towns to the west, including rice and flour.

Families acquire the money needed to make these purchases in a variety of ways. Perhaps the most common source of income is panning for gold. Residents of Arang Dak exploit the headwaters of nearby streams, and the banks of Arang Dak Was in particular are pocked with the deep holes that gold prospectors leave behind after working a site. Men often pan for gold alone or in pairs. Women and adolescents also pan for gold, usually in tandem with an adult man who helps them by shoveling the mud from the hole onto their pan. Gold prospecting is not without its risks, as one man suffered an injured shoulder (possibly a dislocation) when the walls of his hole collapsed onto him. Most gold prospectors return home at the end of the day, but residents of Suma Pipi in particular seem to prefer overnight stays at their sites, which saves them the time needed to walk back and forth to the community. The success of gold prospectors varies widely, with many days yielding only one to three dollars worth of gold while the occasional jackpot might be worth up to several hundred American dollars.

In addition to prospecting for gold, there are a few other options for earning money in Arang Dak and Suma Pipi. Three men and one woman were teachers in the local schools, with salaries provided by the Nicaraguan ministry of education. External projects offer job opportunities, either as research assistants or day laborers (e.g. several adolescent males from Arang Dak worked for a few days on a latrine project in Wail Lahka, a nearby community). Men can also work as agricultural laborers, usually by helping to clear fields or pastures. One owner of a chainsaw made money during the rainy season by cutting lumber for house construction. Owners of livestock occasionally sell their cattle to outside merchants. Many of these opportunities are sporadic in nature, however, and those in search of consistent sources of income might leave the community to work as wage laborers elsewhere. The option of choice during the study period was a road construction project in Mayangna Sauni As, a neighboring territory. During the rainy season, many community members left to work on this project, with women sometimes taking jobs in the project kitchen. Some men who worked on this project were reluctant to uproot their entire families, and they traveled alone to Mayangna Sauni As while their families remained behind in Arang Dak or Suma Pipi.

The rainy season is also a time when men can work on various construction projects, such as home improvements and maintenance. Bamboo walls and roofs made of *suita* leaves need to be replaced periodically, and families might work on this project when they have few competing demands on their time. Dugout canoes are also a priority, as families without boats must attempt to borrow a canoe from others, pending availability. When I conducted a census in August 2005, one-third of the households did not own a boat while four households possessed two boats. Much of the work on canoes is done at the site where the tree is felled. After completing the initial work on the boat, owners of particularly large boats might enlist friends and extended family to help them move the boat to the river. After assessing how the boat rides in the water, owners then refine the shape of the hull as needed. A well-constructed boat might last several years, but the canoes sometimes develop cracks that are patched with metal skid plates. In the past, some residents of Arang Dak have constructed larger freight boats for sale to merchants on the Coco River, but nobody in the community engaged in such a project during the study period. McSweeney (2004) provides further details on the construction and trade of dugout canoes in the Mosquitia.

At times throughout the year, the residents of Arang Dak and Suma Pipi expect all households to contribute to cooperative community labor. For example, in an effort to control the breeding of mosquitoes, the weeds on the edge of the community are cleared every few months. All families are expected to contribute at least one adult worker for this task, and those that do not are forced to provide food for the workers or a cash donation to the church. Similar expectations apply to the periodic cleaning of the water system, which becomes clogged and unusable if neglected for more than a couple months. The church is the subject of cooperative fund-raising efforts, and the community created rice and bean fields from which they could sell the crop to raise money for the church. Cooperative labor is also used to meet the needs of the school.

Women's work seems to exhibit less seasonality than men's work, as they are generally responsible for food preparation and domestic chores, such as housecleaning and washing laundry. Food process is a time-consuming task, but the absence of "bitter" manioc varieties spares women the laborious task of straining out the prussic acid (cf. Dufour 1993). Of the crops in Bosawas, rice needs the most processing prior to cooking, as the husks must be removed by pounding the rice in a mortar. This task is often given to children, who sometimes make it a

social occasion by taking the rice to a friend's house for processing. Before processing, rice must be left out to dry in the sun, and sometimes children are left in charge of supervising it and protecting it from chickens. All cooking is done over open flame, and firewood provides the fuel. Men and adolescent boys generally gather most of the firewood, but women and children sometimes gather smaller sticks and branches on the outskirts of the community if larger pieces are not available. Similarly, splitting the firewood is generally a chore for men and adolescent boys, but women and adolescent girls sometimes split wood when the need arises.

Women sometimes accompany their husbands or adolescent sons on trips to the fields. On such outings, they might help with routine agricultural tasks, such as weeding fields or carrying bananas. Sometimes they go along primarily to fish or prepare lunch for others in the party. Their presence is especially helpful when men would otherwise be traveling upstream alone, as it is easier to manage the canoes with someone in the bow to help with navigation. When all adults in the household are away from the community, their children are often left to care for the house and younger siblings. Adolescent children are preferred for this chore, but I occasionally observed 10-year old children caring for their siblings in an otherwise empty house. The youngest children (i.e. infants and toddlers) are usually brought along when their mothers leave the community, especially on lengthier outings.

The task of caring for domestic animals is typically shared by all family members. Many Mayangna and Miskito households keep cattle, pigs, chickens, ducks, or turkeys. One household owned two horses, and another household had two goats before selling them midway through the study period. There were also two mules in the community that had been donated to the community in general, and they were used infrequently to gather large quantities of firewood. Some of the cattle in the community had also been donated by an outside organization, and the offspring of these cows are in the process of being divided among the households until every family has received a calf. Although some households did not own cows during the study period, two men in Arang Dak had independently purchased cattle and kept multiple cows, some of which were sold near the end of my tenure in the community. Cattle are viewed as an investment by the Mayangna and Miskito, and owners will administer medications to their cows if they suspect an illness. Compared to cattle, ownership of pigs is more widespread, as less than 10% of the households in Arang Dak and Suma Pipi did not own pigs at some point during the study period. Unlike cattle, pigs must be fed at regular intervals, and I observed males and

females of all ages preparing manioc for consumption by the pigs. In addition to feedings, pigs cause work for their owners when they wander off into the woods (sometimes to give birth), and adult men occasionally leave with one of their children to go looking for missing pigs. The care of fowl is generally handled by women and children, although several men built chicken-houses during the study period.

Most children in Arang Dak and Suma Pipi attend school until they are at least 13-14 years old. Some older children attend secondary schools in Walakitang or Raiti (there are no secondary schools in the Lakus River watershed), but the costs of room and board for the student are prohibitive for some families. Of those who do attend secondary schools, though, some students are able to earn scholarships to study in major Nicaraguan cities (for example, one of the schoolteachers in Arang Dak had studied for a year in León). The school year lasts from about early February to the end of November, with occasional breaks throughout the year. Classes last about 4-5 hours per day from Monday to Friday, with the younger grades attending class in the morning while the older students attend in the afternoon (or vice versa). This class schedule conflicts with students' availability to join their parents on daylong outings away from the community during the week. When households reside at upstream *champas* for several days (perhaps to harvest beans), school-age children often remain behind to attend school, although it is not uncommon for adolescent students to miss a few days of class to help with agricultural tasks. For a few weeks, a couple of students made the daily commute back and forth to school from a *fincas* located a few miles upstream of Arang Dak.

Children are assigned a wide variety of chores, such as washing dishes, helping with laundry, washing floors, milking cows, sweeping the patio, helping with house construction, running errands in the community, and making purchases at the store. When family members return from the fields, children help carry bananas and other things from the river to the house. These chores do not consume all of their free time, however, and children have lots of time to play. Swimming is a very popular activity, and both girls and boys enjoy playing sports such as baseball and soccer. Children also improvise slides and teeter-totters. There are a number of games that involve dancing and chants and another that roughly resembles the American game, duck-duck-goose.

Most community members are Christians, and they observe the Sabbath on Sundays. There is a formal worship service at the community church on Sunday mornings and an informal

sing-along in the evening. On Sunday afternoons, men might organize a game of baseball or soccer while women spend much of their time visiting friends and family. Traveling to other communities for a visit is an acceptable way to spend a Sunday, and some people visit friends and family in nearby communities. Sundays are also a popular time for community meetings, as attendance is higher than it would be on workdays.

5.3 Time allocation methods

To investigate time allocation in Arang Dak, I used instantaneous scan sampling methods (Altmann 1974). These methods have been used widely by ethnographers since Johnson (1975) adapted them for anthropological purposes. The logic of the method is fairly straightforward. The researcher notes the activity of individuals at randomly selected times, collecting data that resemble a series of snapshots instead of the continuous movie-like data that I gathered on focal observations of hunters. With a sufficiently large sample size, common activities will be represented more frequently in the data set, and researchers can infer how much time those individuals devote to the activities. If, for example, adolescent males are fishing in 14% of the observations, then the researcher can conclude that they spend about 14% of their time fishing.

I conducted time allocation observations for a week every month, beginning in September 2004 and ending in August 2005. Community leaders initially objected to data collection on Sundays, but two months into the study they agreed that I could work on Sunday provided that I did not ask my research assistants to accompany me on the observations. I therefore have data from 82 days, six days a month for September and October and seven days for all other months. Data collection usually began on the 15th of the month and continued for seven consecutive days. I deviated from this schedule on only a few occasions when factors such as personal illness and meetings with territorial leaders precluded data collection. Individual households did not receive additional compensation beyond the thirty-two cordobas that they received for participating in the hunting and fishing study (see chapter 4), but I agreed to donate materials (notebooks, pencils, soccer uniforms, etc.) to the school in exchange for their participation in the time allocation study.

A 24-hour sampling period is ideal, but this is seldom practical for anthropological research (Borgerhoff Mulder and Caro 1985). I collected data between 5:30 A.M. and 6:00

P.M., which generally corresponds to daylight hours. The first observation began at a randomly selected time between 5:30-6:00 A.M., after which I conducted an observation every thirty minutes. For example, if data collection began at 5:45 A.M., the second observation would be at 6:15 A.M., the third at 6:45 A.M., and so on until 5:45 P.M. This schedule allowed for 25 observations per day, which worked well for this setting because the number of households in Arang Dak during the study period fluctuated between 22-25 households.

On each day of time allocation work, households were randomly selected without replacement. I would begin by randomly selecting a household for the 5:30-6:00 A.M. time slot, then randomly selecting one of the remaining households for the following slot until I had exhausted all households and time slots. For days in which there were fewer than 25 households in the community, I added “dummy” households to the sample, and then I would simply not make an observation during the particular time slot associated with the dummy.

Accompanied by a research assistant to assist with translation, I visited the households at the appointed times. I collected data on all household members, and I noted the presence and activities of visitors. One difficulty in conducting instantaneous scan observations of people is that subjects can alter their behavior upon seeing the researcher approach (Borgerhoff Mulder and Caro 1985:326). Especially at the beginning of the study, I noted that subjects would cease their activity when I arrived at the house. In such cases, it was sometimes necessary to reconstruct what the subject had been doing (cf. Gross 1984:539). For example, if a woman was seated on a bench next to a skirt and sewing supplies, I might conclude that she had been sewing when she saw me approach. If there was ever ambiguity, I would ask the research assistant to inquire. Sometimes the research assistants would have clarifying comments if I did not completely understand an activity.

Working with a research assistant was also very helpful for inquiries about absent household members. Following Hames (1979*b*), when subjects were not in the house or the immediate vicinity, I asked family members where they were and what they were doing. I recorded this information and then verified that data with the individuals upon their return to the community. In most cases, family members were reasonably accurate in their reports of the subjects’ activities. One problem with this method, however, is that such reports generally convey the intent of the outing but not the behavior of the individual at that particular moment (Betzig and Turke 1985:647). For example, family members could tell me that the male head of

the household and his son went to harvest corn, but they could not say if the two were poling upstream or working together in the field, if the younger had stopped to fish for a while, or if they had stopped to pursue an animal scared up by the family dog. Interviewing subjects upon their return did not resolve this problem, as individuals often cannot be certain what they were doing exactly four and a half hours before (for example).

Accordingly, when I asked informants about their activities when away from the community, I generally recorded the main purpose of the outing. In the data that follow, time spent in agricultural activities, for example, includes time spent traveling to the fields, stopping for lunch, other breaks, and possibly other activities (such as the acquisition of firewood, hunting, fishing, etc.). To be precise, time spent in agricultural labor should be described as time spent on outings in which agricultural labor was the primary purpose. To avoid such cumbersome phraseology throughout the chapter, I refer to such activities just as “agricultural labor,” but this distinction should not be overlooked. When subjects were away from the community, I also made a point to record their companions (including those from other households), their means of travel (on foot or by boat), their destination, and all the items brought back to Arang Dak. For these latter data, informants typically underreported small or perceptually insignificant items. For example, informants would report a bag of oranges that they had collected, but they would not mention a single orange. By contrast, items such as firewood, bunches of bananas, and sacks of manioc or corn were typically reported without fail, and data collection for these items was aided by the fact that they were often conspicuously present on the porch or patio when we arrived to interview the subject.

I recorded data in a spiral notebook, writing out longhand descriptions of subjects’ activities. Albeit a little tedious, this method allowed me to refrain from making coding distinctions until I had gained a fuller appreciation of the process and intent of various activities. Upon returning to the United States, I used these longhand descriptions to create a coding scheme with 53 activities and various modifiers (e.g. I recorded “weeding fields” as the primary activity, but I attached a modifier to denote what type of crop was planted in the field). For analytical purposes, I then condensed these 53 activities into a broader scheme with 20 activities (Table 5.1). Not surprisingly, some coding distinctions overlook subtleties in the situation (cf. Hames 1992:213). When milking cows, for example, caretakers assure that the calf is fed while also acquiring some milk for household use. A case could be made for classifying this activity as

food preparation or livestock care. Similarly, in terms of childcare, parents might be watching their children while simultaneously peeling bananas for supper. In both of these cases, I opted for the latter code because these activities seemed to take precedence in a functional sense. Such coding distinctions should have little bearing on the questions pursued in this chapter, but other researchers should take note of these distinctions before applying these data to cross-cultural comparisons.

Most of the data in this chapter are presented in terms of age and sex classes.¹ I collected information on age while conducting my initial census of the community, and subsequent genealogical interviews provided an additional source of data. Determining age in remote fieldwork settings is often a challenge, as individuals usually lack birth certificates or other official documents and identification. Parents could usually state the ages of their children, but it was more difficult to establish accurate ages for adolescents and adults above 16 years of age. In some cases, I assigned ages after inquiring about the subject's age at the time of memorable historical events, such as the beginning and end of the Contra-Sandinista conflict. For example, informants might say, "Julio was born about two years after we came back from the refugee camp." Such methods are admittedly imprecise but generally suitable for assigning individuals to their respective age classes.

The creation of age classes for analytical purposes is always somewhat arbitrary, but I tried to focus on relevant distinctions in the expectations for children. Children younger than six are seldom given chores to complete independently (although they might help older siblings with some tasks). Children between six and twelve often have regular chores around the house, and they might tag along with parents or older siblings to conduct work away from the community. Adolescents between thirteen and seventeen can travel independently, and they might be entrusted with tasks such as the harvesting of bananas or firewood. Eighteen appears to be the age at which males and females begin to think about conceiving children and forming an independent household, although they typically live with parents for at least a couple years after forming the union. Adults older than fifty are generally in a post-reproductive stage, and there were no adults older than fifty with children who had not yet been weaned.²

¹ For data on household demographics, see Appendix B.

² I do not mean to imply that men older than 50 are incapable of reproducing. That said, because the reproduction of older men generally matches that of their spouses, the fact that older men are married to post-reproductive women effectively limits their reproduction as well.

Table 5.1. Coding scheme for time allocation observations

Activity	Description
Sleeping and idle	Sleeping or resting with no discernible work or social interaction
Personal care	Grooming, dressing, visiting latrine, medical care, eating
Leisure	Play, visiting within the community, talking on radio
Hunting	Outings specifically designed to acquire hunted game
Fishing	Outings specifically designed to acquire fish
Agriculture	Clearing fields, burning fields, planting, weeding, and harvesting crops
Childcare	Active care of children, including breastfeeding
Housework	Washing floors, sweeping patio, washing dishes, doing laundry, straightening up
School	Attending class or school-related functions
Religious	Attending church or church-related functions
Manufacture / repair	House or boat construction, manufacture or repair of tools (bows, machetes, etc.)
Food preparation	Cooking, preparation of food (including de-husking corn and rice, peeling fruit)
Livestock care	Medical care of domestic animals, milking cows, feeding animals
Other household work	Tending store, firewood, bringing water, errands, on outing to cook for others
Gold	Panning for gold, preparing the site
Non-household work	Community labor or meetings, working for projects, helping other households, teaching school, bartering with others
Out of community	Away from community for multiple days to work as wage laborer, to visit, for medical reasons, to attend school, for school or church-related functions, or to bring friends and family to another locale
Pet care	Feeding or caring for dogs, cats, or parrots
Upstream	Staying at upstream site, usually to conduct agricultural labor but also as part of a multi-day hunting or fishing expedition
Gathering	Gathering non-timber forest products, usually for medicinal purposes

5.4.1 Time allocation results

The time allocation to activities by females and males is depicted in figures 5.1 and 5.2, respectively. I use these data to make these preliminary observations:

1. Neither male nor female children in the youngest age class contribute much toward household labor. The vast majority of their day is devoted to leisure or idleness. Except when they accompany family members to an upstream *finca* or *champa*, they rarely leave the community.
2. Although the use of time by children between ages 6-12 is likewise dominated by leisure and idleness, they begin to work at household tasks. Girls in particular begin to make meaningful contributions to childcare, housework, and food preparation (especially de-husking grains, which comprises more than half of their food preparation time, compared to 20% and 13% for adolescent girls and women, respectively). Boys and girls in this class spend proportionately more time in school than do adolescent children, perhaps in part because of the absence of a secondary school in Arang Dak.
3. Adolescents enjoy much less leisure time than younger children. Interestingly, whereas adolescent males spend more than twice as much time as adult males in leisure activities, adolescent females have slightly less leisure time than adult females. By contrast, adult women spend much less time out of the community than adolescent females, who are more often away in secondary school or visiting in other communities, whereas adolescent males spend less time away than adult men, primarily because of the time that men spend in wage labor elsewhere.
4. The sexual division of labor is particularly apparent in a comparison of reproductive-aged adults. Whereas women spend more time in childcare, food preparation, and housework, men devote a larger amount of time to agricultural labor, hunting, gold prospecting, manufacture and repair, and non-household work (community labor, working for projects). Although it appears that women spend more time fishing than men, these data are somewhat deceptive because men do much of their fishing at night (i.e. outside the sampling period). The data also do not account for short-term fishing bouts by men who are on outings for other purposes (e.g. fishing for fifteen minutes after weeding fields). I elaborate on fishing strategies later in this chapter.

Figure 5.1. Time allocation by female age classes

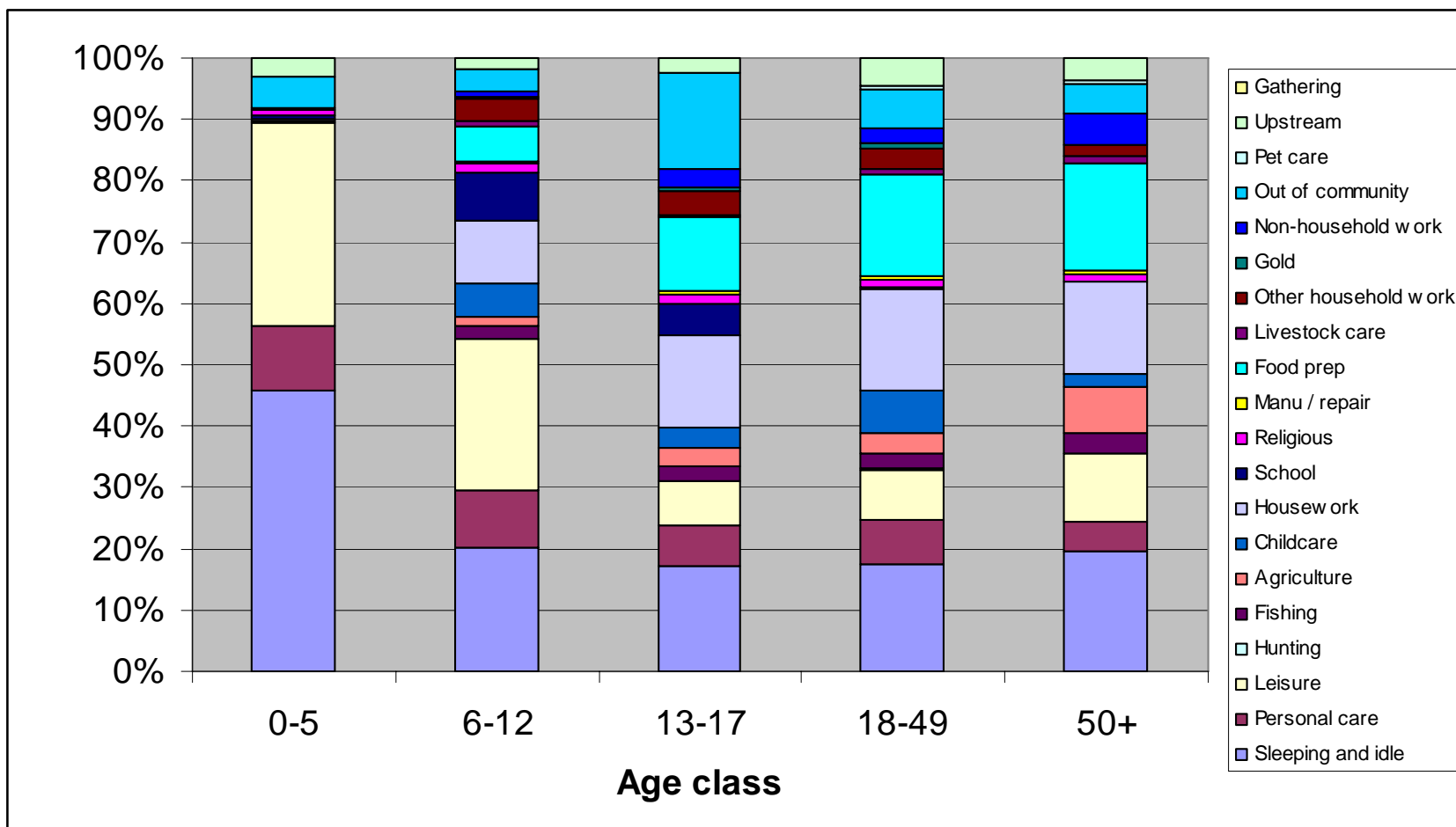
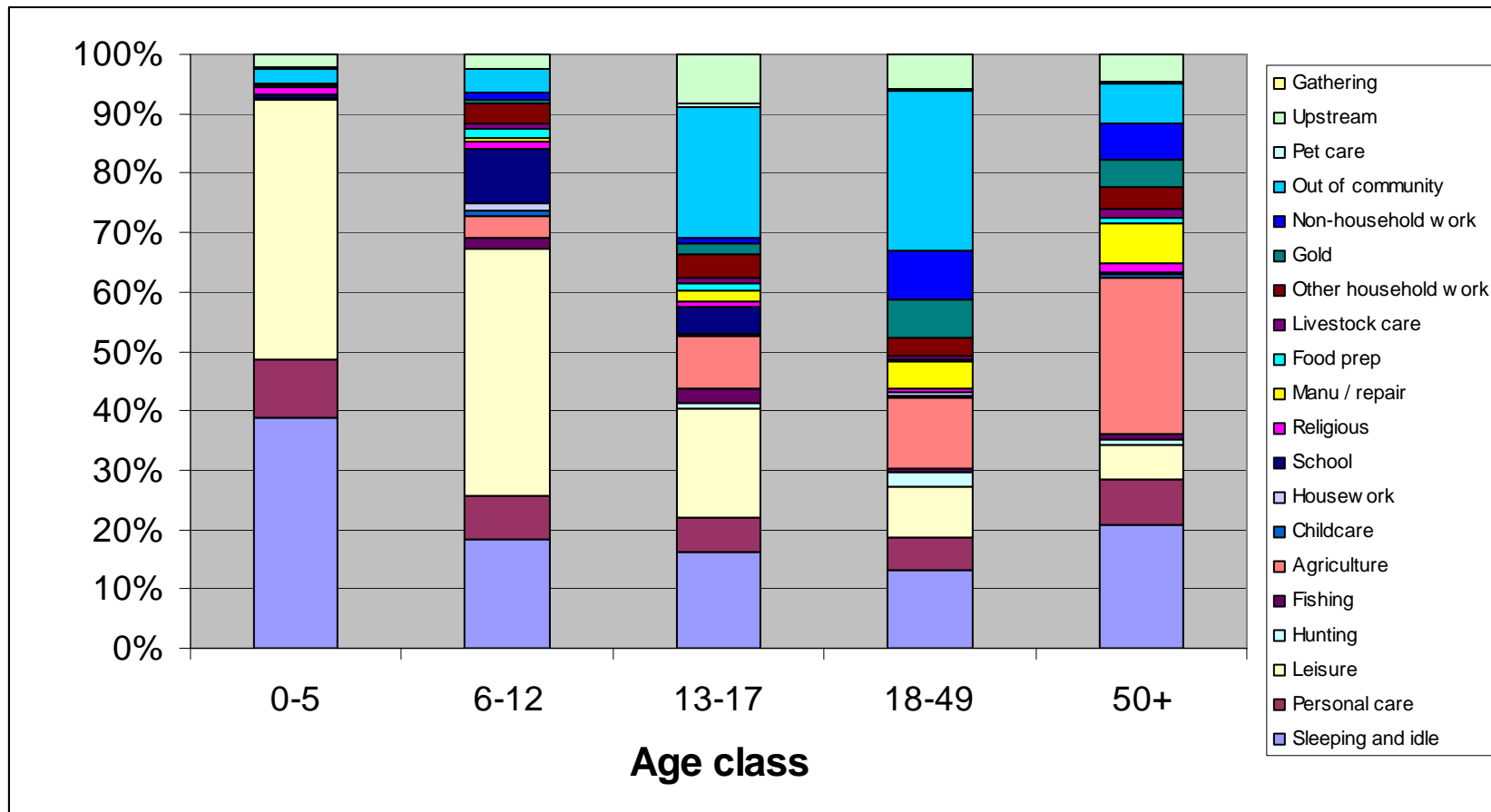


Figure 5.2. Time allocation by male age classes



5. There are many similarities in the time allocation of reproductive-aged adults (18-49) and post-reproductive adults. However, women older than fifty devote less time to childcare but more to agriculture, and they also have more leisure time. Men older than fifty also spend more time in agricultural labor than reproductive-aged adult men, and the difference is dramatic: older men devote more than twice as much time to agriculture as do younger men. By contrast, younger men spend more time hunting and much more time away from the community working as wage laborers.

5.4.2 Significance testing: Fisher's exact test

To see if there are significant differences in the time allocation of these age and sex classes, I follow Lu (1999) and Tucker (2001) in their use of Fisher's exact test. Like a chi-square test, a Fisher's exact test can be used in the analysis of categorical data, and its advantage over the chi-square is its applicability to a contingency table that includes some small expected counts. Meanwhile, a general disadvantage of consolidating multiple individuals into age and sex classes is the possibility of losing the heterogeneity between those individuals. For example, some men are avid gold prospectors whereas many others devote almost no time to panning for gold. To the extent that these individual tendencies affect the results of these tests, I attempt to highlight variation within specific age and sex classes.

For this analysis, I eliminated the "upstream" category from the dataset. The rationale for this decision stems from the observation that the time budget for many individuals at upstream *champas* overlaps significantly with their activities while in Arang Dak. For instance, women staying upstream appear to devote comparable amounts of time to washing clothes, food preparation, childcare, housework, etc. Because it was not possible to obtain accurate data on these activities with the methodology that I used in this study, I coded these observations simply as "upstream." By eliminating these observations from the analysis, the dataset better reflects what individuals do on a day-to-day basis, whether they are in Arang Dak itself or an upstream site.

The numbers of observations for each age and sex class that I used for the Fisher's exact tests are listed in Table 5.2. There are approximately equal numbers of observations for males and females in each class, but the number of observations for post-reproductive adults is much

lower than that for other ages. However, the number of observations for all classes exceeds the 150 observations cited by Baksh (1990) as the minimum needed to generate reasonably accurate estimates of time allocation.³ In general, though, the accuracy of estimates for behaviors (especially infrequent behaviors) increases with sample size, so the estimates for post-reproductive adults are perhaps the least accurate of those addressed in this analysis (cf. Bernard and Killworth 1993). The smaller sample sizes also diminish the statistical power of the Fisher's exact tests that involve these age classes.

Table 5.2. Number of observations by age and sex class used to calculate the Fisher's exact tests that are presented in Tables 5.3, 5.4, and 5.5.

	Females	Males
0-5	1661	2034
6-12	1746	1855
13-17	1202	1040
18-49	2218	2113
50+	319	465

5.4.3 *Sex-related differences in time allocation*

The results of the comparisons between males and females (separated by age class) are presented in Table 5.3. Perhaps the most striking observation is that the sexual division of labor is already apparent in the 6-12 year age class. As with the older age classes, girls between six and twelve devote significantly more time to childcare, housework, and food preparation than boys of the same age. By contrast, like older males, boys between six and twelve spend significantly more time in agricultural labor and panning for gold than similarly-aged girls. In this age class, it is also interesting to note that boys have significantly more leisure time than girls.⁴ Adolescent boys likewise have more leisure time than adolescent girls. By comparison, there are no significant differences between male and female reproductive-aged adults, and post-

³ By contrast, Bernard and Killworth (1993:214) give 176 observations as a recommended minimum.

⁴ In this analysis, male infants and toddlers also have significantly more leisure time than girls, but I attribute this result in large part to the age profiles of the two samples. The average age of girls in this age class is 2.5 years whereas the boys are 3 years old on average. Because small differences in age for this age class might have more bearing on time schedules than for any other age class, it should perhaps not be surprising that the girls spend significantly more time sleeping whereas the boys spend significantly more time playing.

reproductive females actually have significantly more leisure time than men in the same age class. There is no immediately obvious explanation for this trend, but it is worth noting that three of the four women in the post-reproductive age women who contributed at least 80 observations to the sample reside in households with adult daughters. By comparison, only half of the six men in the post-reproductive age class lived in households with other adult men (a son, a step-son, and a son-in law), and this co-residence varied seasonally as the younger men each spent at least several months away from the community during the study period. It could be that the women in the sample enjoy more leisure time because they are able to share household chores with their daughters whereas men must fulfill all of the traditional duties of men. As for the higher leisure time for adolescent males, this finding accords well with my general impression, as boys in this age class are particularly prone to ambling around the community, often paying visits to other households. Finally, the significant differences in time outside the community reflect greater male participation in wage labor and external projects. This tendency is not restricted to just a few individuals, as thirty adult men (i.e. older than eighteen) were away from the community for at least seven observations.

Table 5.3. Minutes allocated to different activities (per 12.5 hour day) and results of Fisher's exact tests on differences between males and females of the same age class

	For all age classes, females are listed first, then males (females vs. males)				
Age class	0-5 years	6-12 years	13-17 years	18-49 years	50+
Sleeping and idle	354 vs. 299 **	155 vs. 141	132 vs. 132	136 vs. 104 **	153 vs. 163
Personal care	81 vs. 74	70 vs. 57 *	52 vs. 48	57 vs. 45 *	38 vs. 61
Leisure	256 vs. 336 **	189 vs. 319 **	55 vs. 151 **	66 vs. 67	87 vs. 45 **
Hunting	0 vs. 0	0 vs. 1	0 vs. 9 **	1 vs. 19 **	0 vs. 8
Fishing	0 vs. 0	15 vs. 15	19 vs. 20	20 vs. 6 **	26 vs. 6 **
Agriculture	0 vs. 1	12 vs. 28 **	22 vs. 71 **	25 vs. 94 **	59 vs. 208 **
Childcare	3 vs. 0 **	42 vs. 6 **	26 vs. 0 **	56 vs. 3 **	16 vs. 3 *
Housework	4 vs. 2	78 vs. 9 **	115 vs. 1 **	130 vs. 4 **	115 vs. 3 **
School	4 vs. 5	59 vs. 71 *	40 vs. 38	1 vs. 0	0 vs. 0
Religious	6 vs. 9	12 vs. 9	12 vs. 9	9 vs. 7	9 vs. 13
Manu / repair	0 vs. 0	3 vs. 6	4 vs. 15 **	5 vs. 35 **	5 vs. 52 **
Food prep	2 vs. 0	44 vs. 13 **	93 vs. 10 **	132 vs. 2 **	136 vs. 8 **
Livestock care	0 vs. 1	7 vs. 6	2 vs. 7	7 vs. 6	9 vs. 11
Other household work	0 vs. 1	27 vs. 26	31 vs. 32	24 vs. 24	14 vs. 29
Gold	0 vs. 0	1 vs. 6 **	4 vs. 15 **	7 vs. 50 **	0 vs. 37 **
Non-household work	1 vs. 1	8 vs. 8	22 vs. 9 **	19 vs. 66 **	40 vs. 48
Out of community	39 vs. 20 **	27 vs. 30	121 vs. 179 **	51 vs. 215 **	38 vs. 52
Pet care	0 vs. 0	0 vs. 0	0 vs. 4 **	4 vs. 2	5 vs. 2
Gathering	0 vs. 0	0 vs. 0	0 vs. 0	0 vs. 1	0 vs. 0

* = significant at $p = 0.05$

** = significant at $p = 0.01$

5.4.4 Age-related differences in time allocation

Comparisons between female and male age classes are presented in tables 5.4 and 5.5, respectively. Not surprisingly, there are substantial differences between the time budgets of the two youngest age classes for both females and males. As noted previously, children younger than six spend most of their time playing, sleeping, and eating. Their older peers engage in a broader diversity of activities, including school, fishing, and household chores. There are also many significant differences between the 6-12 and the 13-17 age classes, as older adolescents of both sexes devote less time to school and leisure activities while adopting a time budget more similar to adults. One somewhat surprising result was the significant difference in childcare between adolescent and 6-12 year old girls. Girls of both age classes had reasonably similar access to infants and toddlers, the most frequent recipients of active childcare. It appears, however, that adolescent girls do not prioritize allo-mothering to the extent that their younger sisters do, or perhaps they are less often assigned this job by their parents.

There were also some significant differences between adolescent girls and reproductive-aged women, including childcare, food preparation, and school attendance. The difference in time devoted to school is not surprising, as only one woman (an 18-year-old) in the older category attended classes. Similarly, school helps to explain why adolescent girls are more often away from the community, as many of the observations in this category pertained to an adolescent girl attending school in Raiti. Although other adolescent girls spent some time away from the community to visit family, I should mention that more than half of the adolescent girls in the sample were very rarely away from the community.

With only four women contributing over 95% of the observations in the post-reproductive age class, it is difficult to draw many firm conclusions about the significant differences between this age class and women in the 18-49 age class. For example, although there is a significant difference in agricultural labor between the two age classes, just one post-reproductive woman contributed over 70% of the observations to this category (although it should be noted that all women in this age class were observed in agricultural labor at least once). The other two significant differences, childcare and non-household work, seem more generally applicable. Although three of the four women mentioned above lived in households with infants and toddlers (i.e. grandchildren), their contribution to the care of those children was

more typically indirect. For instance, the aforementioned older woman who spent so much time in agricultural labor was helping to support her daughter, a young single mother who generally stayed at the house to cook and care for her children while her parents worked in the fields. The majority of non-household work involved elderly women caring for the houses (and sometimes the offspring) of their adult children.

In some respects, the time budgets of reproductive-aged men are the most diverse and also the most intense. Men in this age class spend the least amount of time idle or sleeping, and only post-reproductive men devote less time to leisure activities. However, it is interesting to note that reproductive-aged men outrank all other male age classes in only four noteworthy activities: panning for gold, hunting, non-household work (especially project-related work), and time away from the community.⁵ In other words, men in this age class devote themselves to a wide variety of activities, but these activities are seldom exclusive to this age class. For example, whereas reproductive-aged men devote more time to agricultural labor than adolescent males, they are in turn outranked by post-reproductive men, and the same applies to manufacture and repair. Among the other notable results from the age class comparisons for males is the observation that prepubescent boys (ages 6-12) spend minimal time on hunting trips. This tendency was apparent on the focal follows, as the adult hunters with sons in that age class seldom brought them along when hunting. Adolescent boys, by contrast, were often preferred companions.

⁵ I do not mention housework and gathering here because the number of observed cases was small and the differences between age classes were not significant.

Table 5.4. Female time allocation by age class. Data are presented in terms of minutes per 12.5 hour workday. Significance between adjacent age categories is reported in the column between the respective age classes.

Activity	0-5	Sig.	6-12	Sig.	13-17	Sig.	18-49	Sig.	50+
Sleeping and idle	354	**	155	*	132		136		153
Personal care	81		70	*	52		57		38
Leisure	256	**	189	**	55		66		87
Hunting	0		0		0		1		0
Fishing	0	**	15		19		20		26
Agriculture	0	**	12	**	22		25	**	59
Childcare	3	**	42	**	26	**	56	**	16
Housework	4	**	78	**	115		130		115
School	4	**	59	**	40	**	1		0
Religious	6	*	12		12		9		9
Manu / repair	0	*	3		4		5		5
Food prep	2	**	44	**	93	**	132		136
Livestock care	0	**	7	*	2	*	7		9
Other household work	0	**	27		31		24		14
Gold	0		1	*	4		7		0
Non-household work	1	**	8	**	22		19	**	40
Out of community	39	**	27	**	121	**	51		38
Pet care	0		0		0	**	4		5
Gathering	0		0		0		0		0

Table 5.5. Male time allocation by age class. Data are presented in terms of minutes per 12.5 hour workday. Significance between adjacent age categories is reported in the column between the respective age classes.

Activity	0-5	Sig.	6-12	Sig.	13-17	Sig.	18-49	Sig.	50+
Sleeping and idle	299	**	141		132	**	104	**	163
Personal care	74	**	57		48		45		61
Leisure	336		319	**	151	**	67	*	45
Hunting	0		1	**	9	**	19	*	8
Fishing	0	**	15		20	**	6		6
Agriculture	1	**	28	**	71	**	94	**	208
Childcare	0	**	6	**	0	*	3		3
Housework	2	**	9	**	1		4		3
School	5	**	71	**	38	**	0		0
Religious	9		9		9		7		13
Manu / repair	0	**	6	**	15	**	35	*	52
Food prep	0	**	13		10	**	2	*	8
Livestock care	1	**	6		7		6		11
Other household work	1	**	26		32		24		29
Gold	0	**	6	**	15	**	50		37
Non-household work	1	**	8		9	**	66		48
Out of community	20	**	30	**	179	**	215	**	52
Pet care	0		0	**	4		2		2
Gathering	0		0		0		1		0

* = significant at $p = 0.05$

** = significant at $p = 0.01$

5.5 Discussion of time allocation results

In general, the time budgets of adults in Arang Dak appear similar to those reported elsewhere in the Neotropics. When residing in the community, for example, adult men devote 4.13 hours to subsistence activities (agriculture, fishing, hunting, gathering, food preparation), which is within the observed range of variation (4-6 hours) cited in a cross-cultural sample of lowland South American societies (Beckerman 1993:413). Also, even without the rigors of detoxifying bitter manioc, food preparation remains the most time-consuming task for adult women, as is true in another cross-cultural sample compiled by Hames (1989:49). For both sexes, resting and leisure activities consume a fairly large percentage of the day (cf. Hames 1989:51; Beckerman 1993:413)

There are also some noteworthy differences. Although garden labor by adult females is still within the range of variation noted by Hames (1989:49), Mayangna and Miskito women spend much less time (i.e. less than half) in agricultural work than the average for Amazonian women. Whereas weeding and harvesting crops are often handled primarily by women in Neotropical societies, the contributions of Mayangna and Miskito women are largely restricted to the planting and harvesting of grains and, less often, the harvesting of bananas. Also interesting is the minimal amount of time devoted to gathering: during no observations were adult women in Arang Dak on an outing to gather wild forest products. By contrast, in the cross-cultural sample compiled by Hames (1989), women spend almost forty minutes per day gathering. Men in Arang Dak likewise devote little time to gathering, and the few observations in this category primarily relate to the collection of medicinal plants.⁶ Another interesting observation is that Mayangna and Miskito women fish more than men, as the opposite is true in most Neotropical societies (Hames 1989). However, as noted earlier, the timing of this time allocation work affected the results, as men did much of their fishing at night after data collection had ceased. I elaborate on fishing below.

In terms of age-related differences, there are a number of examples in which individual differences in strength and skill seem to dictate the extent to which people engage in certain activities. Children younger than six work only at low-strength, low-skill activities, such as

⁶ The coding scheme might explain part of the discrepancy, as I coded the collection of *suita* and posts for house construction as manufacture and repair, not gathering. The same applies to cutting firewood, which is coded in this study as other household work.

bringing water from the well or transporting small pieces of firewood. On the other hand, only girls older than about eleven help butcher animals, peel bananas, and cut manioc, which are described by Gurven and Kaplan (2006:20) as “low strength, high skill” activities. Children are often assigned the task of shooing away chickens from rice as it dries in front of the houses, a “low strength, low skill” activity that frees older household members to devote more time to chores that require more physical strength and cognitive skill (cf. Bock 2002).

Some of the more obvious age-related differences appear in the older age classes, especially for men. Gurven and Kaplan (2006:34) report that, as age increases and strength declines, Machiguenga and Piro men spend more time in low strength, high skill activities, particularly in manufacture and repair. In Arang Dak, older men likewise devote significantly more time to manufacture and repair, whereas younger men spend more time on hunting trips and in physically demanding wage labor (i.e. road construction). As with the Gurven and Kaplan data (2006), older men in Arang Dak also spend significantly more time in agricultural labor. Although gardening can be physically demanding, particularly when clearing new fields, it might be less demanding than high-endurance activities such as hunting. It is also noteworthy that men in the oldest age class were the only ones to plant cash crops such as coffee and tobacco whereas younger men seem to rely more heavily on high-strength activities such as wage labor and panning for gold as a source of income.

For scholars of human evolution, ethnographic studies of hunting have long held substantial appeal, in large part because of the evidence for increased carnivory in later hominids (Hill 1982; Foley 2001). Accordingly, recent studies have examined the extent to which different hunting skills (e.g. interpreting tracks, locating game, killing prey) develop and decline over the life span (Walker et al. 2002; Gurven et al. in press). The observation that reproductive-aged men spend more time hunting than other age classes might be interpreted as evidence that only men in this age class have the combination of strength and cognitive abilities needed to make hunting profitable enough to merit much attention. In this particular setting, however, the widespread use of hunting dogs makes the interpretation of these data somewhat difficult. I have mentioned elsewhere that some men effectively stopped hunting altogether once their dogs died. Such time allocation decisions are largely independent of the hunter’s physical and mental abilities, and it therefore seems inappropriate to draw far-reaching conclusions about data that can be affected so dramatically by the survival and development of hunting dogs. As anecdotal

evidence, I will mention also that the oldest man in Suma Pipi (a 60-year-old) hunted fairly regularly with his dogs until they were lost in the forest, after which he basically stopped hunting altogether.

Although hunting is not the best candidate activity for an examination of age-specific trends, there is another subsistence activity in Arang Dak for which differences in physical prowess and cognitive abilities are more apparent: fishing. As is common throughout the Neotropics, the Mayangna and Miskito employ a wide range of technologies when fishing (cf. Gragson 1992a). These technologies differ in their ease of use, and they can yield markedly different return rates (kg/hr). Some of the most productive technologies are effective only at certain times of the year, however, and the Mayangna and Miskito adjust their fishing strategies accordingly. These factors make fishing a promising topic for an examination of the ways in which skillfulness with the various technologies affect time allocation decisions. Whereas other studies have examined hunting, I focus in particular on the age-specific factors that impact fishing in Arang Dak and Suma Pipi. The methodology used to collect the quantitative data was described in Chapter 4.

5.6 An ethnographic description of fishing in Bosawas

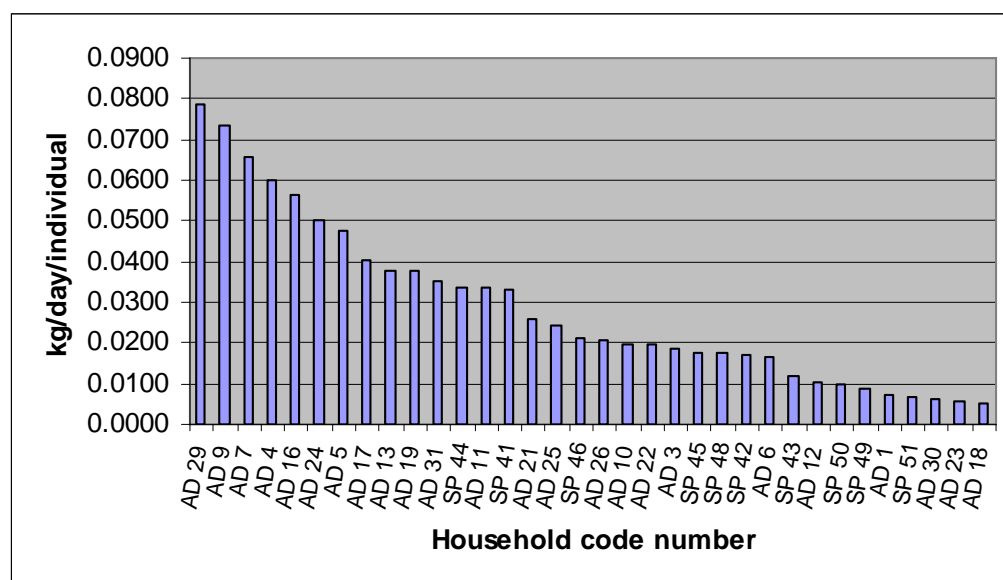
Although hunting tends to receive more attention from researchers, fishing often contributes more dietary protein to Neotropical diets (Beckerman 1979; Gragson 1992b). Although that is not the case in Arang Dak, fishing does have some advantages over hunting, the most obvious of which is the accessibility of fishing technologies to the population as a whole. Whereas hunting is generally restricted to those with good hunting dogs or rifles, both of which can be difficult or expensive to acquire, relatively cheap fishhooks can be purchased from local vendors and both bows and arrows can be fashioned from local trees.⁷ Although there are more expensive fishing technologies, such as diving masks, these are still much less expensive than a new rifle.

Given the accessibility of fishing technologies, it is not surprising that the fishing harvest exhibits less inter-household variability than the hunting harvest. Unlike hunting, for which

⁷ On one occasion, I observed a Mayangna man making a bow from the wood of a wild palm (*Bactris gasipaes*), but other woods might also be suitable for the construction of bows.

eight households harvested the vast majority of the biomass (see Chapter 4), the fishing harvest is more evenly distributed among households. There is a significant linear relationship between household size and the household acquisition of fish from Dec 15, 2004 to August 31, 2005.⁸ I therefore present data in terms of kilograms/day/individual (Figure 5.3). Although it is clear that some household harvests are well above the norm, fishing appears to be a relatively important activity for most households in Arang Dak and Suma Pipi.⁹

Figure 5.3. Daily harvest of fish per individual, according to household



The most widely-used fishing technology is hook-and-line, and this technology contributes the most biomass to the yearly harvest (Figure 5.4). All households owned fishhooks at some point during the study period, and the average household had 3.4 in their possession (based on census data conducted at six-month intervals). The Mayangna and Miskito do not use poles, but they instead wrap the fishing line around a small piece of carved wood. This piece of

⁸ The regression equation is $Y = 0.0326X - 0.0217$, where Y is kg/day and X is household size, as measured in the number of individuals, including infants and toddlers ($r^2 = .296$; $p = .001$). I do not include the fishing data collected in Arang Dak before December 15, 2004 because I do not have comparable data for Suma Pipi.

⁹ The harvest of fish in Arang Dak and Suma Pipi might not be representative of other communities in the reserve. Data from a TNC survey indicate that communities along the Lakus River fish considerably more often than those along the Coco River (The Nature Conservancy 1997).

Figure 5.4. Fishing harvest by technology in Arang Dak, 9/1/04-8/31/05

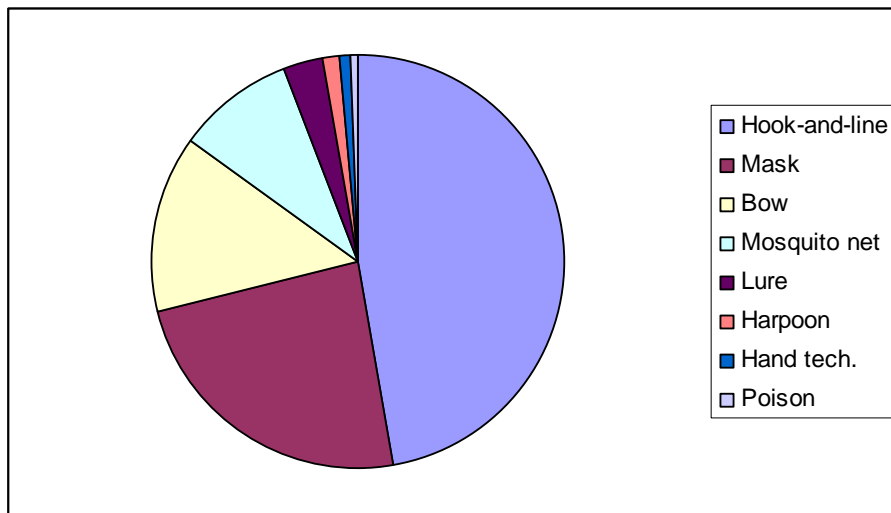


Figure 5.5. A young woman fishes with hook-and-line. (Photo courtesy of Menuka Scetbon-Didi)



wood is used primarily to store the extra line while the line itself is held in the fisher's hands (Figure 5.5). Bait varies seasonally and includes earthworms (the most common), crayfish, palm fruit, animal intestines, and sardines, among others. With no pole, the hook and bait are allowed to dangle in the water, and for that reason fishers prefer working from a boat, as the water is generally too shallow when fishing from shore. Most hook-and-line fishing takes place in the Lakus River itself, but this technology can also be used in small streams, especially when the river is flooded (although the fish in the streams are generally much smaller). Fishing with hook-and-line is not exclusive to any sex or age category, as both males and females of all ages fished with this technology throughout the year. Sometimes women in particular leave in small groups on fishing outings (i.e. outings on which they fish and little else), and the group can occasionally travel several miles to favorite fishing spots. Much fishing occurs on other outings, as when women or children fish while the male head of household works in the fields. Men might fish in between other tasks, and they also fish with hook-and-line from boats tied up at the community beach, especially in the late afternoon. Children fish with hook-and-line at all hours of the day, but for a while some children made a point of fishing for an hour or so before school started, when boats were more readily available.

While hook-and-line fishing can be done even when the water is murky, other fishing technologies depend on clear water. When fishing with bows, for example, it is obviously important to identify the target visually before attempting a shot. Unlike hook-and-line fishing, fishing with bows is almost exclusively a male-oriented activity. Bow-fishermen generally seem to prefer fishing from their boats, but they sometimes stand at the water's edge. They are especially prone to patrolling the shore when fishing in the mouth of a stream on days when streams afford better visibility than the river. When fishing from the boat, bow-fishermen find it especially helpful to have another person to steer the boat as they ready themselves for a shot. Nearly any companion can be entrusted with this task, but men on planned fishing trips often seem to assign this task to their adolescent and prepubescent sons. When someone else is available to command the boat, the bow-fisherman will remain poised in the front of the boat, scanning the water in search of fish (Figure 5.6). Stalking the fish sometimes requires considerable back-and-forth navigation after the fish has initially been spotted, and the fisherman directs his companion in the desired direction. In sufficiently shallow water, the bow itself might also be used as a *palanca* to help steer the boat (and this is especially true when fishing alone).

Figure 5.6. A man fishes with bow and arrow. (Photo courtesy of Menuka Scetbon-Didi)



Successfully shooting the fish is not easy, and I observed that many shots do not hit their target. The bows themselves do not carry much poundage, and the arrows do not travel with great velocity. Arrows have a wooden shaft while the point is often improvised and shaped from scrap metal.¹⁰ Only 12% of households in Arang Dak and Suma Pipi did not have a bow on one of the three days that I conducted censuses during the study period.

As with bow-and-arrow, fishing with a mask requires clear water to be effective. The masks are the kind used by SCUBA divers. Imported from outside the reserve, masks might sell for as much as \$25 U.S. Masks are used in tandem with either a *varilla* or *pistoleta*, both of which incorporate elastic rubber tubing. A *varilla* is essentially a long metal shaft with a barbed point, which is attached to the tubing. Upon seeing a fish, the diver grasps the tubing in his opposite hand and pulls back on the shaft, releasing a shot with a slingshot-like effect. By holding onto the tubing, the diver prevents loss of the weapon. The effective range of the *varilla* is no more than several feet. The *pistoleta* is similar to the *varilla* except that the tubing is affixed to a wooden frame, creating a weapon akin to a cross-bow. As with the *varilla*, the shaft remains attached to the tubing, thus preventing its loss. Of the two, the *varilla* is more commonly used, but their use is very similar. Divers remain fairly close to the surface of the water, but they remain submerged for as long as a minute while they wait for an opportunity to strike. As with bow-fishers, divers are often accompanied by younger companions, who wait in the boat for the diver to surface with fish, which are collected and kept in the boat. Groups of adult men sometimes form to go diving, and whatever masks are available are shared by all those in the party. In many respects, diving is the most exhausting of the fishing strategies in Bosawas, and men in Arang Dak seldom dive for more than 30-40 minutes at a time. After that, they are usually happy to give their companions a chance, especially when the air and water are cooler than normal. Cold water is the most oft-cited reason for ending a diving trip earlier than expected. Only 41% of the households owned a mask at some point during the year. Men without masks can usually borrow one from friends or relatives, but they are generally expected to repay the loan by sharing a fairly large percentage of their catch, perhaps as much as 30-40%.

In the dry season, especially between February and April, men do much of their fishing at night with the aid of a flashlight. The flashlight can be used in combination with a variety of technologies, including bows, the *varilla*, and the *pistoleta*. In addition to these technologies,

¹⁰ For example, I saw one man fashioning a new point from the wiry handle on a spool of barbed wire.

nocturnal fishing with flashlights can also be done with machetes, harpoons, and even with bare hands as fishermen capitalize on the inactivity of the fish. Men fishing at night often go in groups so that one person can hold the flashlight and illuminate the water while another uses his weapon to kill the fish. However, although it can be awkward, a single fisherman can usually manage both the flashlight and any of the above technologies (even while diving, as the flashlight can be protected in a plastic bag). Flashlights are common in the reserve, but the batteries are considered relatively expensive. The lack of fresh batteries can undermine plans to go on a nighttime fishing trip, but occasionally someone might donate batteries to the group in exchange for a share of the catch (again, a sizeable percentage).

As with bows and masks, other technologies are used primarily on a seasonal basis. From April to July, for example, mosquito nets can be used to harvest large quantities of “miniature fish” (i.e. smaller than two centimeters) called *golomina* in Spanish or *tunki* in Mayangna.¹¹ Fishing with such nets is generally done by children and adolescents, especially girls. This method involves dragging the net through the shallows along the river bank, then pulling it ashore to collect the fish. Younger children often tag along with a bucket in which they keep the collected fish while their older siblings and cousins manage the net. The time of day seems to impact the effectiveness of this technique, as the most productive fishing with nets generally occurs at dusk.

Nets are also used in the fishing of “lagoons,” depressions near the course of the Lakus River that fill with water (and fish) during the rainy season. Although these lagoons generally lack the most frequently-caught fish species, the *tuba*, they are often a rich source of turtles (cf. Stocks 1983:250). However, the lagoons are characterized by rapid diminishing returns and are usually not exploited multiple times per year.

The use of natural fish poisons is common throughout the Neotropics (Århem 1976:32; Jackson 1983:42; Stocks 1983:249; Gragson 1992*b*). Often, these toxins do not kill the fish but rather stun them or force them to the surface where they can be caught with nets or baskets or killed with hand technologies. The Mayangna and Miskito likewise have a technique that relies on the use of natural poisons, which is used primarily in creeks. Different toxins might be used, including the bark of a heavy vine or the leaves of the *bla bla* plant (Gros et al. in preparation). This method is not used frequently.

¹¹ These fish can also be caught with mosquito nets in March and August, but the method is generally less effective.

Another seldom-used traditional technique is the use of a wooden harpoon in combination with the leaves of the *tapal* plant (Gros et al. in preparation). The leaves are attached to the shaft of the harpoon and trailed in the water, which draws the attention of some species, especially the *robalo*. When the fish comes near, the fisherman stabs it with the sharpened wooden point of the harpoon.

A few fishermen have fishhooks with lures similar to those used in the United States. The census data suggest that there were three such lures in Arang Dak during the study period, and a couple of these might have been brought into the community as part of the LINKS project. At least one was purchased in a mestizo town to the west. As with regular fishhooks, the lures are not used with poles. Instead, while standing in a boat, the fisherman tosses the lure toward shore and rapidly reels it in by hand, hoping to catch a fish in the process. Sizeable fish (especially *guapote* and *robalo*) can be caught with this method, but its usefulness seems limited to a couple months out of the year.

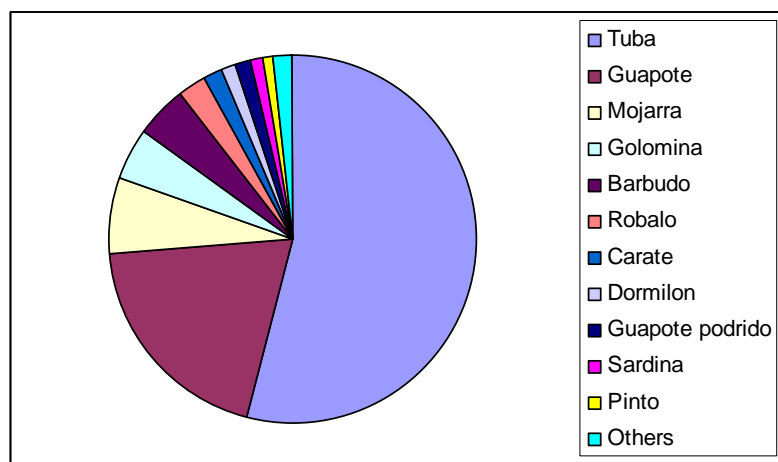
A final technology that is sometimes seen in the Mosquitia is the *taraya*.¹² A *taraya* is a large circular net with attached weights. Fishermen cast this net across the water and are able to catch most of the fish in the immediate vicinity. There was one *taraya* in Suma Pipi during the study period, and it was used to catch 6% of the fish biomass harvested in that community.

The fish in the reserve have only recently begun to receive attention from ichthyologists. Most of the species are cichlids with an average weight of less than 1 kg. The Lakus River apparently lacks the very large (50-100 kg) fish that characterize some of the larger Amazonian rivers (Gragson 1992a). One species, the *tuba*, contributes over half of the total biomass acquired by the residents of Arang Dak (Figure 5.7).¹³

¹² An alternate spelling, *atarraya*, appears to be common elsewhere in Latin America.

¹³ I rely only on the data from Arang Dak for many calculations in this chapter because the data from Suma Pipi do not encompass a full calendar year.

Figure 5.7. Harvested biomass of fish species in Arang Dak as a percentage of the total harvest. The names listed here are the common Spanish names.



5.7.1 Age-specific and sex-specific fishing patterns

As with time allocation in general, differences in age and sex have a strong bearing on the fishing patterns in Arang Dak. I examine this question in light of the recent scholarship on age-specific foraging that I described earlier in this chapter. In particular, I bear in mind a few assumptions that are common to research in human behavioral ecology. First, as with the hunting observations, I assume that the goal of fishing is to maximize the rate at which fish biomass is acquired. Second, pursuant to that goal, individuals with access to multiple fishing technologies will choose the one that promises the best return rate given the conditions. Elsewhere, anthropologists have treated the availability of different technologies as a patch choice problem, and the general conclusion is that people usually choose the technology that they expect to be the most profitable on any given outing (Sosis 2002).¹⁴ Third, following from the theory of time allocation described earlier, the benefits of fishing must be weighed against the opportunity costs. Those individuals who must choose between multiple fitness-enhancing activities will view the value of fishing differently than individuals with fewer options (Tucker, unpublished manuscript). With these assumptions in mind, I examine the hypothesis that sex and age-related effects have a bearing on fishing strategies in Arang Dak.

The first point to establish is that technologies differ in their productivity. There have been several studies of fishing in the Neotropics, and the general conclusion is that technology joins habitat and season (especially water conditions) as powerful predictors of fishing productivity (Gragson 1992a). Among the Cocamilla, for example, Stocks (1983) shows that fishing returns can vary from 0.29 to 7.00 kg/fisher-hour depending on fishing method, season, and habitat (e.g. streams vs. drying oxbow lakes). In many settings, rainfall is a powerful predictor of fishing returns, owing in large part to the effect of rainfall on river depth and clarity (Beckerman 1994a). For that reason, the problems with the Zoo's weather station are particularly lamentable, as there is probably a significant relationship between rainfall and fishing productivity on the Lakus River.¹⁵ This relationship might be apparent not only on a monthly but also a daily basis. The headwaters of the Lakus do not encompass a vast area, and

¹⁴ Following Beckerman (1983), decisions about whether to go hunting or fishing can also be treated as a patch choice problem in large part because fish and game meat are generally considered substitutable resources (cf. Behrens 1981).

¹⁵ This situation with the weather station was described in Chapter 2.

the level of the river can rise dramatically overnight and then drop again soon afterward as the rainwater drains out of the watershed. People in Arang Dak seldom fish when the river is at its highest, but they generally resume fishing shortly after the waters have receded.

While acknowledging that the absence of detailed weather data hinders a full understanding of fishing productivity, I examine the extent to which fishing returns vary between technologies. Although I conducted some opportunistic observations of fishers in Arang Dak, fishing was not a focus of this project to the extent that hunting was. I therefore combine my focal observations with fishing data collected by my research assistants (see Chapter 4 for a description of the methodology). I focus in particular on data collected from March-August 2005, as I introduced a modified fishing questionnaire in early March that allowed me to identify the time spent fishing with greater accuracy. Even with the modified form, the compilation of data for analysis was complicated by another challenge in data collection. Specifically, I used only fishing events for which my assistants and I were able to weigh the entire catch. In some cases, informants would report that their catch included not only the fish brought back to the household but also some fish that were consumed or distributed before the assistant arrived to weigh them. Data from such outings were not included in this analysis, which introduces a possible bias. Productivity for each technology was calculated by dividing the total catch by the total number of hours devoted to fishing. In situations where multiple individuals contributed to the catch, I counted each person's contribution as a fisher-hour. For example, if two girls spent an hour fishing together with a mosquito net, that trip would count for two fisher-hours.

The results of this analysis are presented in Table 5.6. To some extent, it is a little misguided to summarize these data without first accounting for seasonal (and daily) variations in fishing conditions, but the table nevertheless reveals the relative merits of the technologies. In general, fishing with hook-and-line appears to be the least productive method whereas fishing with a SCUBA mask and accompanying technologies seems to be the most productive. These observations accord well with the opinions of the Mayangna and Miskito, who mentioned in informal interviews that fishing with masks is the most effective technique.

It is tempting to examine age-related effects in this dataset. Would children have a lower return rate than adults, for example? As is common in ethnographic research, however, such analysis is complicated by the inability to account for other relevant variables. Even if return rates were lower for children, it is not possible to rule out the possibility that children are more

Table 5.6. Average productivity of fishing technologies in Arang Dak. Fisher-hours and fishing events refer to the size of the sample used in the calculations.

Technology	Return (kg/fisher-hr)	Fisher-hours	Fishing events
Hook-and-line	0.22	2015.8	580
Mosquito net	0.35	340.5	121
Bow-and-arrow	0.49	220.4	69
Lure ¹⁶	2.50	2.1	1
Mask and varilla	2.71	381.2	107
Mask and pistola ¹⁷	5.03	3.8	36

likely to fish on days when rates are less favorable. Focal observations of multiple individuals fishing in the same conditions would be particularly beneficial to an examination of age and sex-related effects. Based on a few observations of several residents fishing simultaneously on the beach by the community, my impression is that age and sex have little effect on the return rates of hook-and-line fishing, but this question merits further study.

Based on the harvest data, it is apparent that adult men are closely associated with the most physically demanding technologies: bow-and-arrow, harpoon, and diving with a mask and *varilla* or *pistola*. Men between 18-49 contribute over 85% of all fish biomass caught with these technologies, with the remainder caught either by older men or adolescent boys (Figure 5.8). The male 18-49 age class also contributes over half of the biomass caught with lures and with hand technologies.¹⁸ By comparison, the harvest with fishhooks is much more evenly distributed among age and sex classes, with no class contributing more than one-third of the harvest.¹⁹

Another way of looking at these same data is to examine the extent to which the various fishing technologies contribute to the overall harvest by different age and sex classes (Figure 5.9). The association of men with bow, harpoon, diving masks, and lures is reinforced by the fact that these four technologies contribute over 80% of all fish biomass captured by men

¹⁶ The estimate for this technology comes from a focal observation that I conducted in December, 2004.

¹⁷ The calculation for mask and *pistola* includes a focal observation in which I observed a fisherman acquire 4.6 kg of fish in 30 thirty minutes for a rate of 9.2 kg/hour.

¹⁸ For the “hand technologies” code, it is worth repeating that this category includes a few different methods. Much of the contribution by men to this harvest stems from their use of machetes on nocturnal fishing outings. By contrast, the use of hand technologies by women primarily involves the use of nets and bare hands in lagoons.

¹⁹ Neither males nor females in the youngest age class (less than six years old) caught any fish during the study period, and they are therefore excluded from these analyses.

Figure 5.8. Proportionate contributions by age and sex classes to the total harvest caught with different fishing technologies

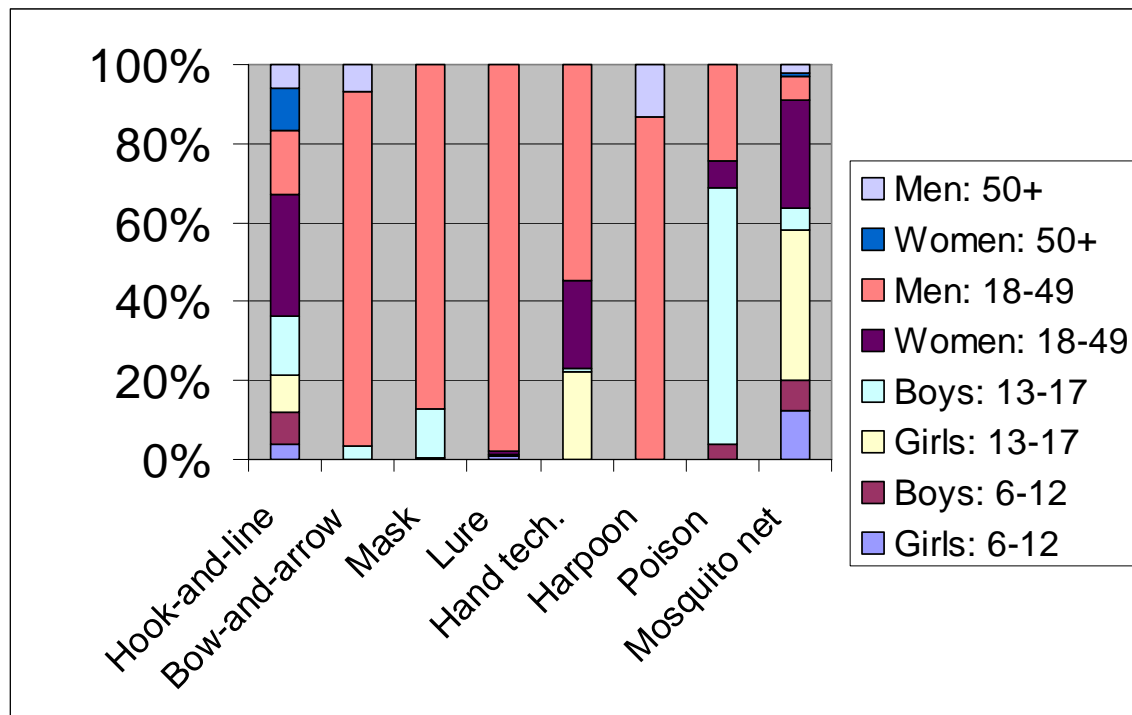
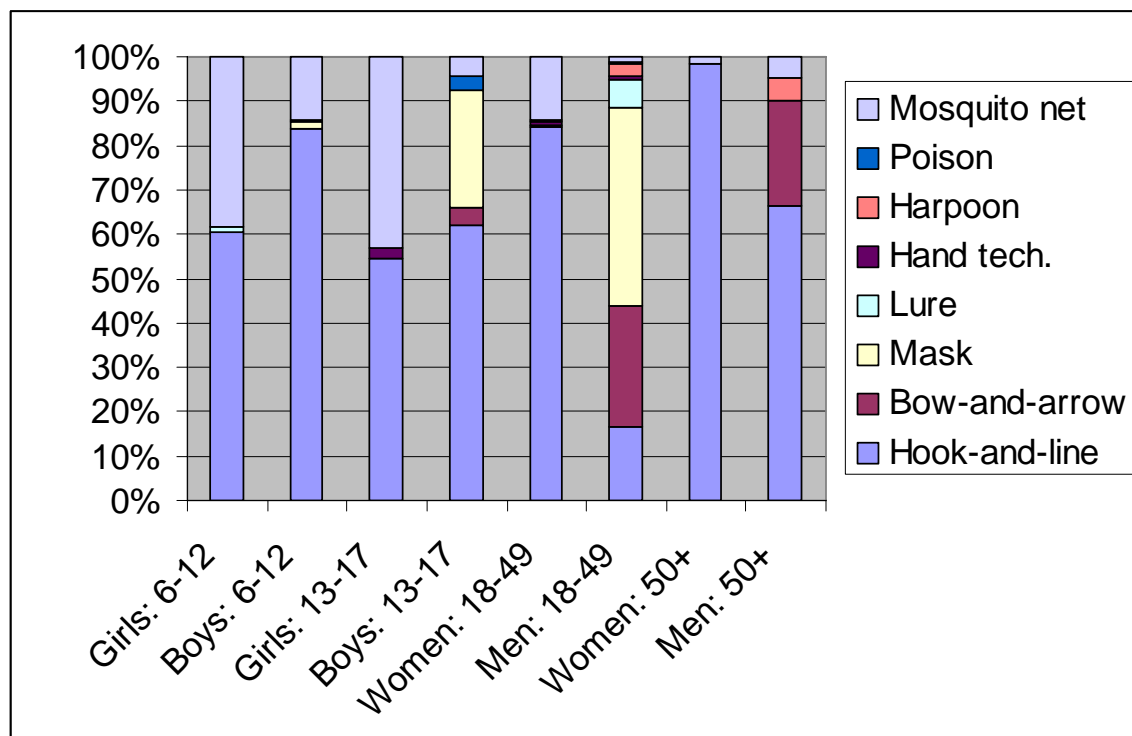


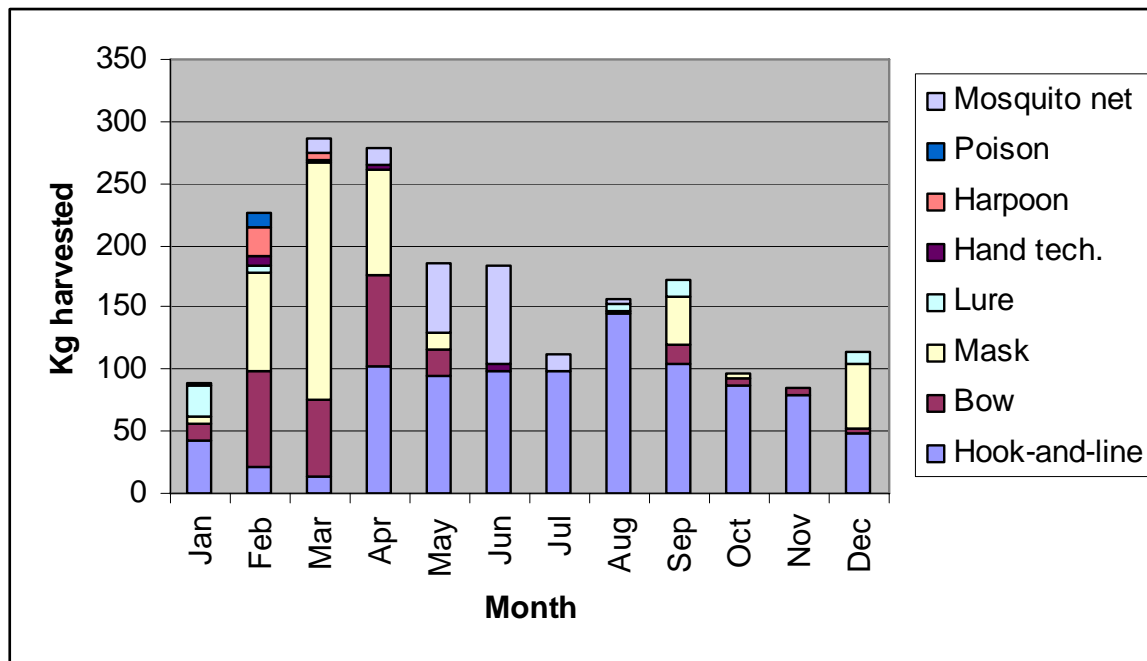
Figure 5.9. Proportionate contributions of fishing technologies to the total harvest of fish by age and sex classes



between ages 18-49. For all other age and sex classes, hook-and-line fishing contributes at least half of the biomass in the class-specific harvest. Even in these other classes, however, some age and sex-related trends are apparent. First, for all female age classes, the mosquito net is ranked second in terms of its contribution to the harvest of fish. Women do not fish with SCUBA masks or bows, the two technologies that rank first and second in the harvest by reproductive-aged men. Second, for males, the relative importance of technologies seems to change over the lifespan. For boys in the youngest age class, fishing with a mosquito net (including time spent assisting their older sisters) ranks behind only hook-and-line fishing in its contribution to their total harvest. For adolescent boys, by contrast, fishing with masks makes the second-greatest contribution to their overall harvest. Finally, when not fishing with hook-and-line, men in the oldest age class appear to rely more heavily on bows than other technologies. In short, males use a variety of technologies, but the repertoire of fishing techniques appears to change as they age.

As noted earlier, however, the effectiveness of technologies varies seasonally. The technologies that depend on the clarity of the water, such as bows and diving masks, are most effective during the dry season (January-May, with especially favorable conditions from February to April). Given the high productivity of these technologies, perhaps it is not surprising that the overall harvest of fish peaks at the same time (Figure 5.10). In large part because of the large amount of fish caught with the use of diving masks (and bows to a lesser extent), more fish biomass is captured in March than any other month. Together, bows and diving masks also contribute over 50% of the biomass in April and February, the two months that rank second and third in terms of harvested fish biomass. Interestingly, the importance of hook-and-line fishing in March is minimal, and this is also the month in which adult men (ages 18-49) contribute the smallest percentage of biomass captured with this technology (7%). In other words, compared to other months, the other age and sex classes harvest a greater percentage of the fish caught with hook-and-line in March, perhaps reflecting the adult males' focus on more productive technologies at this time. In general, the fishing efforts of adult men have a strong impact on the overall monthly harvest, as reproductive-aged men account for at least 60% of the overall harvest in February, March, and April, the three months with the highest harvest. By comparison, men capture only 28% of the harvest in all other months (May-January). In July, one of the months with the lowest overall harvest, men between ages 18-49 acquired only 9% of the fish biomass.

Figure 5.10. Harvest of fish by month and technology



5.7.2 Discussion of age-related fishing patterns

How should these data be interpreted in light of the ongoing debate about age-related effects in foraging skill and time allocation? Although the analysis would benefit greatly from detailed focal observations of fishing in a wide variety of contexts, it is possible to offer some tentative explanations. Particularly interesting is the way in which males use different technologies over the course of their lifespan. While the youngest boys focus almost exclusively on fishing with hook-and-line and mosquito nets, the diversity of technologies in male fishing repertoires increases with age until the post-reproductive age class (50+), at which point the techniques are similar to those of younger men except for the lack of fishing with diving masks in this older age class. If the assumption is correct that individuals choose technologies that permit them to maximize the rate at which they acquire fish, then fishermen in Arang Dak presumably use the technologies that best suit their strengths.

Perhaps the most pressing question is why adolescent males tend toward fishing with masks while men in the oldest age class elect to use bows instead of masks.²⁰ If the model of life history evolution proposed by Kaplan et al. (2000) is accurate, then we might expect older men to focus in particular on fishing methods that require detailed ethno-ichthyological knowledge and other cognitive skills in lieu of physical capabilities. In other words, perhaps older men are particularly skilled at “stalking” fish, which could require detailed awareness of their preferred habitats and anti-predator behavior. The construction of bows and arrows might be another factor. My impression is that adolescent and young adult males have little experience constructing these technologies, which might effectively preclude their use of bows for fishing.²¹

Alternatively, perhaps older men avoid fishing with masks because this method is too demanding physically. Given the evidence that fishing with masks is several times more productive than fishing with bows, one might imagine that older men would likewise fish with masks if they were able. One possibility is that the pulmonary demands of diving with masks might not be possible for older men. Divers with masks usually remain submerged for at least 20

²⁰ While there are relatively few individuals in the sample of post-reproductive men, men older than about 40 also seldom fish with diving masks while relying more heavily on fishing with bows. The one exception to this generalization is a 42-year-old male who had previous experience diving for lobsters in the Honduran Caribbean (cf. Dodds 1998). This man fished quite extensively with mask and *pistoleta*, and his skill with this method was mentioned in an earlier footnote.

²¹ Although I lack quantitative data on this point, my impression is that bows are shared between households much less frequently than diving masks.

seconds and sometimes as long as 50 seconds, with fairly short intervals (about 20 seconds) between dives to catch their breath.²² Pulmonary function declines with age (Cohn and Donoso 1963; Turner et al. 1968), and older men might not be able to remain submerged long enough to make diving sufficiently productive. Another consideration is that masks are a relatively recent introduction to the fishing technologies in the reserve. None of the informants with whom I spoke could remember seeing masks in Arang Dak until after their return from the Honduran refugee camps in 1991. With few opportunities to practice with masks as adolescents and young adults, older men might be reluctant to adopt this technology despite the evidence of its effectiveness. In general, although there are compelling reasons to believe that masks are better suited for younger men, more research is needed to obtain conclusive support for this hypothesis.

Fishing with mosquito nets presents another interesting age-related topic. This technology is used primarily by women and children, especially by adolescent girls and their younger siblings. Although it is more productive than hook-and-line fishing, fishing with mosquito nets seems to require little skill or strength.²³ Although more observational data are needed for comparisons, it is likely that the productivity of adults with this technique is not significantly better than that of children. Households might maximize overall production by allowing children to handle this task while adults focus on tasks that children cannot do well (Bock 2002).

Children also spend a considerable amount of time fishing with hook-and-line, and they sometimes suffer through fairly meager returns (e.g. catching only a couple very small fish in an hour of fishing). On such occasions, I hesitate to attribute their poor success to age-related inadequacies, as poor fishing conditions often seem to trump undeveloped abilities as the reason for their small catch. Therefore, instead of focusing on their fishing skills, the question is why children are willing to fish on days when adults deem the conditions to be too unfavorable for an outing. To answer this question, I hearken back to Tucker and Young's (2005) observation that

²² On one focal observation of fishing with mask and *pistoleta*, I was able to collect detailed data on the time spent underwater versus time spent at the surface. During 22 minutes and 48 seconds of observation, the diver spent 9 minutes and 57 seconds diving, and he spent 12 minutes and 51 seconds on the surface. The average dive lasted 35 seconds. Time spent on the surface depended on the success of the previous dive. On the seven dives when the fisherman surfaced with a fish, the average time spent tossing the fish to his companion and resetting the *pistoleta* was 1 minute and 24 seconds. After unsuccessful dives, by comparison, the individual spent an average of only 21 seconds on the surface before diving again.

²³ An added advantage is that this method can be used very near the community and is therefore not subject to the availability of boats.

children generally lack the competing demands that characterize adult time budgets. With fewer alternative uses for their time, the opportunity costs of fishing are less significant for children, and they might deem it worth their time to fish for a while in search of a garnish for their supper.²⁴

In conclusion, fishing in Arang Dak exhibits age-specific patterns that generally conform to predictions derived from current models of human life history evolution. Specifically, individuals appear to devote attention to the fishing techniques that match their physical and cognitive capabilities. For example, children focus primarily on technologies that are both cognitively and physically undemanding, such as hook-and-line and mosquito nets. By contrast, reproductive-aged men capitalize on their increased cognitive and physical skill to employ technologies with a high return rate, such as bows and diving masks. As they age, males seem to rely more heavily on bow fishing in place of diving with masks, which might stem from the physically demanding nature of the latter.

Although this research contributes to the ongoing debate by demonstrating that these patterns exist, more research is needed to tease apart the importance of cognitive familiarity and physical size to the use of fishing technologies. For example, although I have data on age-specific fishing returns with several technologies, these data provide only limited insight because it is not possible to account for variations in fishing conditions. In addition, this research question would benefit from investigations that do not include only focal observations of fishing trips. In hunting studies, for example, experimental evidence complements the observational data by showing that peak hunting productivity does not depend solely on changes in physical size and strength (Walker et al. 2002; Gurven et al. in press). Hunting studies have also examined age-specific patterns in the components of hunting, with evidence suggesting that detecting and stalking prey are more closely connected to increased age and experience than marksmanship, which is more dependent on physical size (Walker et al. 2002). Comparable fishing studies in Bosawas might examine the extent to which components of fishing (especially distinguishing between the detection and capture of fish) are related to age-specific changes in growth and experience. Although hunting has received a disproportionate amount of attention

²⁴ In general, I do not focus on the value of information, but there might also be value in learning to appreciate the conditions that lead to poor fishing returns. Being able to identify poor fishing conditions might be advantageous in adulthood, when individuals must make discerning choices about the best use of their time.

from human behavioral ecologists, additional work on challenging fishing tasks might also provide valuable insight into age-related trends in foraging tasks.

5.8 Conclusions

It is reasonably clear that individuals vary in their physical and cognitive abilities, and much of this variation is associated with age and sex-related differences. To the extent that those differences affect subsistence decisions, research into sex-specific and age-specific foraging remains a promising area of study. This study contributes to the discussion primarily by affirming that these patterns exist in a setting that differs somewhat from those that have been studied previously. The results here support some of the qualitative predictions derived from current models of life history evolution, particularly the observation that age and sex-related characteristics affect not only the potential productivity of subsistence activities but also the opportunity costs and relative value of those activities.

The debate about human life history evolution can be basically divided into two positions: (1) those who view the extended juvenile period as an unsurprising product of longer human lifespans in general, and (2) those who see the extended juvenile period as an adaptation in and of itself. For the former, the attention is on the selective advantages of long lives (e.g. the Grandmother hypothesis). By contrast, the latter seek to explain the long-term fitness benefits of an extended juvenile period, and these researchers have focused in particular on the lengthy time needed to master complex foraging tasks. As noted previously, I do not use these results to argue strongly for either of these positions. Part of this reticence stems from the lack of the complementary experimental data that would be needed to tease apart the relative importance of cognitive development and physical growth as factors in differential return rates. Although I believe that age and sex-related patterns of fishing in Bosawas represent a topic worthy of further study, it is difficult to make strong conclusions without additional research similar to that employed in other recent studies (e.g. Gurven et al. in press).

More generally, I remain at least somewhat unconvinced on the question of causality in current models of life history evolution. On the one hand, researchers on both sides of the debate have marshaled the usual sources in support of their positions, including a wide variety of ethnographic studies, comparisons with non-human primates, and paleo-anthropological

evidence. On the other hand, there is naturally some skepticism when relying on contemporary ethnographic evidence to make broad conclusions about hominid evolution. The social and ecological challenges faced by individuals in Arang Dak may differ profoundly from those that impacted the evolution of distinctive life history traits in prehistoric humans. Perhaps the lasting legacy of anthropology as a scientific discipline is its continuing discovery of human adaptability to new surroundings and challenges. Traits that evolved in response to one ecological challenge might later be applied productively to a novel, unrelated challenge. In this case, the observation that time budgets and fishing patterns in Arang Dak vary across the lifespan does not imply that human life history traits evolved as Pleistocene hunter-gatherers attempted to meet similar challenges. The apparent benefits of these age-related subsistence patterns in Arang Dak might indeed be adaptive given the constraints imposed by human life histories, but the thread of causality in the evolution of those life history characteristics is not immediately evident.

Despite my skepticism, I do not believe that these questions are hopelessly unanswerable. Therefore, my hope for this research is that it will draw further attention to the importance of age-related characteristics in the subsistence decisions of both contemporary and prehistoric foragers. As more studies report similar results, these age-related trends might eventually be viewed as a defining hallmark of our species. Consideration of age-related abilities would also be essential to a unified theory of time allocation that weighs the fitness-enhancing benefits of competing activities, such as childcare, reproductive effort, food production, social activities, and leisure.

Chapter 6

Conclusions

To a large extent, the adaptive strategies of the Mayangna and Miskito in the Bosawas Reserve are similar to those employed by indigenous horticulturalists throughout the Neotropics. Hunting is the primary focus of this dissertation, and hunting in Arang Dak and Suma Pipi shares a number of similarities to hunting practices elsewhere in lowland Latin America. As elsewhere, hunting is largely a male-oriented activity, and mammals contribute a large percentage of biomass to the harvest (Vickers 1984). As predicted by central place foraging theory (Orians and Pearson 1979), kill sites are generally clustered around the communities, and the close proximity of anthropogenic habitats suggests that there are elements of “garden-hunting” in Bosawas (Linares 1976). To the extent that these observations mirror trends from other indigenous societies, this study supports a cross-cultural model of Neotropical hunting (Redford and Robinson 1987).

In other ways, hunting in Arang Dak and Suma Pipi differs from that described elsewhere. Perhaps most importantly, the Mayangna and Miskito hunters in Bosawas apparently rely on dogs more heavily than hunters in many Neotropical societies. As noted in Chapter 2, there are numerous ethnographic reports of hunting dogs in the literature, but previous optimal foraging studies of hunters generally occurred in settings where bows, rifles, or blowguns were the primary hunting weapons (Hames and Vickers 1982; Hill and Hawkes 1983; Alvard 1993). Dogs receive greater attention in other studies (e.g. Smith 1976; Kaplan and Kopischke 1992), but it is not particularly clear if dogs are as important in those settings as they are in Arang Dak and Suma Pipi, where they contribute to 85% of the kills of mammalian prey. Although some anthropologists have commented that hunting dogs do not appear to be especially effective in Neotropical settings (Alvard and Kaplan 1991), this research shows that the average return rate when hunting with dogs compares favorably to rates reported with other technologies elsewhere (Beckerman 1994a).

From an optimal foraging perspective, the use of hunting dogs necessitates a modification to the basic optimal foraging model that has been used to understand prey choice by human hunters (Smith 1983; Kaplan and Hill 1992). As described in Chapter 3, hunters with dogs incur some unique costs. Specifically, dogs routinely chase after prey types that hunters consider

undesirable or impossible to kill (e.g. deer pursuits in the absence of rifles). Because hunters are effectively powerless to prevent their dogs from chasing such prey items upon encounter, the time lost to such fruitless pursuits serves to lower their overall return rate. These costs can be incorporated into the diet breadth model as an additional constraint. This expanded model has been applied occasionally in the biological sciences (Elner and Hughes 1978; Houston et al. 1980), but it has received little attention in the last two decades. Because hunting with dogs probably entails similar costs in settings throughout the world, this model merits additional consideration as a means of explaining prey choice by hunters with dogs in both contemporary and prehistoric settings.

For rifle hunters, the results of the optimal foraging analyses are generally similar to those of previous OFT work with shotgun hunters (Hill and Hawkes 1983; Alvard 1993). The observation that all regularly-pursued prey types increase the overall return rate provides additional support for the usefulness of the diet breadth model to explain prey choice decisions by human hunters. However, rifle hunters regularly forego opportunities to pursue howler monkeys, which would almost certainly be included in the optimal diet breadth if they were pursued. Similarly, hunters with dogs do not consume anteater species despite the fact that they would be among the most profitable prey types available. These aversions are particularly surprising because many other indigenous societies consume these species (and related species) on a regular basis. When asked, Mayangna and Miskito informants cite taste as the most important factor in their reluctance to consume these prey types. From an optimal foraging perspective, taste is difficult to quantify, and it is also difficult to separate taste on a purely sensual basis from cultural beliefs and food preferences. It is clear, however, that hunters are considering factors beyond just the OFT profitability of these prey types. For that reason, it might be unwise to declare OFT models an unquestioned success in their applicability to Neotropical hunting decisions. Of the questions raised by this dissertation project, the aversions to these species are perhaps the most promising candidates for future anthropological study. As with human behavioral ecology in general, the reductionism of optimal foraging models ensures their widespread applicability (Winterhalder and Smith 2000). However, to explain seemingly incongruous observations, such as the apparently suboptimal aversions to the aforementioned species, anthropologists must give consideration to other variables, some of which might not be immediately reconcilable to an optimal foraging perspective.

As seen in Chapter 4, the widespread use of hunting dogs is reflected in the composition of the harvest. Three species that can be killed with dogs – agoutis, pacas, and nine-banded armadillos – together represent over half of the kills in the harvest. Coupled with the reluctance to pursue howler monkeys and capuchin monkeys, the use of hunting dogs appears to be the primary reason that rodents are relatively more important to the harvest in Arang Dak and Suma Pipi than they are in a cross-cultural sample. By contrast, primates are relatively unimportant to the harvest, and the consumption of primates per consumer in Arang Dak and Suma Pipi is much lower than it is in the average Neotropical setting. These patterns might be characteristic of societies that rely more heavily on hunting dogs than projectile weapons, and this study might therefore be valuable for ethno-archaeological reconstructions of hunting harvests in the pre-Columbian Neotropics (cf. Cooke and Ranere 1992).

Along with primates, the per-consumer harvests of several other species in Suma Pipi and Arang Dak are below the norm for Neotropical societies. The apparently low level of hunting pressure on these species is matched by the observation that few of the harvests definitely exceed sustainable limits, as calculated in the production model (Robinson and Redford 1991). That generalization is not true of all species, however, as the harvest of pacas and tapirs in the core hunting zone clearly exceeds the maximum sustainable yield. The persistence of tapirs in the core hunting zone probably represents a source-sink system, where the unsustainable harvest is balanced by in-migration from lightly-hunted areas (Pulliam 1988). The apparently excessive harvest of pacas is a little puzzling given their abundance near the communities and alongside the Lakus River. It is possible that sustainable estimates should be altered to reflect the abundance of species that seem to thrive in anthropogenic habitats. A third species, the spider monkey, receives only minimal hunting pressure around the communities, but this pattern more likely reflects their absence in the core hunting zone, perhaps owing to past over-hunting or the lack of suitable habitat near Suma Pipi and Arang Dak. Most of the spider monkeys in the sample were harvested far upstream of the communities, but if these animals had all been captured in the core hunting zone, this harvest would likewise have been conclusively unsustainable. Overall, most kill sites are located within five kilometers of the communities, and the extirpation of most species from the Lakus River watershed does not appear imminent provided that the largely unexploited tracts of forest upstream of Arang Dak remain intact.

Wildlife management plans for Bosawas should include attention not only to wildlife harvests but also to the preservation of forest habitats in non-agricultural areas.

Several anthropologists have commented on the extent to which kill sites are clustered around communities (e.g. Hames and Vickers 1982; Alvard 1994), a pattern that accords well with predictions derived from central place foraging theory. Less attention has been given to the distribution of kill sites around individual hunters' fields. Mayangna and Miskito hunters often combine hunting excursions with visits to their fields, which results in a geographic pattern of kill sites around those fields. This pattern is further reinforced by many opportunistic kills, as when farmers interrupt their agricultural chores to kill an animal that their dogs have corralled nearby. The dynamic between fields, dogs, and hunting might explain why "garden game" species seem so pervasive in Neotropical harvests (Linares 1976; Smith 2005). More generally, this dissertation is the second study to use sketch-mapping methods and GIS to plot the locations of kill sites, and the relationships between wildlife habitats and behavior, hunting technologies, and patterns of extraction will become clearer as further studies help to identify the range of geographic variation in hunting harvests throughout the Neotropics (Smith 2003*b*).

Although the heavy reliance on hunting dogs largely precludes the analysis of age-related differences in hunting skills, patterns of time allocation and fishing in Arang Dak generally conform to patterns that human ecologists have observed elsewhere (Gurven and Kaplan 2006). Specifically, in comparison to younger age classes, adult men are more devoted to high-strength, high-skill activities, such as hunting and agricultural labor. As adult men reach their post-reproductive years, they spend increasing amounts of time in agricultural labor, including the cultivation of cash crops. The dedication of adult men to high-strength, high-skill activities is particularly evident in the fishing harvest. As detailed in Chapter 5, men between the ages of 18-49 employ a wider variety of fishing technologies than any other age-and-sex class, including many highly-efficient technologies that demand both advanced cognitive and physical skills. At this time, the data do not permit compelling arguments for the extent to which either physical abilities or cognitive skills limit the use and effectiveness of the various fishing technologies, but this topic remains a promising opportunity for future research.

As with the hunting research, the fishing data and especially the time allocation work represent a new contribution to the ethnographic literature on the Mayangna and the Miskito. Like many other indigenous societies, the Mayangna and Miskito are integrated into the external

market economy, and the acculturation to the norms of their mestizo neighbors is ongoing. In some cases, the effects of these interactions are obvious, as in the presence of chainsaws, rifles, SCUBA masks, American clothes, Nicaraguan currency, silverware, barbed wire, plastic bins, etc. In other cases, the influences are more subtle, as in the use of western kinship terms to describe relatives. Despite these changes, however, the persistence of traditional indigenous culture is readily apparent in a number of ways. According to informants, for example, hunting with dogs has changed little in the last half-century. Some fishing technologies are similarly unchanged, such as the bow and arrow and the use of natural poisons. With allowances for the introduction of new crop varieties, the timing of the agricultural calendar differs little from that described by elderly Mayangna informants. These observations do not imply that these aspects of indigenous culture somehow exist in a vacuum, unaffected by interactions with other cultures. Nevertheless, although introduced ideas and technologies affect all aspects of Mayangna and Miskito culture, some of the subsistence practices in Suma Pipi and Arang Dak have apparently changed little in response to that cultural diffusion, and the study of these practices can contribute to ethno-archaeological reconstructions of indigenous lifestyles in the Mosquitia.

In conclusion, hunting in Bosawas is unique. Although Mayangna and Miskito hunting strategies generally resemble those reported by ethnographers elsewhere, this particular constellation of game species, habitats, hunting technologies, and the overall role of hunting in the local economy is unlike any other in the literature. This dissertation therefore adds to our understanding of the ways in which hunting strategies respond to changes in wildlife abundance, available technologies, and the overall subsistence landscape. The interaction of wildlife, habitat, and hunting is a dynamic process, however, and both conservationists and indigenous leaders have expressed concerns about the long-term prognosis of the Bosawas forest ecosystem. Although the conservation literature is replete with reports of unsustainable hunting and habitat destruction, there are reasons for optimism in Bosawas. Perhaps most importantly, the indigenous leadership has repeatedly expressed its commitment to the conservation of forest resources, which they recognize as valuable to indigenous livelihoods. Now that the Nicaraguan government has granted legal land title to the indigenous territories, the necessary conditions for a communal approach to conservation are largely in place. Finally, conservationist organizations remain committed to the Bosawas Reserve and its inhabitants, and the cooperative implementation of scientifically-based management plans bodes well for the future. This

dissertation provides additional perspectives on hunting strategies and indigenous subsistence, which will, I hope, prove beneficial not only to the long-term conservation of the Bosawas Reserve but also to the conservation of inhabited forests throughout lowland Latin America.

Appendix A: List of large mammals (generally greater than 1 kg) in Kipla Sait Tasbaika. The confirmed presence of a species in the Bosawas Reserve is based primarily on linear transect work by the Saint Louis Zoo (Williams-Guillen et al. 2006). In some cases, the English name is abbreviated. For example, the coati is called a white-nosed coati in some publications (Reid 1997). Indigenous names generally follow spellings from Williams-Guillen et al. (2006). Species are organized by edibility. Listed first are species that are almost invariably considered edible. The second subset includes species that were consumed by some residents but are considered inedible by at least some members of the community. The last subset lists species that are apparently never eaten by residents of Suma Pipi and Arang Dak.

	Scientific name	English name	Spanish name	Mayangna	Miskito
Apparently considered edible by all residents	<i>Dasyus novemcinctus</i>	Nine-banded armadillo	Cusuco	Ukmik	Taira
	<i>Ateles geoffroyi</i>	Spider monkey	Mono	Urus	Urus
	<i>Sciurus variegatoides</i>	Variegated squirrel	Ardilla	Buskah	Butsung
	<i>Dasyprocta punctata</i>	Agouti	Guatusa	Malaka	Kiaki
	<i>Agouti paca</i>	Paca	Guardiola	Wiya	Ibihna
	<i>Tayassu tajacu</i>	Collared peccary	Sahino	Mulukus	Buksa
	<i>Tayassu pecari</i>	White-lipped peccary	Chanco de monte	Siwi	Wari
	<i>Tapirus bairdii</i>	Tapir	Danto	Pamka	Tilba
	<i>Mazama Americana</i>	Red brocket deer	Venado rojo	Sana Pauni	Sula pauni
	<i>Odocoileus virginianus</i>	White-tailed deer	Venado blanco	Sana Pihni	Sula pihni
Eaten by some residents	<i>Cebus capucinus</i>	White-faced capuchin	Mono cara blanca	Wakrih	Wakrih
	<i>Alouatta palliata</i>	Howler monkey	Congo	Kungkung	Kunkun
	<i>Sylvilagus brasiliensis</i>	Forest rabbit	Conejo	Tibam	Bang bang
	<i>Nasua narica</i>	Coati	Pisote	Almuk Ahsla	Wistiting
	<i>Puma concolor</i>	Puma	Léon	Nawah Pauni	Limi pauni
Considered inedible by residents of Arang Dak and Suma Pipi	<i>Philander opossum</i>	Gray four-eyed opossum	Zorro colapelada	Sikiski waika susupra	Sikiski waika susupra
	<i>Didelphis virginiana</i>	Virginia opossum	Zorro de Balsa	Wasalah	Trin skiskika
	<i>Didelphis marsupialis</i>	Common opossum	Zorro Colapelada	Wasalah	Sikiski waika susupra
	<i>Myrmecophaga tridactyla</i>	Giant anteater	Oso caballo	Wingku tara	Wingku tara
	<i>Tamandua mexicana</i>	Northern tamandua	Oso hormiguero	Karking	Wingku (sirpi)
	<i>Cyclopes didactylus</i>	Silky anteater	Hormiguero sedoso	Wisurh	Likur
	<i>Bradypus variegatus</i>	Three-toed sloth	Perezoso	Um Pihni	Siwaiku
	<i>Choloepus hoffmanni</i>	Two-toed sloth	Perezoso	Um Pauni	Siwaiku
	<i>Cabassous centralis</i>	Naked-tailed armadillo	?	Takan Takan	?
	<i>Procyon lotor</i>	Northern raccoon	Mapachin	Suksuk	Suk suk
	<i>Potos flavus</i>	Kinkajou	Cuyu	Uyuk	Uyuk
	<i>Galictis vittata</i>	Greater grison	?	?	?
	<i>Eira barbara</i>	Tayra	Culumuco	Kulum	Arari
	<i>Conepatus semistriatus</i>	Striped hog-nosed skunk	Zorromión	Piskrawat	Piskrawat
	<i>Panthera onca</i>	Jaguar	Tigre	Nawah Bulni	Limi bulni
	<i>Leopardus wiedii</i>	Margay	Peludo	Kuruh Bini	Buhru
	<i>Leopardus pardalis</i>	Ocelot	Tigrillo	Kuruh	Buhru

Appendix B: Household structure data for participating households in Arang Dak and Suma Pipi at the time of the initial census in August, 2004. Note that this table does not reflect changes in household structure due to marriages during the study period, nor does it reflect demographic changes in the community due to immigration, births or deaths. The exception is household code AD 31, which immigrated as a family to Arang Dak in the middle of the study period (February, 2005).

Household code	Sex	Age	Relationship to head
AD 1	M	27	(Head)
	F	26	W
	M	8	S
	M	6	S
	F	4	D
	M	2	S
	M	0+	S
	F	45	M
	F	16	Z
	M	14	B
	M	12	B
	F	10	Z
AD 3	M	38	(Head)
	F	31	W
	F	15	D
	F	13	D
	F	10	D
	F	8	D
	F	6	D
	M	3	S
	F	0+	D
	F	65	WM
AD 4	M	29	(Head)
	F	34	W
	M	18	WS
	M	16	WS
	F	13	D
	F	11	D
	M	7	S
	M	5	S
	F	3	D
	M	1	S

Household code	Sex	Age	Relationship to head
AD 5	M	28	(Head)
	F	37	W
	M	15	WS
	F	13	WD
	M	10	WS
	M	7	S
	M	4	S
	M	1	S
AD 6	M	25	(Head)
	F	24	W
	F	8	WD
	M	5	S
	M	4	S
	M	2	S
	F	0+	D
AD 7	M	62	(Head)
	F	60	W
	M	28	S
AD 9	M	41	(Head)
	F	38	W
	F	18	D
	M	16	S
	M	13	S
	F	13	D
	F	11	D
	F	9	D
	M	7	S
	M	4	S
AD 10	M	46	(Head)
	F	32	W
	F	13	D
	M	11	S
	F	9	D
	M	7	S
	M	5	S
	M	3	S
	F	1	D

Household code	Sex	Age	Relationship to head
AD 11	M	45	(Head)
	F	45	W
	F	20	D
	M	17	S
	F	12	D
	F	9	D
	F	6	D
	M	3	S
AD 12	M	32	(Head)
	F	24	W
	M	12	S
	F	4	D
AD 13	M	60	(Head)
	F	45	W
	WS	18	WS
	F	15	WD
	F	15	WD
	M	13	WS
	F	10	WD
	WD	20	WD
	WDD	2	WDD
	WDD	0+	WDD
AD 16	M	29	(Head)
	F	23	W
	M	8	WS
	F	6	D
	F	4	D
	F	2	D
AD 17	M	31	(Head)
	F	29	W
	F	14	WD
	F	11	D
	M	9	S
	M	7	S
	F	5	D
	F	3	D
	F	0+	D

Household code	Sex	Age	Relationship to head
AD 18	M	40	(Head)
	F	32	W
	M	16	S
	M	15	S
	F	13	D
	M	11	S
	F	9	D
	M	6	S
	F	3	D
	M	2	S
AD 19	M	70	(Head)
	F	55	W
	F	28	D
	M	11	DS
	M	2	DS
AD 21	M	50	(Head)
	F	36	W
	F	15	D
	F	10	D
	M	6	S
	M	4	S
	F	19	D
	M	1	DS
	F	17	D
	M	2	DS
AD 22	M	57	(Head)
	F	39	W
AD 23	M	40	(Head)
	F	20	W
	M	5	S
	M	3	S
	F	1	D
AD 24	M	35	(Head)
	F	35	W
	M	18	WS
	M	16	WS
	M	12	WS
	M	9	S
	M	7	S
	M	4	S
	F	2	D

Household code	Sex	Age	Relationship to head
AD 25	M	40	(Head)
	F	34	W
	F	11	D
	M	8	S
	F	6	D
	F	3	D
	F	67	WM
AD 26	M	23	(Head)
	F	16	W
	M	2	S
AD 29	M	36	(Head)
	F	26	W
	M	13	S
AD 30	M	27	(Head)
	F	26	W
	M	5	S
	M	2	S
	M	0+	S
AD 31	M	50	(Head)
	F	30	W
	M	19	S
	F	14	D
	M	12	S
	M	5	S
	F	3	D
SP 41	M	30	(Head)
	F	36	W
	F	14	WD
	M	11	S
	M	8	S
	M	6	S
	M	4	S
	M	1	S

Household code	Sex	Age	Relationship to head
SP 42	M	41	(Head)
	F	33	W
	F	15	D
	M	12	S
	M	9	S
	F	7	D
	F	5	D
	M	3	S
	F	19	D
	F	2	DD
	F	18	D
	F	2	DD
SP 43	M	70	(Head)
	M	18	S
	F	15	D
	M	5	WSS
	F	18	D
	M	0+	DS
SP 44	M	59	(Head)
	F	60	W
	M	21	WS
SP 45	M	48	(Head)
	F	36	W
	M	16	WS
	F	13	WD
	M	11	WS
	F	9	WD
	M	6	WS
	F	4	WD
	M	1	S
	M	28	B
	F	19	WD (and BW)
	F	2	WDD
SP 46	M	28	(Head)
	F	28	W
	F	5	D
	M	4	S
	F	2	D

Household code	Sex	Age	Relationship to head
SP 47	M	26	(Head)
	F	24	W
	F	6	D
	M	4	S
	F	3	D
SP 49	M	36	(Head)
	F	34	W
	M	15	S
	M	14	S
	F	12	D
	M	10	S
	M	8	S
	M	6	S
	F	4	D
	F	2	D
SP 50	M	52	(Head)
	F	60	W
	M	12	WSS

Bibliography

- Alcorn, J.B. 1993. Indigenous peoples and conservation. *Conservation Biology* 7:424-426.
- Allchin, B. 1966. *The Stone-Tipped Arrow*. New York: Barnes and Noble.
- Altrichter, M. 2005. The sustainability of subsistence hunting of peccaries in the Argentine Chaco. *Biological Conservation* 126:351-362.
- Altmann, J. 1974. The observational study of behavior: Sampling methods. *Behaviour* 48:1-41.
- Alvard, M.S. 1993a. Testing the "Ecologically Noble Savage" Hypothesis: Interspecific Prey Choice by Piro Hunters of Peru. *Human Ecology* 21:355-387.
- . 1993b. Testing the Ecologically Noble Savage Hypothesis: Conservation and Subsistence Hunting by the Piro of Amazonian Peru. Ph.D. Dissertation, University of New Mexico, Albuquerque.
- . 1994. Conservation by native peoples: Prey choice in a depleted habitat. *Human Nature* 5:127-154.
- . 1995a. Intraspecific prey choice by Amazonian hunters. *Current Anthropology* 36:789-818.
- . 1995b. Shotguns and sustainable hunting in the Neotropics. *Oryx* 29:58-66.
- Alvard, M., and H. Kaplan. 1991 "Procurement technology and prey mortality among indigenous neotropical hunters," in *Human Predators and Prey Mortality*. Edited by M. Stiner, pp. 79-104. Boulder, CO: Westview Press.
- Alvard, M.S., J.G. Robinson, K.H. Redford, and H. Kaplan. 1997. The sustainability of subsistence hunting in the Neotropics. *Conservation Biology* 11:977-982.
- Alvarez, H. 2000. Grandmother hypothesis and primate life histories. *American Journal of Physical Anthropology* 113:435-450.
- Alvarsson, J. 1988. *The Mataco of the Gran Chaco: An Ethnographic Account of Change and Continuity in Mataco Socio-Economic Organization*. Stockholm, Sweden: Almqvist & Wiksell International.
- Anderson, A. 1981. Pre-European hunting dogs in the South Island, New Zealand. *New Zealand Journal of Archaeology* 3:15-20.
- Anholt, B.R., D. Ludwig, and J.B. Rasmussen. 1987. Optimal pursuit times: How long should predators pursue their prey? *Theoretical Population Biology* 31:453-464.
- Århem, K. 1976. Fishing and hunting among the Makuna: Economy, ideology and ecological adaptation in the northwest Amazon. *Göteborgs Etnografiske Museum Årstryck* 27-44
- . 1998. *Makuna: Portrait of an Amazonian People*. Washington: Smithsonian Institution Press.
- Aunger, R. 1994. Are food avoidances maladaptive in the Ituri Forest of Zaire? *Journal of Anthropological Research* 50:277-310.

- Bailey, R.C., G. Head, M. Jenike, B. Owen, R. Rechtman, and E. Zechenter. 1989. Hunting and gathering in tropical rain forest: Is it possible? *American Anthropologist* 91:59-82.
- Baksh, M. 1990. The spot observation technique in time allocation research (continued). *Cultural Anthropology Methods Newsletter* 2:4-5.
- . 1995. "Changes in Machiguenga quality of life," in *Indigenous Peoples and the Future of Amazonia: An Ecological Anthropology of an Endangered World*. Edited by L.E. Sponsel, pp. 187-205. Arizona Studies in Human Ecology. Tucson, AZ: University of Arizona Press.
- Balée, W. 1985. Ka'apor ritual hunting. *Human Ecology* 13:485-510.
- Balmford, A., and T. Whitten. 2003. Who should pay for tropical conservation, and how could the costs be met? *Oryx* 37:238-250.
- Barrientes, R. 1993. *Evolucion en el Tropico: Los Amerindios de Costa Rica y Panama*. San Jose, Costa Rica: Editorial de la Universidad de Costa Rica.
- Basso, E.B. 1973a. *The Kalapalo Indians of Central Brazil*. New York: Holt, Reinhart, and Winston.
- . 1973b. The Kalapalo dietary system. *Atti del XL Congresso Internazionale degli Americanisti* 2:629-637.
- Beckerman, S. 1979. The abundance of protein in Amazonia: A reply to Gross. *American Anthropologist* 81:533-560.
- . 1980. Fishing and hunting among the Bari of Colombia. *Working Papers in South American Indians* 2:67-109.
- . 1983. "Carpe diem: An optimal foraging approach to Bari fishing and hunting," in *Adaptive Strategies of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 269-299. New York: Academic.
- . 1987. "Swidden in Amazonia and the Amazon rim," in *Comparative Farming Systems*. Edited by B.L. Turner II, and S.B. Brush, pp. 55-94. New York: Guilford Press.
- . 1993. "Major patterns in Amazonian subsistence," in *Tropical forests, people and food*. Edited by C.M. Hladik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple, and M. Hadley, pp. 411-24. Paris: UNESCO.
- . 1994a. "Hunting and fishing in Amazonia: Hold the answers, what are the questions?" in *Amazonian Indians From Prehistory to the Present*. Edited by A. Roosevelt, pp. 177-200. Tucson: The University of Arizona Press.
- . 1994b. Homage to San Sebastian: Or, why do the Bari have so many different kinds of arrows? *Boletín del Museo Arqueológico de Quibor* 3:37-47
- Beckerman, S., and T. Sussenbach. 1983. "A quantitative assessment of the dietary contribution of game species to the subsistence of South American tropical forest tribal peoples," in *Animals and Archaeology I: Hunters and their Prey*. Edited by J. Clutton-Brock and C. Grigson, pp. 337-350. Oxford, England: British Archaeological Reports.

- Beck-King, H., O. von Helversen, and R. Beck-King. 1999. Home range, population density, and food resources of *Agouti paca* (Rodentia: Agoutidae) in Costa Rica: A study using alternative methods. *Biotropica* 31:675-685.
- Behrens, C.A. 1981. Time allocation and meat procurement among the Shipibo Indians of eastern Peru. *Human Ecology* 9:189-220.
- Bell, C.N. 1862. Remarks on the Mosquito territory, its climate, people, productions, etc., etc., with a map. *Royal Geographic Society* 32:242-268.
- . 1989[1899]. *Tangweera: Life and Adventures among Gentle Savages*. Austin: University of Texas Press.
- Belt, T. 1911[1874]. *The Naturalist in Nicaragua*. London: J.M. Dent & Sons, Ltd.
- Benedicto, E., and K. Hale. 2000. Mayangna, a Sumu language: Its variants and its status within Misumalpan. *University of Massachusetts Occasional Papers in Linguistics* 20:75-106. Edited by E. Benedicto. Amherst, MA: University of Massachusetts.
- Bennett, C.F. Jr. 1962. The Bayano Cuna Indians, Panama: An ecological study of livelihood and diet. *Annals of the Association of American Geographers* 52:32-50.
- Bennett, E.L. 2002. Is there a link between wild meat and food security? *Conservation Biology* 16:590-592.
- Bergman, R.W. 1980. *Amazonian economics: The simplicity of Shipibo wealth*. Dellplain Latin American studies 6. Syracuse, N.Y.: Syracuse University Department of Geography.
- Berlin, B., and E.A. Berlin. 1983. "Adaptation and ethnozoological classification: Theoretical implications of animal resources and diet of the Aguaruna and Huambisa," in *Adaptive Strategies of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 301-325. New York: Academic.
- Bernard, H.R., P. Killworth, D. Kronenfeld, and L. Sailer. 1984. The problem of informant accuracy: The validity of retrospective data. *Annual Review of Anthropology* 13:495-517.
- Bernard, H.R., and P.D. Killworth. 1993. Sampling in time allocation research. *Ethnology* 32:207-215.
- Betzig, L.L., and P.W. Turke. 1985. Measuring time allocation: Observation and intention. *Current Anthropology* 26:647-650.
- Bird, D.W., and R. Bliege Bird. 2002. Children on the reef: Slow learning or strategic foraging? *Human Nature* 13:269-297.
- Bliege Bird, R., and D.W. Bird. 2002. Constraints of knowing or constraints of growing? Fishing and collecting by the children of Mer. *Human Nature* 13:239-267.
- Bliege Bird, R., E.A. Smith, and D.W. Bird. 2001. The hunting handicap: Costly signaling in human foraging strategies. *Behavioral Ecology and Sociobiology* 50:9-19.

- Blurton Jones, N.G., K. Hawkes, and J.F. O'Connell. 1997. Hadza women's time allocation, offspring provisioning, and the evolution of long postmenopausal life spans. *Current Anthropology* 38:551-577.
- Blurton Jones, N., and F.W. Marlowe. 2002. Selection for delayed maturity: Does it take 20 years to learn to hunt and gather? *Human Nature* 13:199-238.
- Bock, J. 2002. Evolutionary demography and intrahousehold time allocation: Schooling and children's labor among the Okavango Delta peoples of Botswana. *American Journal of Human Biology* 14:206-221.
- Bodmer, R.E. 1991. Strategies of seed dispersal and seed predation in Amazonian ungulates. *Biotropica* 23:255-261.
- . 1994. "Managing wildlife with local communities in the Peruvian Amazon: The case of the Reserva Communal Tamshiyacu-Tahuayo," in *Natural Connections: Perspectives in Community-Based Conservation*. Edited by D. Western and R.M. Wright, pp. 113-134. Washington: Island Press.
- Bodmer, R.E., J.F. Eisenberg, and K.H. Redford. 1997. Hunting and the likelihood of extinction of Amazonian mammals. *Conservation Biology* 11:460-466.
- Bodmer, R.E., and J.G. Robinson. 2005. "Evaluating the sustainability of hunting in the Neotropics," in *People in Nature: Wildlife Conservation in South and Central America*. Edited by K.M. Silvius, R.E. Bodmer, and J.M.V. Fragoso, pp. 299-323. New York: Columbia University Press.
- Borgerhoff Mulder, M., and T.M. Caro. 1985. The use of quantitative observational techniques in anthropology. *Current Anthropology* 26:323-335.
- Bolton, T.M. 1998. Facilitating indigenous management of a conservation area in Nicaragua: A participatory action research application. M.A. Thesis, Idaho State University.
- Bonaudo, T., Y. Le Pendu, J.F. Faure, and D. Quanz. 2005. The effect of deforestation on wildlife along the transamazon highway. *European Journal of Wildlife Research* 51:199-206.
- Branan, W., and R. Marchinton. 1987. "Reproductive ecology of white-tailed and red brocket deer in Suriname," in *Biology and Management of the Cervidae*. Edited by C. Wemmer, pp. 344-351. Washington, D.C.: Smithsonian Institution Press.
- Brewer, S.W., and M. Rejmanek. 1999. Small rodents as significant dispersers of tree seeds in a Neotropical forest. *Journal of Vegetation Science* 10:165-174.
- Brooks, D.M., R.E. Bodmer, and S. Matola (compilers). 1997. *Tapirs – Status Survey and Conservation Action Plan*. IUCN/SSC Tapir Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. viii + 164 pp.
- Brown, D.E. 1991. *Human Universals*. New York: McGraw-Hill.
- Brown, J.L., S.B. Citino, J. Shaw, and C. Miller. 1994. Endocrine profiles during the estrous cycle and pregnancy in the Baird's tapir (*Tapirus bairdii*). *Zoo Biology* 13:107-117.
- Brown, M.F. 1984. The role of words in Aguaruna hunting magic. *American Ethnologist* 11:545-558.

- Buckland, S., D. Anderson, K. Burnham, and J. Laake. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. New York and London: Chapman Hall.
- Bulmer, R. 1968. The strategies of hunting in New Guinea. *Oceania* 38:302-318.
- Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs* 72:1-202.
- Carey, M. 1999. "Natural resources, markets, and land use among Nicaragua's Mayangna Indians, 1800 to the present," in *Proceedings of the Rocky Mountain Council on Latin American Studies*. Edited by J.F. Schwaller. Las Cruces, NM: Rocky Mountain Council on Latin American Studies.
- . 2000. "Creating remoteness: Geographical obstacles and indigenous resistance in Nicaragua's Bosawas Nature Reserve." Paper presented at the American Society for Environmental History conference, Tacoma, Washington, March 16-19.
- Carneiro, R.L. 1974. "Hunting and hunting magic among the Amahuaca of the Peruvian montaña," in *Native South Americans: Ethnology of the Least Known Continent*. Edited by P.J. Lyon, pp. 122-131.
- . 1979a. "Tree felling with the stone ax: An experiment carried out among the Yanomamö Indians of southern Venezuela," in *Ethnoarchaeology*. Edited by C. Kramer, pp. 21-58. New York: Columbia University Press.
- . 1979b. Forest clearance among the Yanomamö: Observations and implications. *Antropològica* 52:39-76.
- . 1983. "The cultivation of manioc among the Kuikuru of the Upper Xingú," in *Adaptive Responses of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 65-111. New York: Academic Press.
- . *Indians of the Tropical Forest*. Unpublished manuscript.
- Chagnon, N., and R. Hames. 1979. Protein deficiency and tribal warfare in Amazonia: New data. *Science* 20:910-913.
- Charnov, E.L., and G.H. Orians. 1973. Optimal foraging: Some theoretical explanations. Unpublished manuscript.
- Charnov, E.L. 1976. Optimal foraging: The marginal value theorem. *Theoretical Population Biology* 9:129-136.
- Cohn, J.E., and H.D. Donoso. 1963. Mechanical properties of lung in normal men over 60 years old. *The Journal of Clinical Investigation* 42:1406-1410.
- Clutton-Brock, J. 1977. Man-made dogs. *Science* 197:1340-1342.
- Colding, J., and C. Folke. 1997. The relations among threatened species, their protection, and taboos. *Conservation Biology* [online] 1:6. Available from the Internet. URL: <http://www.consecol.org/vol1/iss1/art6/>

- Cole, L.C. 1954. The population consequences of life history phenomena. *Quarterly Review of Biology* 29:103-137.
- Collett, S.F. 1981. Population characteristics of *Agouti paca* (Rodentia) in Colombia. *Publications of the Museum, Michigan State University, Biological Series* 5:489-602.
- Conzemius, E. 1932. *Ethnographical Survey of the Miskito and Sumu Indians of Honduras and Nicaragua*. Smithsonian Institution, U.S. American Ethnology Bulletin 106, Washington, D.C.: Smithsonian Institution.
- Cooke, R. 1987. "La arqueología del Panamá precolombiano y su importancia para los estudios de los pueblos de habla chibcha," in *Memorias del Primer Simposio Científico sobre Pueblos Indígenas de Costa Rica*. Edited by R. Barrantes, M.E. Bozzoli, and P. Gudino, pp. 81-95. San Jose, Costa Rica: Instituto Geografico de Costa Rica.
- Cooke, R.G., and A.J. Ranere. 1989. "Hunting in pre-Columbian Panama: A diachronic perspective," in *The Walking Larder: Patterns of Domestication, Pastoralism, and Predation*. Edited by J. Clutton-Brock, pp. 295-315. London: Unwin Hyman.
- , and ---. 1992. Precolumbian influences on the zoogeography of Panama: An update based on archaeofaunal and documentary data. *Tulane Studies in Zoology and Botany*, Supplementary publication number 2:21-58.
- Cormier, L.A. 2003. *Kinship with Monkeys: The Guajá Foragers of Eastern Amazonia*. New York: Columbia University Press.
- . 2006. A preliminary review of Neotropical primates in the subsistence and symbolism of indigenous lowland South American peoples. *Ecological and Environmental Anthropology* 2:14-32.
- Costenla Umaña, A. 1991. *Las lenguas del Area Intermedia: Introduccion a su estudio areal*. San Jose, Costa Rica: Editorial de la Universidad de Costa Rica.
- Craig, C., and K. Hale. 1992. A possible Macro-Chibchan etymon. *Anthropological Linguistics* 34:173-201.
- Crocker, J.C. 1985. "My brother the parrot," in *Animal Myths and Metaphors in South America*. Edited by G. Urton, pp. 13-47. Salt Lake City: The University of Utah Press.
- Cruz, G.A., and E. Benitez. 1994. *Diagnositco Etnologico y Ecologico de la Biosfera Tawahka Asangni*. Programa Integral de Protección Ecologica y Rescate de Herencia Cultural. Tegucigalpa, Honduras.
- Cunha, M. Carneiro da, and M.W.B. de Almeida. 2000. "Indigenous people, traditional people, and conservation in the Amazon," in *Brazil: Burden of the Past, Promise of the Future*. *Daedalus, Journal of the American Academy of Sciences* 129:315-338.
- Daily, G.C., G. Ceballos, J. Pacheco, G. Suzán, and A. Sánchez-Azofeifa. 2003. Countryside biogeography of Neotropical mammals: Conservation opportunities in agricultural landscapes of Costa Rica. *Conservation Biology* 17:1814-1826.

- Dana, P.H. 1998. Nicaragua's "GPSistas." Mapping their lands on the Caribbean coast. *GPS World* 9:32-42.
- Denevan, W.M. 1992a. The pristine myth: The landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82:369-385.
- . 1992b. Stone vs. metal axes: The ambiguity of shifting cultivation in Prehistoric Amazonia. *Journal of the Steward Anthropological Society* 20:153-165.
- Descola, P. 1994. *In the Society of Nature: A Native Ecology in Amazonia*. Cambridge: Cambridge University Press.
- Dodds, D.J. 1998. Lobster in the rain forest: The political ecology of Miskito wage labor and agricultural deforestation. *Journal of Political Ecology* 5:83-108.
- Drummond, L. 1977. Structure and process in the interpretation of South American myth: The Arawak dog spirit people. *American Anthropologist* 79:842-846.
- Dufour, D.L. 1987. Insects as food: A case study from the Northwest Amazon. *American Anthropologist* 89:383-397.
- . 1993. "The bitter is sweet: A case study of bitter cassava (*Manihot esculenta* crantz) use in Amazonia," in *Tropical forests, people and food*. Edited by C.M. Hladik, A. Hladik, O.F. Linares, H. Pagezy, A. Semple, and M. Hadley, pp. 575-578. Paris: UNESCO.
- Dunn, M. 2004. Re-interpreting the impacts of indigenous hunting: A participatory geographic analysis of Miskito wildlife use in eastern Honduras. Master's thesis. Carleton University.
- Ellen, R. 1999. Categories of animality and canine abuse. *Anthropos* 94:57-68.
- Elnor, R.W., and R.N. Hughes. 1978. Energy maximization in the diet of the shore crab, *Carcinus maenus*. *Journal of Animal Ecology* 47:103-116.
- Escamilla, A., M. Sanvicente, M. Sosa, and C. Galindo-Leal. 2000. Habitat mosaic, wildlife availability, and hunting in the tropical forest of Calakmul, Mexico. *Conservation Biology* 14:1592-1601.
- Estioko-Griffin, A.A. 1985. "Women as hunters: The case of an eastern Cagayan Agta group," in *The Agta of Northeastern Luzon: Recent Studies*. Edited by P.B. Griffin and A.A. Estioko-Griffin, pp. 18-32. Cebu City, Philippines: University of San Carlos Publications.
- Fan, C., K. Su, W. Chung, Y. Tsai, H. Chiou, C. Lin, C. Su, M. Tsai, and P. Chao. 1998. Seroprevalence of *Toxoplasma gondii* antibodies among Atayal aboriginal people and their hunting dogs in Northeastern Taiwan. *Japanese Journal of Medical Science and Biology* 51:35-42.
- FAO/WHO (United Nations Food and Agriculture Organization and World Health Organization). 1973. Energy and protein requirements: Report of a joint FAO/WHO ad hoc expert committee. WHO Technical Report, series no. 522. Geneva: World Health Organization.
- Fessler, D.M.T., and C.D. Naverrete. 2003. Meat is good to taboo: Dietary proscriptions as a product of the interaction of psychological mechanisms and social processes. *Journal of Cognition and Culture* 3:1-40.

- Fiedel, S.J. 2005. Man's best friend – mammoth's worst enemy? A speculative essay on the role of dogs in Paleoindian colonization and megafaunal extinction. *World Archaeology* 37:11-25.
- Fiorello, C.V., A.J. Noss, and S.L. Deem. 2006. Demography, hunting ecology, and pathogen exposure of domestic dogs in the Isoso of Bolivia. *Conservation Biology* 20:762-771.
- Fitzgibbon, C.D., H. Mogaka, and J.H. Fanshawe. 1995. Subsistence hunting in Arabuko-Sokoke, Kenya, and its effects on mammal populations. *Conservation Biology* 9:1116-1126.
- Foerster, C. 2002. Baird's tapir project, Corcovado National Park, Costa Rica. *Tapir Conservation* 11:11-13.
- Foerster, C.R., and C. Vaughan. 2002. Home range, habitat use, and activity of Baird's tapir in Costa Rica. *Biotropica* 34:423-437.
- Foley, R.A. 2001. "The evolutionary consequences of increased carnivory in hominids," in *Meat-eating and Human Evolution*. Edited by C.B. Stanford and H.T. Bunn, pp. 305-331. Oxford: Oxford University Press.
- Fragoso, J.M.V. 1991. "The effect of hunting on tapirs in Belize," in *Neotropical Wildlife Use and Conservation*. Edited by J.G. Robinson and K.H. Redford, pp. 154-173. Chicago: University of Chicago Press.
- Gácsi, M., A. Miklósi, O. Varga, J. Topál, and V. Csányi. 2004. Are readers of our faces readers of our minds? Dogs (*canis familiaris*) show situation-dependent recognition of human's attention. *Animal Cognition* 7:144-153.
- Glanz, W.E. 1990. "Neotropical mammal densities: How unusual is the community on Barro Colorado Island, Panama," in *Four Neotropical Rain Forests*. Edited by A.H. Gentry, pp. 287-313. New Haven: Yale University Press.
- Godoy, R., V. Reyes-García, E. Byron, W.R. Leonard, and V. Vadez. 2005. The effects of market economies on the well-being of indigenous peoples and on their use of renewable natural resources. *Annual Review of Anthropology* 34:121-138.
- Goldman, I. 1963. *The Cubeo: Indians of the Northwest Amazon*. Urbana, IL: The University of Illinois Press.
- Good, K.R. 1987. "Limiting factors in Amazonian ecology," in *Food and Evolution: Toward a Theory of Human Food Habits*. Edited by M.H. Harris and E.B. Ross, pp. 407-421. Philadelphia: Temple University Press.
- Gragson, T.L. 1989. Time allocation of subsistence and settlement in a Chu Kho Nome Pume village of the Llamos of Apure. Ph.D. dissertation. Penn State University.
- . 1992a. Fishing the waters of Amazonia: Native subsistence economies in a tropical rain forest. *American Anthropologist* 94:428-440.
- . 1992b. Strategic procurement of fish by the Pumé: A South American "fishing culture." *Human Ecology* 20:109-130.

- Gravlee, C. C. 2002. Mobile computer-assisted personal interviewing with handheld computers: The Entryware System 3.0. *Field Methods* 14:322-36.
- Green, T.M. 1999. A lexicographic study of Ulwa. Ph.D. dissertation. Massachusetts Institute of Technology.
- Greenberg, L.S.Z. 1992. Garden hunting among the Yucatec Maya: A coevolutionary history of wildlife and culture. *Etnoecológica* 1:23-33.
- Greene, P. D. 2001. Handheld computers as tools for writing and managing field data. *Field Methods* 13:181-97.
- Gregor, T. 1977. *Mehinaku*. Chicago: University of Chicago Press.
- Gros, P., G. Camilo, K. Bauman, C. Asa, L. Bradshaw, K. Williams-Guillen, and J. Polisar. 2004. *Proyecto Biodiversidad y Sostenibilidad de la Caceria*. Technical report by the Saint Louis Zoo.
- Gros, P., et al. Conocimientos tradicionales del pueblo Mayangna sobre la convivencia Hombre y Naturaleza: Pescados y Tortugas. UNESCO (LINKS). In preparation.
- Gross, D.R. 1975. Protein capture and cultural development in the Amazon Basin. *American Anthropologist* 77:526-549.
- . 1984. Time allocation: A tool for the study of cultural behavior. *Annual Review of Anthropology* 13:519-558.
- Gurven, M., and H. Kaplan. 2006. Determinants of time allocation across the lifespan: A theoretical model and an application to the Machiguenga and Piro of Peru. *Human Nature* 17:1-49.
- Gurven, M., H. Kaplan, and M. Gutierrez. How long does it take to become a proficient hunter? Implications for the evolution of delayed growth. *Journal of Human Evolution*. In press.
- Haberland, W. 1957. Black-on-red painted ware and associated features in the Intermediate Area. *Ethnos* 22:148-161.
- Hames, R. 1979a. A comparison of the efficiencies of the shotgun and bow in Neotropical forest hunting. *Human Ecology* 7:219-252.
- . 1979b. "Relatedness and interaction among the Ye'kwana: A preliminary analysis," in *Evolutionary Biology and Human Social Organizations*. Edited by N.A. Chagnon and W. Irons, pp. 201-209. North Scituate, MA: Duxbury Press.
- . 1980. "Game depletion and hunting zone rotation among the Ye'kwana and Yanomamo of Amazonas, Venezuela," in *Working Papers on South American Indians*. Edited by R. Hames, pp. 31-66. Bennington, VT: Bennington College.
- . 1987. "Game conservation or efficient hunting?" in *The Question of the Commons*. Edited by B. McCay and J. Acheson, pp. 97-102. Tucson: University of Arizona Press.

- . 1989. Time, efficiency, and fitness in the Amazonian protein quest. *Research in Economic Anthropology* 11:43-85.
- . 1991. "Wildlife conservation in tribal societies," in *Biodiversity: Culture, Conservation, and Ecodevelopment*. Edited by M. Oldfield and J. Alcorn, pp. 172-199. Boulder: Westview Press.
- . 1992. "Time Allocation," in *Evolutionary Ecology and Human Behavior*. Edited by E.A. Smith and B. Winterhalder, pp. 203-235. New York: Aldine de Gruyter.
- Hames, R., and W. Vickers. 1982. Optimal foraging theory as a model to explain variability in Amazonian hunting. *American Ethnologist* 9:353-378.
- Hare, B., and M. Tomasello. 2005. Human-like social skills in dogs? *Trends in Cognitive Sciences* 9:439-444.
- Harner, M.J. 1972. *The Jivaro: People of the Sacred Waterfalls*. Garden City, NY: Doubleday/Natural History Press.
- Harris, M. 1974. *Cows, pigs, wars, and witches: The riddles of culture*. New York: Random House.
- Hawkes, K., K. Hill, and J. O'Connell. 1982. Why hunters gather: Optimal foraging and the Aché of Eastern Paraguay. *American Ethnologist* 9:379-398.
- Hawkes, K., J. F. O'Connell, N.G. Blurton Jones, H. Alvarez, and E.L. Charnov. 1998. Grandmothering, menopause, and the evolution of human life histories. *Proceedings of the National Academy of Science* 95:1336-1339.
- Heath, G.R. 1915. Bocay. *Moravian Missions* 14:182-185.
- Heckadon-Moreno, S. 1997. "Spanish rule and independence," In *Central America: A Natural and Cultural History*. Edited by Anthony G. Coates, pp. 177-214. New Haven and London: Yale UP.
- Heinen, H.D. 1972. Adaptive changes in a tribal economy: A case study of the Winikina-Warao. Ph.D. dissertation. UCLA Anthropology.
- Helms, M.W. 1971. *Asang: Adaptations to Culture Contact in a Miskito Community*. Gainesville, FL: University of Florida Press.
- Henfrey, T.B. 2002. Ethnoecology, resource use, conservation, and development in a Wapishana community in the South Rupununi, Guyana. Ph.D. dissertation, University of Kent at Canterbury.
- Henley, P. 1982. *Tradition and Change on the Amazonian Frontier*. New Haven: Yale University Press.
- Henry, J. 1964[1941]. *Jungle People: A Kaingáng Tribe of the Highlands of Brazil*. New York: Vintage.
- Herlihy, P.H. 1995. "Sumu," in *Encyclopedia of World Cultures: Middle America and the Caribbean*, Vol. VIII. Edited by J.W. Dow and R. Van Kemper, pp. 236-240. Boston: G.K. Hall & Co.
- Hill, J.D. 1983. Wakuenai society: A processual-structural analysis of indigenous cultural life in the Upper Rio Negro region of Venezuela. Ph.D. dissertation. Indiana University.

- Hill, K. 1982. Hunting and human evolution. *Journal of Human Evolution* 11:521-544.
- . 1988. Macronutrient modifications of optimal foraging theory: An approach using indifference curves applied to some modern foragers. *Human Ecology* 16:157-197.
- . 2002. Altruistic cooperation during foraging by the Aché, and the evolved human predisposition to cooperate. *Human Nature* 13:105-128.
- Hill, K., and K. Hawkes. 1983. "Neotropical hunting among the Aché of Eastern Paraguay," in *Adaptive Responses of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 223-267. New York: Academic Press.
- Hill, K., K. Hawkes, M. Hurtado, and H. Kaplan. 1984. Seasonal variance in the diet of Ache hunter-gatherers in Paraguay. *Human Ecology* 12:101-135.
- Hill, K., H. Kaplan, K. Hawkes, and A.M. Hurtado. 1985. Men's time allocation to subsistence work among the Aché of Eastern Paraguay. *Human Ecology* 13:29-47.
- , ---, ---, and ---. 1987. Foraging decisions among Aché hunter-gatherers: New data and implications for optimal foraging models. *Ethology and Sociobiology* 8:1-36.
- Hill, K., and J. Padwe. 2000. "Sustainability of Aché hunting the Mbaracayu Reserve, Paraguay," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 79-105. New York:: Columbia University Press.
- Hill, K. and T. Tykuearangi. 1996. "Case study: the Mbaracayu Reserve and the Ache of Paraguay." in *Traditional peoples and Biodiversity Conservation in Large Tropical Landscapes*. Edited by K. Redford and J. Mansour, pp. 159-196. Arlington, VA: America Verde Publications: The Nature Conservancy.
- Holmberg, A.R. 1969. *Nomads of the Long Bow: The Siriono of Eastern Bolivia*. Prospect Heights, IL: Waveland Press.
- House, P.R. 1997. Ethnobotany of the Tawahka: Agricultural Practice and Forest Management in Lowland Central America. Ph.D. Dissertation, The University of Reading.
- Houston, A.I., J.R. Krebs, and J.T. Erichsen. 1980. Optimal prey choice and discrimination in the great tit (*Parus major* L.). *Behavioral Ecology and Sociobiology* 6:169-175.
- Howard, C.V. 2001. Wrought identities: The Waiwai expeditions in search of the "unseen tribes" of northern Amazonia. Ph.D. dissertation. The University of Chicago.
- Ice, G. H. 2004. The advantages and limitations of computer-assisted data collection. *Field Methods* 15(2): 1-23.
- Ikeya, K. 1994. Hunting with dogs among the San in the central Kalahari. *African Study Monographs* 15:119-134.
- Im Thurn, E.F. 1967[1883]. *Among the Indians of Guiana*. New York: Dover Publications.

- Irvine, D. 1987. Resource management by the Runa Indians of the Ecuadorian Amazon. Ph.D. dissertation, Department of Anthropology, Stanford University.
- Jackson, J.E. 1983. *The Fish People: Linguistic Exogamy and Tukanoan Identity in Northwest Amazonia*. Cambridge: Cambridge University Press.
- Janzen, D.H. 1974. Tropical blackwater rivers, animals, and mast fruiting by the Dipterocarpaceae. *Biotropica* 6:69-103.
- Jerozolinski, A., and C.A. Peres. 2003. Bringing home the biggest bacon: A cross-site analysis of the structure of hunter-kill profiles in Neotropical forests. *Biological Conservation* 111:415-425.
- Jeske, R.J., and L.A. Kuznar. 2001. Canine digging behavior and archaeological implications. *Journal of Field Archaeology* 28:383-394.
- Jett, S.C. 1991. Further information on the geography of the blowgun and its implications for early transoceanic contacts. *Annals of the Association of American Geographers* 81:89-102.
- Johnson, A. 1975. Time allocation in a Machiguenga community. *Ethnology* 14:301-310.
- . 1982. Reductionism in cultural ecology: the Amazon case. *Current Anthropology* 23:413-428.
- . 2003. *Families of the Forest: The Matsigenka Indians of the Peruvian Amazon*. Berkeley: The University of California Press.
- Jones, R. 1970. Tasmanian Aborigines and dogs. *Mankind* 7:256-271.
- Jorgenson, J.P. 1993. Gardens, wildlife densities, and subsistence hunting by Maya Indians in Quintana Roo, Mexico. Ph.D. Dissertation. Gainesville: The University of Florida.
- . 1995. Maya subsistence hunters in Quintana Roo. *Oryx* 29:49-57.
- . 2000. "Wildlife conservation and game harvest by Maya hunters in Quintana Roo, Mexico," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 251-266. New York: Columbia University Press.
- Joshi, N.V., and M. Gadgil. 1991. On the role of refugia in promoting prudent use of biological resources. *Theoretical Population Biology* 40:211-229.
- Kahn, M.C. 1931. *Djuka: The Bush Negroes of Dutch Guiana*. New York: Viking.
- Kaimowitz, D., A. Faune, and R. Mendoza. 2003. Your biosphere is my backyard: The story of Bosawas in Nicaragua. Working Paper no. 25. Center for International Forestry Research.
- Kaplan, H., and K. Hill. 1992. "The evolutionary ecology of food acquisition," in *Evolutionary Ecology and Human Behavior*. Edited by E.A. Smith and B. Winterhalder, pp. 167-201. New York: Aldine de Gruyter.
- Kaplan, H., K. Hill, J. Lancaster, and A.M. Hurtado. 2000. A theory of life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology* 9:156-185.

- Kaplan, H., and K. Kopischke. 1992. "Resource use, traditional technology, and change among native peoples of Lowland South America," in *Conservation of Neotropical Forests: Working From Traditional Resource Use*. Edited by K.H. Redford and C. Padoch, pp. 83-107. New York: Columbia University Press.
- Kensinger, K.M. 1981. Food taboos as markers of age categories in Cashinahua. *Working Papers on South American Indians* 3:157-171.
- . 1983. On meat and hunting. *Current Anthropology* 24:128-129.
- . 1995. *How Real People Ought to Live: The Cashinahua of Eastern Peru*. Prospect Heights, IL: Waveland Press.
- Kloos, P. 1971. *The Maroni River Caribs of Surinam*. Assen, The Netherlands: Van Gorcum & Comp.
- Koster, J.M. 2006. The use of The Noldus Observer 5.0 and Psion handheld computer in a remote fieldwork setting. *Field Methods* 18:430-436.
- Kracke, W.H. 1981. Don't let the piranha bite your liver: A psychoanalytical approach to Kagwahiv (Tupi) food taboos. *Working Papers on South American Indians* 3:91-142.
- Krebs, J., and R. McCleery. 1984. "Optimization in behavioral ecology," in *Behavioral Ecology: An Evolutionary Approach*. Edited by J. Krebs and N. Davies, pp. 91-121. Sunderland, MA: Sinauer Associates.
- Krech, S. 1999. *The Ecological Indian: Myth and History*. New York: Norton.
- Kroeber, A.L. 1942. Cultural element distributions XV. Salt, dogs, tobacco. *University of California Anthropological Records* 6:1-20.
- Kuchikura, Y. 1988. Efficiency and focus of blowpipe hunting among Semaq Beri hunter-gatherers of Peninsular Malaysia. *Human Ecology* 16:271-305.
- Lans, C., T. Harper, K. Georges, and E. Bridgewater. 2001. Medicinal and ethnoveterinary remedies of hunters in Trinidad. *BMC Complementary and Alternative Medicine* 1:10.
- Layrisse, M., Z. Layrisse, and J. Wilbert. 1963. Blood group antigen studies of four Chibchan tribes. *American Anthropologist* 65:36-55.
- Leeuwenberg, F., and J. Robinson. 2000. "Traditional management of hunting in a Xavante community in Central Brazil," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp.375-394. New York: Columbia University Press.
- Leonard, J.A., R.K. Wayne, J. Wheeler, R. Valadez, S. Cuillén, and C. Vilá. 2002. Ancient DNA evidence for Old World origin of New World dogs. *Science* 298:1613-1616.
- Levin, M.G., and L.P. Popatov. 1964. *The Peoples of Siberia*. 1964.
- Linares, O.F. 1976. "Garden hunting" in the American tropics. *Human Ecology* 4:331-349.

- Lizzaralde, M. 2002. "Ethnoecology of monkeys among the Barí of Venezuela: Perception, use, and conservation," in *Primates Face to Face: The Conservation Implications of Human-Nonhuman Primate Interactions*. Edited by A. Fuentes and L.D. Wolfe, pp. 85-100. Cambridge: Cambridge University Press.
- Lopes, M.A., and S.F. Ferrari. 2000. Effects of colonization on the abundance and diversity of mammals in Eastern Brazilian Amazonia. *Conservation Biology* 14:1658-1665.
- Lu, F. 1999. Changes in subsistence patterns and resource use of the Huaorani Indians in the Ecuadorian Amazon. Ph.D. dissertation. The University of North Carolina.
- . 2001. The common property regime of the Huaorani Indians of Ecuador: Implications and challenges to conservation. *Human Ecology* 29:425-447.
- Lucas, J.R. 1983. The role of foraging time constraints and variable prey encounter in optimal diet choice. *American Naturalist* 122:191-209.
- Malkin, B. 1956. Sumu ethnozoology: Herpetological knowledge. *Davidson Journal of Anthropology* 2:765-780.
- Mangel, M., and C.W. Clark. 1986. Towards a unified foraging theory. *Ecology* 67:1127-1138.
- Martin, J. 1983. Optimal foraging theory: A review of some models and their applications. *American Anthropologist* 85:612-629.
- Mathieu, J.R., and D.A. Meyer. 1997. Comparing axe heads of stone, bronze, and steel: Studies in experimental archaeology. *Journal of Field Archaeology* 24:333-351.
- Maybury-Lewis, D. 1967. *Akwe-Shavante Society*. Oxford: Clarendon Press.
- McCullough, D.R. 1996. Spatially structured populations and harvest theory. *Journal of Wildlife Management* 60:1-9.
- McDonald, D.R. 1977. Food taboos: A primitive Environmental Protection Agency (South America). *Anthropos* 72:734-748.
- McSweeney, K. 2000. "In the forest is our money": The changing role of commercial extraction in Tawahka livelihoods, eastern Honduras. Ph.D. Dissertation. McGill University Geography.
- . 2004. The dugout canoe trade in Central America's Mosquitia: Approaching rural livelihoods through systems of exchange. *Annals of the Association of American Geographers* 94:638-661.
- . 2005. Indigenous population growth in the lowland Neotropics: Social science insights for biodiversity conservation. *Conservation Biology* 19:1375-1384.
- Mena V., P., J.R. Stallings, J. Regalado B., and R. Cueva L. 2000. "The sustainability of current hunting practices by the Huaorani," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 57-78. New York: Columbia University Press.
- Merriam, J.C. 1998. Community wildlife management by Mayangna Indians in the Bosawas Reserve, Nicaragua. M.A. Thesis, Idaho State University.

- Messer, E. 1984. Anthropological perspectives on diet. *Annual Review of Anthropology* 13:205-249.
- Metcalf, D., and K.R. Barlow. 1992. A model for exploring the optimal tradeoff between field processing and transport. *American Anthropologist* 94:340-356.
- Milner-Gulland, E.J., E.L. Bennett, and the SCB 2002 Annual Meeting Wild Meat Group. 2003. Wild meat: The bigger picture. *Trends in Ecology and Evolution* 18:351-357.
- Milner-Gulland, E.J., and H. Resit Akçakaya. 2001. Sustainability indices for exploited populations. *Trends in Ecology and Evolution* 16:686-692.
- Milton, K. 1984. Protein and carbohydrate resources of the Makú Indians of northwestern Amazonia. *American Anthropologist* 86:7-27.
- Milton, K., C.D. Knight, and I. Crowe. 1991. Comparative aspects of diet in Amazonian forest-dwellers. *Philosophical Transactions: Biological Sciences* 334:253-263.
- Minzenberg, E. 2005. Hunting and household in PDS São Salvador, Acre, Brazil. Ph.D. Dissertation. The University of Florida.
- Morey, D.F. 2006. Burying key evidence: The social bond between dogs and people. *Journal of Archaeological Science* 33:158-175.
- Mueller, K. 1932. *Among Creoles, Miskitos, and Sumos: Eastern Nicaraguan and its Moravian Missionaries*. Bethlehem, PA: Comenius Press.
- Muñoz, V., M. Sauvain, G. Bourdy, J. Callapa, I. Rojas, L. Vargas, A. Tae, and E. Deharo. 2000. The search for natural bioactive compounds through a multidisciplinary approach in Bolivia. Part II. Antimalarial activity of some plants used by Mosekene Indians. *Journal of Ethnopharmacology* 69:139-155.
- Murphy, Y., and R. Murphy. 1985. *Women of the Forest*, 2nd edition. New York: Columbia University Press.
- M.W. 1732. "The Mosquito Indian and His Golden River (Written in or about the year 1699)," in *A Collection of Voyages and Travels*. Edited by A. Churchill, pp. 284-298. London: [J. Walthoe].
- Naranjo, E.J. 1995. Abundancia y uso de hábitat del tapir (*Tapirus bairdii*) en un bosque tropical húmedo de Costa Rica. *Vida Silvestre Neotropical* 4:20-31.
- Naranjo, E.J., and R.E. Bodmer. 2002. Population ecology and conservation of Baird's tapir (*Tapirus bairdii*) in the Lacandon Forest, Mexico. *Tapir Conservation* 11:25-33.
- Naranjo, E.J., and E. Cruz. 1998. Ecología del tapir (*Tapirus bairdii*) en la reserva de la biosfera la Sepultura, Chiapas, Mexico. *Acta Zoologica Mexicana* 73:111-123.
- Naughton-Treves, L. 2002. Wild animals in the garden: Conserving wildlife in Amazonian agroecosystems. *Annals of the Association of American Geographers* 92:488-506.

- Naughton-Treves, L., J.L. Mena, A. Treves, N. Alvarez, and V.C. Radeloff. 2003. Wildlife survival beyond park boundaries: The impact of slash-and-burn agriculture and hunting of mammals in Tambopata, Peru. *Conservation Biology* 17:1106-1117.
- Naughton-Treves, L., M. Buck Holland, and K. Brandon. 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment & Resources* 30:219-252.
- Newson, L. 1982. The depopulation of Nicaragua in the sixteenth century. *Journal of Latin American Studies* 14:253-286.
- Nietschmann, B. 1969. The distribution of Miskito, Sumu, and Rama Indians, Eastern Nicaragua. *Bulletin of the International Committee on Urgent Anthropological and Ethnological Research* 11:91-102.
- . 1972. Hunting and fishing focus among the Miskito Indians, Eastern Nicaragua. *Human Ecology* 1:41-67.
- . 1973. *Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua*. New York: Seminar Press.
- . 1978. Comments on Ross. *Current Anthropology* 19:24-25.
- . 1989. *The Unknown War: The Miskito Nation, Nicaragua, and the United States*. New York: Freedom House.
- . 1990. Conservation by conflict in Nicaragua. *Natural History* 11:42-49.
- Nimuendajú, C. 1967. *The Apinaye'*. Translated by R.H. Lowie. Edited by R.H. Lowie and J.M. Cooper. Oosterhout N.B. – The Netherlands: Anthropological Publications.
- Novaro, A.J., K.H. Redford, and R.E. Bodmer. 2000. Effect of hunting in source-sink systems in the Neotropics. *Conservation Biology* 14:713-721.
- O'Connell, J. and K. Hawkes. 1981. "Alyawara plant use and optimal foraging theory." In *Hunter-Gatherer Foraging Strategies*. Edited by E. Smith and B. Winterhalder, pp. 99-125. Chicago: University of Chicago Press.
- Offen, K.H. 2003. Narrating place and identity, or mapping Miskitu land claims in northeastern Nicaragua. *Human Organization* 62:382-392.
- . In press. Creating Mosquitia: Mapping Amerindian spatial practices in Eastern Central America, 1629-1779. *Journal of Historical Geography*.
- Ohnuki-Tierney, E. 1976. Regional variations in Ainu culture. *American Ethnologist* 3:297-329.
- Ojasti, J. 1991. "Human exploitation of capybara," in *Neotropical Wildlife Use and Conservation*. Edited by J.G. Robinson and K.H. Redford, pp. 236-252. Chicago: University of Chicago Press.
- Oldfield, S. 1987. *Buffer-zone Management Techniques*. Gland, Switzerland: International Union for the Conservation of Nature.

- Orejuela, J.E. 1992. "Traditional productive systems of the Awa (Cuaiquer) Indians of southwestern Colombia and neighboring Ecuador," in *Conservation of Neotropical Forests: Working From Traditional Resource Use*. Edited by K.H. Redford and C. Padoch, pp. 58-82. New York: Columbia University Press.
- Orians, G.H., and N.E. Pearson. 1979. "On the theory of central place foraging," in *Analysis of Ecological Systems*. Edited by D.J. Horn, R.D. Mitchell, and G.R. Stairs, pp. 154-177. Columbus, OH: Ohio State University Press.
- Orr, C.M., D.L. Dufour, and J.Q. Patton. 2001. A comparison of anthropometric indices of nutritional status in Tukanoan and Achuar Amerindians. *American Journal of Human Biology* 13:301-309.
- Ortega, M. 1991. *Nicaraguan Repatriation to Mosquitia*. Washington: Hemispheric Migration Project, Center for Immigration Policy and Refugee Assistance, Georgetown University, c1991.
- Paolisso, M., and R. Sackett. 1985. Traditional meat procurement strategies among the Irapa-Yukpa of the Venezuela-Colombia border area. *Research in Economic Anthropology* 7:177-199.
- Parsons, J.J. 1955a. Gold mining in the Nicaragua rain forest. *Yearbook of the Association of Pacific Coast Geographers* 17:49-55.
- . 1955b. The Miskito pine savanna of Nicaragua and Honduras. *Annals of the Association of American Geographers* 45:36-63.
- Peres, C.A. 2000a. "Evaluating the impact and sustainability of subsistence hunting at multiple Amazonian forest sites," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 31-56. New York: Columbia University Press.
- . 2000b. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. *Conservation Biology* 14:240-253.
- Peres, C.A., and B. Zimmerman. 2001. Perils in parks or parks in peril? Reconciling conservation in Amazonian reserves with and without use. *Conservation Biology* 15:793-797.
- Picchi, D.S. 1982. Energetics modeling in development evaluation: The case of the Bakairi Indians of central Brazil. Ph.D. dissertation, The University of Florida.
- . 2000. *The Bakarí Indians of Brazil: Politics, Ecology, and Change*. Prospect Heights, IL: Waveland Press.
- Pongrácz, P., A. Miklósi, and V. Csányi. 2005. Human listeners are able to classify dog (*Canis familiaris*) barks recorded in different situations. *Journal of Comparative Psychology* 119:136-144.
- Posey, D.A. 1985. Indigenous management of tropical forest ecosystems: The case of the Kayapó Indians of the Brazilian Amazon. *Agroforestry Systems* 3:39-158.
- Pulliam, H. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652-661.
- Redford, K.H. 1991. The ecologically noble savage. *Orion* 9:24-29.
- . 1992. The empty forest. *Bioscience* 42:412-422.

- Redford, K.H., and P. Feinsinger. 2001. "The half-empty forest: Sustainable use and the ecology of interactions," in *Conservation of Exploited Species*. Edited by J.D. Reynolds, G.M. Mace, K.H. Redford, and J.G. Robinson, pp. 370-399. Cambridge: Cambridge University Press.
- Redford, K.H., and J.A. Mansour, editors. 1996. *Traditional Peoples and Biodiversity Conservation in Large Tropical Landscapes*. Arlington, VA: America Verde Series of The Nature Conservancy.
- Redford, K.H., and J.G. Robinson. 1987. The game of choice: Patterns of Indian and colonist hunting in the Neotropics. *American Anthropologist* 89:650-667.
- , and ---. 1990. A research agenda for studies of subsistence hunting in the Neotropics. *Florida Journal of Anthropology* 6:117-120.
- Redford, K.H. and Sanderson, S.E. 2000. Extracting humans from nature. *Conservation Biology* 14:1362-1364.
- Reed, R.K. 1995. *Prophets of Agroforestry: Guaraní Communities and Commercial Gathering*. Austin: University of Texas Press.
- Reid, F.A. 1997. *A Field Guide to the Mammals of Central America and Southeast Mexico*. New York: Oxford University Press.
- Reyna-Hurtado, R. 2002. Hunting effects on the ungulate species in Calakmul forest, Mexico. Master thesis. University of Florida, Gainesville, Florida.
- Reyna-Hurtado, R., and G.W. Tanner. 2005. Habitat preferences of ungulates in hunted and nonhunted areas in the Calakmul Forest, Campeche, Mexico. *Biotropica* 37:676-685.
- Richey, J.E., R.L. Victoria, E. Salati, and B.R. Forsberg. 1991. "The biogeochemistry of a major river system: The Amazon case study," in *Biogeochemistry of Major World Rivers*. Edited by E.T. Degens, S. Kempe, and J.E. Richey, pp. 57-74. New York: Wiley and Sons.
- Robinson, J.G., and E.L. Bennett. 2000. "Carrying capacity limits to sustainable hunting in tropical forests," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp.13-30. New York: Columbia University Press.
- , and ---. 2004. Having your wildlife and eating it too: An analysis of hunting sustainability across tropical ecosystems. *Animal Conservation* 7:397-408.
- Robinson, J.G., and R.E. Bodmer. 1999. Towards wildlife management in tropical forests. *Journal of Wildlife Management* 63:1-13.
- Robinson, J.G., and K.H. Redford. 1986a. Intrinsic rate of natural increase in Neotropical forest mammals: relationship to phylogeny and diet. *Oecologia* 68:516-520.
- , and ---. 1986b. Body size, diet, and population density of Neotropical forest mammals. *The American Naturalist* 128:665-680.

- , and ---. 1991. "Sustainable harvest of Neotropical forest mammals," in *Neotropical Wildlife Use and Conservation*. Edited by J.G. Robinson and K.H. Redford, pp. 415-429. Chicago: University of Chicago Press.
- , and ---. 1994a. "Community-based approaches to wildlife conservation in Neotropical forests," in *Natural Connections: Perspectives in Community-based Conservation*. Edited by D. Western and R.M. Wright, pp. 300-19. Washington: Island Press.
- , and ---. 1994b. Measuring the sustainability of hunting in tropical forests. *Oryx* 28:249-256.
- Romanoff, S. 1983. Women as hunters among the Matsigenka of the Peruvian Amazon. *Human Ecology* 11:339-343.
- Ross, E.B. 1978. Food taboos, diet, and hunting strategy: The adaptation to animals in Amazon cultural ecology. *Current Anthropology* 19:1-36.
- . 1987. "An overview of trends in dietary variation from hunter-gatherer to modern capitalist societies," in *Food and Evolution: Toward a Theory of Human Food Habits*. Edited by M. Harris and E. B. Ross, pp. 7-55. Philadelphia: Temple UP.
- Ruddle, K. 1970. The hunting technology of the Maraca Indians. *Antropologica* 25:21-63.
- Salas, L.A., and J.B. Kim. 2002. Spatial factors and stochasticity in the evaluation of sustainable hunting of tapirs. *Conservation Biology* 16:86-96.
- Saraydar, S., and I. Shimada. 1971. A quantitative comparison of efficiency between a stone axe and a steel axe. *American Antiquity* 36:216-217.
- Savolainen, P., Y. Zhang, J. Luo, J. Lundeberg, and T. Leitner. 2002. Genetic evidence for an East Asian origin of domestic dogs. *Science* 298:1610-1613.
- Schoener, T.W. 1971. Theory of feeding strategies. *Annual Review of Ecology and Systematics* 2:369-404.
- . 1979. Generality of the size-distance relation in models of optimal feeding. *American Naturalist* 114:902-914.
- Schwartz. M. 1997. *A History of Dogs in the Early Americas*. New Haven: Yale University Press.
- Schwartzman, S., A. Moreira, and D. Nepstad. 2000. Rethinking tropical forest conservation: Perils in parks. *Conservation Biology* 14:1351-1357
- Shepard, G.H. 2002. "Primates in Matsigenka subsistence and world view," in *Primates Face to Face: The Conservation Implications of Human-Nonhuman Primate Interactions*. Edited by A. Fuentes and L.D. Wolfe, pp. 101-136. Cambridge: Cambridge University Press.
- Sih, A., and B. Christensen. 2001. Optimal diet theory: When does it work, and when and why does it fail? *Animal Behaviour* 61:379-90.
- Singer, M. 1978. Pygmies and their dogs: A note on culturally constituted defense mechanisms. *Ethos* 6:270-277.

- Sioli, H. 1967. Studies in Amazonian waters. *Atas Do Simpósio Sobre a Biota Amazônica: Limnologia* 3:9-50.
- . 1984. "The Amazon and its main affluents: Hydrography, morphology of the river courses, and river types," in *The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin*. Edited by Harald Sioli, pp. 127-65. Dordrecht: W. Junk.
- Sirén, A., P. Hamäck, and J. Machoa. 2004. Including spatial heterogeneity and animal dispersal when evaluating hunting: A model analysis and an empirical assessment in an Amazonian community. *Conservation Biology* 18:1315-1329.
- Siskind, J. 1973a. *To Hunt in the Morning*. New York: Oxford University Press.
- . 1973b. "Tropical forest hunters and the economy of sex," in *Peoples and cultures of Native South America*. Edited by D.R. Gross, pp. 226-241. Garden City, NY: Doubleday/Natural History Press.
- Slade, N.A., R. Gomulkiewicz, and H.M. Alexander. 1998. Alternatives to Robinson and Redford's method of assessing overharvest from incomplete demographic data. *Conservation Biology* 12:148-155.
- Smith, D.A. 2003a. Participatory mapping of community lands and hunting yields among the Buglé of Western Panama. *Human Organization* 62:332-343.
- . 2003b. Hunting, Habitat, and Indigenous Settlement Patterns: A Geographic Analysis of Buglé Wildlife Use in Western Panama. Ph.D. Dissertation. The University of Kansas.
- . 2005. Garden game: Shifting cultivation, indigenous hunting, and wildlife ecology in Western Panama. *Human Ecology* 33:505-537.
- Smith, E.A. 1979. Human adaptation and energetic efficiency. *Human Ecology* 7:53-74.
- . 1983. Anthropological applications of optimal foraging theory: A critical review. *Current Anthropology* 24:625-651.
- . 1987. On fitness maximization, limited needs, and hunter-gatherer time allocation. *Ethology and Sociobiology* 8:73-85.
- . 1991. *Inujjuamiut Foraging Strategies*. New York: Aldine de Gruyter.
- Smith, E.A., and R.L. Bliege Bird. 2000. Turtle hunting and tombstone opening: Public generosity as costly signaling. *Evolution and Human Behavior* 21:245-261.
- Smith, E.A., and M. Wishnie. 2000. Conservation and subsistence in small-scale societies. *Annual Review of Anthropology* 29:493-524.
- Smith, J.H. 2001. Land cover assessment of indigenous communities in the BOSAWAS region of Nicaragua. *Human Ecology* 29:339-347.
- Smith, N.J.H. 1976. Utilization of game along Brazil's transamazon highway. *Acta Amazonia* 6:455-466.

- Smole, W.J. 1976. *The Yanoama Indians: A Cultural Geography*. Austin, TX: University of Texas Press.
- Sosis, R. 2000. Costly signaling and torch fishing on Ifaluk atoll. *Evolution and Human Behavior* 21:223-244.
- . 2002. Patch choice decisions among Ifaluk fishers. *American Anthropologist* 104:583-598.
- Souza-Mazurek, R.R. de., T. Pedrinho, X. Feliciano, W. Hilário, S. Gerôncio, and E. Marcelo. 2000. Subsistence hunting among the Waimiri Atroari Indians in central Amazonia, Brazil. *Biodiversity and Conservation* 9:579-596.
- Spath, C.D. 1981. Getting to the meat of the problem: Some comments on protein as a limiting factor in Amazonia. *American Anthropologist* 83:377-379.
- Stearman, A.M. 1990. The effects of settler incursion on fish and game resources of the Yuquí, a native Amazonian society of eastern Bolivia. *Human Organization* 49:373-385.
- . 1991. Making a living in the tropical forest: Yuquí foragers in the Bolivian Amazon. *Human Ecology* 19:245-260.
- . 2000. "A pound of flesh: Social changes and modernization as factors in hunting sustainability among Neotropical indigenous societies," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 233-250. New York: Columbia University Press.
- Steen, J.B., and E. Wilsson. 1990. How do dogs determine the direction of tracks? *Acta Physiologica Scandinavica* 139:531-534.
- Stephens, D.W., and J.R. Krebs. 1986. *Foraging Theory*. Princeton, NJ: Princeton University Press.
- Steward, J.H. 1947. American culture history in the light of South America. *Southwestern Journal of Anthropology* 3:85-107.
- Stocks, A. 1983. "Cocamilla fishing: Patch modification and environmental buffering in the Amazon várzea," in *Adaptive Strategies of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 239-267. New York: Academic.
- . 1996. "The BOSAWAS Natural Reserve and the Mayangna of Nicaragua," in *Traditional Peoples and Biodiversity Conservation in Large Tropical Landscapes*. Edited by K.H. Redford and J.A. Mansour, pp. 1-32. America Verde Series of The Nature Conservancy. Arlington, VA.
- . 1998. "Indigenous and mestizo settlements in Nicaragua's BOSAWAS Reserve: The prospects for sustainability." Paper presented at the 1998 Annual Meeting of the Latin American Studies Association, Session on Prospects for Sustainability of Human Settlement in Latin American Rainforest II: Broader Perspectives and Issues. Chicago, September 24-26, 1998.
- . 2003. Mapping dreams in Nicaragua's Bosawas Reserve. *Human Organization* 62:344-356.
- . 2005. Too much for too few: Problems of indigenous land rights in Latin America. *Annual Review of Anthropology* 34:85-104.

- Stocks, A., L. Jarquin, and J. Beauvais. 2000. El activismo ecologico indigena en Nicaragua: Demarcacion y legalizacion de tierras indigenas en BOSAWAS. *Wani* 25:6-21.
- Stocks, A., B. McMahan, and P. Taber. Beyond the map: Indigenous and colonist impacts and territorial defense in Nicaragua's BOSAWAS reserve. Unpublished manuscript.
- Taylor, B.W. 1963. An outline of the vegetation of Nicaragua. *Journal of Ecology* 51:27-54.
- Taylor, D.M. 1951. *The Black Carib of British Honduras*. New York: Wenner-Gren Foundation for Anthropological Research, Incorporated.
- Tenaza, R., and R.L. Tilson. 1985. Human predation and Kloss's Gibbon (*Hylobates klossii*) sleeping trees in Siberut Island, Indonesia. *American Journal of Primatology* 8:299-308.
- The Nature Conservancy (TNC). 1997. Kipla Sait Tasbaika: Tradición oral y estudio socioeconómico de las comunidades indígenas del sector raudales. Managua, Nicaragua: Impresiones Modernas.
- Thesen, A., J.B. Steen, and K.B. Døving. 1993. Behaviour of dogs during olfactory tracking. *Journal of Experimental Biology* 180:247-251.
- Townsend, W.H. 1969. Stone and steel tool use in a New Guinea society. *Ethnology* 8:199-205.
- Townsend, W.R. 1995. Living on the edge: Sirionó hunting and fishing in lowland Bolivia. Ph.D. dissertation. The University of Florida.
- . 2000. "The sustainability of subsistence hunting by the Sirionó Indians of Bolivia," in *Hunting for Sustainability in Tropical Forests*. Edited by J.G. Robinson and E.L. Bennett, pp. 267-281. New York: Columbia University Press.
- Tucker, B.T. 2001. The behavioral ecology and economics of variation, risk, and diversification among Mikea forager-farmers of Madagascar. Ph.D. dissertation. The University of North Carolina.
- . Opportunity costs and the value of time: Motivation as an explanation for age-specific foraging efficiency. Unpublished manuscript. Available online at <http://anthro.dac.uga.edu/people/tucker.htm>. Retrieved on August 1, 2006.
- Tucker, B., and A.G. Young. 2005. "Growing up Mikea: Children's time allocation and tuber foraging in Southwestern Madagascar," in *Hunter-gatherer Childhoods*. Edited by B. Hewlett and M. Lamb, pp. 147-171. New York: Aldine de Gruyter.
- Turner, J.M, J. Mead, and M.E. Wohl. 1968. Elasticity of human lungs in relation to age. *Journal of Applied Physiology* 25:664-671.
- Vickers, W.T. 1975. Meat is meat: The Siona-Secoya and the hunting prowess-sexual reward hypothesis. *Latinamericanist* 11:1-5.
- . 1980. "An analysis of Amazonian hunting yields as a function of settlement age," in *Working Papers on South American Indians*. Edited by R. Hames, pp. 7-29. Bennington, VT: Bennington College.
- . 1984. The faunal components of lowland South American hunting kills. *Interciencia* 9:366-376.

- . 1988. The game depletion hypothesis of Amazonian adaptation: Data from a native community. *Science* 239:1521-1522.
- . 1991. "Hunting yields and game composition over ten years in an Amazon Indian territory," in *Neotropical Wildlife Use and Conservation*. Edited by J.G. Robinson, and K.H. Redford, pp. 53-81. Chicago: University of Chicago Press.
- . 1994. From opportunism to nascent conservation: The case of the Siona-Secoya. *Human Nature* 5:307-337.
- Vilá, C., P. Savolainen, J.E. Maldonado, I.R. Amorim, J.E. Rice, R.L. Honeycutt, K.A. Crandall, J. Lundenberg, and R.K. Wayne. 1997. Multiple and ancient origins of the domestic dog. *Science* 276:1687-1689.
- von Houwald, G.F. 2003. *Mayangna: Apuntes Sobre la Historia de los Indígenas Sumu en Centroamérica*. Translated by Edgard Arturo Castro Frenzel. Managua: Fundación Vida.
- Wagley, C. 1977. *Welcome of Tears: The Tapirapé Indians of Central Brazil*. New York: Oxford University Press.
- Walker, R., K. Hill, H. Kaplan, and G. McMillan. 2002. Age-dependency in hunting ability among the Ache of Eastern Paraguay. *Journal of Human Evolution* 42:639-657.
- Wayne, R.K., and C. Vilá. 2003. "Molecular genetic studies of wolves," in *Wolves: Behavior, Ecology, and Conservation*. Edited by L.D. Mech and L. Boitani, pp. 218-238. Chicago: University of Chicago Press.
- Wells, D.L., and P.G. Hepper. 2003. Directional tracking in the domestic dog, *Canis familiaris*. *Applied Animal Behaviour Science* 84:297-305.
- Werner, D. 1983. "Why do the Mekranoti trek?" in *Adaptive Responses of Native Amazonians*. Edited by R.B. Hames and W.T. Vickers, pp. 225-238. New York: Academic Press.
- . 1984. *Amazon Journey: An Anthropologist's Year Among Brazil's Mekranoti Indians*. New York: Simon and Schuster.
- Werner, D., and N.M. Flowers, M.Lattman Ritter, and D.R. Gross. 1979. Subsistence productivity and hunting effort in Native South America. *Human Ecology* 7:303-315.
- White, I.M. Hunting dogs at Yalata. *Mankind* 8:201-205.
- Wilbert, J. 1972. *Survivors of Eldorado: Four Indian Cultures of South America*. New York: Praeger.
- Wiley, G.R. 1984. "A summary of the archaeology of lower Central America," in *The Archaeology of Lower Central America*. Edited by F.W. Lange and D. Stone. Albuquerque, NM: University of New Mexico Press.
- Williams, K.D. 1984. The Central American tapir (*Tapirus bairdii*) in northwestern Costa Rica. Ph.D. thesis. Michigan State University. East Lansing, MI.

- Williams-Guillen, K., C. Asa, G. Camilo, P. McDaniel, and O. Dixon. 2004. "Subsistence Hunting by Indigenous People in Bosawás Biosphere Reserve, Nicaragua." Presented at the 18th Annual Meeting of the Society for Conservation Biology. New York. July 30-August 2, 2004.
- Williams-Guillen, K., D. Griffith, J. Polisar, O. Dixon, G. Camilo, C. Asa, K. Bauman, P. McDaniel, L. Bradshaw, S. Shank, A. Zidek-Vanega, J. Koster, and V. Espinoza Mendiola. 2006. Poblaciones de animales silvestres y sostenibilidad de la cacería en Kipla Sait Tasbaika Kum, Bosawás, Nicaragua. Unpublished manuscript.
- Winterhalder, B. 1981. "Foraging strategies in the boreal environment: An analysis of Cree hunting and gathering," in *Hunter-Gatherer Foraging Strategies*. Edited by B. Winterhalder and E. Smith, pp. 66-98. Chicago: University of Chicago Press.
- Winterhalder, B., and E.A. Smith. 1992. "Evolutionary ecology and the social sciences," in *Evolutionary Ecology and Human Behavior*. Edited by E.A. Smith and B. Winterhalder, pp. 3-23. New York: Aldine de Gruyter.
- , and ---. 2000. Analyzing adaptive strategies: Human behavioral ecology at twenty-five. *Evolutionary Anthropology* 9:51-72.
- Yde, J. 1965. *The Material Culture of the Waiwái*. Copenhagen: The National Museum of Copenhagen.
- Yin, S., and B. McCowan. 2004. Barking in domestic dogs: Context specificity and individual identification. *Animal Behaviour* 28:343-355.
- Yost, J., and P. Kelley. 1983. "Shotguns, blowguns, and spears: An analysis of technological efficiency," in *Adaptive Responses of Native Amazonians*. Edited by R. Hames and W. Vickers, pp. 189-224. New York: Academic Press.
- Zahavi, A. 1975. Mate selection: Selection for a handicap. *Journal of Theoretical Biology* 53:205-214.

VITA

Jeremy M. Koster

EDUCATION

Ph.D. Anthropology. Penn State University. 2007.

M.A. Anthropology. Penn State University. 2003.

B.A. English, Philosophy & Religion. Bridgewater College. 1998.

RESEARCH INTERESTS

Human behavioral ecology, optimal foraging theory, resource conservation, Central and South American indigenous societies, quantitative and qualitative ethnographic methods, applied GIS (Geographic Information Systems)

RESEARCH EXPERIENCE

Dissertation research: The Bosawas Biosphere Reserve, Nicaragua. July 2004-September 2005.

- The project uses focal observations of hunters, instantaneous scan sampling, household questionnaires, and GIS to investigate the hunting practices of the reserve's indigenous inhabitants.
- Funded by a U.S. Fulbright grant, an NSF doctoral dissertation improvement award, a Hill Foundation grant from Penn State, a Sanders departmental dissertation award, and a Noldus publication grant.

Pre-dissertation research: The Bosawas Biosphere Reserve, Nicaragua. July 2003.

- This pilot study provided an opportunity to test and refine observational methodologies employed during the dissertation research.
- Funded by a Hill Foundation grant from Penn State

TEACHING EXPERIENCE

Instructor: Cultural Anthropology, Penn State Summer Session I, 2003

Teaching Assistant: Cultural Anthropology, North American Archaeology, Comparative Social Organization, Penn State 2001-2004

DISTINCTIONS

- NSF Graduate Research Fellowship Competition, Honorable Mention (2003)
- Best student presentation, Evolutionary Anthropology Society, 2006 AAA conference