

CHAPTER 5

Neotropical Hunting among the Aché of Eastern Paraguay

Kim Hill and Kristen Hawkes

Introduction

Hunting has long been considered a behavior of primary importance in the physical and social evolution of humans (e.g., Dart 1953; Washburn 1960; Washburn and Lancaster 1968). The importance of hunting has been stressed in theories concerning bipedalism, cranial expansion, tool manufacture, sharing, territoriality, warfare, development of the nuclear family, sex roles, and a wide variety of other topics. Recent debates about hunting have centered on the importance of meat in the diet of hunter-gatherers (Hawkes et al 1982; Lee and Devore 1968; Lee 1979; Teleki and Harding 1981), the relative efficiencies of various hunting technologies (Hames 1979), local game depletions in South America (Hames 1980; Vickers 1980), and, especially in lowland South America, the amount and adequacy of protein in the diet supplied by hunting (Chagnon and Hames 1979; Gross 1975; Harris 1974, 1977; Meggers 1971; Ross 1978).

Despite the long-standing interest in human hunting, surprisingly few precise and quantitative data have appeared in the anthropological literature (however, see K. Hill [in press] and R. Hames [n.d.]). In this chapter we present data on the hunting behavior of the Aché of eastern Paraguay that should be useful in the comparative analysis of lowland South American economies in which hunting plays a key role, and more generally in developing models of both the evolution of hominids and the temporal and spatial variations in their behavior.

Aché hunters are quite efficient predators. Hunting supplies over 1 kg of

meat (live weight) and over 150 g of animal protein per person per day, accounting for 80% of the calories in the diet (Hawkes *et al.* 1982). This contradicts currently held ideas about the importance of meat in the diet of nonarctic hunter-gatherers (Hayden 1981; Lee and DeVore 1968) and the abundance of game in tropical South America (e.g., Gross 1975; Meggers 1971). We present a tabulation of time utilization and hunting returns for adult hunters. Differences in returns from different technologies are compared, and the effect of hunting pressure in a heavily hunted area is reported. We use models derived from optimal foraging theory to account for the total set of species hunted, using different technologies. Hunting returns at the group level are calculated, and then a more detailed analysis of variance in returns between individuals and across age categories is presented. Finally, we explore the problem of optimal group size based on maximizing returns and reducing risk. The implications of these results are discussed with respect to hypotheses concerning lowland South American economies, and the evolution of human hunting behavior.

Environmental and Historical Background

An area of about 5000 km² between 54–56° W and 24–25° S in the forests of eastern Paraguay is the traditional range of the northern Aché (see Figure 5.1). The area is drained to the east by the Paraná river and to the west by the Paraguay. It is characterized by gentle rolling hills composed of soft sedimentary rock and weathered basalt, interspersed with low flat valleys. The hills are covered with tropical broadleaf evergreen forest, while the valleys are filled with tall broadblade grasses. The Aché prefer to inhabit and hunt in the forest which comprises many microhabitats including wet lowlands; floodlands adjacent to large rivers; forest thick with several species of small or large bamboo; forests of smaller trees, dense vines and undergrowth; and forests with large towering trees and little ground level plant growth. The Aché themselves divide all forest areas into two categories: nice (clean) forest and ugly (tangled) forest, the latter being defined by difficulty of mobility, thorns, spiny plants, and thick, tangled understory.

The eastern extreme of the Aché territory is more tropical than the western part. This correlates with a rainfall gradient ranging from approximately 1500 to 1700 mm annually, as well as to an increase in altitude from about 250 to 350 m and to a 1°C decrease in the mean temperature as one moves eastward. The dominant characteristic of the weather pattern is extreme unpredictability from month to month and year to year. Although March–September is a somewhat drier time of the year, with the usual

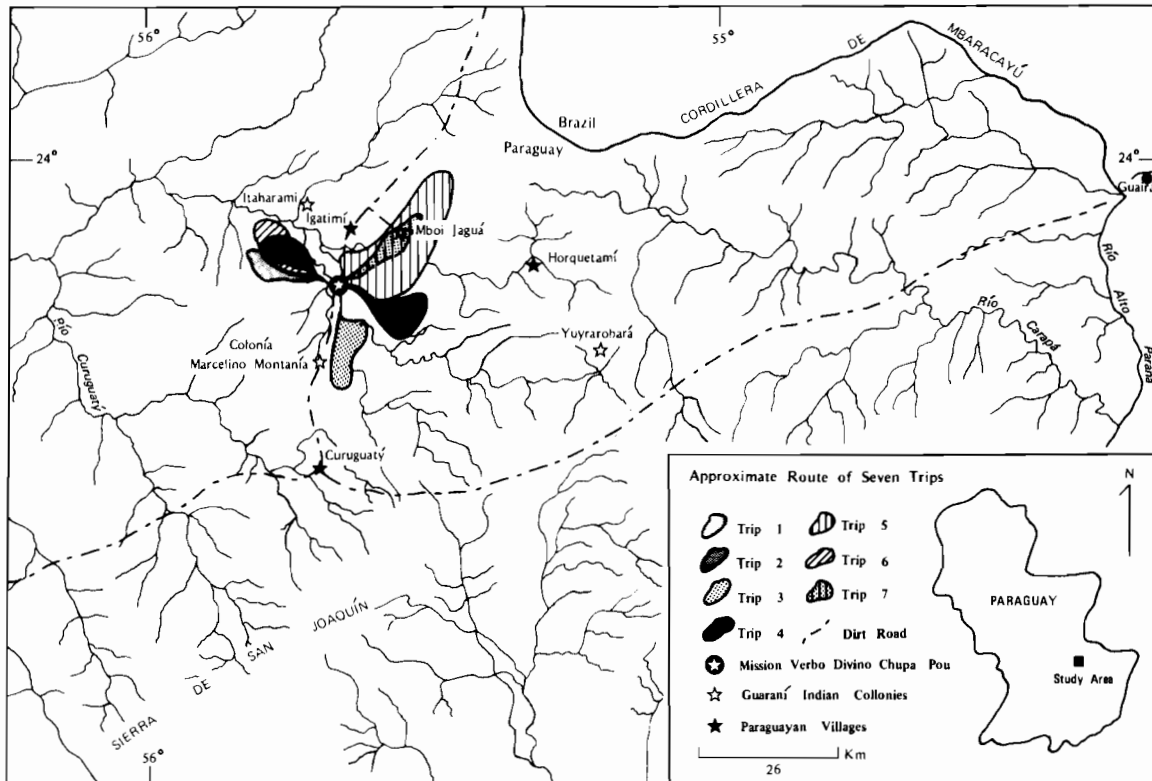


Figure 5.1 Study area and route of foraging trips. The route followed by the women and children on each foraging trip is that described by the circumference of each shaded area. Hunters spread out in all directions from this route, and the shaded areas do not represent hunted areas, but are only used to illustrate clearly the routes.

“rainy season” falling between October and February, in any single year almost any month may be the wettest or driest. The fluctuations in temperature are far more predictable, and it is temperature change rather than precipitation that marks seasonality. The average daily temperature for the region is 17°C in July and 27°C in January. The extremes are approximately 41°C and -3°C with several days of frost every year. The Aché break down the year by referring to “hot time,” “cold time,” or the time when a particular resource is in season.

The flora and fauna in this region, as is the case in most tropical areas, are very poorly described. We have identified 33 mammals hunted by the Aché, and they have named several others which we have not yet seen or identified. In addition, the Aché eat at least 10 species of reptiles and amphibians, more than 15 species of fish and a seemingly endless number of birds. We have thus far identified only a few of these. Edible products of

more than 40 plants and trees are exploited in most years. The major species, used for both food and a variety of tools, is the palm *Arecastrum romanzofianum* which is very abundant throughout eastern Paraguay. Cerambycid larva, which feed on rotting palms, and at least 10 other larval types are eaten frequently. The adult forms of at least 5 insects are eaten, and at least 14 different kinds of honey are taken, the most common being that of *Apis melifera*.

Due to the ample rainfall and numerous streams, water is rarely in short supply. On occasion, when camping far from a water source, the Aché extract water from hollow bamboo, bottle trees, or the center of large vines. In addition to hundreds of small streams and rivers, there are a handful of large rivers that crosscut this region and present temporary barriers to the Aché in times of heavy rainfall.

The Aché (also called Guayaki) divide themselves into three categories based on differences of culture, dialect, and geographic range. All speak a language of the Guaraní family. They have been foragers in the jungles of eastern Paraguay, surrounded by hostile sedentary farmers, since before the arrival of the Spanish.

There are some references to the Aché in historical accounts before the 1960s (see Metraux and Baldus 1963) but the first extensive ethnographic reports come from Pierre Clastres (1968, 1972) who studied two of the three Aché groups. This research deals with the third, the northern Aché who have only come into unarmed contact with outsiders within the past decade (see K. Hill n.d.).

Ecology and Area of Study

The area covered by this study is located near two drainage systems, the Jejui Guasu and the Jejui Mi rivers near Igatimí, Alto Paraná (see Figure 5.1). This represents the extreme northern portion of the traditional Aché foraging range, and the forest of this area appears to be slightly less tropical than in the majority of the traditional home-range forests. Nevertheless, the animal species found in both areas seem to be identical, even though their densities may differ slightly. Most of the economically important plant species are found in both areas, although, once again, densities may differ somewhat.

The area covered by this study is approximately 600 km², or about 12% of the total traditional home range for the northern Aché. During the study period, approximately 155 Aché were resident in this area, for a density of 1 person/4 km². This is slightly higher than the precontact density of ap-

proximately 1 person/5–10 km² and in addition there is considerable population of Paraguayans, Chiripa, and Mbya Indians (about 2000 total) who also live in the area.¹ Summing up these conditions, it is our impression that the area is more heavily hunted than was the case for traditional hunting ranges before contact, even though the Aché currently spend a good deal of time at a mission settlement where they are provisioned.²

- The ecology of the area has not been well studied. Five primary ecotypes which are relevant to hunting can be distinguished. Four of these are similar to those described by Hames (1980)³ for the Ye'kwana and Yānomamö in southern Venezuela. (One of the ecotypes described by Hames, that produced by human gardening activity, is not hunted by the Aché.)

PRIMARY FOREST

The vast majority of eastern Paraguay is covered by this tall dense forest which develops on high ground with adequate drainage. Direct sunlight rarely reaches the ground level and, thus, ground cover is medium to sparse. But the density of vines hanging from trees is a strong impediment to travel in many areas and large stands of bamboo also make traveling difficult at times. Important prey items commonly encountered in this ecotype include tapir, deer, monkeys, peccaries, and coatis.

SEASONAL FLOODLAND FOREST

Found behind natural levees of rivers, floodland forest floods seasonally, or once every few years. Areas which may have been near major river courses within the past 10 years, but are now situated some distance from the current water flow, may also be covered with this forest. Trees are usually small-to-medium size, and several species of bamboo are found. All forest areas immediately adjacent to large (greater than 10 m across) streams or rivers have characteristics of this ecotype. Important prey items of this zone are paca and armadillo.

RIVERINE LAGOONS

Riverine lagoons are connected to the river systems during the wettest times of the year, but throughout the driest seasons they slowly shrink, sometimes becoming mere swampland. If not too deep, they are filled with tall broadblade grasses. Important prey items of this zone are capybara, otter, fish, and caiman.

SWAMP FOREST

Wet areas are found in low undrained depressions or at water sources anywhere within the primary forest, where the water table comes to the surface over a large area. This ecotype is often marked by an abundance of palm trees, which are of primary importance in the Aché diet, and is frequented by feeding tapirs and peccaries. The Aché prefer to camp within reasonable walking distance of this ecotype (but never in it, due to the water on the ground) in order to exploit the palms found there.

MEADOW GRASSLAND

Meadows are characterized by tall grasses of various species and by a complete lack of trees. It is frequently, though not always, somewhat swampy. These grasslands are rarely greater than ½ km in diameter and are seldom used by the Aché except to cross from one forest area to another. The large Paraguayan antlered deer and the rhea (a large flightless bird) frequented these meadows in times past, but both now seem to be locally extinct. This zone has been of some importance historically because many Paraguayan horses and cows found in meadows near the fringes of white settlements were killed and eaten by Aché hunters, leading to a recent period of intensified hostilities between the Aché and their neighbors (see K. Hill n.d.)

Prey Species and Hunting Techniques

Although the overall foraging pattern of the Aché, and the return rates for different resource items have been described (Hawkes *et al.* 1982) the precise details of hunting should be elaborated further. Table 5.1 lists the animal species that are known to be eaten by the Aché. In addition to their use as food, the young of most mammals are captured live and kept as pets, especially monkeys, coatis, and peccaries. While the mammalian list presented is nearly complete, there are many more species of birds occasionally included in the diet that have not been listed. This list should potentially include all animal species in eastern Paraguay, as the Aché seem to have no generally tabooed food items.⁴

The Aché are bow hunters, and their techniques seem to be similar to those of many other lowland South American archers. The bow is made of palm wood and is approximately 2 m in length. It is nearly identical to the bow of the Siriono, and is slightly larger than the Yānomamö bow. Arrow shafts are made from reeds about 1.5 cm in diameter, and the head is

Table 5.1

Aché Prey Species

Common name	Scientific name	Aché name	Weapon used ^a
MAMMALS		Bue	
(Rodentia)			
Agouti	<i>Dasyprocta aguti</i>	Kuchi	H, B
Capibara	<i>Hydrochoerus hydrochaeris</i>	Pywa	B, C
Paca	<i>Cuniculus paca</i>	Bywa	H
? Rat	?	Buja	H
(Edentata)			
Giant anteater	<i>Myrmecophaga tridactyla</i>	Kware	C
Tamandua	<i>Tamandua tetradactyla</i>	Kwaremini	B, C, H
Nine-banded armadillo	<i>Dasybus novemcinctus</i>	Tatu	H, S
Giant armadillo	<i>Priodontes giganteus</i>	Krypura	H, S, C
? Armadillo	?	Kry'y	H, S
(Artiodactyla)			
Red brocket deer	<i>Mazama americana</i>	Wachu	B
Pampas deer	<i>Ozotoceros bezoarticus</i>	Wachupuku	B
White-lipped peccary	<i>Tayassu pecari</i>	We'e (chachu)	B
Collared peccary	<i>Tayassu tajacu</i>	Kanje	B, C, S
(Perissodactyla)			
Tapir	<i>Tapirus terrestris</i>	Brevi	B
(Primates)			
Black howler monkey	<i>Alouatta caraja</i>	Kraja	B
Brown capuchin monkey	<i>Cebus apella</i>	Pwa'a	B
(Carnivora)			
Crab-eating racoon	<i>Procyon carnivorus</i>	Bejywa	H, B
Coati	<i>Nasua nasua</i>	Kane	H, B
Bush dog	<i>Speothus venaticus</i>	Juape	H, B
Crab-eating fox	<i>Cerdothyon thous</i>	Krachowa	B
Jaguarundi	<i>Felis jaguarondi</i>	Betapa	H, B
Margay	<i>Felis wiedi</i>	Kajamini	H, B
Ocelot	<i>Felis pardalis</i>	Kaja	B
Puma	<i>Puma concolor</i>	Juku	B
Jaguar	<i>Panthera onca</i>	Jamo	B
Tayra	<i>Eira barbara</i>	Aira	H, B
Otter	<i>Petonura brasiliensis</i>	Chery	H, B, C
Giant otter	?	Cherywachu	B, C
Prehensile-tailed porcupine	<i>Coendu prehensilis</i>	Gui'i	
(Lagomorpha)			
Forest rabbit	<i>Sylvilagus brasiliensis</i>	Ata	B, H
(Marsupialia)			
? Opossum	?	Kyre	H, B
(Not identified)			
?	?	Bechi	H
?	?	Bywa tapi	H
?	?	Beche kruma	H, B

(continued)

Table 5.1 (Continued)

Common name	Scientific name	Aché name	Weapon used ^a
REPTILES and AMPHIBIANS			
Iguana (various species)	?	Cheju	H, C, S
? Turtle	?	Krombe	H
Caiman	?	Jamongi	B, S, H
? Toad	?	Wypy	H
? Frog	?	Pepa	H
(Snakes)			
Anaconda	<i>Eunectes murinus</i>	Memboruchu	C
? Boa	?	Membopura	C
? Rattlesnake	?	Chinipura	C
<i>Jararaca</i> (fer-de-lance)	<i>Bothrops atrox</i>	Membo	C
?	?	Kimina	C
?	?	Chei	C
BIRDS ^b			
? Vulture	?	Wyra	
? Vulture	?	Tayja	B
? Buzzard	?	Chivura	B
? Curassow	?	Briku	B
?	?	Jaku	B
?	?	Nambu	B
?	?	Kuachi	B
?	?	Uru	B
? Toucan	?	Toka	B
Macaw	<i>Ara macao</i>	Wyraraka	B
? Parrot	?	Akwa	B
? Parrot	?	Bero	B
Rhea	?	Bewyra	B
? Eagle	?	Kane	B
?	?	Doko	B

^aB refers to bow; H, hand; C, club; S, bow or arrow used as spear.

^bNot all bird species listed.

carved from hardwood, with barbs along one edge. Occasionally, arrow heads are more flattened and sharpened on both edges to produce a double-edged knifelike point useful for killing very large game. Bird arrows with blunt striking points are also employed. The overall length of the arrow varies considerably, but an average seems to be about 1.8 m. Clastres (1972) has described Aché technology in some detail.

Several real and potential differences between Aché hunting and other hunting patterns described in the literature should be mentioned before elaborating on the specifics. First, the Aché do not hunt with dogs. Recently this has begun to change, but all information in this chapter concerns human hunters using only their skills. Aché hunters are of course, very good trackers, and we witnessed a group of four men track a single

Aché adult, who had become lost, for an entire day through thick jungle without losing the trail. Tracking animals through thick forest with much organic litter on the ground is very difficult, yet the Aché almost never lose the track of a single animal unless it begins to travel a heavily run trail, or it passes through a swampy area. If the animal is not wounded badly, the hunters will not track it, as it is likely to cross a swamp (especially tapir); however, if it is well shot, and does not move further than ½–1 km they can almost always find it. Thus, the estimation of the initial wound is very important when deciding whether to track. Second, the Aché frequently kill animals by hand; the bow is used as a supplementary weapon only for certain animals, rather than as a kill-all tool. This is discussed in a later section, as weaponless hunting may provide important information concerning early hominid hunting behavior. Third, the Aché employ no poisons of any kind for hunting or fishing and thus differ from most other South American groups. Fourth, the Aché use all of the generalized capabilities of humans in order to pursue game. This includes digging, climbing, running, entering deep water, using fire, and inventing a wide variety of on-the-spot tools in order to reach less accessible prey. They also frequently use touch and smell to supplement other sensory input. Only animals which are much swifter on the ground and run long distances rather than seeking shelter (i.e., climbing trees or entering burrows) are safe from continued pursuit. Finally, it should be noted that although hunting is "men's work," due to the daily movement pattern of the band, women are frequently present at or near the kill site and help in the hunt when necessary as spotters. Women make occasional kills (never with arrows, however). The young of both sexes, if they are present (but especially males), are used to climb trees in order to fetch arrows or killed game, or to flush out arboreal game for continued pursuit. Descriptions of several commonly used techniques (see Table 5.2) for various game animals follow.

PACA (*CUNICULUS PACA*)

The paca is a large rodent that makes its burrow near a permanent water source. The burrow has one primary entrance and several escape exits that are difficult to see but which can be found by noting small disturbances in the leaves that cover the exits. When the Aché hunt in an area with signs of paca, they stay quite close together and, when a burrow with fresh signs (as determined visually, or by feeling for warmth, or by smelling) is located, the finder whistles to the other searchers. The men who are nearby respond with a similar whistle, and the finder then whistles twice, which gives an exact fix on his location and means "come here." The additional hunters approach slowly in order not to disturb the sleeping paca. They locate all escape exits, and assign one man to cover each. Positioning is

Table 5.2

Aché Kill Verbs^a

Verb	Technique
Biri	To choke, strangle, or suffocate, by applying pressure with foot or knee on animal's chest or neck.
Bio'ó	To break its neck by twisting its head with both hands.
Bopo	To stun with bird arrow. Small animals and birds suffer broken ribs and neck.
Bro'ó	To puncture in the gut region with a projectile (arrow or bullet).
Bwapi	To slam to death by grabbing tail or limbs and whacking head against tree or on ground.
Ity	To knock it down or make it fall into a hole (trap).
Juka	(Generalized kill verb).
Jywo	To shoot with an arrow (anywhere on body).
Krapi	(Literally means "to gut it.")
Pacho	To beat it to death with a club.
Pycho	To stab or puncture it with a hand-held object (usually knife or spear).
Ruka	To split it open with a machete or the sharp edge of a club.

^aThese verbs would all translate as "kill" in an Aché narrative.

done without the use of language because the process is well understood by all. If there are more exits than the number of men, some exits are plugged with dead wood. When all outlets are attended, a log is introduced into the main entrance and thumped vigorously. This noise causes the sleeping rodent to dash out one of its escape exits where an awaiting hunter grabs it and suffocates (*biri*) it.

CAPYBARA (*HYDROCHOERUS HYDROCHAERIS*)

The capybara is the world's largest rodent and represents the second largest game item in Paraguay, weighing up to 60 kg. Large grassy lagoons which are their primary feeding grounds are inspected closely. If fresh tracks are discovered on the bank, the lagoon is surrounded by hunters. Several men enter the lagoon and try to drive the animals to one end where they will attempt to flee onto land. Waiting hunters shoot the escaping prey with arrows (*jywo*), club them to death (*pacho*), or split them open with a machete (*ruka*). In the rainy times of the year, capybaras are not usually hunted due to the depth of the lagoons and their ability to remain submerged for long periods.

GIANT ANTEATER (*MYRMECOPHAGA TRIDACTYLA*)

The giant anteater is the largest of the two anteaters found in Paraguay. They are slow but have long sharp claws which are supposedly able to kill

both man and jaguar. To kill anteaters, the Aché use a long club in order to stay out of range of the claws. The club is often fashioned on the spot.

ARMADILLOS

There are at least four species of armadillo in Paraguay ranging in size from about 4 kg to over 50 kg. When encountered aboveground foraging, armadillos are run down and their necks are broken by hand (*bio'o*). Frequently they manage to reach their burrows, and the pursuing hunter immediately thrusts in a foot in order to prevent the animal from escaping deeper or digging. A companion will unstring the hunter's bow and it is thrust into the hole to spear the prey (unstrung bows are almost straight). If the armadillo manages to escape deep into its burrow, or if a fresh burrow is discovered and determined to contain a sleeping animal (the smell and feel of the entrance are the major clues) it is dug out using the hands or an unstrung bow as a digging tool. Success rate with armadillos in their burrows is virtually 100%. If a burrow is discovered late in the day it is often plugged up with a log in order to be dug out the following day.

DEER (*MAZAMA AMERICANA*)

The brocket deer found in eastern Paraguay weighs about 30–35 kg. They are usually discovered sleeping during the day, and the single hunter who happens upon the animal will approach quietly to within 15 m and shoot an arrow at the heart. If the animal is shot well, the hunter will track it, especially noting blood loss. Sometimes others are called in order to track more rapidly. If blood loss is minimal after about 150 m of tracking, the chase is abandoned. Deer call imitations are also used in order to lure feeding deer within bow range.

TAPIR (*TAPIRUS TERRESTRIS*)

Tapirs are the largest game animals in South America, weighing up to 150 kg. The primary hunting technique for this prey is essentially identical to that used for deer. Hunters often imitate tapir whistles while walking, in hopes of receiving an answer. The second method of hunting tapir, which we have never witnessed but have heard retold in many narratives, is the pit trap. A large hole is dug (about 3 × 3 × 3 m) on a tapir trail and covered over with branches, leaves and dirt. When a tapir (or jaguar) falls in (*ity*), it is clubbed to death or shot with arrows.

COATI (*NASUA NASUA*)

The coati is a raccoonlike animal that is often found in groups and can weigh up to 7 kg. Coatis seem to be much more common in the Aché diet

than has been reported for many other South American groups. Although sometimes shot with arrows, they are most frequently killed by hand. Hunters are alert to signs of very recent coati foraging and will track down the animals if the signs appear less than an hour old. Once the animal, or more usually, animals, are found, the hunter stands at the base of the tree in which they take refuge and begins to repeat a low sound ("ooh, ooh") which seems to prevent the coatis from jumping immediately to the ground to escape. This effect is mysterious, but may be due to the similarity of the sound to the grunting of a jaguar (*Felis onca*). Meanwhile, the hunter calls for help and continues chanting at the base of the tree until a sufficient number of companions arrive. If there is much undergrowth around the tree it is quietly cleared out of the way so that the hunters are not impeded when they chase the animals. When all the undergrowth is cleared, and there are a sufficient number of hunters in position, one person will grab a nearby sapling and begin bending it back and forth and make a swishing noise with the mouth. This frightens the coatis sufficiently that they begin to leap from the tree (often from a height of 20–30 m or more) and as they hit the ground they are grabbed by the tail or hind limbs and slammed against the ground or a tree (*bwapi*). This can be quite dangerous, and bites to the arms are common. Although traditionally the Aché sometimes wrapped their forearms with a cord to protect themselves from bites, only once during the study period did we observe this technology used.

WHITE-LIPPED PECCARY (*TAYASSU PECARI*)

The white-lipped peccary would by all accounts seem to be the primary target prey of Aché hunting. As these peccaries live in large hordes, a well-executed hunt can bring several animals, each weighing in excess of 30 kg. Signs of white-lipped peccaries that are less than ½ day old are usually followed. Many hunters track the horde together. Due to their numbers and foraging behavior, these animals leave a trail that is hard to miss (for an Aché). Men will often trot for 2-hour stretches trying to catch up with the animals. Once they are within hearing distance of the feeding horde (which makes a great deal of noise) the lead hunters slow down and allow all others to catch up. Group hunting is most important, and an attempt by a single hunter to kill one of the animals is severely chastized regardless of success. If a lone hunter comes upon a horde of white-lipped peccaries, he is expected to run and find other hunters, if he is aware of their location, in order that a group effort may be made. When all hunters have surrounded the peccaries, they begin to close in and shoot. No signal is given, but all approach the prey at about the same time and the same speed. Once the hunters begin to shoot, the peccaries will either run to escape or to charge. The latter behavior is preferred by the hunter as it allows the hunter to jump into a nearby tree and continue shooting. It is also quite dangerous,

as peccaries can bite viciously. If the animals begin to stampede they are not pursued further because they can easily outdistance the hunters. The Aché seem to spend a good deal of their hunting time in what could be considered as pursuit of these animals (i.e., they are following fresh tracks). However, encounter with several other prey items seems just as likely even when peccary tracks are being followed. The pursuit of this animal can be time-shared with the search for others (see the section on Methods and Discussion).

COLLARED PECCARY (*TAYASSU TAJACU*)

Collared peccaries are frequently encountered in small groups, or individually. They can weigh up to about 25 kg. Unlike white-lipped peccaries, they have a permanent burrow in the ground or in a hollow tree, to which they run if disturbed. If the hunter can pursue them to this burrow, or find one that is occupied, a kill is ensured. Usually, the main entrance is blocked off and then small holes are cut into the burrow to locate the prey. We have witnessed the Aché spear the animal through one of these holes, or smoke it out and club it to death, or, ingeniously, introduce a looped bowstring into the hole and around the neck of the peccary to strangle it. Imitation calls occasionally are used to lure it. The size of these animals along with the high probability of a kill upon locating the burrow, seems to make them especially vulnerable to predation. Colonists using shotguns and dogs are extremely efficient at wiping out local populations in a very short time.

CAPUCHIN MONKEY (*CEBUS APELLA*)

Capuchin monkeys are extremely abundant in the forests of eastern Paraguay, and the largest adults weigh about 4.5 kg. They are killed almost every day of the year by Aché hunters. Capuchins can flee quite quickly through the trees, but hunters on the ground can always keep up with a single monkey. Pursuit lasts quite some time after the prey is located because capuchins are skilled at hiding in the branches of tall trees and hunters sometimes have to climb the tree to flush them. 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. Upon encountering monkeys, many hunters will be called in order to pursue more efficiently the troop without losing the majority of the members. If fewer than 10 hunters are present, some members of a monkey troop almost always escape. Hunters occasionally climb trees with bow and arrows in order to shoot monkeys in high branches. Imitation calls are often successful at both locating a troop, and

inducing it to come close. Monkeys kept as pets also elicit the calls of nearby troops.

HOWLER MONKEY (*ALOUATTA CARAJA*)

Large howler monkeys can weigh more than 10 kg. They live high in the treetops in single-family groups. Once their feces are discovered at the base of a tree (they are extremely odorous) or their calls are heard, they have a high probability of being killed. This is because they are very territorial, and if the hunter fails to kill them on one day, he can usually find the same family again nearby on a subsequent day. Frequently, the hunter must climb the tree in order to flush them originally, but aside from that they are hunted with the same methods as for capuchin monkeys.

OTHER MAMMALS

Other mammals are not major prey items but are all taken upon encounter. Small mammals are usually killed by hand and larger ones are shot with arrows.

SNAKES

There are many species of snakes in Paraguay, but most of those eaten weigh between 1 and 4 kg. Poisonous snakes are killed as a defensive response, but they are also eaten. When a snake is encountered, a long pole or unstrung bow is used to club it to death without getting too near. The heads of poisonous snakes are immediately cut off and buried.

CAIMAN

The Paraguayan caiman that we have seen are rarely larger than 1.5 m in length. Although the caiman is hunted with bow and arrow from the banks of lagoons, the Aché also hunt them by entering shallow lagoons and feeling along in the mud with their feet, hoping to locate the body of a sleeping reptile. Once the body is located, an arrow is used to spear the prey and bring it to the surface. Surprisingly, we have never heard of anyone being bitten.

BIRDS

Most birds are hunted with bow and arrow. If the bird is large, a pointed arrow will be used. Blunt bird-arrows are used for smaller birds. Hunters

will sometimes plan to return to a rotting carcass that has been found, in hopes of killing the vultures likely to be there. A variety of bird calls are used to locate or lure particular species. Sticks are sometimes thrown in boomerang style at small birds; however, most small birds are ignored by adult hunters.

Daily Hunting Routine

An Aché hunter's day begins with the first predawn light. Occasionally, calls from capuchin monkeys will be heard at this time and one or more men will quickly take up their weapons and start off in the direction of the prey. Other men in camp imitate the monkey calls, trying to keep the prey continually voicing its location. As the sun rises, men begin eating whatever meat is left over from the previous night and sometimes they spend a few minutes extracting palm fiber from nearby trees. More often, however, women do the palm extraction while men tell stories and jokes and begin to sharpen their arrows. Men spend between about 10 and 30 minutes restringing bows, sharpening arrows, readjusting the feathers on their arrows, and making other minor repairs. Any man who is in the process of manufacturing a new bow or new arrows will be continually working on that project throughout the morning.

There is always some discussion as to what direction the hunters should set off, and what will be the approximate camping destination for that day. Both men and women participate in this discussion, voicing their desires and the information that they may have concerning resource sightings that have been made in the recent past, or even sometimes in the distant past. At some point, a consensus is apparently reached although we have not been able to pinpoint the decision nor the most important factors in reaching it. Jokes and conversation continue for about 2 hours after sunrise and then suddenly, with little warning, the men take up their weapons and leave the camp, walking in single file. The lead man often breaks a trail, either with a machete or with his bow. Women back in camp begin packing up their things and follow behind in the men's trail. Aché camps move almost every day.

During the day, a small number of men will always continue in a specific direction with the women following behind them, or just out of sight, tracking them. The trailbreakers are frequently old men or older boys. The group of trailbreakers, women, and children travel in a reasonably straight line in single file. Changes in direction are minor and seem predictable to the Aché (but not to us). Feedback from the hunters concerning a successful kill usually turns the group in the direction of the kill site. The majority

of the adult hunters begin spreading out perpendicular to the direction of travel after about ½ hour, and continue spreading and coming back together throughout the day. Their direction of travel is determined by game encounters and animal tracks, and may double back considerably. The direction of the women's movement is kept in mind as a general reference for orientation of travel during search for game. The men seem to have a good idea of where the women are throughout the day, although we have not been able to determine how this is possible (it is probably due to years of experience with the overall foraging pattern) or how accurate their knowledge is at any point in time. Men search widely and probably cover an average of three times the distance covered by the women's group. Because the camps move about 5 km/day (measured with a pedometer), men are probably covering 15 km on an average hunting day. This, of course, varies considerably, and it should be kept in mind that the jungle is quite dense and thus the effort is considerably greater than would be the case in open country.

Adult hunters usually break up into smaller groups of two to four men and space themselves while searching. Although the men often space themselves so as to be out of sight, but within earshot, this is by no means always the case. Small groups of men frequently walk together in single file and men who spread out often totally lose auditory contact with each other. The importance of this spacing will be discussed further in another section.

Several game items are taken by single hunters upon encounter. The most important of these are deer, collared peccary, tapir, armadillos, birds, and other solitary animals. Social animals, as well as those for which cooperation can yield significantly higher results, are usually preyed upon by multiple hunters. When a single hunter encounters such prey he will yell or whistle to nearby hunters. They usually reply and he signals once again his exact location. All hunters within earshot respond by converging on the spot. The range of these signals depends greatly on the topography and precise location of the sender and the receiver. Based on walking times to received signals we estimate the range between 0.5 and 1.5 km. Single hunters who have wounded large solitary animals will sometimes call for help to track that animal.

The hunter's day, then, consists of spreading out to search for game, a common period of recounting the hunt after a successful pursuit (the length of which seems to correlate with the size of the kill), occasional short periods of gathering and eating vegetable foods, and a continuance of the search-pursuit cycle. We rarely recorded cases of men spending more than 3 hours without auditory or visual contact with other hunters.

Near the end of the day the hunters begin to find their way back to the women and children, or call the women to come to their location if a large animal has been killed. Men who become widely separated from the group

are called by group members as dusk approaches. Several times men were guided back to the camp in complete darkness by yells from camp members. Although we have not witnessed such a case, Aché narratives do mention that men occasionally wander too far and are forced to spend the night alone in the forest. This is especially arduous in the winter because men do not carry fire and have no method for producing it.

At the end of the day the meat is butchered by both males and females and is cooked at several fires. The hunter who kills an animal sometimes butchers it, but rarely cooks it. For many animals there are taboos against the hunter's consumption of his own kill and these taboos extend to his siblings and parents as well. These taboos were not broken in any case in which we monitored closely the precise consumption of a game item, although we do not have enough data to feel confident that they are never broken. The day's total take is widely shared among band members.

Data Collection

Hill has spent about 450 days living with the Aché, of which approximately 165 days were spent in the jungle hunting and gathering, and the remainder at a mission settlement. The longest period spent in the jungle before returning to the mission camp was 28 days. All qualitative data presented are extracted from interviews, taped narratives, or firsthand observation during hunting trips and periods of jungle residence. All data from informant accounts will be identified as such, and all other data presented come from direct observation.

Quantified data concerning subsistence were collected on 66 observation days between March and July of 1980 (see Table 5.3). Data were collected on seven separate trips out from a mission base camp, ranging in length from 4 to 15 days. On one trip (4 days) men used only shotguns, on one trip (12 days) some men used shotguns and some used bows, and on five trips (50 days) men used only bows, at our request. The study produced measurements on rate of hunting returns per hour and per day. Because six of the observation days were spent primarily walking on dirt roads rather than hunting in the jungle, they have been eliminated from the data set. Two half-days of hunting are eliminated from the daily returns data, but the hours spent actually foraging on those days are included in the calculations of hourly return rates. The remaining 58 days are the basis of all calculations of average hunting activities or returns per day. They can be divided into 53 days of active hunting, 1 day of fishing, and 4 days of heavy rain (see Table 5.3). Time and returns for fishing have been excluded from this analysis because they have been discussed previously (Hawkes *et al.* 1982).

Table 5.3*Days of Data Collection, 1980*

March	31 ^a						
April	1 ^a	2 ^a	3 ^{a,b}	4	5 ^a	6 ^a	
	7 ^a	8 ^a	9 ^a	10 ^a	11 ^a	12 ^a	13 ^a
	14 ^a	15 ^a	16 ^{a,b}	17	18	19	20
	21	22	23	24	25 ^a	26 ^a	27 ^{a,c}
	28 ^a	29 ^a	30 ^a				
May			1 ^{a,d}	2 ^a	3 ^{a,e}	4	
	5	6	7	8	9	10	11
	12	13	14	15 ^a	16 ^a	17 ^a	18 ^a
	19 ^a	20 ^{a,b,d}	21	22	23	24	25
	26	27	28	29	30 ^{a,b}	31 ^a	
June							1 ^{a,d}
	2 ^a	3 ^a	4 ^a	5 ^a	6 ^a	7 ^a	8 ^a
	9 ^a	10 ^a	11 ^a	12 ^a	13 ^{a,b}	14	15
	16	17	18	19	20	21 ^a	22 ^a
	23 ^a	24 ^a	25 ^{a,d}	26 ^a	27 ^a	28 ^a	29 ^{a,e}
	30						
July		1	2	3	4	5 ^a	6 ^a
	7 ^a	8 ^a	9 ^{a,d}	10 ^a	11 ^a	12 ^a	13 ^a
	14 ^a	15 ^{a,b}	16	17	18	19	20

^a = Days foraging in jungle for which quantitative data were collected.^b = Days excluded from data set.^c = Days spent fishing.^d = Days of heavy rain.^e = Incomplete foraging days.

We accompanied the Aché on most foraging expeditions between March and July of 1980. Hawkes stayed with the women and recorded all activities pertinent to time allocation and returns from women's subsistence efforts. In addition, she clocked all adult men arriving and departing from the women each day, and weighed all game killed during this period. This was possible because animals killed early in the day were brought to the women to carry and all game was brought back to the camp before consumption. Hill accompanied one or more hunters each day and recorded the time breakdown of the men's activities for that day at the end of the day. The name of the hunter who killed each game item was obtained by questioning the person who brought the item to the women or into camp (not necessarily the hunter himself), if not observed directly. The men who were monitored were not chosen randomly but were picked because of Hill's proximity to them at the time that the hunters began to split up. This tends to weight the sample in favor of those men who carried on the most amicable relations with Hill; however, nearly every adult hunter was monitored for part or all of one day using this procedure.

Time hunting is defined as the number of hours between taking up weapons and starting to walk in the morning, and the arrival of hunters at

the location that is to be the camping spot for that night. In all cases, this includes time spent eating gathered items along the way, time spent in pursuit of those items, time spent in the company of other hunters resting and talking (especially after a successful hunting episode), and time spent carrying the kill to the campsite. Estimates will be presented of time spent in these activities, considered as part of the gross hunting time, in order to allow comparison with other hunting studies that also include these activities. Periods of rest or eating with women and children present are subtracted from men's hunting time. These events were rare.

The optimality approach that we use in this analysis requires measurements of encounter rates, pursuit times, and processing times for all resources. In order to collect these data, Hill timed the pursuit of all game hunted by the men whom he accompanied. These measured pursuits for any given species were then used to calculate the expected pursuit time for each kilogram of that species killed, regardless of whether or not each kill event was actually observed. Pursuit time starts with the first behavioral indication that a specific prey target was being hunted. This was usually visual or auditory contact with the prey item followed by a rapid reaction on the part of the hunter. In some cases, pursuit time was defined by intensive tracking of a single prey item (or items) to the exclusion of total search alertness. This, however, is somewhat ambiguous. Pursuing a fresh track did not always exclude the simultaneous search for other items. These "warm pursuits" were sometimes temporarily halted in order to engage in the "hot pursuit" (i.e., with visual and auditory contact) of other prey items. Further problems with precise measurement of pursuit time were encountered due to the continual arrival of hunters at a prey site over a period of time when hunting cooperatively. For these cases the number of man hours of pursuit is an approximation rather than a precise measurement. It is unlikely, however, that the pursuit times given in this paper are more than 20% off the actual value if it were precisely measurable. Such a margin of error would not change any of the conclusions presented in this paper. A revision of the defining moment that pursuit begins might have strong consequences for the rank order of resources (see Table 5.7) but once again would not alter the conclusions presented.

Search time in this paper is considered to be the total of all time hunting, minus the total of all pursuit time necessary to kill the total game take. This means that all time spent during the day that is not recorded as pursuit time, is considered search time. Once again, there are some difficulties with this due to the activities that take place throughout the day that are not actually active search for prey items. Our search time estimates are therefore rough but, again, a 20% error would not change the conclusions presented in this chapter. Refinements in concepts and methods are necessary. We look for further improvement and hope to collect more accurate measurements of search and pursuit times for further analyses.

Processing time for resources in this paper is equivalent to butchering time. Observations were made on the required butchering time for each species, and these are extrapolated to give the total processing times for any resource item listed. All animals were weighed with hanging scales (10, 20, or 50 kg scales) and are presented as live weights. Several measurements have indicated that the Aché consume between 65 and 85% of the kill by weight, depending upon the particular species. Many internal organs are eaten, as well as blood, skin (with the hair that remains after singeing), brain, bone marrow, and, occasionally, intestinal contents. We use 65% of live weight as the edible portion in order to calculate caloric value; however, we consider this to be a minimum estimate. Many South American game animals are quite fat (e.g., peccaries, coatis, armadillos, tapirs, caviomorph rodents) and we estimate their caloric value at 3000 Cal/kg (as taken for medium-fat whole pork). In addition, we estimate deer at 1250 Cal/kg, monkeys at 2000 Cal/kg, birds at 1900 Cal/kg, reptiles at 1500 Cal/kg and fish at 1370 Cal/kg. These estimates are derived from USDA Agricultural Handbook No. 456, food composition table for use in Latin America, or Meehan (1977), and are extrapolated where no equivalent items are listed, taking into account primarily the proportion of fat for each animal. These estimates should be considered rough and subject to revision when more precise measurements are made.

As the flora and fauna of this area are poorly studied and described, we have provisionally identified animal species ourselves. This should be taken as tentative. A detailed study of the area by a qualified ecologist would be especially appropriate and welcome.

The study population from which data were recorded totalled 35 adult men, 6 old men (over 50 years), and 13 young men (between 10 and 17 years), although all hunters were not present at any one time. For most of the analyses presented, only adult men are considered because the time spent and the hunting returns for the other two age groups were quite erratic and were not accurately recorded. One old man and one young man are included with the adult hunters, as their time allocation and returns were comparable to the adult group.

Time Allocation for Subsistence

Hunting is the major activity of adult men in Aché society. During foraging trips, all adult men hunted or fished every day except the 4 days of heavy rain.⁵ Young men (under 17) and old men (over 50) hunt somewhat less frequently, although we do not have precise data on these groups. Activities directly related to subsistence (i.e., food procurement and pro-

Table 5.4*Time Allocation for Adult Hunters^a*

Activity	Man-hours	Percentage
Outside normal foraging hours ^b		
Gathering	56.4	30.0
Butchering ^c	<u>131.9</u>	<u>70.0</u>
	188.3 ^d	100.0
Normal foraging hours		
Gathering vegetable	21.4	0.5
Extracting honey	37.8	0.9
Fishing	85.0	2.1
Active pursuit of game	1005.1	25.2
Search	<u>2839.3</u>	<u>71.2</u>
	3988.6 ^e	99.9
Total subsistence work	4176.9 hr/604 man-days ^f	

^aIncludes all whole foraging days.^bRefers to activities that take place in the morning before hunters take up their weapons, or in the evening, after returning to camp.^cSome of this work may have been done by males in the older or younger age groups, or women.^dEquals 5% of total subsistence work.^eEquals 95% of total subsistence work.^fApproximately equal to 6.9 hr/man-day.

cessing) were recorded for all men, and the time breakdown in man hours is shown in Table 5.4. It can be seen that 95% of an adult hunter's subsistence effort is hunting, and over 70% of this time is spent searching for game. Spot checks on the time recorded as search time allow us to estimate that about 10% of this time is spent resting, talking or eating, and about 5% of the time is spent transporting the kill to the camping spot (although some search does continue during transport). It is notable that the time spent gathering by men was less than 2% of their total work time, and most of this occurred on rainy days or outside normal hunting hours. During the study period there were approximately 11 hours of daylight each day. An average of almost 7 hours daily (including rainy days in the average) were devoted to the procurement and processing of food by adult men. The remaining 4 hours of daylight were spent in manufacturing and maintaining weapons, playing with children, joking, eating, and various other activities.

Around these averages there is marked variation in the length of the hunting day, from a maximum of 10 hours average among hunters on a specific day, to a minimum of less than 2 hours (excluding days of no hunting). Daily return rates vary from a maximum of 14.3 kg/hunter to a minimum of 0.0 kg/hunter. Figure 5.2a shows the correlation between total hours hunted on a given day and the total weight of game for that day. Grouping the data emphasizes this relationship. On the 22 hunting days

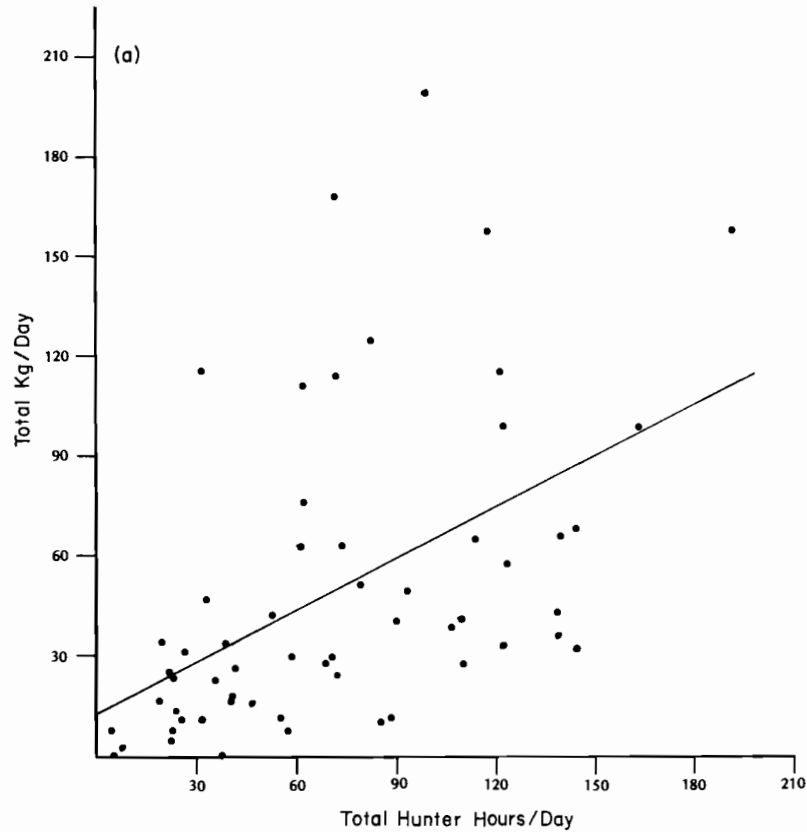


Figure 5.2 Hunting returns per time spent foraging. (a) Total number of hours hunted by men in the foraging band, and total kg of game killed on that day. Each point represents one day ($r = 0.50$, $p > .01$). (b) Average returns/hunter, and the average number of hours hunted/hunter on the day following those returns. Each point represents one day. There is no correlation ($r = -0.04$). (c) Relationship of average hunting return rate (kg/hr) during sample period to average number of hours hunted per day, for individual hunters. Each point represents one hunter. Sample includes all men for whom seven or more days of bow hunting returns were recorded. The correlation is significant ($r = .64$, $p > .01$).

on which the hunters brought more than 2 kg of meat per consumer, the average number of hours hunted was 7.3 hours per hunter-day. On 31 days on which they brought back less than 2 kg per consumer, the average was 6.0 hours per hunter-day. Hunting success does correlate with the number of hours hunted for a group of men over a period of 53 days. In other words, if the group desires more meat, one strategy that will be successful is simply to hunt more hours per day. In this sense, hunting as an occupation is not a gamble, and average daily rewards are a function of labor input.

Table 5.5 shows the relationship between hours hunted and days of high

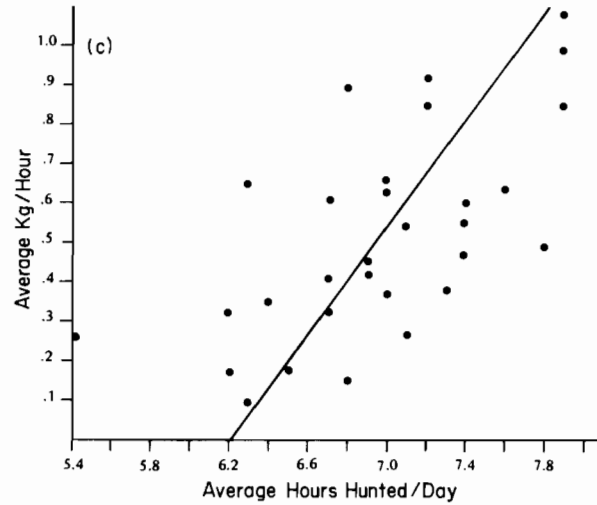
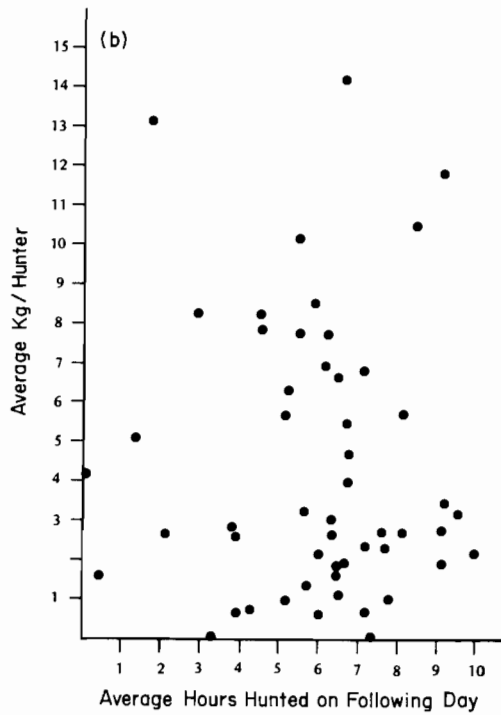


Table 5.5

Hunting Returns and Time Spent Foraging

	More	Same	Fewer	Significance (χ^2)
Individuals^a				
Day-of-return rate > 1.5 kg/hr	25	00	16	not significant
Day after total returns > 9 kg/day	13	01	26	$p < .05$
Groups^b				
Day-of-return rate > 1 kg/man hour	05	—	08	not significant
Day after total return > 2.5 kg/consumer	04	—	12	$p < .05$

^aEach individual was scored daily as to whether he hunted more, the same, or fewer hours than his own average throughout the study period. Numbers are in man-days (604 man-days sampled).

^bEach group was scored as to whether it hunted more or less than the group average over the study period (6.9 hr/man-day). Numbers are in group days (53 group days sampled).

return rates, and the hours spent hunting on the day *following* high total meat returns for both individuals and groups. The data show a tendency for individuals to hunt more hours than average on days that they get a high hourly return rate (kg/hr); however, this is not significant. Groups do not hunt more or fewer than normal hours per man per day on the days when the return rate is high. On the other hand, total meat returns for individuals or groups on any single day *do* influence the number of hours hunted by those individuals or groups on the *following* day. Both individuals and groups hunt fewer man-hours per day on the day following high returns ($p < .05$ for both). However, as Figure 5.2b shows, there is no linear correlation between the average returns/hunter on a given day and the average number of hours hunted on the following day.

Despite the lack of *linear* correlation between the same variables, the significant X^2 correlation for the grouped data results because long average hunting days rarely follow high returns, whereas short average hunting days are not related to the preceding day's success rate. In other words, hunters as a group are unlikely to spend long hunting days subsequent to an unusually successful day (the relatively empty upper right quadrant in Figure 5.2b), but they are as likely to quit early on a day following poor hunting as on a day following high returns.

Adult men spend an average of 6.9 hours/day foraging on days of good weather. The averages for individual men ranged from 5.4 to 7.9 hours per day for the subset of 30 adult men that we observed for 7 or more complete foraging days. Figure 5.2c shows the relationship between individual hunting returns in kg/hour over the study period, and the average number of hours hunted per day for those individuals. There is a significant correlation ($r = 0.64$) between a man's average return rate, and his average number of hours hunting per day. (Hames [1979:241ff.] demonstrates that this correlation is not found for Yānomamö or Ye'kwana hunters.) It is important to note that this is a correlation between return *rate* and time hunted, and thus the two are not interdependent (as would be the case if overall returns were used instead of rate). Multiplying the hourly return rate by the average number of hours hunted gives an even greater discrepancy between the average daily returns for the best and worst hunters.

One final point concerning time allocation is the consistency that hunters display throughout the sample period in the average number of hours that they hunt daily. This study samples a period of about 100 days from the end of the warm season to the middle of the coldest part of the year. Dividing the sample period into thirds allows us to determine if there are trends to hunt more or fewer hours as days become somewhat shorter and significantly colder (morning temperatures dropped from about 24 to 2°C from March to July). The average number of hours hunted per man-day was 7.1 during the final third of the study period, and 6.7 during the first third. The difference is not significant.

Hunting Returns and Comparison of Technologies

About one-eighth of the men in the study population have acquired a shotgun, by trading with local colonists or mission personnel. Although most of the guns are quite old, they are cleaned and oiled daily while hunting and are maintained in good condition. Most gun owners possess fewer than five brass cartridges which are reloaded in the morning or evening with black powder, newspaper wadding, 00 (double-ought)-sized lead fishing weights, and are sealed with beeswax. Occasionally, the lead weights are melted down in a can and poured into a hole made in the ground with the finger in order to produce a slug which is then carved or pounded to the correct gauge (12, 16, or 20). Slugs are used for tapir and jaguar, while all other game are killed with the large shot.

The techniques employed are similar to those described by Hames (1979) for the Ye'kwana, except that only very large shot is used; thus, the scatter pattern is not as wide and small arboreal animals are difficult to hit. Hunters refrained from using shotguns, at our request, for the final 50 foraging days, and thus we were able to make a comparison between bow and shotgun hunting.

It is our impression that Aché hunters are not more accurate with a shotgun than they are with a bow, nor do they seem to use it to increase shooting range. However, the effective knockdown and kill rate at any distance is much higher than with a bow. In addition, the hunter does not need to position himself as carefully because leaves and branches do not deflect buckshot to the same extent as they do an arrow. Nevertheless, most game taken with shotgun is approached to within 15 m or less before firing. The Aché rarely use shotguns to kill monkeys or birds. This will be discussed in the following section.

The key to bow-hunting success is persistence rather than high accuracy. Bow hunters pursuing arboreal game will shoot again and again until the game is mortally wounded. Men sometimes organize target shoots and take turns shooting and laughing. In two target shoots organized by the Aché during our study period, 60 arrows out of 288 shot (21%) stuck in a target 15 cm in diameter placed 25 m away at an angle 45° from horizontal. It was our impression that the men were shooting rather poorly compared to other target shoots we have witnessed, and the hunters definitely shoot more accurately as the angle to the target approaches 90°.⁶ Arboreal game is usually shot at an angle of between 75 and 85° in order that the calculation of the trajectory arc not be too difficult. Aché bow hunters rarely shoot horizontally more than 15m.

The results from the 66 days of observations on hunting returns for 37 adult hunters, compiling a total of 3984.6 hours of hunting, show that

2622.3 kg of game (live weight) were killed, or 0.66 kg/hour. The effects of technology can be shown clearly by comparing the returns for bow hunting to those for shotgun hunting. Shotgun hunters killed 744.1 kg of game in 464.1 hours, for an average return of 1.60 kg/hour. The same men bow hunting in the same areas killed 1878.2 kg of game in 3520.5 hours, for an average return of only 0.53 kg/hour. Hames (1979) has also demonstrated that shotguns are more effective for Yānomamō and Ye'kwana hunters.

Table 5.6 demonstrates the difference in the composition of animal species taken by hunters using either shotgun or bow. Most notable is the fact that large game makes up about 87% of the take with shotgun and only 24% of the take with a bow. Examining the returns for each species in kg/hour of hunting, we see that the returns for the two peccary species and for deer are 5–30-fold higher with shotgun than with bow. For smaller game, there is no increase in the return rate with shotguns, and in fact there is a significant decrease in the kilograms taken/hunting hour for both monkey and paca. These results will be examined in more detail in the next section.

Table 5.6

Game Species Killed by Bow and Shotgun Hunters

Game species	kg	kg killed/ man-hour hunting	% of total	
Shotgun hunting (464.1 man-hours)				
Collared peccary	163.8	0.35	22.0	} 86.8
White-lipped peccary	212.1	0.45	28.5	
Deer	270.0	0.58	36.3	
Paca	12.4	0.03	1.7	} 13.1
Coati	36.8	0.08	4.9	
Armadillo	31.5	0.07	4.2	
Monkey (capuchin) ^a	7.8	0.02	1.0	
Birds	6.2	0.01	0.8	
Snakes	3.5	0.01	0.5	
Total	744.1	1.60	100.0	
Bow hunting (3520.5 man-hours) ^b				
Collared peccary	77.0	0.02	4.1	} 24.3
White-lipped peccary	307.1	0.09	16.4	
Deer	71.5	0.02	3.8	
Paca	315.5	0.09	16.8	} 75.8
Coati	242.2	0.07	12.9	
Armadillo	348.3	0.10	18.5	
Monkey (capuchin)	484.2	0.14	25.8	
Birds	18.4	0.01	1.0	
Snakes	4.8	0.00	0.3	
Miscellaneous	9.2	0.00	0.5	
Total	1878.2	54.00	100.0	

^aIn these cases shotgun hunters called for a bow and took the game with an arrow.

^bThe following items were also captured live: 14 monkeys, 3 coatis, 1 deer, 1 tamandua, and 1 collared peccary.

A second and extremely interesting comparison of technology can be made by considering the take in kg/hour for bow hunters using only their hands. Since all armadillos and pacas were taken by hand, and almost all the coatis and miscellaneous small animals, we can calculate that Aché foragers are able to kill a minimum of 0.27 kg of game/hour hunting using only their hands! This represents over 50% of the total game taken by bow hunters. It is likely that they could raise the return rate even higher if bows were not available and if all foraging time were devoted only to those animals which can be taken by hand or with a club. It is also noteworthy that all fishing done by the Aché during this period used only the hands and the take was greater than 10% (by weight) of the total game take listed above for nonfish items. These results should be of some interest in the calculation of possible hunting efficiencies of early hominids and other prebow hunters.

Several authors (e.g., Hames 1980; Vickers 1980) have recently demonstrated quantitatively that hunting returns diminish as a function of the time that an area has been hunted frequently. Mission Verbo Divino, Chupa Pou, where the Aché are now settled, was established in August 1978 and has over 150 Aché residents. In order to test for diminishing hunting returns as a function of hunting pressure, we calculated the average return rate per hour on the first day of each foraging trip and compared it to the average return rate for all days. The first day usually represents a distance of not greater than 8 km from the mission. The average returns for first days of each trip, including all shotgun and bow hunting, was only 0.28 kg/hour ($N = 686.9$ man-hours). This is less than half the average returns for all days combined for all hunters, and demonstrates that a population this size can have considerable impact on the nearby game populations in less than 2 years.

The Optimal Diet Model and Hunting Strategy

As we have noted in the previous section, the composition of game species taken by bow or shotgun hunters differs dramatically. Not surprisingly, large game is killed more effectively with a shotgun. The rate of returns from coatis and armadillos, which are found throughout the primary forest and are usually killed by hand, is approximately the same for bow or shotgun hunters. Pacas are found in much greater concentrations near riverbanks in seasonal floodland forest. Because all three of the large game animals taken occur mainly in the primary forest, and because shotgun hunters do quite well hunting large game, it is not surprising that pacas are

somewhat underrepresented in the game taken by shotgun hunters. Shotgun hunters spend larger portions of time in the primary forest and thus do not encounter pacas as frequently as do bow hunters. Monkeys, however, do inhabit the primary forest and are quite frequently encountered there. Nevertheless, Aché men killed only three monkeys while shotgun hunting, whereas 218 monkeys were killed by bow hunters. Our hypothesis is that the returns from shotgun hunting are just enough higher than bow hunting that they eliminate monkeys from the optimal diet of shotgun hunters, even though all other game items are still in the optimal diet.

We have previously used optimal foraging models to account for the overall mix of resources exploited by an entire Aché foraging band (Hawkes *et al.* 1982). The underlying assumption of this theory is a simple one: people will continue to use or adopt foods and techniques which increase the ratio of returns to cost (measured conventionally as calories per unit time) and they will stop using or fail to copy the use of foods and techniques which decrease their ratio of returns to cost. Although seemingly simple and logical, some nonintuitive propositions flow from models built on this assumption.

The optimal diet model (Charnov 1976; Charnov and Orians 1973; Emlen 1966; MacArthur 1972; MacArthur and Pianka 1966; Pulliam 1974; Pyke *et al.* 1978; Schoener 1971) can be used to predict whether or not a given resource will be taken by foragers upon encounter with that resource. Food items are ranked according to the ratio of returns they provide (Cal) to the cost of acquiring and processing the resources (handling time) once they have been encountered. This model shows that returns will be maximized if foragers take only those resources for which this ratio is equal to or higher than the average returns they get from foraging in general, *including search time*. They should ignore all potential resources for which this ratio is lower than their average returns will be if they keep searching for some other resource. Thus, according to this model, whether or not a potential resource is in the optimal diet *does not depend upon its encounter rate*.⁷

The resource rankings of this model say nothing about the quantitative importance of a resource to optimal foragers. High-ranked items may be so rarely encountered that they contribute only a very small proportion of the diet. Low-ranked items, which are nevertheless in the optimal set, may be encountered with sufficient frequency to contribute the bulk. The ranking shows instead which resources are likely to enter or leave the diet, and in what order. This knowledge, combined with density estimates (encounter rate) for resources at any given time, can be used to predict the actual diet. If the encounter rate with high-ranked resources fluctuates widely, the optimal diet will also fluctuate widely and only the very highest ranked resources will never be excluded.

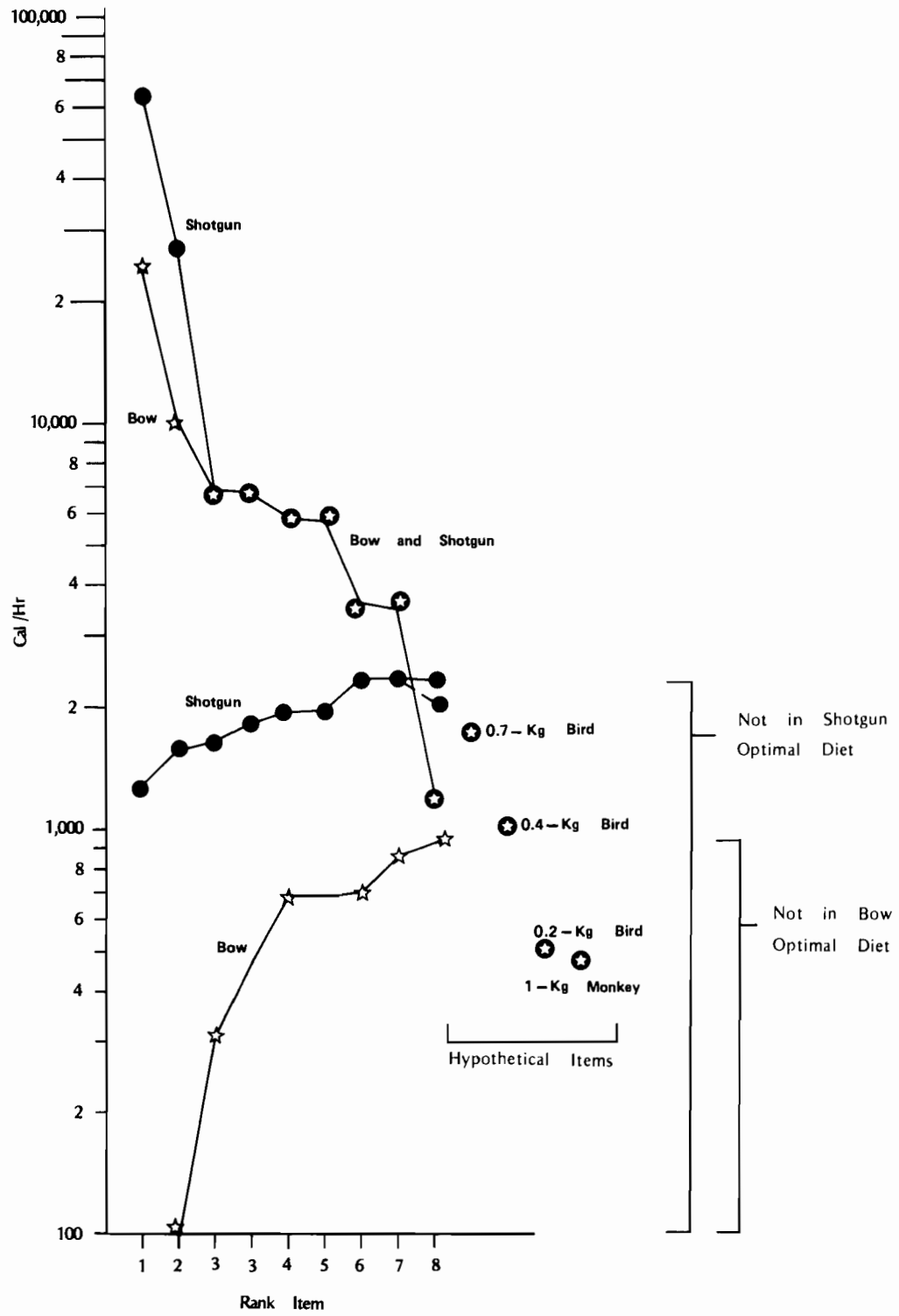
Table 5.7 shows the caloric returns to handling time for all the game hunted, and thus gives the rank of each item according to returns upon

Table 5.7

Caloric Returns to Handling Time for All Game Hunted

Item	(total kg taken)		(number of measured pursuits)	(X hr pursuit/kg)		(X hr butchering/kg)	(Cal/kg live weight [assume 65% edible])	[X Cal/hr upon encounter]		(rank of item)	(Cal/hr if item is taken upon encounter)	
	Shotgun	Bow		Shotgun	Bow			Shotgun	Bow		Shotgun	Bow
Collared peccary	163.8	77.0	est.	0.01	0.06	0.02	1950	65000	24375	1	1	1290
Deer	270.0	71.5	est.	0.01	0.06	0.02	819	27300	10237	2	2	1580
Paca	12.4	315.5	33		0.24	0.04	1950	6964	6964	3	3	1648
Coati	36.8	242.2	20		0.22	0.06	1950	6964	6964	3	3	1803
Armadillo	31.5	348.3	20		0.27	0.06	1950	5909	5909	4	4	1949
Snake	3.5	4.8	03		0.01	0.16	1000	5882	5882	5	5	1956
Birds (X = 1.4 kg)	6.2	18.4	est.		0.10	0.25	1240	3542	3542	7	6	2373
White-lipped peccary	212.1	307.1	8 ^a	13 ^a	0.51	0.02	1950	3679	3421	6	7	2372
Capuchin monkey	7.8	484.2	37		0.97	0.10	1300	1215	1215	8	8	2362

^aSome estimates.



encounter. Handling time for a specific item is the sum of the pursuit time for that item upon encounter (including unsuccessful pursuits) and the necessary processing time before consumption of the item. It also shows the number of Calories per hour that a hunter can expect to get foraging by adding each ranked resource to the set of items that he will take upon encounter, starting from the highest ranked item. Shotgun hunters spent 464.1 hours hunting and 26.3 hours butchering their take, for an average foraging return of 2362 Calories/hunter hour. Bow hunters spent 3520.5 hours hunting and 111.1 hours butchering their take, for an average foraging return of 910 Calories/hunter hour (note that both of these return rates include all search time).

Figure 5.3 shows the ratio of Calories returned to handling time for each of the game items ordered by rank (the circular points and stars descending from left to right) and the average returns for hunting that will result from the addition of each animal to those that will be taken upon encounter (circular points ascending from left to right). The latter numbers are derived as follows: Search time for the entire set is calculated by subtracting the pursuit time of all items from the total number of hours hunted. If hunters took only the number 1-ranked item, their returns would be the total Calories of the number 1 item taken per total search time, plus the total pursuit time for the number 1 item, plus the total processing time for the number 1 item. In order to calculate the returns provided by adding in subsequently lower ranked items, one need simply add in their caloric contribution to the numerator and their pursuit and processing times to the denominator. The optimal diet model predicts that all items which increase the overall rate of returns for foraging should be taken upon encounter, whereas any item which upon addition to the diet decreases the overall rate of returns for foraging will not be taken.

The difference in returns for shotgun and bow hunting, and the effect upon foraging returns of taking capuchin monkeys with either weapon, strongly supports our hypothesis. Monkeys should not be taken by shot-

Figure 5.3 Rank of prey items according to returns upon encounter (total Cal/total handling time) shown descending left to right, and hourly returns from hunting, as each ranked item is added to the diet shown ascending left to right. The optimal diet model predicts that ranked items should not be included in the diet when returns upon encounter with an item fall below the overall average foraging returns excluding it (the point at which the line descending from the left crosses the line ascending from the left). Thus, rank item 8 (monkey) should be ignored by shotgun hunters, but included in the diet of bow hunters. The dotted line shows the expected decrease in overall foraging returns from shotgun hunting if monkeys were taken at the same rate (kg/hr hunting) as they were taken by bow hunters. Additional items show the expected returns from birds of 0.7 kg (kuachi), 0.4 kg (uru), and 0.2 kg (> 50 species), as well as returns from small capuchin monkeys (1 kg). The first two birds were taken by bow but not shotgun hunters. The small birds were ignored by all hunters. Small monkeys are discussed in text.

gun hunters because adding them to the list of items taken upon encounter would decrease rather than increase the returns for a shotgun hunter. Conversely, bow hunters will increase their foraging returns by taking monkeys, even though they are the lowest ranked game item.

Although the optimal diet approach may explain why shotgun hunters spent only 1.6% of their foraging time pursuing monkeys, whereas bow hunters spent 13.3% of their foraging time pursuing monkeys, the size distribution of the monkeys taken presents an interesting complication. Monkeys are one of the few game items for which hunters can get a reasonably good estimate of size before deciding whether or not to pursue. Assuming that pursuit time is the same for any monkey regardless of size, and using the measured butchering time, it can be calculated that any monkey under 1.8 kg will decrease the average foraging returns for bow hunting and thus should be ignored.⁸ The hunter may have some difficulty estimating the precise size of a potential prey high in a tree, but prey of one-half this size should be easily recognizable as too small. Nevertheless, 10 monkeys of less than 1 kg each were taken by bow hunters (5.3% of all monkeys). These items are clearly not in the optimal diet (see Figure 5.3). Possibly smaller monkeys require less pursuit time; however, this cannot be determined from our data and will have to be investigated further.

The cutoff point for the size of birds that should be hunted can be determined from these data as well. Because the pursuit and processing time is nearly equivalent for all birds of 1.5 kg or less, and the returns for birds averaging 1.4 kg is 3542 Cal/hr upon encounter (see Table 5.7), one can calculate that shotgun hunters should not take birds smaller than 0.9 kg if they take only the items predicted from the optimal diet model. The smallest bird taken by shotgun hunters weighed 1.4 kg. Bow hunters, on the other hand, can take birds as small as 0.4 kg before decreasing their foraging returns (see Figure 5.3). The smallest bird taken by bow hunters weighed exactly 0.4 kg.⁹ Many species of birds smaller than 0.4 kg were present in this area, but were not pursued by bow hunters.

It is well known that coatis can and do bite, and the use of hands rather than bow and arrow to kill them seems to be a peculiar and dangerous method of hunting. Some strong motivation must be behind this strategy, or the wise hunter would quickly abandon it. Shooting coatis with arrows rather than catching them by hand would be similar to shooting capuchin monkeys (they both are found in troops high in the treetops and try to stay hidden there). Using the figures in Table 5.7 and assuming the pursuit time per item to be the same as for capuchin monkeys, we calculate that hunting coatis with arrows would give only 2600 Cal/hr upon encounter whereas hunting them by hand gives 6964 Cal/hr upon encounter. This is because the method of hand hunting forces the animals to jump quickly to the ground rather than moving through the tree tops.

Variance in Hunting Returns between Individuals and Age Groups

Figure 5.4 demonstrates the difference in average hunting returns for individual men throughout the study period. There is approximately a 10-fold difference in kg meat/hour returns between the bow hunter with highest returns and the bow hunter with the lowest return ratio. This difference along with the trend for hunters with higher returns to hunt more hours per day (see Figure 5.2) produces a daily difference of 14-fold in the kilograms of meat brought back by the most successful and least successful bow hunter during this period. The variance between individual shotgun hunters appears lower but is based on very limited data.

Table 5.8 shows the average daily kill of all adult men who were sampled for 7 or more days (kilograms calculated by multiplying the horizontal by the vertical axis for all points in Figure 5.2b). Although the return ratio for the hunter with the highest return rate is 14-fold higher than for the hunter with the lowest return rate, the overall spread for the group is somewhat less than we had expected. Indeed, it would appear that the hunter with the lowest returns is unrepresentative of the lower return hunters as a subset because his daily returns were less than half those of the hunter with the next lowest returns. During this study period, we calculate that 32% of the men brought back 50% of the game or, alternatively, 57% of the hunters brought back 80% of the game.

Figure 5.5 shows the spread for individual hunters in the percentage of days that each got 0-kg meat returns for an entire foraging day. There is

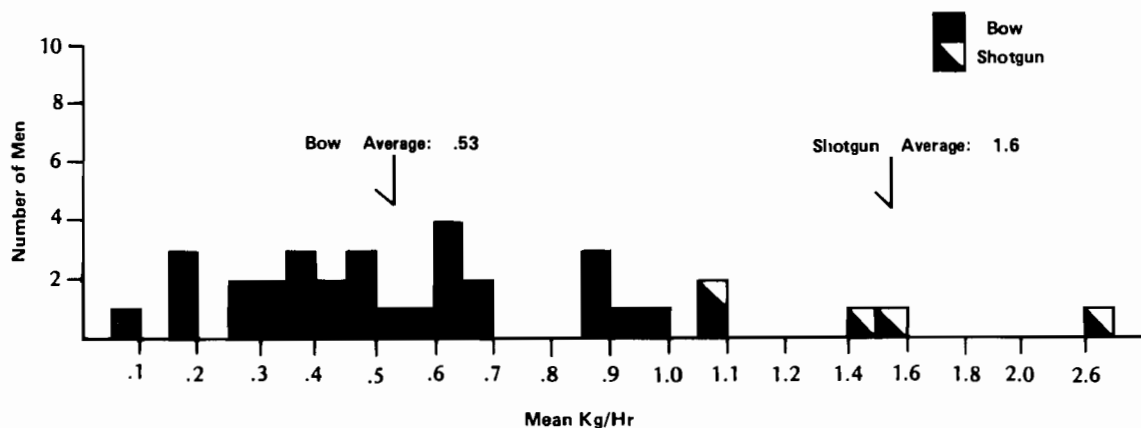


Figure 5.4 Mean hourly return rate (kg/hr) for all adult hunters whose returns were measured for 7 or more days.

Table 5.8
Average Yield for Individual Hunters

Hunters (ranked from lowest to highest)	Average yield (kg/day)
1	0.6
2	1.3
3	1.3
4	1.4
5	1.4
6	2.1
7	2.2
8	2.2
9	2.2
10	2.5
11	2.7
12	2.8
13	3.5
14	3.7
15	3.7
16	3.9
17	4.0
18	4.0
19	4.1
20	4.1
21	4.5
22	4.5
23	4.9
24	5.8
25	6.0
26	6.6
27	7.4
28	8.5

^aCalculated by multiplying horizontal × vertical axis for each point on Figure 5.2b.

approximately a sixfold difference between the hunter with the lowest percentage of 0-kg return days and the hunter with the highest percentage of 0-kg return days. Thus, there is a greater difference in the quantity of game killed per day by individual hunters, than in the probability of getting some game item on any single day. In other words, the discrepancy between the number of days that each hunter is a contributor to the camp’s meat supply is not as great as the discrepancy in the quantitative amounts of meat contributed by each hunter.

Overall returns are a function of both consistency and larger game kills, thus neither can be independently tested for significant correlation. Percentage of days with no kill is, however, not necessarily related to the number of larger animals killed, and thus we can ask whether the same

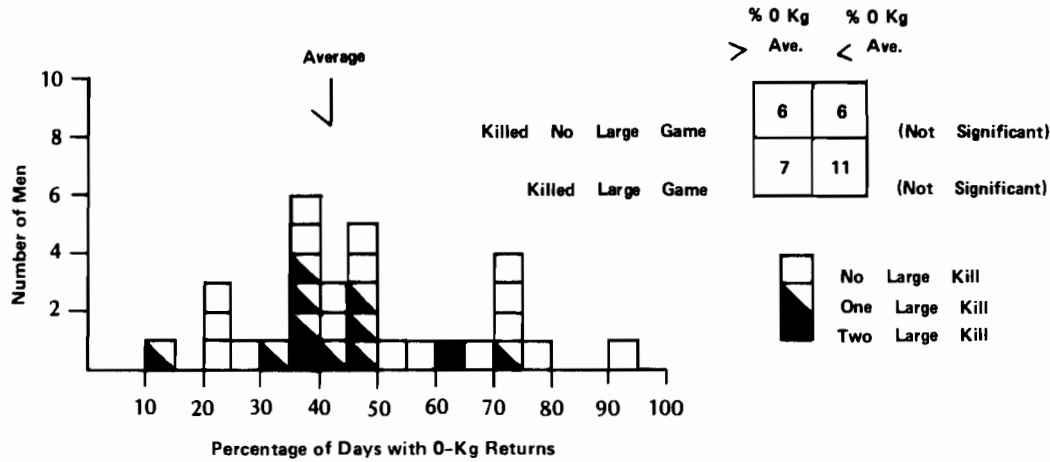


Figure 5.5 Daily consistency of kills (percentage of days with zero kg returns) plotted for each individual hunter versus successful kill of large animals. There is no significant correlation between the two.

subset of men have many large kills and a low probability of 0-kg returns per day (two independent measures of hunting skill). The subset of men who killed large game (≥ 20 kg) during this period is indicated in Figure 5.5. Killing a large game item does not correlate significantly with a low probability of getting 0-kg returns on any foraging day. We interpret this to mean that there are two subsets of men who could be called the best hunters by the criteria of either consistency (low percentage of days with 0-kg returns), or of number of large game items killed. Either of these two strategies will produce high overall hunting returns.

Although there is no significant correlation between estimated age and hunting returns for the set of men that we call "adult hunters," there are some striking differences between these hunters and the other two age groups of hunters. Six old men (over 55 years) and 13 young men (between 10 and 17) accompanied us on some of the hunting trips. One young man who hunted every day and did well (0.35kg/hour) and one old man who also hunted every day with results comparable to adult hunters (0.63 kg/hour) have been included in the adult hunter data set. The remainder of these two age groups hunted much less frequently and less successfully. Although our data concerning time expenditures for these groups are only approximate, we do have exact measures of their kills. The five old men who have not been included in the data presented thus far spent 41 total man-days on foraging trips and contributed 10.4 kg meat in total. We estimate that they spent an average of about 4 hours per day hunting, for a return rate of about 0.06 kg/hour. Their contribution per man-day is therefore only about 7% of the average adult hunter. The 12 young men who

have been excluded from the data presented thus far spent a total of 102 man-days on foraging trips and contributed 45.9 kg meat in total. We estimate that they also spent an average of about 4 hours per day hunting, for an average hourly return rate of 0.11 kg/hour. Their contribution per man-day is about 12% of that of the average adult hunter. Both of these age groups spent considerable portions of their time gathering vegetable items, trailbreaking, and butchering the game killed each day.

Band Size and Hunting Returns

The efficiency of subsistence strategies has long been considered to be a function of, and thus a limiting factor in, the size of hunter-gatherer bands (e.g., Lee and DeVore 1968; Steward 1938). Figure 5.6 demonstrates the effect of band size on two parameters of hunting returns, the returns per man-hour, and the percentage of the men who get 0-kg returns on any single day. The number of points is not sufficient to allow us to construct a

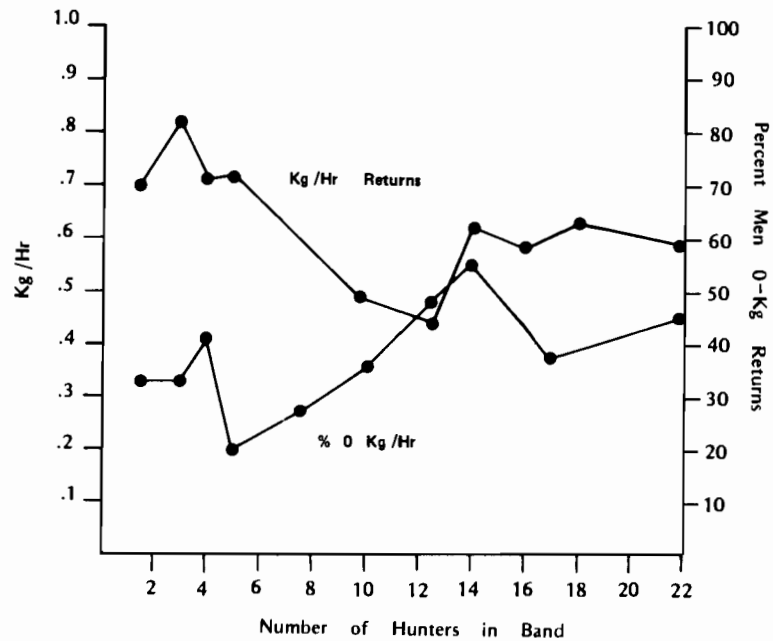


Figure 5.6 Bow hunting returns as a function of foraging band size. Mean return rate (kg/man-hour) and percentage of hunters getting 0-kg returns on any single foraging day, are plotted against the number of adult hunters in the foraging band.

curve in which we are totally confident; however, two trends are apparent. First, the returns per man-hour are higher in very small bands, and the percentage of men who make no kill on any single day is lower. Second, it appears that the drop in the return ratio, and the increase in the percentage of men who get 0-kg returns, levels off as the band size becomes larger. We tentatively conclude that bands of between three and five men get higher hunting returns per man-hour than larger groups, but it is not clear from our data why very large hunting bands are not as common as medium-sized bands. Figure 5.7 shows the actual frequency of different sizes of hunting bands we observed during the study period. It also shows the frequency of randomly selected band sizes before contact, elicited from informants by using what we consider to be an event independent of band size (e.g., "the day your father was bitten by a snake") as a reference point for naming all members in a foraging band on a specific day. The data show that bands rarely get larger than 25 men (80–100 persons), although,

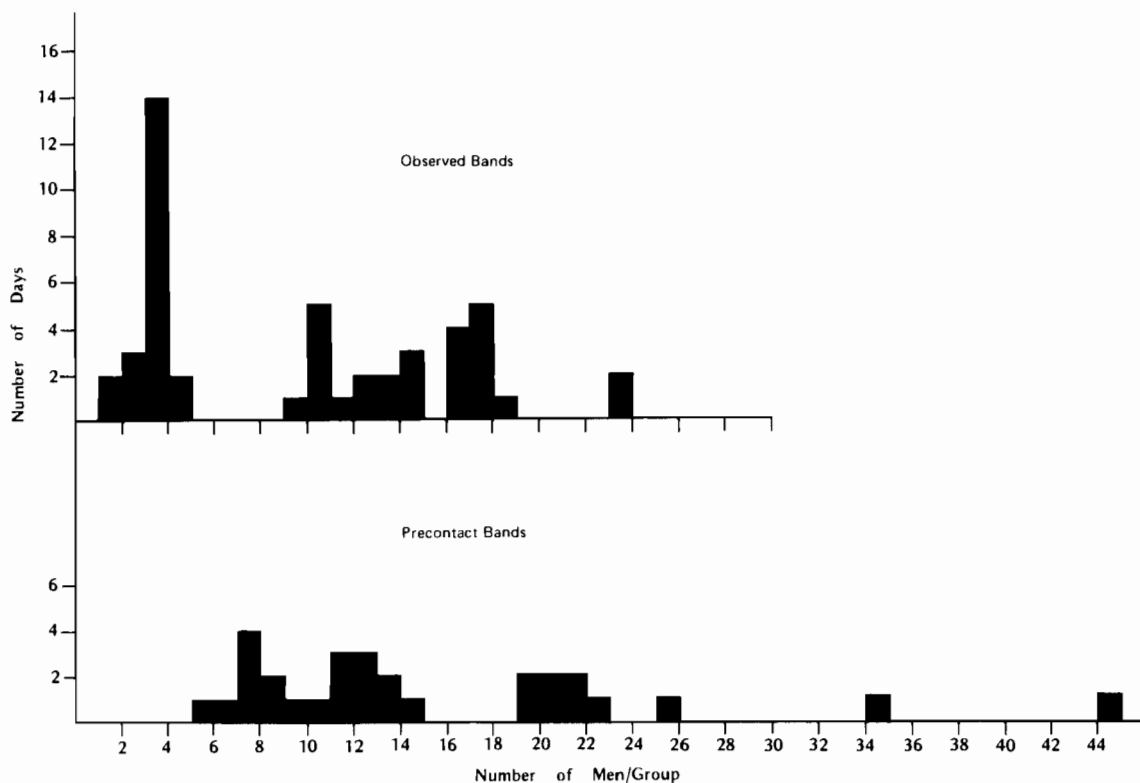


Figure 5.7 Frequency of various-sized foraging bands as measured during the study period for bow hunting trips, and as recalled by informants. Events that we judged to be independent of band size were used to elicit informant recall of band size on a particular day prior to contact.

as we mentioned, it does not appear that decrease in hunting returns can explain this phenomenon.

In order to explore this further, we can calculate the possible effect of having 40 men in the hunting band (120–160 persons). We assume that the major decrease in hunting returns for larger groups will be due to the crowding effect, or an overlap in the area searched. Forty hunters starting off from camp in the morning would take just 15 minutes to be spaced 50 m apart (they walk about 4 km/hour in the jungle), and only 30 minutes to have 100 m of spacing between each of them. The same of course would be true at the end of the day, as they were all coming together to the camping spot. This means that about 7% of the average hunting day the hunters would be less than 50 m apart, and about 14% of the day they would be less

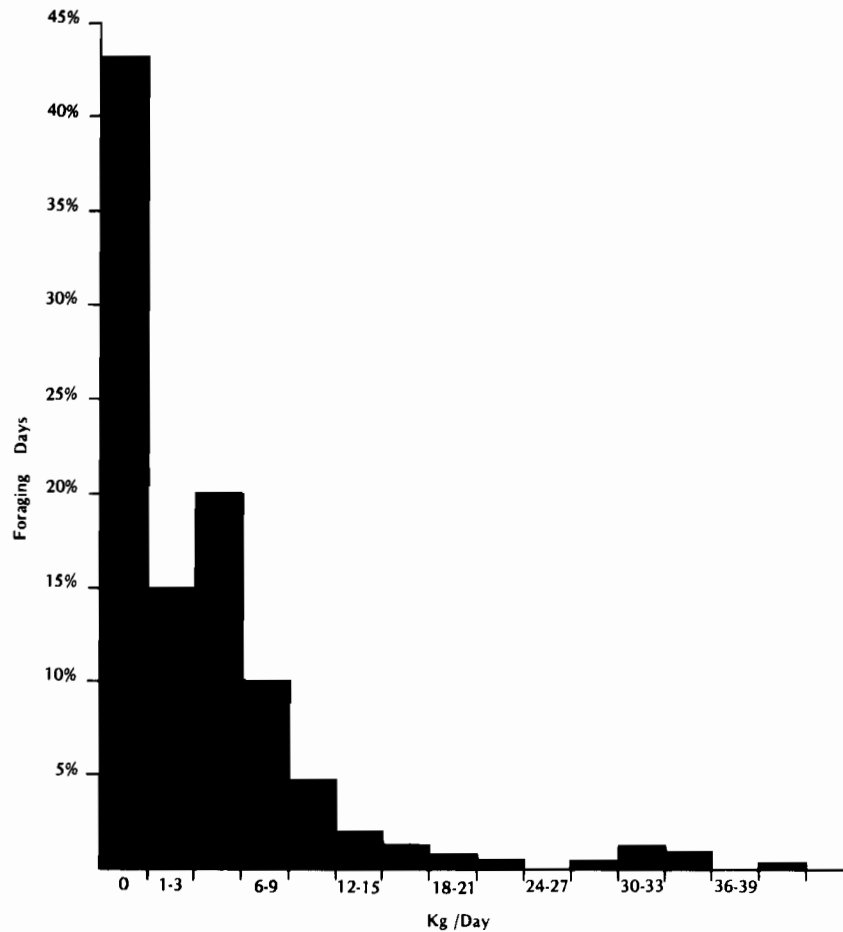


Figure 5.8 Probability of various returns (kg/day) for an average bow hunter on any single day. All full days for individual bow hunters were sampled.

than 100 m apart. Because, as we mentioned earlier, men frequently clump together through much of the day, we find it unlikely that a band of 40 hunters would get hunting returns much lower than those described here. Because of the higher total game take each day, they would have to move camp frequently, but it is not clear how important this difference would be to the Aché, as we observed them to move camp every day even when in small bands.

A common explanation for the minimum size of hunter-gatherer bands is risk reduction. If returns from foraging are not steady, a band of only a few families may have a high probability of days with no food. Although we have the data necessary to calculate the probability of a given sized band getting hunting returns below some limit on any given day, it is somewhat difficult to assess the important physiological limits beyond which risk should be minimized.

Figure 5.8 shows the probability of killing various amounts of game for any *individual* hunter on any one day. It represents a tabulation from the total of all man-days sampled for bow hunters, and does not take into account the fact that hunters do slightly better in smaller groups (see Figure 5.6).

Consider the extreme case: no game at all. For one hunter the likelihood of this is 43.5%. But the probability of no game falls sharply with the addition of a second hunter (18.9%, which is less than 1 day in 5 with no game) and again with the addition of a third hunter (8.2%—less than 1-day in 10). With four hunters this probability (3.6%) is just over 1 day a month. Given that gathering contributes to subsistence, we conclude that risk minimization could only be important for very small band sizes (i.e., 12–15 total members).

Pursuit Group Size

We have already mentioned that many game animals are solitary and are taken by single hunters upon encounter. As long as the spacing is such that there is little overlap in the area searched by each hunter, it is unlikely that group size will have any effect on the returns from these animals. There are, however, three game species that live in large groups and which are usually taken by multiple hunters: white-lipped peccaries, coatis, and monkeys. These animals are usually taken by groups of men who call for each other's help upon encounter. They also make up 55% of the total game taken (by weight) and, therefore, the group hunting strategy employed is quite important and has a significant effect on the overall returns from hunting.

Two alternative motivations may affect goals of individual foragers. One

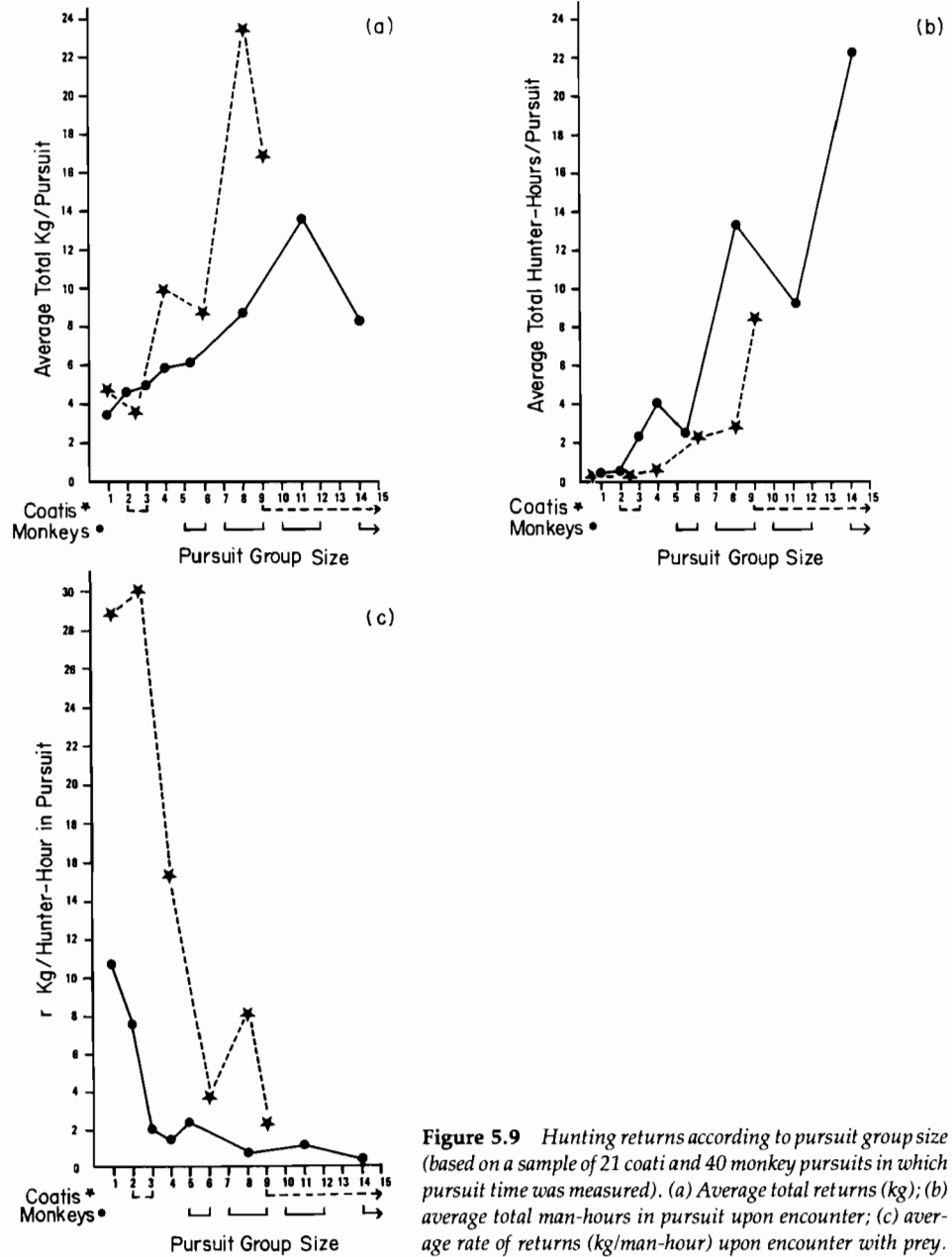


Figure 5.9 Hunting returns according to pursuit group size (based on a sample of 21 coati and 40 monkey pursuits in which pursuit time was measured). (a) Average total returns (kg); (b) average total man-hours in pursuit upon encounter; (c) average rate of returns (kg/man-hour) upon encounter with prey.

possibility is that each man is attempting to maximize his own personal return rate because of the possible rewards of being the best hunter. A second alternative is that since all the men eventually share all game killed, they are all trying to maximize the returns that the whole group gets each day. According to the first model, a hunter should call for help upon encounter or respond to calls only if it is likely to increase his own personal returns. If calling for another hunter or responding to a call decreases the average return *he* expects from the encounter, he will not call or respond, even if the total take is likely to be higher with more men helping (note that he may not make all the kills and thus, while more total game is killed, he may get credit for less). According to the second model, the hunter will always try to add more members to his pursuit group, or join pursuit groups, as long as overall foraging returns for the group are increased by this strategy.

Figure 5.9a,b,c shows the total kilogram returns and total man-hours spent in pursuit, for different-sized pursuit groups, upon encounter with monkeys and coatis (we do not have these data for white-lipped peccaries). It also shows the return ratio in kg/man-hour for each prey item as a function of pursuit group size.

If hunters wish to maximize the average returns of the band because they share all the game killed, the optimal strategy is to continue to add hunters to the pursuit group as long as returns remain higher than the combined returns of a smaller pursuit group plus the foraging returns of hunters not joining the pursuit. For example, if, during a 1-hour hunting period, two men can each expect 7.7 kg/hour in a joint pursuit of monkeys that lasts 0.24 hours, and a third man can expect 0.53 kg/hour (the average for hunting in general) if he continues to search for and pursue other game, their combined total will be 0.24 hours for two hunters at 7.7 kg/hunter-hour for the monkey pursuit, plus 0.24 hours for the solitary hunter at 0.53 kg/hunter-hour during this time, plus the remaining 0.76 hour for all three hunters at 0.53 kg/hunter-hour before or after the monkey pursuit. This is 4.04 kg of game. If the third man joins the others in pursuit of the monkeys, the group total will be 0.78 hours (the average pursuit time for groups of three) for three hunters at 2.2 kg/hunter-hour, plus the 0.22 hours remaining for the three hunters at 0.53 kg/hunter-hour after the pursuit. This is 5.5 kg of game. Thus, to maximize group totals, the third hunter should join the pursuit. This can be stated more generally by defining the following variables:

p = pursuit group size

r_p = the return rate/hunter at group size p

r_a = the return rate for the average hunter in general foraging (0.53 kg/hr)

h = the total number of hunters

T = the total number of hours in a hunting period

t_p = the number of hours in pursuit for group size p

Group returns during a hunting period (G) are then equal to the game taken by the hunters in the pursuit group which is $t_p \cdot p \cdot r_p$, plus the game taken by the remaining hunters during this time which is $t_p (h - p)r_a$, plus the game all the hunters get during whatever time this pursuit is not underway, which is $(T - t_p)h \cdot r_a$. Thus

$$G = (t_p \cdot p \cdot r_p) + [t_p (h - p)r_a] + [(T - t_p)h \cdot r_a]$$

Figure 5.10 shows the value of G for different-sized pursuit groups. For coati hunting, group returns are maximized in pursuit groups of 8 (Figure 5.10a). However, as Figure 5.11 shows, the distribution of actual cases does not support the hypothesis that hunters are maximizing overall returns. There is no preponderance of pursuit groups of this size among those observed. For monkeys, group returns are greatest in pursuit groups of 10–12, although the numbers are fairly constant for groups under 14 (Figure 5.10b). Again the distribution of observed pursuit group sizes (Figure 5.11) does not peak at the group maximum. The data do not support the hypothesis that Aché hunters establish pursuit groups which maximize total band returns.

An alternative hypothesis is that hunters try to maximize their personal return rates. If so, the optimal strategy depends on whether or not they are already in a pursuit group. Those in a pursuit group should continue the pursuit if $r_p > r_a$ and should exclude additional hunters if an increase in pursuit group size would decrease the returns per hunter in the pursuit group. Those outside the pursuit group should join as long as the returns/hunter in pursuit are greater than the returns for continuing to search and pursue other game. In the former case, hunters should solicit additional pursuit group members as long as $t_p \cdot r_p + (T - t_p)r_a < t_{p+1}r_{p+1} + (T - t_{p+1})r_a$. In the latter case hunters should join pursuit groups as long as $r_{p+1} > 0.53$.

Figure 5.10 also shows the individual returns during a hunting period for hunters who are members of pursuit groups of different sizes. The personal returns of hunters in the pursuit group are maximized for both coatis and monkeys when a single hunter remains alone—a pursuit group of one. As group sizes increase, this rate drops for both kinds of game. The frequency of observed cases does not match these rates (Figure 5.11). The distribution of pursuit group sizes does not support the hypothesis that the personal return rates of hunters in pursuit are maximized for either of these animals.

Hunters do not primarily form pursuit groups which would maximize either the returns for the individual who encounters the animal, or the

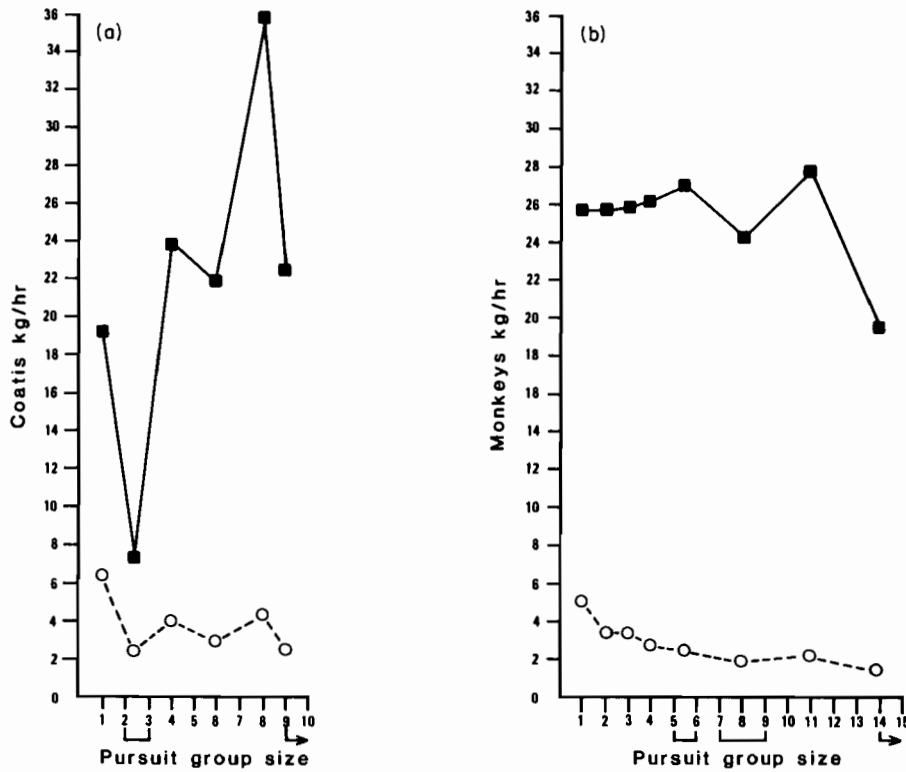


Figure 5.10 Group return for pursuit of (a) coatis and (b) monkeys, by pursuit group size.

Upper curve: G = total group return during a hunting period

Lower curve: I = total individual return for those in the pursuit of interest during a hunting period

Where: p = pursuit group size

r_p = return rate/hunter in the pursuit group at group size p

r_a = average return rate/hunter for general foraging (0.53 kg/hr)

h = number of hunters, here assumed to be 9 for coati hunts, 14 for monkey hunts, to simplify calculations (these are the smallest numbers which allow use of all the data)

T = total number of hours during a hunting period, here assumed to be 3 to simplify calculations (this is the smallest whole number which allows use of all the data).

t_p = number of hours in pursuit at group size p

$$G = [t_p \cdot p \cdot r_p] + [t_p(h-p)r_a] + [(T-t_p)h \cdot r_a]$$

$$I = [t_p \cdot r_p] + [(T-t_p)r_a]$$

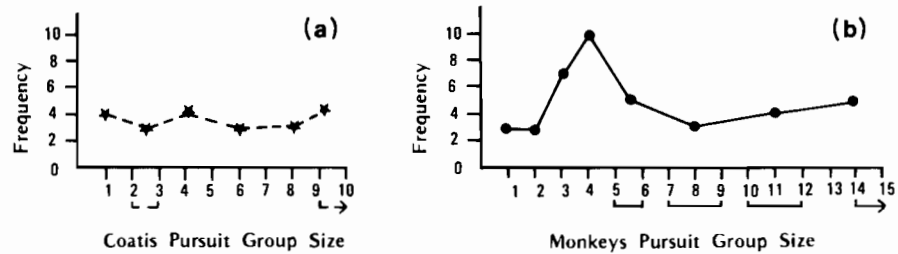


Figure 5.11 The frequency of different pursuit group sizes over the sample of (a) 21 coati pursuits and (b) 40 monkey pursuits.

overall foraging returns for the band. Instead, they form pursuit groups across a wide range of sizes.

There is a conflict of interest between individuals trying to maximize their personal return rates which may lie behind this wide range of band sizes. While a hunter will increase his own efficiency if he pursues the game he encounters by himself, not calling for help, a hunter will also increase his return ratio by joining other hunters in pursuit—as long as the returns for doing so are greater than his average returns for continuing to search for other game (0.53 kg/hour). Thus, while an individual maximizing his personal ratios would not want to be joined by a second hunter (or these two by a third hunter), other hunters *would* want to join him. However, very few cases were ever observed where a hunter failed to call for help upon encounter with either item.

Hunters *outside* the pursuit group increase their personal ratios by joining a pursuit as long as the rate for individuals in the group formed by their addition is higher than 0.53. This holds for coati pursuit groups of all sizes and for monkey pursuit groups of fewer than 14 hunters (Figure 5.11). In other words, individuals outside pursuit groups maximize personal returns by joining pursuits 56 out of 61 times (92%).

Spacing seems to be a major problem for hunters who wish to maximize their foraging returns. If hunters are too far apart, pursuit groups may be small because of a lack of hunters within earshot rather than because hunters fail to call for help or fail to respond to those calls. If hunters stay close together (as they often do), the area searched per man-hour decreases and thus the overlap causes a considerable increase in the search time component of foraging. Since we have shown (Table 5.4) that search time is the major component of foraging time (71.2%), increasing it by any factor would considerably reduce overall foraging returns. The hunters are therefore faced with a dilemma: spacing too far apart as to be out of hearing range decreases foraging returns for those who do not join pursuit groups, but spacing not far enough apart as to cause overlap in the area searched also decreases foraging returns. The perfect spacing needed to solve these

problems is very difficult to maintain in thick jungle. This possibly explains the continual cycle of coming together and spreading out throughout the day.

• Summary and Discussion

It should be emphasized that the results presented are based on observations during a single season of a single year for one hunter-gatherer group. As such, we should be somewhat cautious extrapolating the meaning of these results to the study of Aché subsistence patterns in general, more so to the study of hunter-gatherer economies, and especially to questions concerning human evolution. Nevertheless, with this cautionary note, we will explore what we consider to be some of the possible and likely implications of this study with respect to more general questions.

The primary purpose of our field work was to test hypotheses concerning the applicability of optimal foraging models to hunter-gatherer subsistence behavior. We are interested in the general patterns which may be expected to hold for all human groups and individuals faced with the same types of problems. Specifically, we are aiming to test models concerning foraging behavior of humans in order to allow us to predict what the foraging behavior must have been for groups and periods of time that are no longer observable. If the general principles of foraging behavior for humans (and other organisms) can be adduced, they will apply in all ecological circumstances and all time periods. Thus, with a knowledge about the specifics of the environment in question, we will be able to make accurate predictions about the behavior of interest, which ultimately can be tested archaeologically. This, of course, rests on a strong demonstration of the applicability of the model for currently observable behavior.

The Aché demonstrate that in the appropriate ecological setting humans are quite efficient predators and get very good returns hunting with quite simple technology. The tropical forests of this part of lowland South America seem to be well endowed with game that is easily killed by human hunters. This observation directly contradicts impressionistic statements by many earlier authors (e.g., Gross 1975; Harris 1974; Lathrap 1968; Meggers 1971), but is supported by a growing body of quantitative studies on hunting returns in lowland South America (e.g., Beckerman 1980; Gross *et al.* 1979; Hames 1979; Lizot 1978b; Vickers 1980). Hunting returns in lowland South America using traditional methods and technology range from a high of 1.35 kg/man-hour for a Yānomamö village (Saffirio and Hames in press) to a low of 0.16 kg/man-hour for the Bari (Beckerman 1980). Aché bow hunters get returns of 0.53 kg/man-hour, and hunting with shotguns

the Aché get 1.60 kg/man-hour. These numbers are strikingly similar to the returns reported by Hames (1979) of 0.56 kg/man-hour for Yānomamö bow hunters, and 1.49 kg/man-hour for Ye'kwana men hunting with shotguns in the same ecozone. The large amount of meat that Mbuti Pygmies take daily hunting in the Ituri forest (Harako 1976, 1981; Hart 1979; Tanno 1976), the importance of meat in the Agta diet (Estokio-Griffin and Griffin 1980), and other measured hunting returns for several South American groups (e.g., Werner *et al.* 1979), would all suggest that the prevalent idea of tropical forests's being poor in game for human hunters (e.g., Hayden 1981; Lee and DeVore 1968) should be revised.

Comparison of Aché hunting to other hunter-gatherers shows a remarkably wide range of variation. There are two important differences between the Aché and the !Kung Bushmen. First, the Aché get higher returns per man-hour hunting, and receive a greater portion of their daily caloric intake from meat. Assuming that !Kung men hunt about 8 hours on an average hunting day, we calculate from Lee's data (1979:268) that !Kung hunters at Dobe got 0.33 kg meat/man-hour during July 1964. Because they hunted only 3 days a week, meat provided only 29% of the total caloric intake for the group. Wilmsen (1982) monitored hunting returns for an entire year at /xai/xai and found that only 12% of the calories in the diet for bush dependent !Kung came from meat. He estimates that hunting returns were only 0.2 kg/man-hour (personal communication).

The second important difference in hunting behavior between the Aché and the !Kung is the difference in the game species themselves. The !Kung primarily hunt large game animals, which single men stalk and shoot with poison arrows. The Aché on the other hand primarily hunt game smaller than 10 kg, and group hunting is frequent and important. These two groups therefore represent two extremes in hunting strategy due to differences in their ecological surroundings. Under the right circumstances it is likely that large game hunting would provide much higher returns than small game hunting, as the returns for the highest ranked items would be much higher. These differences point out that a hunter should not be expected to display similar behavior in all ecological circumstances. The particular aspects of the ecology of interest are of primary importance for any theory concerning probable foraging behavior, and any other behavior, including social organization which may be constrained by the subsistence pattern.

From our data we would tentatively conclude that humans, under the conditions we have described, do indeed forage optimally, for the most part. Although the adaptive importance of other conflicting behavioral possibilities may at times outweigh the importance of maximizing energy efficiency, we suggest that this parameter of fitness is likely to be important for all organisms in all environments.

The differences in time spent hunting between the Aché and other hunter-gatherers is an interesting and perplexing problem. It is not clear to us why !Kung hunters for example should hunt only 3 days per week (Lee (1979) whereas the Aché hunt every day that weather permits and get better returns. This is especially difficult to understand in light of the fact that the !Kung are somewhat undernourished and show a greater need for increased calories (Truswell and Hansen 1976; Wilmsen 1979). Blurton-Jones (1978) has suggested that heat exhaustion may be a limiting factor for !Kung gathering, and this may also explain the need for !Kung men to remain in camp several days per week. There may of course be many other explanations for this difference; however, we suspect that more information is needed on what exactly !Kung men do with the time they are not hunting before a likely explanation will be found. Despite their high returns from hunting, our data for the Aché do not support the contention that hunters take the "zen road to affluence," working only a few hours a day (Sahlins 1972).

Two facts seem contradictory: that hunters hunt fewer hours the day after high returns, and that the hunters with highest average returns hunt more hours per day than those with low average returns. This is, however, primarily due to the difference in the measures used. The fact that hours hunted the day after high returns are compared to the hunter's own average is important, as a good hunter may hunt fewer hours than his own average the day after he gets high returns, and yet still hunt more hours than an average hunter. The trend for hunters with high returns to spend more hours hunting per day can be interpreted in several ways. Either the tendency for an individual hunter (for whatever reason) to hunt more hours per day has made him into a better hunter, the differences in hunting ability (for whatever reason) reinforces successful hunters to hunt more hours per day, or both are operating simultaneously. This could be tested by increasing artificially either of the two parameters. When returns were raised by allowing the use of shotguns, we observed no subsequent change in hours hunted per day over a 10-day hunting trip. This may, however, be too short a time period to produce a change in an individual's daily hunting pattern, and thus the mechanism of this correlation is still not understood.

The optimal diet model seems to predict fairly accurately when items will leave the diet (i.e., not be taken upon encounter). The analyses for capuchin monkeys can possibly account for the fact that the Aché consider these monkeys as a game item (the Aché have hunted only with bows until very recently), whereas neighboring Guaraní speaking Indians, Paraguayan and Brazilian peasants, who all hunt with shotguns, do not consider these monkeys as prey (or even edible in some cases). Although taboos based on symbolically mediated proximate mechanisms may be reported

by informants as the explanation of species avoidance in hunting, it would be very useful to analyze the benefits of such beliefs carefully before concluding that they are arbitrary (Ross 1978).

There are, as we have mentioned, some apparent violations of optimality. Figures 5.3 and 5.9c show that the rank of some items can be adjusted considerably depending on the strategy used during their pursuit. Other things being equal, we expect that the most efficient strategy will be chosen. If single shotgun hunters took monkeys alone upon encounter, aiming only for large monkeys, they would still be in the optimal diet (see Table 5.7). Nevertheless, we did not observe this hunting strategy. It is possible that monkeys leave the diet of shotgun hunters for some other reason; however, we conclude tentatively that they are excluded because returns from an average encounter are lower than average foraging returns from shotgun hunting. Although much further testing is necessary, we calculate that both shotgun and bow hunters spend less than 5% of their foraging time pursuing items that should not be included in the set predicted by the optimal diet model.

Although no tapirs were killed this period, it is instructive to consider them in order to realize the effects of large game on hunting returns. Several tapir were shot during the study period, and we recorded 10 man-hours spent in pursuit of them without success. If one tapir were to have been killed during this period it would have been the number-1 ranked item in the optimal diet. The hunter who killed the tapir would then have an average hourly foraging return of more than double the next highest man during our study period, even if the hunter who killed the tapir were the man that we recorded with the lowest average returns throughout our study period. These changes that might have resulted in the hunting returns, due to one single event, point out both the impact of large game items on the picture we present (Hames [1979] observes this effect), and the weakness of data from such a short study period.

Precise measurements of Aché hunting returns should allow for more complete models concerning the economies of the pre-Columbian societies in South America. Subsistence returns for hunter-gatherers, even at the level of the Aché, who do quite well, do not compare to the caloric returns per man-hour from horticulture in South America. Although Aché bow hunters get 910 Cal/hour for their subsistence work, returns from horticulture reported in South America are much higher (Hames n.d.)

This leaves us with the difficult problem of explaining why the Aché continued as hunter-gatherers into the 1970s. We suggest that the answer to this question is likely to be found from consideration of factors other than subsistence behavior. Clastres (1968) proposed that continued warfare with neighboring Guaraní Indians drove the Aché to adopt their nomadic hunting and gathering life style.

The data presented on group size and hunting returns may explain why Aché bands rarely contain fewer than five hunters, but we cannot at this time demonstrate the relevant factors constraining maximum band size. It is also possible that precontact Aché bands moved camp less frequently than we observed during the study period, and we have some indication of the existence of large (greater than 100 people) semipermanent camps prior to outside contact. These questions will have to be further investigated before any satisfactory explanation is found.

Finally, from an evolutionary perspective, we can ask what are the implications of the individual variation in returns that we measured. It should once again be pointed out that this is a very short term study and thus the variance over a longer period more relevant to reproductive success may be quite different. Two things, however, should be considered. First, we have the impression that, over a longer time period, the position of some of the best and worst hunters may not change too much. A much longer period of observation of hunting before we began to measure returns allowed us to predict in advance who some of the best and worst hunters were going to be. This supports the contention that the results are probably representative for the extreme cases, even if there is considerable change in the hunting returns for men near the average. Second, because of the sharing pattern, which is not yet well studied, we suspect that actual differences in amount of game killed do not reach the level of individual or familial consumption. Thus, if any morphological or physiological bases of differences in hunting ability are being selected for, there must be a difference in the access to mates for hunters getting high and low returns. It seems likely that this comes from increased status due to hunting success relative to other men. Other alternatives are of course possible, but it is very difficult for us to accept the possibility that hunting ability in this society, and those which may be like it, plays no part in the evolutionary trajectory of the individuals who compose it. On the contrary, the importance of hunting success to the nutritional well-being of all the individuals in the group suggests that there should be quite heavy selective pressure to produce competent hunters, although the precise mechanism of that selection is currently obscure.

Any useful application of these data in order to address questions of larger scope requires the comparison of this case to other cases in which some of the variables have different values. We suspect that when comparable data for other hunter-gatherers, and nonhuman primates, are available, the comparative approach will make diet and general subsistence activities of our ancestors much more accessible than they can ever be using direct archaeological approaches alone. The patterns revealed *and* the questions raised by hypotheses drawn from optimal foraging theory are grounds for optimism.

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Notes

¹Before contact, in 1970, we estimate 700 ± 200 northern Aché in an area approximately 5000 km².

²During the study period, we recorded 736 man-days in the jungle, out of a possible of approximately 4800. We could not monitor all man days, as we spent considerable time on foraging trips. This means that this group of men spent a minimum of 15% of their time in the jungle foraging and we estimate the maximum for the group at about 25% of the time foraging during the study period. Several individual men spent more than 50% of the time in the jungle and the most active hunters were also most likely to be included in our sample.

³The seasonal *várzea* described by Hames (1980) is here divided into two ecozones in order to separate actual lagoons from a much larger area of floodland forest that is not always closely correlated with the presence of a lagoon.

⁴Not all animals are likely to be hunted, however, as some may be too small to be worth the bother. Young boys do hunt small prey (e.g., rats and birds) which are ignored by adult hunters. Various age-specific or situation-specific taboos exist but never apply to the entire population. Some food taboos elicited from informants have been observed to be broken.

⁵Two adult men did not hunt on single days because they were quite ill. Several of the men in the older age bracket also did no hunting on various occasions, due to illness.

⁶The angle chosen here was deliberately low in order to make the competition more difficult. Aché men frequently comment that their ability with the bow has gone steadily downhill as they spend more and more time at the mission. They are not able to predict on any given day who the likely winner of the competition will be, as they feel that any hunter could win if he is having an "on" day. Our impression is that some hunters do shoot consistently better, but we agree that the winner is unpredictable.

⁷Encounter rate may, however, alter the handling cost, but it is the change in handling cost, and not abundance, which will determine whether the item is included in the optimal diet.

⁸From our data, the average capuchin monkey taken weighs 2.5 kg and requires 2.4 hours pursuit to kill. Thus, $(1.8 \text{ kg} \times 1300 \text{ cal}) / (2.4 \text{ hours} + 0.2 \text{ hours}) = 900 \text{ cal/hour}$.

⁹We do recall several occasions in the camp late in the evening or early in the morning when adult hunters tried to shoot birds that were smaller than 0.4 kg; however, these attempts were accompanied by considerable laughter and joking, and we consider them to be play rather than foraging. The Aché by their own account do take many of the small birds in this area occasionally, although this seems to be primarily an activity of young boys between about 6 and 12 years old. We observed seven small birds killed by this age group.

II

Hunting and Fishing

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