Hunting Dogs in the Lowland Neotropics

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KEY WORDS: Dogs, *Canis lupus familiaris*, Subsistence hunting, Technology, Tropical forest, Domesticated animals

Once absent in much of Amazonia, dogs are now commonly used for hunting throughout the lowland Neotropics. Although some ethnographers have questioned their usefulness, dogs are particularly effective in pursuits of several mammalian prey species. The return rates of hunting with dogs appear to compare favorably with those of hunting with firearms, and dogs may be especially beneficial in anthropogenic habitats. There is considerable cross-cultural variation in the training and care of dogs. Good hunting dogs typically receive better care than their less-talented conspecifics. Mortality rates for dogs in the Neotropics are high, and the causes of death include malnutrition and attacks by other animals. Although isolated Neotropical societies may not have initially recognized the overall value of hunting dogs, a more likely explanation for the absence of dogs in prehistoric Amazonia is the high mortality of dog populations in the region. Additional research is needed to resolve ethnological questions about the use of dogs in the lowland Neotropics.

LONG AN OBJECT OF SCIENTIFIC INTEREST, THE DOMESTIC DOG (*Canis lupus familiaris*) continues to receive considerable scholarly attention as geneticists and archaeologists attempt to reconstruct the process of domestication (Morey 2006; Savolainen et al. 2002). The exact timing and circumstances of domestication remain a subject of debate, but there is little doubt that dogs represent the first domesticated animal (Clutton-Brock 1995). Given the length of their interaction with people, it is not surprising that dogs exhibit a unique ability to interpret human social and communicative cues (Hare and Tomasello 2005). Humans have taken advantage of canine physical and social skills in many ways, including the use of dogs to pull sleds and travois, protect domiciles, and herd domestic animals (Coppinger and Coppinger 2002). Perhaps foremost among all of their assignments, however, is the use of dogs for hunting.

The ethnographic literature includes numerous references to the use of hunting dogs in the eastern hemisphere, and an abbreviated list exemplifies their usefulness to subsistence hunters in a broad range of locations and habitats, including New Guinea (Bulmer 1968), Taiwan (Fan et al. 1998; Nobayashi 2006), the Philippines (Estioko-Griffin 1985), Indonesia (Ellen 1999), India (Allchin 1966), Siberia (Levin and Popatov 1964), Finland (Ruusila and Pesonen 2004), Kenya (Fitzgibbon et al. 1995), Botswana (Ikeya 1994), Zaire (Singer 1978), Equatorial Guinea (Colell et al. 1994), and Australia (Jones 1970; White 1972).

Journal of Anthropological Research, vol. 65, 2009

In the Americas, dogs probably accompanied the first Paleoindians to enter temperate North America, and faunal remains in Argentina suggest that Paleoindians may have also brought dogs into South America (Fiedel 2005; cf. Caviglia et al. 1986:304–5). Dogs subsequently proliferated throughout much of the Americas, and evidence of their use in hunting is common (Schwartz 1997). Outside of Mesoamerica, however, archaeological evidence of dogs in the lowland Neotropics is rare. Cooke and Ranere (1992:36–37) report a canid humerus from the Archaic period in central Pacific Panama (see also Cooke and Ranere 1989). In coastal Ecuador, canine osteological remains have been dated to the Formative period (Stahl 2003). Because of the notoriously poor preservation of bones in Neotropical settings, however, it is difficult to infer much from the absence of osteological evidence (Roosevelt 1989). Yet, the apparent paucity of iconographic evidence of dogs in the region is noteworthy (cf. Lathrap 1976).

In the absence of archaeological evidence, historical and linguistic evidence may be used to reconstruct the geographic distribution of dogs in prehistoric settings. For instance, societies that did not have dogs until the historical period tend to either borrow European words for dogs (e.g., *perro*) or use derivations of already-familiar animals, such as calling dogs "little jaguar" (Schwartz 1997). Based on this evidence, Schwartz (1997) concludes that dogs were present in the Guianas and the Orinoco River basin. However, many Amazonian societies apparently lacked dogs until the historical period, a detail that had earlier attracted the attention of anthropological luminaries such as Lowie (1941:189), Kroeber (1942:6), and Murdock (1951:424). Genetic evidence suggests that, following contact, dogs of European ancestry began to replace native dogs throughout the Americas (Leonard et al. 2002). In Amazonia, the timing of this diffusion varied, and some societies did not acquire dogs until the twentieth century (Coppens 1983:266; Forline 1997:122; Holmberg 1969:69; Yost and Kelley 1983:205; see also Métraux 1946:451).

Although anthropologists have focused on the influx of firearms into previously isolated Neotropical societies (e.g., Hames 1979; Yost and Kelley 1983), many of these societies were simultaneously acquiring dogs, and their use for hunting is now common throughout lowland Latin America. Compared with firearms, however, hunting dogs have received less systematic attention from human ecologists, and there are lingering questions about the overall effectiveness of hunting with dogs. Although there are few comprehensive reports, the ethnographic record includes numerous references to the use of hunting dogs, and it is becoming evident that dogs can be valuable hunting accessories. Given their increasing ubiquity throughout the region and their apparent value to hunters, the longstanding absence of dogs in some societies is an interesting anthropological problem. This paper reviews the available literature to examine and inform hypotheses about the distribution and relative importance of hunting dogs in the Neotropics.

GEOGRAPHIC PATTERNS

Many of the sources that mention the use of hunting dogs provide enough geographic information about the study site to be plotted on a map (Figure 1). The

literature review that uncovered these sources was thorough but not exhaustive, and there are undoubtedly other locations at which hunting dogs are used. Also, only reports by anthropologists, geographers, and biologists with firsthand observations of hunting dogs are included on the map, thus neglecting several historical sources. For some indigenous groups (e.g., the Huaorani), multiple researchers have noted the use of hunting dogs. In such cases, a representative source was selected.

The widespread distribution of sites in Figure 1 suggests that there are few settings in which dogs cannot be at least moderately useful in hunting. The relative sparseness of documented sites in the Brazilian state of Amazonas is somewhat surprising given references to dogs in early geographic reports (Chandless 1866a:111, 1866b:123; Steere 1903:390; see also Tastevin 1925:16–18). Nevertheless, dogs in some Neotropical societies are kept as pets but are rarely used for hunting (Hill and Kintigh 2009; Maybury-Lewis 1967; Nimuendajú 1967; Politis 2007; Ruddle 1970). In other reports the importance of dogs in hunting is not entirely clear (e.g., Crocker 1990:97).

Even in settings where dogs are regularly used for hunting, some ethnographers question the overall effectiveness and value of dogs (Hugh-Jones 1979:30; Lizot 1988:503; Wagley 1977:60). Interestingly, native informants in the same group may vary in their esteem for hunting dogs, with some hunters lauding their merits while others express disregard for their abilities (Herlihy 1986:225; Smith 1976:456). Sometimes hunters who own capable hunting dogs choose to hunt without them (Descola 1994:234; Koster 2007:126). At such times, the hunters may be targeting prey species for which dogs offer little assistance, as dogs reportedly scare away some animals before shots can be fired (Alvard and Kaplan 1991:85; Werner 1984:113). Given such reports, it is perhaps not surprising that ethnographers occasionally conclude that dogs are ineffective.

THE ETHNOGRAPHY OF HUNTING WITH DOGS

Native informants make qualitative distinctions between hunting with dogs and hunting with other kinds of accessories (Koster 2007:41; Romanoff 1984:106; Taylor 1951:58–59). Whereas hunters with only projectile weapons typically move stealthily through the forest, hunters with dogs may require considerable exertion to keep up with the dogs as they dart through the undergrowth in search of game (Romanoff 1984:106; Werner 1984:114). Although dogs may be kept on a leash until the hunters discovers tracks (Descola 1994:234), they are more commonly allowed to roam freely (Kaplan and Kopischke 1992:99; Koster 2008a:935; Smith 1976:456). Hunters communicate with their dogs by calling loudly, and the dogs bark upon detecting the presence of prey, usually by smell (Im Thurn 1967:23; Koster 2007:45 2; D. A. Smith 2003:110–11; N. J. H. Smith 1976:456). Typically, after the animal is brought to bay or corralled in a burrow or trunk, the dogs' barking enables the hunters to locate and dispatch the animal (Alvarsson 1988:284; Koster 2008a:935; Paolisso and Sackett 1985:187).

An alternative technique involves patrolling the riverbanks, profiting from the tendency of some prey species to flee into the river when pursued by dogs.

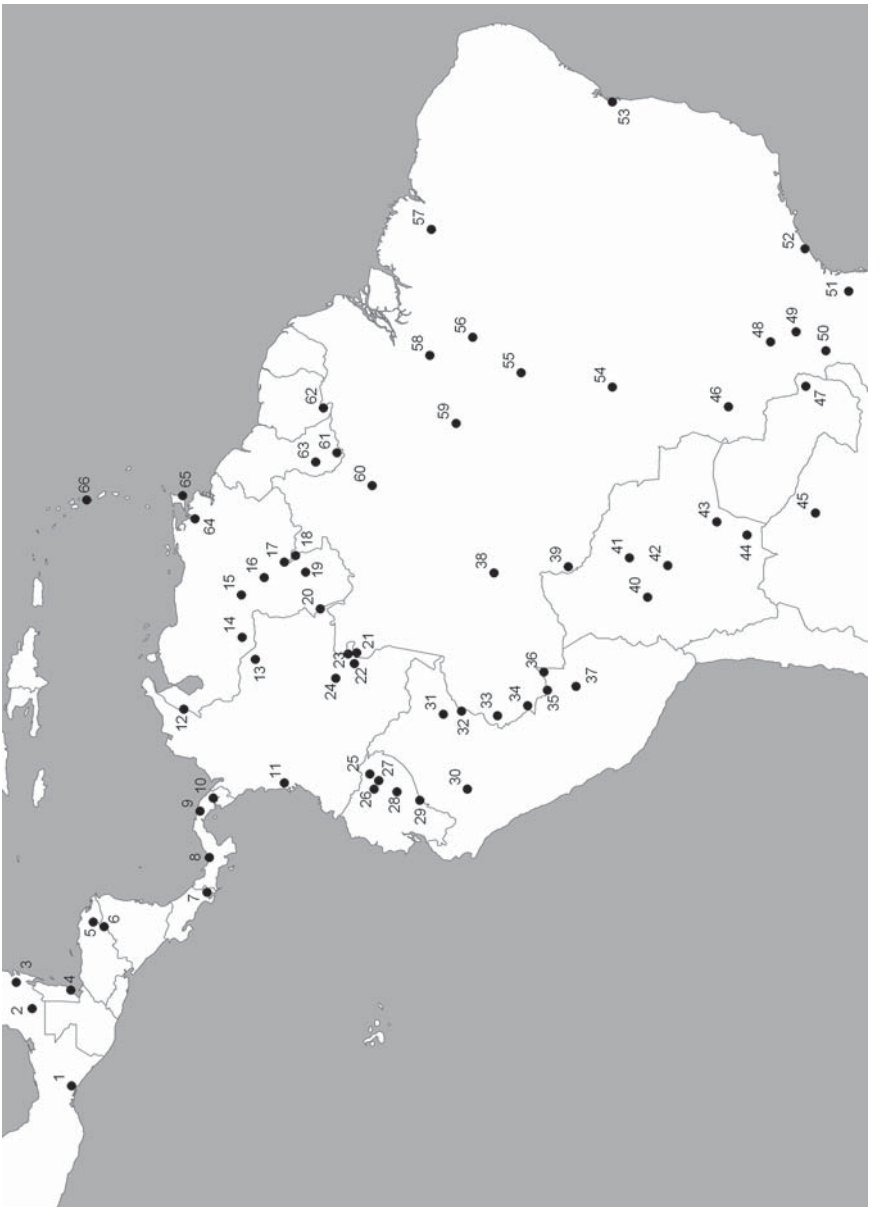

Figure 1. Locations in the lowland Neotropics at which researchers have reported the use of hunting dogs.

Legend to Figure 1.

Map ID	Group	Source
1	Rural Mexicans	Naranjo and Cruz 1998
2	Rural Mexicans	Reyna-Hurtado 2002
3	Maya	Jorgenson 1993
4	Black Caribs	Taylor 1951
5	Miskito	Dunn 2004
6	Mayangna / Miskito	Koster 2007
7	Guaymí	Koshear 1995
8	Buglé	Smith 2005
9	Cuna	Bennett 1962
10	Emberá & Wounan Chocó	Herlihy 1986
11	Noanamá	Reichel-Dolmatoff 1960
12	Irapa-Yukpa	Paolisso and Sackett 1985
13	Cuiva	Arcand 1972
14	Pume	Greaves 1997
15	Panare	Henley 1982
16	Hoti	Zent 1999
17	Makiritare (Yekwana)	Wilbert 1972
18	Sanumá	Taylor 1974
19	Yanomamö	Hames 1979
20	Wakuenai (Curripaco)	Hill 1983
21	Hupdu Maku	Reid 1979
22	Bara	Jackson 1983
23	Tatuyo	Dufour 1981
24	Cubeo	Goldman 1963
25	Siona-Secoya	Vickers 1991
26	Runa	Irvine 1987
27	Waorani	Yost and Kelley 1983
28	Quichua	Sirén et al. 2004
29	Jívaro	Harner 1972
30	Aguaruna	Brown 1984
31	Peruvian caboclos	Coomes 1992
32	Matses	Romanoff 1983
33	Brazilian peasants	Minzenberg 2005
34	Brazilian rubber tappers	Carneiro da Cunha & de Almeida 2000
35	Amahuaca	Carneiro 1974
36	Cashinahua	Kensinger 1995
37	Machiguenga	Kaplan and Kopischke 1992
38	Jarawara	Dixon 2004
39	Wari’	Conklin 1989
40	Tsimane	Gurven et al. 2006
41	Sirionó	Townsend 2000
42	Yuquí	Stearman 1990
43	Izoceño	Fiorello et al. 2006
44	Mataco	Alvarsson 1988
45	Rural Argentinians	Altrichter 2005
46	Terena	Oberg 1949
47	Paraguayan peasants	Hill and Padwe 2000
48	Rural Brazilians	Cullen 1997
49	Rural Brazilians	Rocha-Mendes et al. 2005
50	Brazilian colonists	Fernandes-Pinto and Krüger 2000
51	Kaingáng	Henry 1964
52	Caiçara	Sanches 2001
53	Rural Brazilians	Flesher 2006
54	Bakairí	Picchi 2000
55	Mekranoti	Werner 1984
56	Parakana	Milton et al. 1991
57	Guajá	Cormier 2003
58	Brazilian colonists	Smith 1976
59	Mundurucú	Murphy and Murphy 1985
60	Waimiri Atroari	Souza-Mazurek et al. 2000
61	Waiwái	Yde 1965
62	Trio	Rivière 1969
63	Wapishana	Henfrey 2002
64	Warao	Heinen 1972
65	Afro-Trinidadian	Lans et al. 2001
66	Caribs	Taylor 1938

In many cases, the dogs are allowed to roam the river margins and gallery forest unaccompanied by human hunters, who wait expectantly in canoes for prey to plunge into the water (Arcand 1972:33; Dunn 2004:81; Herlihy 1986:225; Im Thurn 1967:232; St. Clair 1834:317–18; see also Crevaux 1883:49). Wilbert (1972:144) describes a cooperative hunt in which some of the men bring the dogs ashore to drive prey toward companions waiting in the river. In Nicaragua, individual hunters may also instruct family members to wait in the boat while they roam inland in case the dogs chase a deer into the water (Koster 2007:55).

Several authors have commented on the number of dogs brought on hunting expeditions. For small hunting parties, including individuals hunting alone, the use of one to four dogs is common (Fiorello et al. 2006:766; Kaplan and Kopischke 1992:99; Koster 2007:45; Jorgenson 1993:94; Smith 1976:456; Townsend 1995; Vickers 1976:99). Fiorello et al. (2006:766) report that successful hunts included significantly more dogs than unsuccessful outings. On collective hunts, larger numbers of dogs may be employed (Mandujano and Rico-Gray 1991:178; Smith 2003:110; Wilbert 1972:144).

The overall percentage of hunting outings on which dogs are brought varies cross-culturally. Koster (2008a) reports that dogs are present on 83% of daytrips by Mayangna and Miskito hunters in Nicaragua. In descending order, the corresponding percentages at other sites include 75% of trips by Machiguenga bow hunters in Peru (Alvard and Kaplan 1991:84), 49% of trips by Huaorani hunters in Ecuador (Lu 1999:95), 17% of trips by Maya hunters in Mexico (Jorgenson 1993:94), 10% of trips by Matses hunters in Peru (Romanoff 1984:102), 4.5% of trips by Guajá hunters in Brazil (Forline 1997:243) and 3% of trips by Piro shotgun hunters in Peru (Alvard and Kaplan 1991:84).

Hunters with dogs typically bring additional hunting technologies, including projectile weapons such as bows or firearms (Alvard and Kaplan 1991:84; Arcand 1972:41; Koster 2007:125; Rivière 1969:44; Romanoff 1984:117). However, many hunters with dogs bring only hand technologies, such as machetes, spears, lances, axes, knives, or sharpened sticks (Barbarán 2000:519; Koster 2007:120; Romanoff 1984:106; Stearman 1992:114; D. M. Taylor 1938:149; K. I. Taylor 1974:21; Yost and Kelley 1983:206). Dogs are rarely used in nocturnal hunting, but Smith (1976:458) notes that dogs can be used in combination with flashlights and machetes to hunt armadillos at night. Fire is another tool used by hunters with dogs. When prey items are ensconced in hiding places that are difficult to access, such as deep burrows or thick trunks, hunters sometimes attempt to smoke them out (Husson 1978:266; Irvine 1987:108; Koster 2007:53; Mena et al. 1997:406; Paolisso and Sackett 1985:187; Smith 2003:125; Taylor 1974:23).

Although hunting is primarily a male occupation throughout the Neotropics (Hames 1989), women sometimes assume important roles when hunting with dogs. When accompanying other hunters, women may be responsible for controlling dogs on leashes (Brown 1984:549; Descola 1994:234; Romanoff 1983; Sponsel 1981:210–11). Women sometimes use dogs and hand technologies to hunt independently, often pursuing species like agoutis, pacas, and armadillos (Alexiades 1999:128; Balée 1994:58; Conklin 1989:54; Dufour 1981:163–64;

Hurtado and Hill 1987:175; Jackson 1983:47; Lorrain 2000:299; Lu 1999:72; Sponsel 1981:210; Wilbert 1996:52).

Hunting with dogs may also be a preferred strategy for juvenile and older males (Smith 1976:458; Taylor 1974:21), an observation that has relevance for ongoing debates about human life history evolution (Hawkes 2003; Kaplan et al. 2000). Research among the Ache of Paraguay (Walker et al. 2002) and the Tsimane of Bolivia (Gurven et al. 2006) suggest that hunting return rates peak long after physical maturity, with maximum rates achieved by hunters at about age 40, in large part because the skills needed to locate and stalk prey animals take considerable time to develop. By detecting and corralling prey for their owners, hunting dogs may reduce age-related disparities in hunting return rates (cf. Sugiyama and Chacon 2005:258).

PREDATOR-PREY INTERACTIONS

The effectiveness of dogs depends on the anti-predator behavior of prey species. Redford and Robinson (1987:661) note that dogs are particularly useful in hunting species that seek refuge or assume a defensive posture when pursued by dogs. Some authors comment specifically on the species that can be effectively hunted with dogs, and these sources were compiled to make preliminary inferences about the prey species that are most closely associated with hunting dogs (Table 1). From a year-long study of Mayangna and Miskito hunters in Nicaragua (Koster 2008b), also included in Table 1 are the total number of animals acquired with the assistance of dogs and the percentage of total kills in which dogs provided assistance for each game species.

Intersite differences in animal densities limit the comparability of the sample. Relatively rare species might be hunted only infrequently and therefore escape an ethnographer's notice.[1] In some cases, certain species are not present or are extremely rare at the study site. For example, capybaras are not found in Nicaragua or western Panama (Koster 2007; Smith 2003), tapirs are absent among the Yukpa (Paolisso and Sackett 1985:188), and white-lipped peccaries and tapirs have vanished from the Atlantic forest studied by Flesher (2006). Also, tabooed species might be killed with the assistance of dogs but left in the forest. Despite these limitations, the sample provides an initial overview of the prey species that are commonly hunted with dogs.[2]

Researchers who mention few other prey species that can be hunted with dogs almost invariably cite agoutis and pacas as common targets (Conklin 1989:54; Cormier 2003:115; Kensinger 1995:14). The agouti has been described as the game animal "par excellence" for hunters with dogs (Heinen 1972:139). When pursued, this medium-sized rodent usually seeks refuge in a hollow trunk or an earthen burrow (Balée 1994:58; Wilbert 1972:89; see also Ventocilla et al. 1995:37). Upon arriving at the site, hunters typically use machetes, axes, or sticks to gain access to the animal, which is killed with the same tools or bare hands (Heinen 1972:140; Koster 2007:49).

Pursuits of pacas are generally similar to those of agoutis. However, pacas are nocturnal foragers (Collett 1981:514), and these relatively large rodents are

TABLE 1

Number of times that prey species are mentioned as being particularly vulnerable to dogs in a cross-cultural sample of ten Neotropical societies. Also, the number of animals taken with the assistance of dogs and the percentage of overall kills for each species in which dogs provided assistance as recorded ethnographically in Nicaragua (Koster 2008a).

			Nicaragua	
Common name	Scientific name	Cross-cultural *N*	*n*	%
Agouti	*Dasyprocta* spp.	10	349	96.1
Paca	*Cuniculus paca*	9	112	92.6
Collared peccary	*Tayassu tajacu*	7	36	90.0
Brocket deer	*Mazama* spp.	6	8	44.4
Tapir	*Tapirus* spp.	5	11	78.6
Nine-banded armadillo	*Dasypus novemcinctus*	5	153	93.9
Capybara	*Hydrochoerus hydrochaeris*	4	—	—
Jaguar	*Panthera onca*	3	3	100
White-lipped peccary	*Tayassu pecari*	3	0	0
Giant anteater	*Myrmecophaga tridactyla*	2	4	100
Coati	*Nasua* spp.	2	6	75
Tamandua	*Tamandua* spp.	1	2	100
Acouchi	*Myoprocta* spp.	1	—	—
Silky anteater	*Cyclopes didactylus*	1	—	—
Porcupine	*Coendon* spp.	1	—	—

Sources: Alvard and Kaplan 1991; Descola 1994; Flesher 2006; Paolisso and Sackett 1985; Romanoff 1984; Sanches 2001; Smith 2003; Taylor 1974; Vickers 1989; Yde 1965.

usually resting in their burrows when discovered by dogs. If they bolt from their burrows, they may attempt to escape by hiding in another hole or a hollow trunk, at which point the methods for killing it resemble those of an agouti pursuit (Koster 2007:72). Alternatively, this semi-aquatic animal sometimes plunges into a nearby river or stream, which may necessitate pursuit by boat (Bates 1962:124; Brett 1868:20–21; Koster 2007:54; see also Begossi et al. 1999:83; Freitas et al. 2004:319).

A Huaorani man once stated that he seldom ate collared peccary meat before his group acquired dogs (Yost and Kelley 1983:206). Souza-Mazurek et al. (2000:593) and Altrichter (2005:356) report that the harvest of peccaries is closely associated with the use of dogs. Like agoutis, this ungulate species tends first to run and then hide in a hollow trunk or earthen burrow (Reyna-Hurtado and Tanner 2007:751).[3] Multiple peccaries may be corralled in the same location (Fragoso 1994:150; Smith 1976:456). Upon arriving at the site, hunters use sticks to plug the entrance and prevent the peccaries from escaping, then kill their prey with guns, spears, or lances (Alvarsson 1988:284; Koster 2007:54; Smith 1976:456). In Guyana, hunters may construct a conical trap at the entrance to the peccary's hiding place in order to gain access to the animal (Farabee 1967:52; Yde 1965:122).

Whereas dogs are widely considered an asset in the hunting of collared peccaries, the literature is equivocal on their benefits for hunting white-lipped peccaries. Larger than collared peccaries, white-lipped peccaries travel in large herds, leaving a characteristic swath of disturbed vegetation that can be tracked by hunters (Hill and Hawkes 1983; Smith 1976). Upon the discovery of these tracks, large hunting parties are commonly formed because groups of hunters can surround the herd and kill multiple animals (Carneiro 1974:124; Koster 2007:43; Yost and Kelley 1983:205). Dogs can interfere with the success of such hunts by scaring off the herd before hunters can shoot (Wilbert 1972:42; see also Cormier 2003:49). However, other researchers mention that hunters may benefit when the herd stops to confront the pursuing dogs, thus giving the hunters opportunities to shoot (Farabee 1967:51; Murphy 1960:54; Smith 1976:456; Wagley 1977:61–62). In some cases, the dogs may be kept on leashes until hunters have fired a first volley, then released to interrupt the escape of the fleeing herd, thereby providing chances for additional shots (Koster 2007:43; Mentore 2005:151; cf. Stirling 1938:105–6).

The usefulness of hunting tapirs with dogs is likewise debatable. Although dogs can be used to track wounded tapirs, Machiguenga hunters in Peru reportedly hunt without dogs when targeting these large ungulates because the dogs scare away the tapirs before shots can be fired (Kaplan and Kopischke 1992:99). However, several other researchers report that tapirs stop to confront dogs in streambeds, opening opportunities for trailing hunters to attack with lances or firearms (Henry 1964:153; Koster 2006:26; Smith 1976:456; Vickers 1976:98). Alternatively, tapirs can be killed when they flee into nearby rivers (Koster 2006:26; Sponsel 1981:210–11; Yde 1965:121). Tapirs might be the prey species for which the combination of dogs and firearms is most beneficial (Koster 2006; Tobler et al. 2006:355).

Brocket deer can also be killed when they are chased into rivers by dogs (Colchester 1997:123; Heinen 1972:140; Henry 1964:156; Koster 2007:54; see also Kroeber 1942:10). In Central America, white-tailed deer are hunted in similar ways (Koster 2007:54; see also Jorgenson 1993:95; cf. Mandujano and Rico-Gray 1991:178). If not flushed into the river, deer can lead dogs on long, fruitless chases (Flesher 2006; Koster 2007; Lans et al. 2001; cf. Henfrey 2002:217).

Like pacas, nine-banded armadillos forage primarily at night (McBee and Baker 1982), and they are therefore encountered relatively infrequently by hunters without dogs (Cuéllar 2000:116; Koster 2008a; Romanoff 1984:110). Upon being roused by the dogs, armadillos may stay in their burrow or flee to a nearby hole. Hunters dig out the animals, often killing them with machetes (Smith 1976:458; see also Koster 2007).

Some wildlife may seek refuge in trees when pursued by dogs, including coatis and jaguars, but usually hunters must also have projectile weapons to attack such prey (Miller 1930:15; Civrieux 1980:165; Koster 2007:48). Jorgenson (1993:116) notes that coatis are particularly vulnerable to hunters with dogs.

There are relatively few reports of capybara hunts with dogs. Ojasti (1991:239) writes: “In coastal areas, dogs are often used to drive the animals from the thickets to the shore or into water, where they are shot, struck down with a heavy stick, or taken with a harpoon.” Similarly, Arcand (1972:33) indicates that dogs drive these large rodents into the river for waiting hunters.

Reports of anteater hunts with dogs are likewise rare. Tamanduas, which are smaller than most dogs, may be attacked directly (Flesher 2006; Koster 2007:83). Dogs are usually more hesitant to attack the larger giant anteaters, which can lead to standoffs in the forest (Hames 1979:233; Koster 2008c).

Several researchers have mentioned the use of dogs in hunting iguanas, and the females can be especially vulnerable when they come to the riverside to lay eggs, particularly in Central America (Alvarsson 1988:284; Koster 2007:58; Taylor 1951:58; Ventocilla 1992:112; see also Herlihy 1986:225). Dogs may also pursue other reptiles, particularly turtles and tortoises (Balée 1994:57; Barrington Brown 1877:146; Bergman 1980:152; Heinen 1972:140).

Ethnographers have commented that dogs are a hindrance in hunting arboreal prey, particularly game birds and primates (Descola 1994:235; Kaplan and Kopischke 1992:99; Werner 1984:113). The data generally agree with this observation, but a few reports indicate that dogs have served as pointers for monkeys or birds (Gumilla 1791:260; Werner 1984:114; see also Thiollay 2005:1125). In some cases, dogs flush game birds, which alight on branches within range of hunters with projectile weapons (Karsten 1920:42; Koster 2007:55). Also, dogs may successfully pursue monkeys when they are on the ground (Oberg 1953:89; Romanoff 1984:109; see also Kitchen 2004:128).

In addition to the aforementioned species, the list of species that can be hunted with the assistance of dogs includes opossums (Taylor 1951:58), ocelots (Harner 1972:58), rabbits (Greaves 1997), and greater grison (Koster 2007:48). In most cases, dogs assist hunters by bringing the animal to bay or corralling it in a hiding place. However, dogs are occasionally able to kill prey independently, particularly smaller species such as agoutis and armadillos (Arcand 1972:59; Heinen 1972:140; Koster 2007:51; Ohl-Schacherer et al. 2007:1179; see also Kohn 2007:9; Roosevelt 1914:107). Townsend (2000:274) reports that dogs killed about 6% of the animals in her sample. Whereas hunters with projectile weapons seldom waste time on prey items that are not worth the effort, such wasted time may be inevitable when hunting with dogs. Some species, including tayras and the aforementioned deer, lead dogs on long fruitless chases, during which the hunters idly wait for the dogs to return (Koster 2007:89). Dogs may bring to bay animals that are not consumed locally (e.g., anteaters), which the hunters kill so the dogs will resume a general search for prey (Hames 1979:233; Koster 2008c; see also Lourival and Fonseca 1997). Hunters occasionally catch up to the dogs only to find that their quarry has been corralled in a particularly inaccessible burrow or trunk (Koster 2007:87). Alternatively, dogs may "lie" by barking at empty burrows, which hold their attention until hunters arrive to lead them away from the site (Kohn 2007:10; Koster 2007:53). Koster (2008a) has developed an optimal foraging model that incorporates these time costs as an additional constraint.

THE EFFECTIVENESS OF HUNTING DOGS

Inspired in part by Ross's (1978) provocative argument that shotguns were generally inferior to the traditional technologies that they were replacing throughout the Neotropics, a generation of human ecologists used quantitative data to test this

counterintuitive opinion. These researchers compared the efficiency of hunting weaponry by examining the return rates of the different technologies, as measured in kilograms of meat acquired per hour of hunting. These studies showed that shotguns provide better returns than either blowguns or bows, which confirmed that indigenous hunters were not inexplicably exchanging a superior weapon for an inferior one (Hames 1979; Hill and Hawkes 1983; Yost and Kelley 1983; see also Alvard 1995).[4]

Although the comparative effectiveness of hunting dogs has received less attention than hunting with firearms, a few authors have presented quantitative data (Table 2). Among the Matses of Peru, the use of dogs appears to provide higher returns than hunting with only shotguns or bows (Romanoff 1984:117).[5] Among the Guajá of eastern Brazil, Forline (1997:241–43) reports that the combination of dogs and shotguns provides the highest return rate and that the use of dogs in combination with bows or hand technologies also provides higher return rates than hunting with only guns or other weapons. Koster (2008a) also reports that the combination of dogs and guns provides the highest return rate, but the sample is heavily influenced by a few tapir kills, and a nonparametric comparison reveals no significant differences between hunting with dogs, hunting with rifles, and hunting with a combination of the two. A comparison among the Huaorani of Ecuador likewise reveals no significant differences associated with the presence or absence of dogs (Lu 1999:95–97). Although additional data are needed from other sites, hunting dogs therefore appear to rival firearms in their overall effectiveness.

This conclusion might be initially surprising given the previously mentioned costs of hunting with dogs (e.g., pursuits of uncatchable species). Also, whereas hunters with firearms typically dispatch their prey quickly, pursuits of animals in burrows are usually much lengthier, sometimes lasting an hour or more (Alvard and Kaplan 1991:93; Irvine 1987:108; Koster 2008a; Smith 2003:115). However, dogs compensate for these costs by encountering prey items more frequently than hunters working alone. In Nicaragua, for example, hunters with dogs encounter more than eight times as many agoutis as hunters without dogs (Koster 2008a). Nocturnal species such as pacas and armadillos may be encountered rarely by hunters with projectile weapons but flushed routinely by hunting dogs. Thus, while it is true that dogs scare away some animals, they also detect more game than unaided human hunters.

FACTORS AFFECTING RETURN RATES

In any given environment, the return rate of hunting with dogs depends greatly on the population density of prey species. Settings in which there are few animals that can be captured with dogs will result in low return rates, and vice versa. To the extent that differences in densities are associated with different habitats, the relative benefits of hunting with dogs may likewise be associated with habitat variation. For example, with the exception of armadillos, comparatively few animals that can be hunted with dogs are found in the savannas of Venezuela and Colombia, and return rates appear to be correspondingly low (Arcand 1972;

TABLE 2
Overview of quantitative data on hunting dogs in the lowland Neotropics

Group, location, source	Complementary technologies	% of trips with dogs	% of animals taken with assistance of dogs	*N* of dogs used per outing	Quantitative comparisons of technological efficiency
Colonists, Brazil (Smith 1976)	Shotgun, machete	—	34	1–4	—
Guajá, Brazil (Forline 1997)	Shotgun, bow, axe, machete	4.5	—	—	Dogs provide the highest return rate and complement projectile weapons
Huaorani, Ecuador (Lu 1999)	Shotgun, spear, machete	49	16.4†	—	No significant differences associated with the use of dogs
Matses, Peru (Romanoff 1984)	Shotgun, bow, spear, machete	10	—	—	Dogs provide higher returns than hunting with only shotguns or bows
Maya, Mexico (Jorgenson 1993)	Shotgun, rifle, machete	17	22	mean = 3.9	—
Mayangna/Miskito, Nicaragua (Koster 2007)	Rifle, axe, lance, machete	83	66	1–8 mode = 2	No significant differences between hunting with guns, dogs, or in combination

† Detected by hearing dogs bark.

Greaves 1997). In forested habitats, mammalian population densities can vary considerably in várzea (floodplain), alluvial, and terra firme (dryland) forests (Peres 2000), and this variation presumably affects return rates accordingly.

Variation in prey population densities may explain the relative unimportance of dogs to Piro hunters in southeastern Peru. Despite indications that their "ancient dogs" were valuable assets in hunting (Pacaya-García 1972), Piro shotgun hunters brought dogs on only 3% of the hunts in Alvard and Kaplan's (1991:84) sample. By contrast, Machiguenga bow hunters living 90 km away bring dogs on approximately 75% of their trips (Alvard and Kaplan 1991:84). Alvard (1995) does not treat the presence of dogs as an independent variable, but he reports that the return rate of shotgun hunters is at least three times greater than the rate of bow hunters, a significant difference. It therefore appears that dogs do not compare favorably with firearms in this setting, perhaps because of the relative scarcity of agoutis, pacas, and nine-banded armadillos. Koster (2008a) shows that the effectiveness of dogs relative to rifles depends largely on an increased encounter rate with these three fossorial species. In part because of the seasonal inundations in and around Peru's Manú National Park, however, the densities of the aforementioned species in this region are among the lowest reported in the ecological literature (Emmons 1987; Nunez-Iturri 2007; Nunez-Iturri and Howe 2007).

Anthropogenic alterations of Neotropical habitats can also affect wildlife population densities, and dogs may be particularly beneficial in agricultural landscapes. When working in their fields, Neotropical farmers (including women) regularly bring dogs, which roam the fallows and forest edge in search of game. When the dogs' barking indicates that they are pursuing an animal, their owners join the chase (Dufour 1990:656; Koster 2007:58; Lu 1999:72; Paolisso and Sackett 1985:186–87; Smith 2005:512; Steward 2008:144; see also Jackson 1983:52). In addition to being an economical use of time, this strategy also helps to protect fields from crop-raiding species (Harner 1972:63).

Based on faunal remains at the Cerro Brujo site in western Panama, Linares (1976) hypothesized that some terrestrial mammals flourish in anthropogenic habitats, thus providing reliable and convenient hunting opportunities for Neotropical farmers. This "garden hunting" hypothesis has subsequently received intermittent attention, with most studies providing general support for the model (Jorgenson 1993; Naughton-Treves et al. 2003; Smith 2005). Interestingly, the species that dominate the Cerro Brujo sample—agouti, paca, nine-banded armadillo, and collared peccary—are species that can be hunted with dogs. Although these species can also be captured with traps (Smith 2003:124), the use of dogs may facilitate garden hunting to a greater extent than the use of projectile weapons.

That dogs can be used to capture species which adapt well to anthropogenic disturbances appears to be reflected in the geographic patterns of hunting with dogs. Several researchers mention that hunting dogs are usually used near communities but less often in remote areas (Dunn 2004:109–10; Kensinger 1995:14; Paolisso and Sackett 1985:187; Sirén et al. 2004:1327). If hunting zones are similarly profitable regardless of distance from the community, then hunters may remain close to minimize unproductive traveling time. In addition, hunters with dogs may

avoid remote forests to lessen the risk that their dogs will be attacked by jaguars (Dunn 2004:110).

In addition to effects related to habitat variation, the effectiveness of dogs may also vary seasonally. Although there has been relatively little research on the effect of rain on tracks (G. Johnson 2003:34; cf. Pearsall and Verbruggen 1982:26–27), some informants claim that dogs are more effective at tracking in the dry season (Claggett 1998:11; cf. Koster 2007:47). During heavy rainstorms, dogs may be unable to follow tracks (Flesher 2006; Smith 2003:112; see also Roosevelt 1914:106), but perhaps a more important factor is the hunters' inability to hear the barking of their dogs (Koster 2007:46–47). There are few quantitative data on the subject, but nonparametric tests reveal no significant differences between the return rates of hunting trips in the wet and the dry season in Nicaragua (author's unpublished data). Among the Machiguenga of Peru, dogs are relatively less important in the wet season when hunters use projectile weapons to target seasonally fatter primates (Kaplan and Kopischke 1992:99).

Although return rates are undoubtedly affected by aspects of local ecology and climate, it is reasonably clear that much of the variation in hunting success is associated with the skill of the hunters' dogs. Several ethnographers have commented on individual heterogeneity in the effectiveness of hunting dogs (Dufour 1981:164; Howard 2001:247; Sponsel 1981:217; Taylor 1974:24; Yde 1965:120). Crediting the skill of their dogs, Descola (1994:247) writes that only some Achuar hunters routinely catch peccaries. In general, the esteem for dogs depends on the animals that they are capable of capturing, with greater regard given to dogs that successfully pursue large prey species (Descola 1994:233; Howard 2001:255; Smith 2003:117). A number of variables could conceivably influence the effectiveness of a given dog, including breeding, training, age, sex, and health, but there has apparently been no research on this subject in the Neotropical literature.

ACQUISITION, TRAINING, AND TREATMENT OF DOGS

Dogs can be acquired in a variety of ways. Many are purchased or traded, as either adults or juveniles. Adult dogs with a reputation for hunting preferred prey species may command a significant price, including shotguns, canoes, axes, machetes, or relatively large sums of cash (Descola 1994:230; Howard 2001:248–49; Koshear 1995:93; Koster 2007:44; Rivière 1969:54; see also Schomburgk 1922:344). In some cases, dogs are traded through relatively elaborate exchange networks, and groups like the Waiwai in Guyana have developed reputations as sources of good dogs (Arcand 1972:60; Butt Colson 1973:52–53; Howard 2001:248; Hurault 1968:6; Rivière 1969:53; Yde 1965:120; Zent 1999:55). Although dogs are traded or gifted locally, a sizeable percentage of dogs appears to be imported from unforested areas (Wassén 1935:88; Fiorello et al. 2006:766; Kohn 2007:11; see also Smith 2003:117).

Although owners may attempt to breed their females with talented males (Arcand 1972:60; Koster 2007:44; cf. Roosevelt 1914:151), managed breeding is seldom a priority. As a result, most dogs are considered mutts, often described

as short-haired, small to medium-sized dogs (Kohn 2007:11; Lauer 2005:281; Nimuendajú 1946:75; Oberg 1949:12; Snethlage 1917:49; Wagley 1977:60; Yde 1965:117). Indigenous societies seem to be impressed with the size and presumed hunting abilities of the purebred dogs that they encounter on occasion (Descola 1994:231; Good and Chanoff 1991:316; see also Carneiro da Cunha and de Almeida 2000:15).

The training of dogs in the Neotropics seldom conforms to Western norms, as dogs rarely receive positive or negative reinforcement for specific behaviors or responses to commands (Lu 1999:75; Metzger and Morey 1983:144; Smole 1976:180). More commonly, adolescent dogs are brought on hunting outings with experienced dogs in the hope that they will learn by imitation (Descola 1994:233; Howard 2001:247; Koster 2007:44; see also St. Clair 1834:316). There are indications that dogs in the Guyana region are trained to hunt specific kinds of prey (Henfrey 2002:100; Roth 1970:174), but this may reflect the dogs' intrinsic tendencies, not intentional training by the hunters (Farabee 1967:51; see also Taylor 1974:24). Immediately following a kill, dogs may be coated with the animal's blood (Karsten 1920:50), rubbed with its stomach contents (Smith 1976:456; Zent 1999:237), or given a piece of the animal's meat (Koster 2007:51; St. Clair 1834:317), but such practices are by no means universal (e.g., Henry 1964:86). In the community, dogs may be deliberately exposed to the flesh or hair of the animal that they should pursue on subsequent hunting trips (Dreyfus 1963:29; Kahn 1931:81–82; Karsten 1920:40; Kohn 2007:8; Métraux 1946:451).

Hunters in the Neotropics employ a broad variety of magic, rituals, and charms to enhance their hunting success (e.g., Carneiro 1974), so it is not surprising that similar methods are used on dogs to promote better performance. Many hunters prepare mixtures of plants and other materials, which are administered to the mouth, nose, or skin of their dogs (Alexiades 1999:252; Carneiro 1974:131; Henry 1964:85–86; Karsten 1920:46–50; Jackson 1983:47; Lans et al. 2001; Metzger and Morey 1983:144; Ruddle 1970:59; Yde 1965:120; Zent 1999:237). Occasionally, some of the ingredients are hallucinogenic (Bianchi 1988:43; Kohn 2007:9); others are meant to mimic the appearance or smell of prey species (Balée 1994:105; Vickers 1976:119). Incantations and songs are also used to enhance the effectiveness of dogs (Brown 1984:552; Descola 1994:232–34; Smole 1976:180). Other methods seem torturous, such as the placement of hot axes on the dog's chest (Balée 1994:145), docking the tails of ineffective dogs (Carneiro 1974:131), or subjecting dogs to the bites and stings of ants or wasps (Farabee 1967:51; Holt et al. 2004:73; Yde 1965:120). There are also numerous remedies for injured or sick dogs (Descola 1994:232; Lans et al. 2001; Werner 1984:115).

Although researchers may take for granted the presence of dogs (Civrieux 1980), their poor condition rarely escapes notice, as numerous ethnographers have mentioned the meager rations given to dogs (e.g., Jackson 1983:41). Many dogs survive by scavenging for refuse and food scraps (Dumont and Hurlich 1981:23; Gregor 1977:97–99; Kracke 1981:138; Petrullo 1939:172). In some settings, dogs appear to consume human excrement on a regular basis (Bergman 1980:152; Dreyfus 1963:29; Myers 1946:21; Werner 1984:103). In other settings, however, dogs receive foods prepared for household consumption, including

vegetable products such as manioc (Descola 1994:231; Howard 2001:243; Koster 2007:44; Nimuendajú 1946:75). Puppies are sometimes fed milk from cows (Koster 2007:44) or human breast milk (Alexiades 1999:157; Descola 1994:231; Roth 1970:551; Wilbert 1972:97).

Although dogs may be subject to taboos that differ from those of their owners (Descola 1994:232), they also receive foods that are not consumed by humans, such as the meat of tabooed species (Descola 1994:233; Sponsel 1981:192), the fetuses of captured prey (Forline 1997:246; Sponsel 1981:263), or the intestines of harvested animals (Montiel Ortega et al. 1999:47). Although Lyon (1970) reports that Wachipaeri dogs in Peru consume virtually all small bones, some groups prevent their dogs from eating bones of certain game species (Karsten 1920:42,50; Métraux 1946:451; Wafer 1934:70). Dogs may be kept hungry, ostensibly to improve their motivation and effectiveness (Crocker 1990:97; Descola 1994:231; Holt et al. 2004:47; Metzger and Morey 1983:144; Wilbert 1972:97; see also Santa Teresa 1959:144). There is abundant evidence that good hunting dogs receive better care than their less-talented peers (Crocker 1985:32; Heinen 1972:140; Im Thurn 1967:232; Koster 2007:128; McSweeney 2000:66; Rivière 1969:41; Sponsel 1981:218).

In addition to their use as hunting companions, dogs also fulfill other roles in the Neotropics. As in other regions, they are frequently given personal names and treated as pets, especially as puppies (Bennett 1962:39; Carneiro n.d.; Koster 2007:129; Yde 1965:119).[6] On excursions away from the community, dogs may provide a buffer against jaguars, which preferentially attack dogs instead of humans (Sponsel 1981:195–96; see also Barrington Brown 1877:53). Finally, there are numerous references to their use as watchdogs (Coimbra et al. 2002; Howard 2001:242; Kloos 1971:59; Wilbert 1972:96; Whitten 1976:68; Yde 1965:119–20; see also Smole 1976:179). The value of this latter service should not be overlooked given the prevalence of intergroup raiding in the Neotropics prior to pacification by national governments (Métraux 1949; see especially Harner 1972:63).

Compared with other regions in the prehistoric Americas (Schwartz 1997), including among the Preclassic Maya (Clutton-Brock and Hammond 1994), there is little evidence for the consumption of dogs by ethnographically known societies in the Neotropics south of Mesoamerica (Dumont and Hurlich 1981:21; Henfrey 2002:121; Taylor 1981:27; Thomas 1983:320; for an exception, see Morey and Morey 1980:262).

DEMOGRAPHIC PATTERNS

Numerous animals, including several species that can be hunted with dogs, are capable of severely wounding the dogs (Table 3). Jaguars are particularly dangerous because they ambush dogs in the forest (Brett 1868:220–21; Siemel and O'Brien 1965:107–8; see also Schomburgk 1837:333). Other feline predators may also attack dogs, probably in self-defense on some occasions. Peccaries attack dogs in self-defense, and their sharp canines can fatally wound dogs (Banner 1961:13; Coimbra et al. 2002:173; Wagley 1977:61–62; see also Werner 1984:115). The

sharp teeth of coatis can likewise prove fatal for dogs, as can the formidable claws of giant anteaters (Bianchi 1988:43; Carneiro n.d.). Porcupine quills might not be lethal at first, but subsequent infections can prove fatal (Flesher 2006). Numerous snake species can inflict fatal wounds, including the bushmaster (*Lachesis* spp.) and the fer-de-lance (*Bothrops atrox*). The increased risk of snakebites at night may discourage nocturnal hunting with dogs (Claggett 1998:13). Finally, whereas scorpion stings can be deadly, the primary risk associated with fire ants seems to be blindness or impaired vision (Moser and Taylor 1963:446; Jackson 1983:48). Dogs may be kept tied up in the community in part to protect them from hazards in the forest (Karsten 1920:50–51).

TABLE 3
Species capable of killing dogs or injuring them sufficiently so they are no longer useful as hunting companions

Common name	Scientific name	Sources
Jaguar	*Panthera onca*	Flesher 2006; Husson 1978; Koster 2007
Puma	*Puma concolor*	André 1904; Bell 1989; Flesher 2006
Ocelot	*Leopardus pardalis*	Husson 1978
Giant anteater	*Myrmecophaga tridactyla*	Bates 1962; Roosevelt 1914; Taylor 1974
Dwarf porcupine	*Coendou insidiosus*	Flesher 2006
Coati	*Nasua* spp.	Flesher 2006; Taylor 1974
Tapir	*Tapirus* spp.	Smith 1976
White-lipped peccary	*Tayassu pecari*	Smith 1976; Wagley 1977
Collared peccary	*Tayassu tajacu*	Koster 2007; Smith 2003
Snakes	Multiple species	Koster 2007; Lans et al. 2001
Ants	Unspecified	Jackson 1983; Moser and Taylor 1963
Scorpion	Unspecified	Lans et al. 2001

In addition to being attacked by other animals, dogs can die from a variety of causes, such as random accidents and hunting injuries (Alexiades 1999:130; Koster 2007:128; Ventocilla 1992:97). Various diseases and mange are also problematic and undoubtedly exacerbated by malnutrition (Fiorello et al. 2006; Lans et al. 2001). Malnutrition also appears to explain the low survivorship of puppies (Balée 1994:57; Kohn 2007:11; Smole 1976:180; Yu 1997:166).

There are few quantitative data on the demographics of dog populations in the Neotropics. The research of Fiorello et al. (2006) in Bolivia provides the most comprehensive dataset. They report that the average age of dogs is 3.5 years and the annual mortality of adult dogs is 34% (Fiorello et al. 2006:766). The average litter size is 4.2, but 73% of puppies die as neonates, primarily for medical reasons (Fiorello et al. 2006:766). Koster (2008a) reports an annual mortality rate of 49% for adult dogs, and approximately half of the puppies die as neonates. Yu (1997:166) indicates that almost no puppies survive to adulthood in the Venezuelan savanna.

HYPOTHESES FOR THE ABSENCE OF DOGS IN PREHISTORIC AMAZONIA

Two hypotheses for the absence of dogs in prehistoric Amazonia merit attention: (1) Neotropical societies deliberately declined to adopt dogs when presented with opportunities, and (2) other factors prevented the dispersal and acquisition of dogs. These alternatives are not necessarily mutually exclusive, and it is likely that the circumstances surrounding the acquisition of dogs varied throughout the region, both before and during the historical period. Nevertheless, the desirability of dogs from an indigenous perspective is a key question.

Given the evidence that hunters with dogs can enjoy return rates that compare favorably with those of hunters with firearms, the first hypothesis—that Neotropical hunters intentionally rejected dogs—may be somewhat tenuous. However, the available quantitative evidence is limited, and the aforementioned research from the Peruvian floodplains suggests that dogs may be comparatively ineffective in such habitats (Alvard 1995). Three potentially important variables must be considered. First, as noted previously, contemporary dogs are almost invariably descended from European dogs (Leonard et al. 2002). Although it is plausible that the indigenous dogs did not differ significantly from their European replacements in terms of hunting skill, the reportedly smaller size of pre-European dogs makes this a worthwhile research question. Second, hunters in precontact Amazonia lacked steel tools, notably machetes and axes (Carneiro 1979). Given the importance of these tools to pursuits of animals in hollow trunks (e.g., agoutis), the effect that their absence would have had on return rates is an open question.

Third, given that hunting with dogs requires qualitatively different strategies than hunting with projectile weapons, perhaps the benefits of hunting dogs were not immediately apparent. By comparison, the switch from bows and blowguns to shotguns and rifles may have been relatively seamless as hunters recognized the greater range and stopping power of firearms once they had successfully spotted and stalked a prey item—an aspect of hunting with which they were already familiar. In contrast, hunting with dogs requires an understanding of the ways in which prey species will react to dogs, interpretation of the dogs' barking, occasionally frenetic charges through the underbrush, and strategies to kill animals once they have been chased into the river or corralled in burrows or trunks. Given the learning curve and the dogs' tendency to scare away arboreal targets, an initial reluctance to rely on hunting dogs is understandable. Interestingly, whereas Århem (1976:34) writes that the Makuna rarely used their dogs for hunting, he later writes that dogs had become the preferred technology for hunting peccaries (Århem 1998:109). Similarly, whereas the Sirionó did not appreciate the value of a dog introduced by Holmberg (1969:272–73), dogs had become regular companions of Sirionó hunters by the 1990s (Townsend 1995). There seems to be a lag between the first introduction of dogs to a society and their widespread use in hunting.

Other factors may have discouraged societies from acquiring and keeping dogs. First, some groups were initially frightened by dogs, in large part because they attacked members of the community (Holmberg 1969:272–73; Rival 2002:77; see also Steinen 1942:189–90). Also, dogs may attack and kill other domestic

animals (Crocker 1985:33; Henley 1982:47; Koster 2007:128) or otherwise steal food (Holmberg 1969:273; see also Werner 1984:140). These aggressive and mischievous tendencies can lead to disputes within the community (Rivière 1969:176; Werner 1984:233). When combined with doubts about the value of dogs in hunting, these undesirable behaviors could have dissuaded some groups from keeping dogs.

In contrast, anecdotal evidence suggests that dog populations may have been extirpated by "environmental hazards" among groups that were strongly motivated to acquire and keep dogs (A. Johnson 2003:196). Raimondi (1867:131) suggests that dog populations persist in the foothills of the Peruvian Cordillera Oriental because there are no "jaguars and other beasts of prey," which regularly kill dogs in lowland forests. These observations therefore support the alternative hypothesis that the high mortality of dogs in Neotropical environments hindered their diffusion into Amazonia. This view accords well with the geographic distribution of dogs in the prehistoric Neotropics. That is, dogs were found among "groups on the margins of the vast rainforest" (Schwartz 1997:40), perhaps because those societies lived near locales where they could continually acquire new dogs to replace those that they lost. In support of this hypothesis, it is noteworthy that dogs were often acquired from the highlands during the historic period (Belt 1911:159; Borja 1965:248; Oberem 1980:193; see also Salomon 1986:82). Perhaps these dogs were needed to replenish declining populations in the lowlands.

This hypothesis also helps to explain why some societies did not acquire dogs until the twentieth century. On the one hand, Kaplan and Kopischke (1992:99) speculate that, because they can reproduce, dogs of European origin would have spread quickly via the same postcontact trade networks that provided steel tools. However, the inverse is also true, and the high mortality of dogs along those trading routes might have prevented their spread into the forest until other sources emerged. For example, some societies acquired their first dogs from mestizo or cabloco settlers (Nimuendajú 1967:94) or government agencies (Forline 1997:122).

DISCUSSION

The impressive subsistence adaptations of indigenous societies in Neotropical ecosystems have been well-documented (Sponsel 1986), and it is unlikely that prehistoric peoples would have kept dogs if the costs were too great. However, as seen in Smith's (1991) examination of the Inuit transition from sled dogs to snowmobiles, an integrated cost-benefit analysis of technological change is often problematic and contingent on numerous assumptions. Studying the incorporation of dogs into Neotropical societies is similarly difficult because dogs entail a wide variety of costs and benefits (Figure 2), many of which cannot easily be converted into a common economic measure. Nevertheless, it is clear that the costs and benefits and, by extension, the net value of dogs exhibit variation throughout the region, both in contemporary and prehistoric settings. Depending on the availability and effectiveness of alternative hunting accessories, the relative benefits of hunting dogs would likewise vary accordingly.

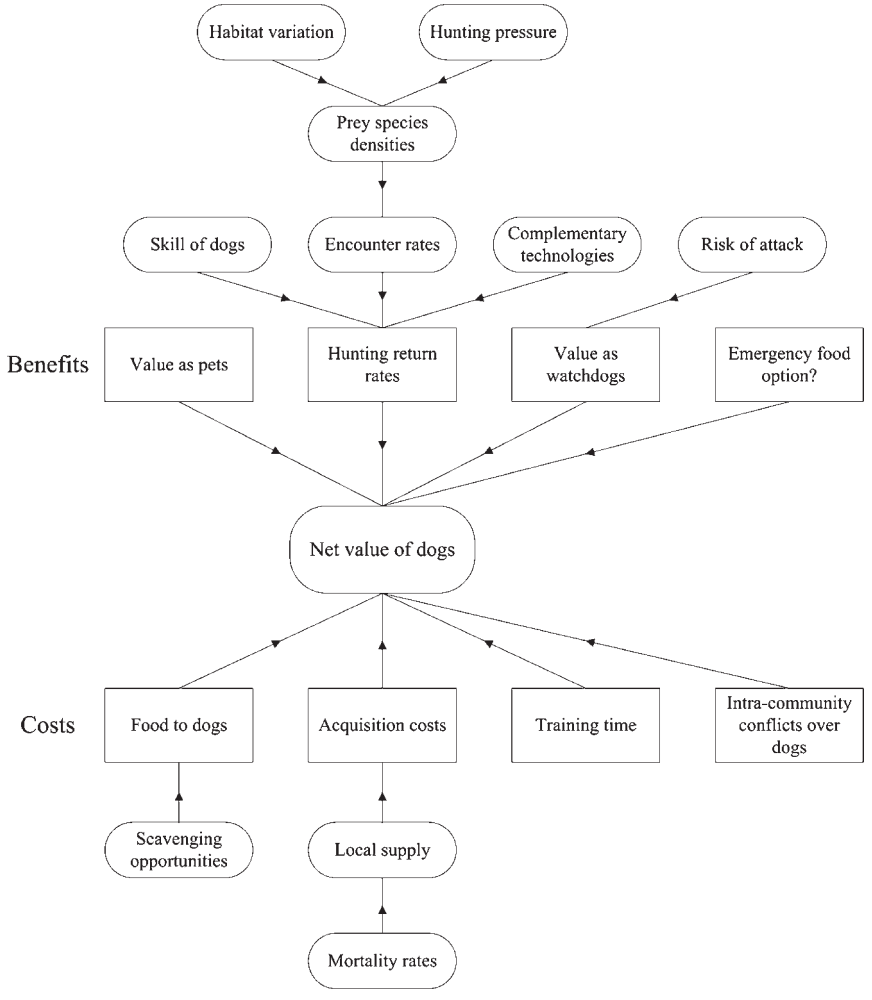

Figure 2. Costs and benefits of dogs and proximate variables affecting the overall net value.

Of the variables shown in Figure 2, perhaps the hardest to quantify is the emotional value of dogs as pets. Indigenous Amazonian societies have habitually tamed a wide variety of wildlife species for no apparent reasons other than companionship and entertainment (Erickson 2000). Perhaps despite some initial fear or skepticism, Neotropical peoples would likely have eventually been eager to acquire dogs as pets, much like the Matis in northwestern Brazil requested dogs from FUNAI contact teams (Anonymous 1978). Given the cross-cultural ubiquity and appeal of dogs as pets, maybe it is unnecessary to discern a clear economic benefit of keeping dogs. Nevertheless, in addition to their value as pets, dogs almost certainly provide enough benefits as watchdogs or companions to at least some hunters (including women and elderly men) that they would be kept unless the costs of acquiring and maintaining dogs were truly impractical. Accordingly,

current evidence suggests that the high mortality of dog populations in the lowland Neotropics prevented the dispersal of dogs into prehistoric Amazonia.

The absence of dogs in Amazonia remains an interesting ethnological problem, and the ethnographic record provides valuable perspectives on the benefits and challenges of keeping dogs. However, quantitative studies remain relatively rare, and one goal of this paper is to highlight the need for additional research on the use of hunting dogs in the Neotropics (Table 4). Compared with hunting with only projectile weapons, use of hunting dogs clearly affects both the rates at which prey are encountered and subsequent pursuit strategies, which in turn impact return rates. To assess how hunting with dogs compares with the use of other technologies, it is therefore important to treat the presence of dogs as an independent variable affecting the outcome of a hunt. In addition, additional data on the demographics of dog populations would be beneficial—particularly how mortality rates vary in relation to diet, care, and other risk factors.

There are limitations to the inferences that can be drawn from ethnographic data, however, and reconstructing the process by which dogs of European ancestry spread throughout the Neotropics will require input from archaeologists and historians. In particular, there are historical references to the exchange of dogs (e.g., Barrere 1743:154), and it might be possible to elucidate the trade networks through which they passed.

TABLE 4
An agenda for research on hunting dogs in the lowland Neotropics

1. How do return rates vary across habitats, seasonally, and in combination with other hunting accessories? How does the use of dogs impact the species composition of the harvest? Human ecologists can use focal observations and hunting questionnaires to assess variability in return rates and harvests.
2. To what extent is there individual heterogeneity in the effectiveness of hunting dogs? What variables (e.g., sex, age, size, training, health, ancestry, etc.) are associated with heterogeneity? In addition to observational data and questionnaires, reports from hunters may reliably indicate the effectiveness of individual dogs.
3. How does the economic importance and status of dogs vary with subsistence strategies, such as the varying forms of foraging and horticulture? Comprehensive ethnographic and archaeological reports, including nutritional research, can inform ethnological studies of the roles that dogs play in different ecological settings.
4. What factors affect the birth and mortality rates of dogs in Neotropical settings? Are populations self-sustaining without immigration? How are dogs acquired? Models used by anthropological demographers could be adapted for research on dog populations.
5. What was the precontact distribution of dogs? Complemented by archaeological data, linguistic research on the terms for dogs can produce a map of their distribution in the prehistoric Neotropics.
6. How and when did dogs disperse throughout Amazonia? How did societies learn to care for dogs and use them for hunting? Historical references can be used to reconstruct trade networks, and ethnohistorical research among societies that recently acquired dogs could provide valuable insight into the ways in which dogs are incorporated into subsistence practices.

CONCLUSION

Dogs can be effectively employed in pursuits of several common Neotropical game species, and hunting with dogs is now common throughout lowland Latin America. The return rates of hunters with dogs generally compare favorably with those of hunters with firearms, which helps to explain the persistence of hunting dogs even in settings where rifles and shotguns are widely used. In the future, the increasing fragmentation of Neotropical forests may lead to a greater reliance on hunting dogs relative to firearms. Some of the species that are frequently pursued by hunters with firearms but rarely with dogs, such as white-lipped peccaries and primates, are highly sensitive to anthropogenic disturbances (Daily et al. 2003). By contrast, species like agoutis, pacas, nine-banded armadillos, and collared peccaries are relatively tolerant of anthropogenic habitats (Daily et al. 2003; Naughton-Treves et al. 2003). Furthermore, the high reproductive rates of these species make them comparatively less vulnerable to overhunting (Bodmer et al. 1997). If fragmented forests become progressively dominated by these adaptable species, hunting with dogs may be increasingly preferred over firearms. Given the possible implications for the sustainability of wildlife harvests, the complex relationships between prey population densities, habitat modification, and the use of different hunting technologies therefore merit increased attention from conservationists (Koster 2008b).

From an anthropological perspective, the use of hunting dogs in the lowland Neotropics remains an understudied topic. On the one hand, there are numerous brief reports about the use and treatment of dogs, which permits generalizations to be made in this review. On the other hand, dogs have rarely been the subject of systematic ethnographic investigations, which are needed to resolve interesting ethnological questions pertaining to cross-cultural variability in the training, care, and relative economic importance of dogs. In addition to providing ethnoarchaeological perspectives on the use of hunting dogs among the prehistoric societies that kept them, such research could also be used to test hypotheses regarding the recent absence of dogs in much of Amazonia. More generally, additional research will contribute to the understanding of worldwide diversity in relationships between humans and the world's first domesticated animal.

NOTES

Portions of this research were funded by a Fulbright student grant, the National Science Foundation (Dissertation Improvement Award #0413037), the Hill Foundation, and a Sanders Dissertation Grant. Three anonymous reviewers provided insightful comments on an earlier draft of this manuscript. Although the list is too lengthy to reproduce here, I would also like to thank the many researchers who recommended sources and shared their opinions on dogs in the Neotropics. Finally, I am especially grateful for the resourceful, diligent staff members in the interlibrary loan departments at Penn State University and the University of Cincinnati.

1. For the 11 species that appear in Koster's (2008b) sample, there is a significant correlation between the number of times that those prey types are mentioned in ethnographic reports and the number of specimens that were harvested with the assistance of dogs in the

Nicaragua sample (Pearson's $r = 0.736$; $p = 0.01$; $n = 11$). By contrast, there appears to be no relationship between the number of ethnographic mentions and the percentage of specimens that were hunted with the help of dogs (Pearson's $r = 0.118$; $p = 0.73$; $n = 11$). These results suggest that ethnographers may take notice of frequently-hunted game species while rarer species that are particularly associated with the use of dogs may be underrepresented in ethnographic reports.

2. Biologists sometimes use dogs to locate many of these same species, including agoutis (Silvius and Fragoso 2003:75), pacas (Collett 1981:513–14), collared peccaries (Arambiza and Guerrero 2000:110; Fragoso 1994:126–27), tapirs (Hernandez-Divers and Foerster 2001), and jaguars (McBride and McBride 2007; Soisalo and Cavalcanti 2006:489).

3. Where they coexist, collared peccaries frequently hide in the burrows of giant armadillos (Fragoso 1999:996; Miller 1930:18).

4. The highest return rate in the Yost and Kelley (1983) sample is provided by spears. Given their comment that dogs "bring some of the largest protein packages in the forest into the range of the spear" (Yost and Kelley 1983:206), it is regrettable that they examine only the technologies carried by the hunters and not the presence of dogs as an independent variable. In their harvest data, virtually all of the animals that were killed with spears can be hunted with dogs, including collared peccaries, white-lipped peccaries, pacas, capybaras, tapirs, and agoutis.

5. Romanoff (1984) reports his data in terms of kilograms per hunt, which makes comparisons problematic given that hunting trips vary in length.

6. Indigenous folklore in the lowland Neotropics includes numerous references to dogs (Villar 2005; Wilbert 1970, 1974; Wilbert and Simoneau 1979, 1982).

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