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## Patterns of Indigenous Resilience in the Amazon: A Case Study of Huaorani Hunting in Ecuador

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## ARTICLES

## Patterns of Indigenous Resilience in the Amazon: A Case Study of Huaorani Hunting in Ecuador



FLORA LU

### ABSTRACT

*This paper takes a resilience approach to examining human forager-prey dynamics using as a case study Huaorani hunting in the Ecuadorian Amazon. I compare methodologically similar datasets collected in the same Huaorani villages in 1996-1997 and 2001. Rather than assuming that human hunters simply act on prey species and linearly drive them to depletion, a resilience approach views this dynamic as a complex social and ecological system characterized by feedbacks, nonlinearities, uncertainty, unpredictability, and non-equilibrium dynamics. Using a computer simulation of human foragers and prey (published previously), I highlight how even using relatively simple assumptions, the human forager-prey relationship exhibits patterns of nonlinearity and feedbacks. I then address one key aspect of a resilience approach: the focus on issues of scale. I note the surprising persistence of primates and cracid birds in the Huaorani harvest—both prey types vulnerable to overexploitation especially by hunters with a relatively long settlement history and use of firearms. I assert that this finding reflects a source-sink dynamic that stems from a distinct Huaorani social history and requires larger spatial scales of analyses to evaluate hunting sustainability. The literature on indigenous neotropical hunting and conservation could benefit greatly from a resilience framework recognizing that human hunter-faunal prey dynamics in the Amazon are complex and require multifaceted and interdisciplinary approaches that are cross-scale and take into account the socio-cultural and political as well as the ecological context.*

### INTRODUCTION

The Huaorani, an indigenous group in Ecuador, are cited as a glaring example of the impact native hunters can have on game populations. For instance, Redford and Robinson (1991:7-8) write, "The numbers of animals taken by subsistence hunters can be very large. Over a period of less than a year the inhabitants of three Waorani villages in Ecuador killed 3,165 mammals, birds, and reptiles...Certainly not all groups hunt at this intensity." This type of faunal exploitation has caused tremendous concern and debate in the conservation literature (e.g., *Conservation Biology* 2000), as various scientists have

asserted that indigenous hunters can contribute to overexploitation of game (e.g., Bodmer et al. 1997; Redford and Robinson 1985, 1987; Redford 1990, 1992; Redford and Stearman 1993; Terborgh 2000). In contrast, Schwartzman et al. (2000:1352) question the presumption that human hunters in tropical forests inevitably deplete populations of large animals. Instead, these authors state that hard evidence of this process is sparse, and that they are "unaware of rigorously documented cases of local extinction, or severe depletion of large animals—or any other species—in indigenous or extractive reserves."

The controversy around indigenous Amazonian hunting and over-harvesting of game has been largely focused on studies which were in essence “snapshots” in time of a certain human population in a certain area for a few years (e.g., Jorgenson 2000; Townsend 2000; but see Hill and Padwe 2000 and Peres 2000 for examples of longer-term studies), for which data are collected on variables such as harvest rates (or catch-per-unit-effort, Puertas and Bodmer 2004), game biomass and density, age structure, and intrinsic rate of natural increase. Such studies are concerned with certain aspects of hunter behavior, such as prey choice (Alvard 1993, 1995) and the taking of individuals of high reproductive value, use of certain technologies (Hames 1979; Kaplan and Kopischke 1992; Yost and Kelley 1983), time allocation (Hames 1989), and hunting in depleted zones (Hames 1980). It appears that a typical assumption of these approaches is that the human-faunal dynamic is linear, one in which human hunting pressure is one of the main factors controlling prey population dynamics, though mediated by parameters of prey life history. In other words, game availability is posited as an inverse function of human density, especially for large terrestrial animals (Vickers 1988). Furthermore, the assumption is that we can use approaches such as stock recruitment, age structure, and unified harvest models (Bodmer and Robinson 2004) to evaluate the sustainability of neotropical hunting.

An alternative approach characterizes these social and ecological systems as complex, nonlinear, adaptive<sup>1</sup> and closely interconnected. In particular, a resilience framework can be a productive approach to understanding hunter and prey dynamics within a larger socio-political and ecological context. But what is the evidence that such a framework would be applicable to an indigenous Amazonian hunting context, and what would be the value added? In this paper, my goals are three-fold: first, to review key concepts and definitions within a resilience framework. Second, using a computer simulation model of human forager-prey dynamics, I provide evidence for the complexity of these relationships and support for the applicability of a resilience approach, as a system with few components and relatively simple rules

exhibits, feedbacks, oscillations and non-linearities. Finally, through examining hunting patterns of two Huaorani communities in the Ecuadorian Amazon, I show how attention to issues of scale can illuminate one potential source of faunal resilience in this social and ecological system: source-sink dynamics.

Some caveats and clarifications are in order. I am not setting out specific hypotheses leading from a resilience framework per se (which at this stage is premature as I did not collect data with this issue in mind). Also, the application of resilience theory to anthropological studies is an emerging but relatively recent endeavor (Berkes and Folke 1998; Berkes et al. 2003), and no one, to my knowledge, has done so with indigenous Amazonian hunting (although Begossi 1998 has examined **caboclo** management in Amazonian Brazil).

## RESILIENCE IN COMPLEX SOCIO-ECOLOGICAL SYSTEMS

Holling et al. (2000) characterize two streams of science relevant to understanding issues of conservation and resource management. The first called a “science of the parts,” exemplified by the maximum sustainable yield concept from stock recruitment models which treats resource stocks as discrete elements in time and space, makes predictions about them in isolation from other elements in the ecosystem, and tries to limit the effects of natural variability. At the risk of presenting a straw man, the science of the parts generates unambiguous data, but does so at the cost of being fragmentary. This existing science appears to have contributed to a crisis of resource management as it seems unable to prescribe sustainable outcomes or explain resource collapses.

The other stream is characterized as a “science of the integration of the parts” in which the coupled natural and human system is recognized for being highly complex, unpredictable, non-linear, cross-scale, evolutionary, and characterized by feedbacks and surprise (Holling et al. 2000). Holling (1973) defined two distinct properties characterizing eco-

logical systems: resilience and stability. Resilience “determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist...Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance” (Holling 1973:17). So systems can be very resilient and still fluctuate greatly (i.e., have low stability). Resilient natural systems with high species diversity and spatial patchiness, for instance, may have more than one domain of attraction and may move between them.

The concept of resilience, further discussed below, is especially applicable to social and ecological systems which can be characterized as complex adaptive systems. Complex patterns can arise from disorder through simple but powerful rules that guide change (Folke 2006). These systems possess certain properties, such as the sustained diversity and individuality of components and an autonomous selection process that chooses from among these components. The former is the source of perpetual novelty, and the latter results in continual adaptation and the emergence of a cross-level organizational structure. Moreover, the local rules of interaction change as the system evolves, demonstrating what is called path dependency. There is an absence of a global controller of the system, and the dynamics are far from a state of equilibrium (i.e., a globally stable system with one basin of attraction); the system instead possesses multiple basins of attraction where feedbacks and thresholds are important and the potential exists for surprise (i.e., shifts from one basin of attraction to another).

## **RESILIENCE**

In a review of the concept of resilience, Gallopin (2006) stresses that resilience has many definitions. Holling's (1973) definition emphasized the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations and state variables. From Walker et al. (2004), the state space is the three-di-

mensional space defined by the state variables that constitute the system and all combinations thereof. The basin or domain of attraction is the region in a state space where the system tends to remain. For systems that tend toward equilibrium, the equilibrium state is defined as an attractor, and the basin of attraction constitutes all initial conditions that tend toward the equilibrium state. But all sorts of disturbances and stochasticities and human decisions tend to move the system off the attractor. If the system's state tends to stay within the boundaries of the domain, the system is resilient (note that this does not assume stability or constancy within the basin). This is what Holling called ecological resilience, and it can be measured by the magnitude of the perturbation that can be absorbed before the state of the system falls outside the domain of attraction.

In extrapolating the concept of ecological resilience to social as well as social and ecological systems, Adger (2000) defines social resilience as the ability of groups to cope with external stresses and disturbances as a result of social, political, and environmental change. Social resilience emphasizes the degree to which the system can build and increase the capacity for learning and adaptation, so that not only is there persistence in the face of change, but innovation and transformation into more desirable configurations (Folke 2006). Thus, the resilience concept, broadly stated, is the capacity of the system to absorb disturbance, withstand shocks, and re-organize so as to still retain essentially the same function, structure, identity and feedbacks.

## **SCALE**

Of the many attributes of complex, adaptive systems and resilience framework, I want to focus on just one of relevance for the discussion to follow: scale. In ecology, scale refers to the spatial and temporal dimensions of a pattern or process; it has two main attributes, grain (the resolution of observations) and extent (the total area or time period under consideration). In the social sciences, scale includes the social structures from individuals to organizations as well

as the social institutions (e.g., rules, laws, policies, and formal and informal norms) that govern the spatial and temporal extent of resource access rights and management responsibilities (Cumming et al. 2006). According to Nelson et al. (2007), different types of scale are important for understanding resilience: (1) length and frequency of perturbations; (2) spatial scale at which perturbations occur; and (3) the organizational scale of focus (i.e., the boundaries of social-ecological systems and the horizontal and vertical linkages used to capture and mobilize resources).

## STUDY POPULATION

The Huaorani, a group of hunter-gatherer-horticulturalists, were contacted peacefully for the first time by Protestant missionaries of the Summer Institute of Linguistics in 1958 (some Huaorani sub-groups still have not been peacefully contacted, and fiercely resist intrusions of outsiders as well as other Huaorani groups). At the time of this contact there were four groups of Huaorani totaling about 500 people (Yost 1981), while Yost's most recent census puts the current number at slightly over 1700 people, spread among approximately two dozen villages in the Napo, Orellana, and Pastaza Provinces of the Ecuadorian Amazon. Beckerman et al. (2009) estimate the present day Huaorani population at approximately 2,000 people. It is likely that instead of two dozen villages, it is greater than double that now. Their language, *huao tededo*, is a linguistic isolate, and their reputation for warfare and spearing raids allowed them to occupy and claim a large pre-contact territory of approximately 20,000 km<sup>2</sup> bordered on the north by the Napo River and on the south by the Curaray and Villano Rivers. In the 1960s their territory was reduced to about 1600 km<sup>2</sup>, but in 1990, the Huaorani were granted the largest indigenous territory in Ecuador (679,130 ha) adjoining Yasuní National Park (Rival 2002). As in pre-contact days, their economy is based on hunting, swidden horticulture, gathering, and fishing. They derive most of their carbohydrates from domestic crops such as sweet manioc, plantains, corn, sweet potatoes, peanuts,

and peach palm (*Bactris gasipaes*) during the first part of the year. Hunted game and fish are the main sources of valued protein. For further description of Huaorani livelihood, resource use, and socio-cultural organization, please see Lu (1999, 2001, 2006), Lu et al. (2010), and Holt (2005).

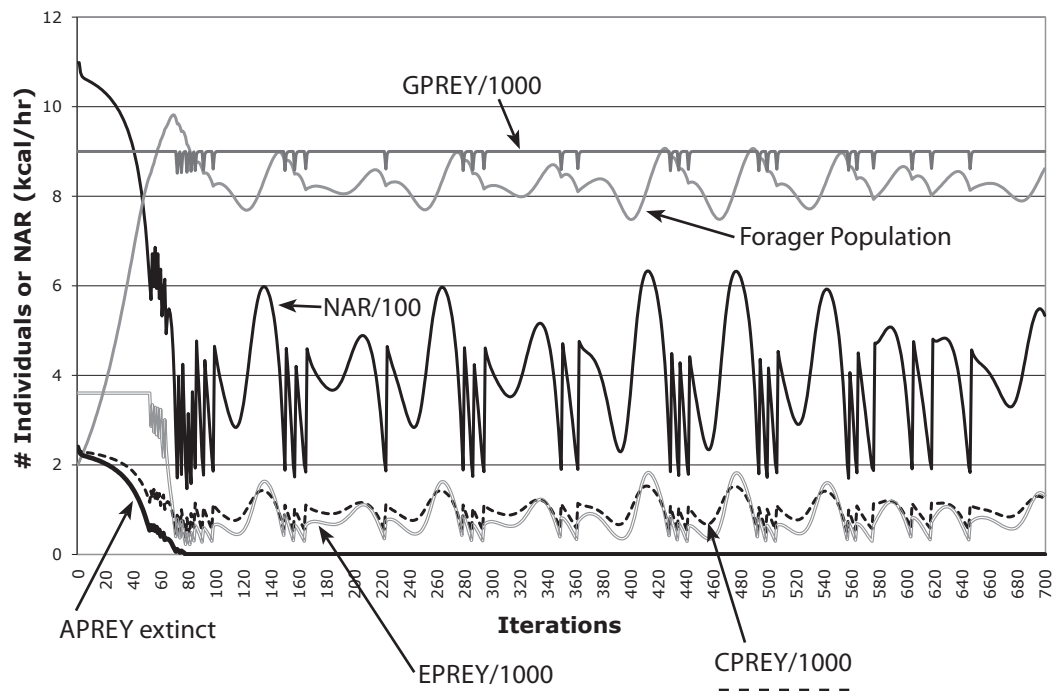
## SIMULATION RESULTS AND DISCUSSION

To examine Huaorani hunting as a complex social and ecological system through a resilience framework, I draw upon simulation modeling of human forager-prey dynamics, empirical hunting data, ecological theory, and ethnographic data. This model was previously published (Winterhalder and Lu 1997), but its application to the topic of resilience is new.

### *HUAORANI FORAGER-PREY DYNAMICS AS COMPLEX SYSTEMS*

Using a computer simulation of human forager-prey dynamics linking population ecology and evolutionary ecology, Winterhalder and Lu (1997) found evidence of complex dynamics based on simple premises and rules of behavior. This was a model designed to explore how characteristics of individual foraging tactics and resource populations might make particular species susceptible to over-exploitation, and findings were applied to the cases of indigenous conservation and resource use in Amazonia. For the human forager, eight basic parameters of the food quest were used as computer simulation inputs: speed, search radius, search cost, intrinsic rate of increase, home range, critical threshold of caloric intake, maintenance requirement of caloric intake, and time spent foraging. For the prey, five population parameters were assigned: caloric value, time required to pursue and capture, cost in energy to pursue and capture, carrying capacity in the absence of exploitation, and intrinsic rate of increase. In the simulation, the human forager and prey populations grew using a variant of the logistic equation and the mechanism by which the human population selects





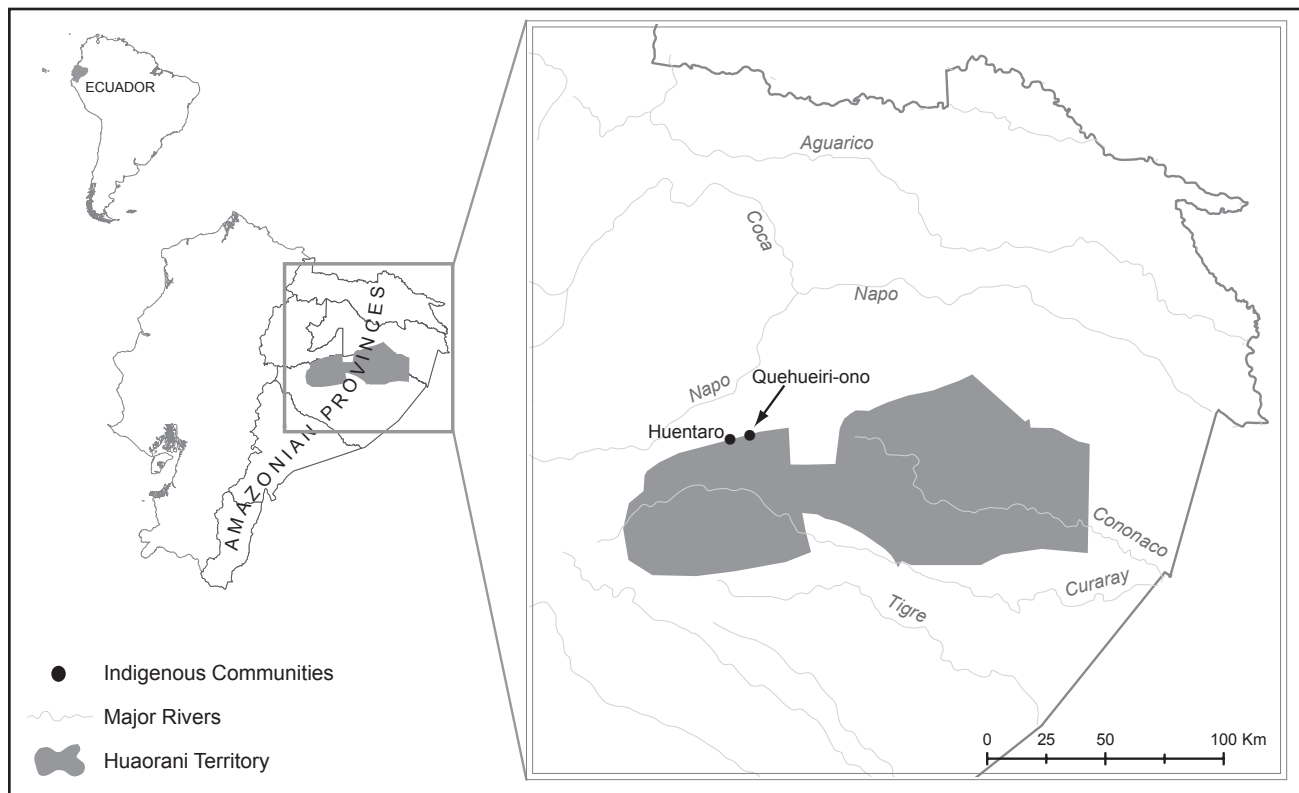
**FIGURE 1: Output of human forager-prey computer simulation from Winterhalder and Lu (1997).**

its prey is through the encounter-contingent foraging model from optimal foraging theory (Stephens and Krebs 1986). This model of diet breadth and prey choice has been successful in characterizing foraging choices for most of the human cases in which it has been applied (Alvard 1994; Kaplan and Hill 1992; Smith 1991; Winterhalder 1983).

In the case of one prey species and a human forager population, the system goes to a stable equilibrium with density dependent feedback as the human population has depleted the prey type to a point that the efficiency of the food quest allows for only individual replacement. However, as one more prey species is added, we see another example of a feedback, that of prey switching, in which depletion of a more desirable prey brings the marginal foraging efficiency down to the point where it becomes profitable to begin harvesting another prey type, which was initially ignored. As exploitation is shared between the two

prey types, the top ranked prey recovers in density, raising the foraging efficiency enough that the lower ranked prey is dropped, and the pattern repeats until the lower ranked prey is permanently added to the diet. Although outside the scope of this paper, it is important to note that prey switching could be an important source of protection for high-ranking resource species and a source of resilience for social and ecological systems.

In multi-species simulations with five prey types, Winterhalder and Lu (1997) noted that the system exhibited damped oscillations, stabilization to equilibrium, and also extirpation of one of the prey types. However, by doubling the intrinsic rate of increase of the extirpated prey type, it was possible to enable it to persist in the system. Furthermore, manipulating the intrinsic rate of increase of an already highly ranked resource was found to place co-harvested species at risk by encouraging rapid forager population growth



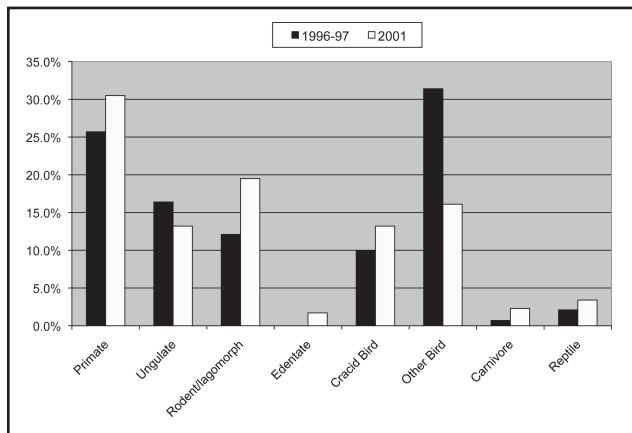
**FIGURE 2: Map of Huaorani villages studied in 1996-1997 and 2001.**

and densities. The result of doubling the intrinsic rate of increase for the top ranked prey is shown in Figure 1, a complex pattern of prey switching and oscillations which does not come to equilibrium but demonstrates a stable limit cycle. This underscores the non-linear nature of human exploitation of faunal resources as small changes can propagate dramatically. Such a simulation model highlights the importance of community-level effects, namely that the resilience of a species depends in part on the suite of the other prey harvested along with it; for instance, a prey with a low intrinsic rate of increase that shares a predator with an abundant, high intrinsic rate of increase prey species may be vulnerable as a result. Thus, hunting studies with a single-species focus may benefit from an expanded community ecological perspective of the other prey within the diet breadth. To find such unexpected patterns in a model which is relatively simple, e.g., it does not

include stochasticity, habitat heterogeneity, or time lags, would indicate that real forager-prey systems would undoubtedly be highly complex.

### ***SPATIAL SCALE AND HUNTING RESILIENCE***

Moving from computer simulation data of human forager-prey systems to empirical data from the field, I will compare the results of hunting data from two Huaorani villages (Huentaro and Quehueiri-ono, see Figure 2) from two time periods. The sample sizes for comparison between 1996-1997 and 2001 are similar: in the earlier dataset, I recorded 92 hunts (representing 645 person-hours of hunting), 229 prey encounters, and 140 individual animals killed. The study population numbered 161 people and a total of 719.15 kg of game were harvested, for an average of 7.8 kg/hunt. In 2001, the field researchers working in the same two villages recorded 84 hunts (encompassing approximately 547 person-hours),

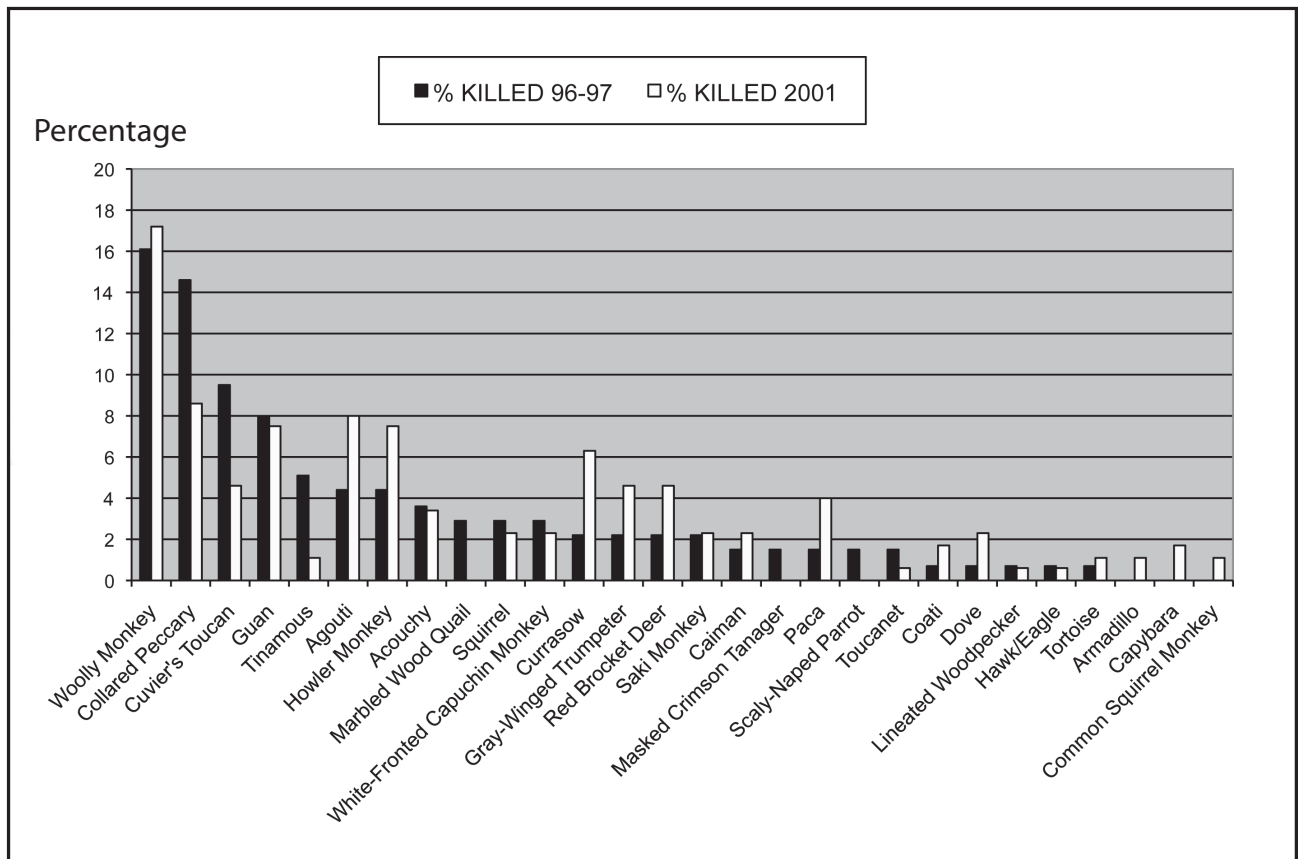


**FIGURE 3: Prey categories by percentage of kills for Huaorani, 1996-1997 and 2001.**

405 encounters of prey, and 174 kills. During this study, an estimated 1054.9 kg of game were acquired for a human population of 110 people (average of 12.6 kg/hunt). In 1996-97, the encounters/hunt ratio was 2.5, and for 2001, it was 4.8 ( $p < 0.0001$ ). In terms of success

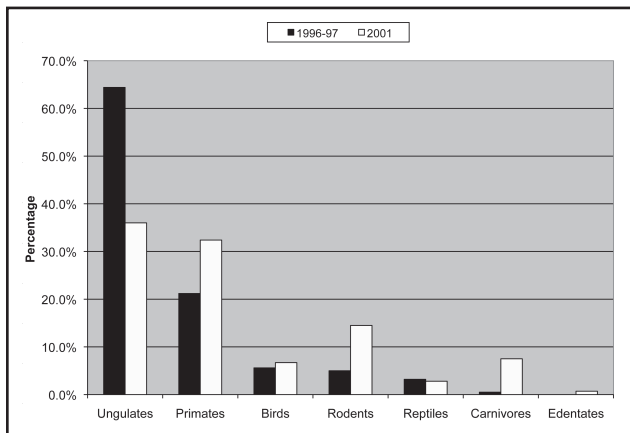
rate (kills/hunt), the earlier period was 1.5, the later period was 2.1 ( $p = 0.016$ ). (Please see Lu 1999 for details on the sampling in 1996-1997. In 2001, data were collected from February to June.)

In terms of the categories of animals killed, Figure 3 compares the findings for 1996-1997 and 2001. As percentage of kills, the two most striking trends are decline over time in the kills of non-cracid birds, and a slight increase in the kills of rodents and lagomorphs. The emphasis on killing primates, ungulates, and cracid<sup>2</sup> birds (family Cracidae) has remained consistent. In terms of prey animals killed, Figure 4 compares the percentage of kills constituted by various game animals during the two studies. The three categories are the percentage of kills which declined over time, increased, or stayed the same. The percentage of kills constituted by collared peccaries (*Tayassu tajacu*), Cuvier's toucan (*Ramphastos cuvieri*)



**FIGURE 4: Prey types by percentage of kills for Huaorani, 1996-1997 and 2001.**





**FIGURE 5: Prey categories by percentage of biomass for Huaorani, 1996-1997 and 2001.**

and tinamous (*Tinamus* sp.) fell during this five year period, while those of agoutis (*Dasyprocta fuliginosa*), howler monkeys (*Alouatta seniculus*), curassows (*Mitu salvini*), trumpeters (*Psophia crepitans*), pacas (*Agouti paca*) and red brocket deer (*Mazama americana*) increased. Woolly monkeys (*Lagothrix lagothricha*), guans (*Penelope* sp.), acouchies (*Myoprocta* sp.), squirrels, white-fronted capuchin monkeys (*Cebus albifrons*), and saki monkeys (*Pithecia pithecia*) tended to remain consistent in terms of percentage of kills.

Figure 5 reports the changes in animal biomass taken in terms of prey categories. The percentage of total biomass constituted by ungulates falls from 64.4 percent to 36.0 percent, while that of primates and rodents increases. The finding pertaining to carnivores should be interpreted with caution, as in 2001 informants reported the killing of one jaguar (*Panthera onca peruvianus*) which by its large size skews the data.<sup>3</sup> In terms of prey types, Table 1 contrasts the top animals by biomass taken for the two time periods. In both, collared peccaries, woolly monkeys, and red brocket deer are the top three, and howler monkeys, caimans (*Caiman crocodilus*), paca, agoutis, and cracid birds are also present.

In comparing Huaorani hunting patterns five years apart between 1996-1997 and 2001, some interesting findings emerge, counter to the idea of indigenous

over-exploitation of game. The Huaorani are encountering and killing more game per hunt in 2001 than 1996-97, but this may be a function of more efficient firearms and longer time spent hunting. More intriguing is the data on prey selection in terms of frequency killed and biomass harvested. As Valenzuela et al. (1997:406) note, “the majority of species of mammals and birds the Huaorani hunt are of large size, such as tapirs, deer, peccaries, primates...and birds like cracids, toucans and tinamous” (translation mine). These prey types are ones with lower reproductive rates and thus are more susceptible to overexploitation. We would expect a decline in percentage of kills coming from those groups over time. In fact, we find the opposite, as primates represented 30.5 percent of kills in 2001 compared to 25.7 percent in 1996-1997, and cracid birds were 13.2 percent in 2001, compared to 10 percent in 1996-1997. Specifically, game animals considered vulnerable to hunting such as woolly monkeys, howler monkeys, saki monkeys, guans, curassows and trumpeters either remained consistent in terms of percentage of kills or increased. This pattern is especially notable given the long period of Huaorani habitation of this area along the Shiripuno River. One of the two villages was established in the late 1980s, and the second splintered off from the first in the mid-1990s.

The data on biomass harvest also calls into question the assertion that the Huaorani have depleted their forest of game. The percentage of biomass harvested of primates and rodents increases, while that of ungulates declines. In terms of species’ ability to bounce back from harvest, we would expect a decline in primate biomass and an increase in both ungulate and rodent biomass. The decline in ungulate biomass may be attributable to the increasing dominance of firearms in hunting, as the shotgun is much more efficient than the spear in harvesting these animals. However, as I found for the data on kill rates, the most important prey animals by biomass hunted by these Huaorani villages has also remained relatively consistent during the five year period.

TABLE 1: Comparison of top 10 prey items by biomass.

1996-97			2001		
Animal	Biomass (kg)	% Total Biomass	Animal	Biomass (kg)	% Total Biomass
Collared Peccary	393.8	54.8%	Woolly Monkey	266.0	25.2%
Woolly Monkey	99.0	13.8%	Collared Peccary	220.8	20.9%
Red Brocket Deer	69.4	9.7%	Red Brocket Deer	156.6	14.8%
Howler Monkey	37.1	5.2%	Capybara	69.3	6.6%
Caiman	20.9	2.9%	Howler Monkey	61.9	5.9%
Paca	16.5	2.3%	Paca	44.4	4.2%
Agouti	13.2	1.8%	Curassow	39.2	3.7%
Guan	10.6	1.5%	Agouti	34.6	3.3%
Capuchin Monkey	10.2	1.4%	Caiman	29.2	2.8%
Cuvier's Toucan	8.1	1.1%	Guan	13.5	1.3%

How can we account for the persistence of these levels of hunting by relatively sedentary hunters over this period of time? Rather than looking only at the observed prey catchment basin, it is important to examine a larger geographic region in which source-sink population dynamics may be at work (Hill and Padwe 2000). It is likely that a source area is re-supplying game to the main hunting zones<sup>4</sup>. In interviews, Huaorani informants have alluded to these population dynamics, noting that there are areas between communities in which animal populations are subject to less hunting pressure, and that these interstitial zones serve as “game reserves.” Where source-sink dynamics exist, studies of human hunting must be careful to encompass a sufficient spatial as well as temporal scale to assess the sustainability of faunal exploitation. A comparison of game densities in hunted and unhunted areas as evidence for depletion (e.g., Mena et al. 2000) is insufficient, as all central place foragers are expected to deplete prey nearby their home base—calculations of hunting sustainability must include source areas (Hill and Padwe 2000).

The existence of such source-sink dynamics is likely not limited to groups like the Huaorani. Gadgil et al. (2000) postulate that many kin-based, small-scale societies who are intimately dependent on natural resources are sensitive to signs of resource depletion and have an awareness of harvesting pressure. One form of restraint for long-term faunal sustainability is the establishment of **refugia**, areas similar to the core zones of protected areas, in which exploitation is limited or prohibited. Reichel-Dolmatoff (1976) in his essay on Tukano “Cosmology as Ecological Analysis,” mentions the shamans’ role in interpreting the biotic impoverishment of certain restricted areas to the action of vengeful spirits. Examples of such refugia tied to spiritual beliefs also include sacred groves and sacred ponds in places like India, Nepal, Mexico and Ghana (Gadgil et al. 2000).

In the Huaorani case, I propose that these source-sink dynamics were not the result of conscious effort at conservation or cosmology but rather an outcome of a history of intra-ethnic warfare which rendered forested areas between hostile Huaorani

longhouses of extended kin (**nanicaboiri**) as interstitial “no-man’s-lands” which functionally acted as game reserves or sources of faunal reproduction. In his description of Huaorani settlement patterns, Yost (1992:99) writes:

When a sustained peaceful contact with them was effected in 1958 the Waorani were divided into four major groups dispersed over their territory. They numbered no more than 500 individuals occupying a land base of approximately 20,000 square kilometers, or 0.025 persons per square kilometer...Each of the neighborhood clusters [nanicaboiri] was situated several days walk from the next one and maintained a relationship of hostility to the others...In most instances the major groups of neighborhood clusters were not entirely certain where the other clusters were, who they were, or how many they numbered...The neighborhood clusters kept a buffer zone between themselves and the borders of **cowode** [‘outsiders’] land.

## INTER-GROUP DYNAMICS AND SETTLEMENT PATTERNS LEADING TO RESILIENCE

Robarchek and Robarchek’s (1998) study of Huaorani warfare emphasizes the prevalence of hostility in this society; internecine spear killing has been going on at least for five generations, and in the past century, more than 60 percent of Huaorani deaths were the result of homicide. It should be emphasized that the stated rationale in spear killing was revenge for earlier killings, not faunal resource defense, but that a by-product of the former was the latter. In the past three decades, the rate of killing has declined more than 90 percent (Robarchek and Robarchek 1998) and the nanicaboiri settlement pattern of dispersed and mobile kin groups has changed to nucleated, sedentary villages centered around a school and landing strip (Lu 1999), but the existence of these interstitial zones has persisted. In interviews I conducted during dissertation fieldwork, I asked Huaorani individuals to draw their community boundary relative to other communities and natural features such as rivers. Informants would circle the general area pertain-

ing to various communities, and when I pointed to the lands between the villages and asked who lived there, the response was “animals.” Socio-economic changes, however, may undermine these source-sink processes, such as the reduction and fragmentation of forest due to rapid demographic growth as well as petroleum extraction, colonization, and logging. In the parlance of a resilience framework, what we may be witnessing is that the persistence of vulnerable game species acts as a slow variable, and that shocks can accumulate and move the system from one set of controlling mechanisms and processes to another. The system may hit a threshold and unexpectedly flip to another domain of attraction, one in which such species may become locally rare; such a “surprise” would be detrimental to the Huaorani, for whom the hunt has profound cultural significance. When asked if they would still hunt even if they could afford to buy all their food, Huaorani informants resoundingly said yes, because hunting was “central to who they are.”

## CONCLUSIONS

Models used to assess the impact of hunting on faunal prey populations in an Amazonian context have generally treated the relationship between human foragers and game as linear, such that game availability is posited as an inverse function of human density. This manuscript utilizes results from a simulation model as well as empirical data of Huaorani hunting over a span of five years to support the applicability of a resilience approach to understand Native Amazonian hunting dynamics. The computer simulation—based on simple premises and rules of behavior—nonetheless illustrated complex patterns of prey switching and oscillations characteristic of a stable limit cycle. I posit that the persistence of vulnerable prey types in Huaorani hunting despite a longstanding village presence and use of firearms is explicable through examining human-prey dynamics on a larger spatial scale of source-sink dynamics, in this case facilitated by cultural practices of warfare. These findings are

consistent with the classic hunting studies of human ecologist William Vickers, who also worked with indigenous groups of the Ecuadorian Amazon.

In 1980, Vickers published a paper which examined the relationship between length of settlement and hunting yields among the Siona and Secoya residents in the Ecuadorian Amazon and concluded that game populations were becoming depleted. He reported a decline in the kills of larger species (e.g., peccaries, curassows, guans, and woolly and howler monkeys) and an increase in the kills of smaller animals (e.g., agoutis, toucans, squirrels) and took this as evidence of depletion of more preferred game. He compared hunting data gathered in 1973-1975 with that from 1979, and found that mean hunting yield declined (from 21.3 to 11.9 kg), length of hunting trips increased (from 7.56 to 8.48 hrs/day), caloric efficiency declined (from 9.3:1 to 4.6:1), and percentage of trips without a kill increased (from 11.3 percent to 18.6 percent) (Vickers 1980).

In 1988, Vickers published another paper, one in which he included hunting data gathered in 1980, 1981, and 1982. He defined a core area of 590 km<sup>2</sup> which received some hunting each day and suggested that three species were depleted in this zone: woolly monkeys, curassows, and trumpeters. However, he concluded that the 1980 data do not support the prediction of impoverished yields due to game depletion, as overall hunting success remained high and kill rates for most prey did not suggest depletion. Furthermore, Vickers suggested that for **terra firme** societies in settlements of 250 individuals or less in hunting territories in excess of 1000 km<sup>2</sup>, prey populations were probably not controlled by human predators; in particular, variation in hunting yields for two species of peccary (*Tayassu pecari* and *Tayassu tajacu*) appear to be extrinsic to the population size of indigenous peoples.

In a later paper using this 10-year data set (1973-1982), Vickers (1991) finds even more support of the sustainability of Amazonian Indian hunting among

communities with low human population density, dispersed settlements and a subsistence economy. For a core hunting zone of 590 km<sup>2</sup> taken in addition to an intermediate hunting zone of 560 km<sup>2</sup> (hunted regularly and year around), only one species—the curassow—exhibited clear-cut evidence for depletion. The implication is that for the vast majority of species, the Siona and Secoya kill rates do not indicate depletion. He writes, “This suggests that Amazonian game availability results from a far more complex set of phenomena than is often assumed by anthropologists, who have tended to propose that game depletion around native settlements is a broad-based and linear process through time” (Vickers 1991:77).

Clearly the scale of analysis matters, both in terms of temporal scale (e.g., Vickers coming to a different set of conclusions with a data set spanning more time) as well as spatial scale (e.g., the core versus intermediate zone as well as source-sink dynamics). In the Huaorani, Siona, and Secoya cases, the finding of long-term persistence is notable, and perhaps indicative of more complex coupled natural and human dynamics with strong interactions, nonlinearities, and feedbacks.

Future study among the Huaorani or other Amerindian hunting populations from a resilience framework should incorporate an interdisciplinary approach with natural, social and spatial scientists documenting not only hunting behaviors and forager-prey dynamics (including faunal population densities, reproductive biology and life histories), but also greater detail of indigenous people’s understandings of what they are doing, for what reasons (e.g., hunting for subsistence, festivals, trade, market, etc.), and how they think animals respond to human actions. Maps of land cover should include aspects of the socio-cultural landscapes, such as the boundaries of community lands and hunting territories, “no-man’s lands,” and corridors attaching these interstitial spaces to a wider system. A historical ecology approach (Balée 1998; Crumley 1994; Rival 2002) could help ascertain not only changes across temporal scales and examples of feedbacks, thresholds, and



surprise, but could also show how resilience could be fostered in anthropogenic landscapes. Perhaps the greatest utility of a resilience approach, however, is to underscore the value and necessity of collaborative, cross-disciplinary work to illuminate the complexities of social and ecological systems.

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## NOTES

1. In light of the extensive adaptationist debate in the Amazonian literature (see summary in Rival 2002), clarification of the use of the term "adaptation" as used by a resilience approach is needed. The statement that social and ecological systems are adaptive illustrates the process-dependent feedbacks among multiple scales that allow systems to self organize but it does not *a priori* presume the forces of natural selection. For instance, humans engage in adaptive management that is an iterative and learning-based process that can take advantage of new opportunities and change in light of new situations. This is the focus of much work in the resilience literature, which goes beyond survival and reproduction and includes things like social and economic viability and quality of life. The diet breadth model from optimal foraging

theory was incorporated into the computer simulation as a means for human foragers to select prey, and should not be construed to mean that a resilience framework is synonymous with an evolutionary approach.

2. The Family Cracidae is composed of large, neotropical forest-dwelling birds, from the smaller chachalacas (genus *Ortalis*) to medium-sized guans (genera *Penelope*, *Penelopina*, *Pipile*, *Chaemepetes*, *Aburria*, *Oreophaps*) to the larger curassows (genera *Crax*, *Mitu*, *Pauxi*, *Nothocrax*). Cracids are strict frugivores, although some species (chachalacas and some guans) also consume flowers and leaves (Silva and Strahl 1991). They probably play an important role in tropical forests as seed dispersers. Cracidae contribute the most avian biomass extracted by hunters in the neotropics. They are susceptible to habitat disturbance and overexploitation because of strict habitat requirements, low reproductive rates (small clutch size, late age of sexual maturity). Silva and Strahl (1991) estimate that it will require at least six years for the average cracid to replace itself in the population.
3. Many Huaorani informants deny that they would ever knowingly eat jaguar, as this would be considered extremely repulsive. As it is unlikely that this jaguar was consumed, I omit it from the analysis of prey types taken.
4. Although source-sink dynamics and prey switching are two likely explanations for the persistence of certain prey types in Huaorani hunting in these communities, more data is needed to test this assertion. In addition, there could be other reasons as well, such as microclimate or habitat shifts favoring some species over others, declining hunting pressure with indigenous market integration, or that the patterns are simply random.

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