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## Juvenile Responses to Household Ecology

### *Among the Yora of Peruvian Amazonia*

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#### I. INTRODUCTION

We explore predictions regarding trade-offs in juvenile time allocation in response to different ecologies of parental and alloparental investment among the Yora of the Peruvian Amazon. The Yora remained relatively isolated until 1984, when they experienced their first peaceful contacts with outsiders. Within two years, approximately half the population died from contact-related diseases (Hill and Kaplan 1989). Although this tragic situation is all too common in the history of first contacts with indigenous groups, the omnipresence of endemic health risks (e.g., Gurven et al. 2000; Sugiyama 2004; Sugiyama and Chacon 2000; Sugiyama and Scalise Sugiyama 2003) means that high parental mortality may be common in such groups even in the absence of contact-initiated epidemics (e.g., Chagnon 1997; Hill and Hurtado 1996). In either case, high postcontact Yora mortality provides an opportunity to analyze juveniles' responses to different parental circumstances.

Other studies have looked at households with one biological parent and one stepparent. Although our sample is small, the study village included a large proportion of juveniles living in households with one biological parent and no stepparent. Single biological parents without a coresident mate do not have to "negotiate" resource allocation to their offspring with a stepparent, who may exert pressure on the biological parent to invest more in their mutual offspring and less in the biological parent's offspring by a previous mate. Examining single-biological-parent households is thus

important because it focuses attention on parental investment and the alloparental investment of nonmates.

Our discussion addresses longstanding issues in hunter-gatherer studies: are there recurrent features of hunter-gatherer childhood that reflect evolved features of human life history, and within that, to what degree do individuals facultatively respond to their particular circumstances? Specifically, we ask whether (1) Yora household composition and feeding patterns indicate that they are cooperative breeders in which mothers enhance alloparental investment to their offspring via recruitment of multiple caregivers; (2) there is facultative variation in juvenile work strategies in response to household parental ecology; and (3) juvenile work and foraging patterns are primarily practice or productive.

## II. STUDY POPULATION BACKGROUND

The Yora are a small group of Panoan-speaking people inhabiting the upper Manu and Mishagua rivers in southeastern Peru, first contacted in 1984. Within two years of contact, epidemics reduced the population from 300 to 150 people (Kim Fowler, personal communication 1990; Hill and Kaplan 1989). Initial reports were that Yora were highly mobile foragers who traveled by canoe, hunted and fished with bow and arrow, and gathered feral plantains and wild resources (Hill and Kaplan 1989). By 1990, there was a Yora horticultural village, Putaya, located in the Mishagua river headwaters near the Putaya confluence. Past village, fishing, and garden sites were located along these rivers. Intermittent periods of riverine mobility and horticultural production may therefore characterize precontact Yora settlement. As of 2003, some Yora continue to be highly mobile, traveling as far south as the Bolivian border (M. Gurven, personal communication, 2003).

In Putaya, eleven open-sided thatched houses with raised palm wood floors were located along both sides of the forty-meter-wide Mishagua river. Houses ranged from 50 to several hundred meters from their nearest neighbors and, with one exception, were within sight of at least one other. Gardens were adjacent to most houses, with houses linked via trails roughly parallel to the river. One could thereby walk a circuit past each village house in just over one half hour. During the dry season, when one could easily walk across the river, walking from one end of the village to the other took half the time it took to make a circuit of the village.

During our study, hunting and fishing continued to occupy half of all time allocated to subsistence; the rest was allocated to horticulture (Sugiyama and Chacon 2000; Walker et al. 1998). Similarly, about half of observed food consumption came from hunting and fishing, and half came from gardening. Hunters stalked game with bow and arrow or pursued it

with hunting dogs (Sugiyama and Chacon 2000; Walker et al. 1998). Large game was butchered near the kill site, and packaged for distribution before returning to the village. A variety of fish were taken with bow and arrow, cast net, or hook and line. Turtle and lizard eggs were also collected, along with wild fruits and nuts. Game and fish were usually consumed the day they were acquired. Members of several households sometimes cooperated in foraging, the catch distributed between participants and members of other households. Once food entered a household, all members present shared the food. The main cultigen, sweet manioc, was served boiled, roasted, or as manioc beer. Plantains, sugar cane, maize, sweet potatoes, achote, tobacco, and cotton were also cultivated (Sugiyama and Chacon 2000; Walker et al. 1998). Because households were the primary economic unit, we use them as a significant unit of analysis in this study.

People living in small, face-to-face, kin-based groups who are dependent on foraging for a livelihood mirror critical aspects of the environment of human life history evolution (e.g., Hagen 1999; Howell 1979; Hrdy 1999; Lee and DeVore 1976; Sugiyama 1996, 2004; Tooby and DeVore 1987). Ethnographic studies of these societies are useful for testing hypotheses about general and facultative human life history features (e.g., Hill and Hurtado 1996). The Yora provide a venue for such study: although they practice horticulture, they depend on subsistence foraging and continue to live in small kin-based groups with little access to Western medicine, contraception, or mechanized technology (Sugiyama 2004; Sugiyama and Chacon 2000; Walker et al. 1998).

### III. LIFE HISTORY THEORY

One goal of hunter-gatherer research has been to identify, document, and explain life history patterns of foragers to gain insight into the evolution of human life history (e.g., Bird and Bliege Bird 2002; Blurton Jones et al. 1994a, 1994b; Blurton Jones and Marlowe 2002; Bock 2002a, Chapter 5 in this volume; Hawkes et al. 1998; Hewlett 1991a, 1991b, 1992a; Hill and Hurtado 1996; Kaplan et al. 2000a; Konner 1981, Chapter 2 in this volume; Walker et al. 2002). Evolutionary environments vary in their ecological and social particulars; thus, within a species' general life-history pattern, selection produces suites of reproductive, decision-making, and other motivational adaptations that elicit adaptively strategic trade-offs in life effort in response to recurrent environmental variables (e.g., Chisholm 1996; Clutton-Brock 1991; Daly and Wilson 1984; Hagen et al. 2001; Hill and Hurtado 1996; Hrdy 1992; Stearns 1992; Tooby and Cosmides 1992; Trivers 1972b, 1974; Trivers and Willard 1973). Understanding how individuals use local environmental cues to adjust their allocation of life resources is a main goal of human life history research (e.g., Belsky 1997; Betzig et al.

1988; Chisholm 1993; Blurton Jones et al. 1989; Blurton Jones et al. 1994a, 1994b; Blurton Jones and Marlowe 2002; Bock 2002a, Chapter 5 in this volume; Draper and Cashdan 1988; Draper and Harpending 1982; Hagen et al. 2001; Hill and Hurtado 1996).

### General Features of Human Life History

In general, successful reproduction entails high maternal investment (e.g., Ellison 2001; Hrdy 1999; Konner 1977; Stern et al. 1986). Humans are altricial: at birth and for years afterward, offspring are helpless and dependent on adult care (e.g., Bogin 1999). Human juvenile success suffers with loss of this investment (e.g., Hill and Hurtado 1996; Hurtado and Hill 1992; Hagen et al. 2001; Marlowe 2003), which is often supplemented by alloparents (individuals other than the biological parents; e.g., Draper and Hames 2000; Hawkes et al. 1998; Hrdy 2001b, 2002, Chapter 3 in this volume; Hill and Kaplan 1999; Kaplan and Hill 1985; Kaplan et al. 1990; Turke 1988). Human life history is also characterized by delayed maturity, long lifespan, and exceptional intelligence and learning capabilities. We focus on one explanation of these characteristics, skills or knowledge acquisition, and on one model of that explanation (see, e.g., Blurton Jones and Marlowe 2002; Bock, Chapter 5 in this volume; Leigh 1999; Pagel and Harvey 1993; Sugiyama 2004).

Kaplan et al. (2000a) propose that as evolution of hominid dietary reliance on high-quality, difficult-to-acquire resources (e.g., game animals) progressed, fitness benefits were realized from a longer prereproductive period of foraging skill and/or knowledge acquisition. This led to coevolution of increased resource flow from older individuals to juveniles to support this period of growth and learning. The higher mortality risk accompanying extended juvenility and lifespan was countered by increased food sharing and provisioning of sick/injured individuals (Kaplan et al. 2000a). This theory prompted tests of juvenile foraging efficiency to see whether efficient adult foraging requires an extended period of knowledge-based skill acquisition (Part II of this volume; Bird and Bliege Bird 2002; Bliege Bird and Bird 2002b; Blurton-Jones and Marlowe 2002; Bock 2002a; Walker et al. 2002). While currently debated, it is clear that juvenile foragers' contributions to their own subsistence varies based on local ecology, technology, and type of foraging practiced (Bird and Bliege Bird 2002; Bliege Bird and Bird 2002b; Blurton Jones et al. 1994a, 1994b; Blurton Jones et al. 1989, 1997; Blurton-Jones and Marlowe 2002; Bock 2002a, Chapter 5 in this volume; Tucker and Young, Chapter 7 in this volume; Walker et al. 2002). We ask whether Yora juvenile foraging patterns support the skills-acquisition hypothesis, are focused on achieving immediate returns, or both (e.g., Bock, Chapter 5 in this volume).

### **Parental Investment Theory and Facultative Responses to Parental Condition**

Parental investment (PI) theory focuses on how individuals allocate resources between existing offspring, current versus future offspring, and quantity versus quality of offspring (e.g., Alexander 1974; Bateman 1948; Lessells 1991; Stearns 1992; Trivers 1972b, 1974, 1985; Trivers and Willard 1973). Hamilton's (1964) theory of kin selection posits that individuals who are genetically related to a juvenile can further their fitness by aiding him/her. By combining kin selection with PI theory, we can extend the study of parental allocation of resources to include alloparental investment. Specifically, we expect adults to invest differentially in juveniles depending on (a) the juvenile's probable relatedness to the adult, (b) the probability that the juvenile will be able to translate investment into future reproductive success, and (c) the alternative potential uses of the resources (Clutton-Brock 1991; Daly and Wilson 1988; Hrdy 1999; Lancaster and Kaplan 2000; Trivers 1972b, 1974).

Conversely, selection is expected to have produced adaptations by which juveniles assess their own condition, their options within their environment, the condition of potential caregivers, and potential caregivers' available alternative avenues of investment, as well as a decision-making psychology that, ancestrally, generated behavioral choices that tended to enhance their ability to survive and reproduce (e.g., Belsky 1997; Chisholm 1993; Draper and Hames 2000; Hill and Hurtado 1996; Hrdy 1999, 2001b; Konner, Chapter 2 in this volume; Sulloway 1996). Juveniles could increase investment in themselves, reduce risks of losing available investment, or acquire more resources on their own. Loss of a biological parent is a significant change in the offspring's socioecological environment, to which strategic responses are expected. In turn, potential caregivers are expected to be sensitive to juveniles' ability to contribute to their own welfare, and to adjust their reproductive and investment strategies accordingly (e.g., Blurton Jones et al. 1994a, 1994b, 1996, 1997; Daly and Wilson 1987, 1988; Draper and Harpending 1982, 1987; Kramer 2002; Strassman 1997; Sulloway 1996; Trivers 1974). We ask whether there is facultative variation in parental and alloparental provisioning and in juvenile work strategies in response to household parental ecology.

## **IV. HYPOTHESES**

### **Hypothesis 1**

All else equal, biological parents (BPs) gain higher fitness by investing in their own offspring rather than those of others. Generally, mothers

invest a lot in their offspring, but among foragers paternal investment is also generally high (e.g., Hewlett 1991a, 1992b, 1992a; Konner, Chapter 2 in this volume). Even among the Hadza, who are cited as an exception (e.g., Hawkes and Bliege Bird, 2002; Konner, Chapter 2 in this volume), males preferentially invest in their own offspring: men living with biological offspring hunt more and bring in more game than those living with stepchildren. This may be particularly important when a man's mate is pregnant (Marlowe 1999a, 1999b, 2003). Further, stepchildren are at risk of neglect or abuse due to stepparental reluctance to invest in the offspring of others (e.g., Bugos and McCarthy 1984; Daly and Wilson 1984, 1988; Hausfater and Hrdy 1992; Hill and Hurtado 1996; Lancaster and Gelles 1987). We therefore predict:

Hypothesis 1: Juveniles are more likely than not to live with all surviving biological parents.  
If biological father is alive, juveniles are more likely than not to live with him.

## Hypothesis 2

Multiple caregivers can increase juvenile survival and reproductive prospects (e.g., Beckerman et al. 1998; Hawkes et al. 1998, 2001b; Hewlett 1989; Hill and Hurtado 1996; Hrdy 1999, 2001b, Chapter 3 in this volume; Marlowe 1999a, 1999b, 2001). Postreproductive females may support their daughters' reproduction (e.g., Hawkes and Bliege Bird 2002; Hawkes et al. 1997, 1998, 2000; Hrdy 1999, 2001b, Chapter 3 in this volume; Sear et al. 2000), while males often contribute resources to mates, other adults, and juveniles (Hewlett 1989, 1991a, 1992b, 1992a; Hill and Hurtado 1996; Ivey 2000; Kaplan et al. 2000a; Marlowe 1999a, 1999b, 2001; Winterhalder 1996). Hrdy (1999, 2001b, Chapter 3 in this volume) thus argues that humans are essentially cooperative breeders—a species in which rearing juveniles involves a number of adult and juvenile conspecifics (i.e., allomothers). If Yora follow a pattern of cooperative breeding, if household residence is highly associated with investment (see below), and if mothers facultatively recruit alloparents for their offspring, we predict that:

Hypothesis 2: (a) Juveniles are more likely to live in extended family than in nuclear family households.  
(b) Juveniles will live in households with multiple potential alloparents.  
(c) Juveniles living with 1BP (and no stepparent) will live in larger households, and have more coresident potential alloparents than those living in 2BP households.

### Hypothesis 3

The Yora household is assumed to be a primary venue for investment. Although age, local environment, technology, and foraging strategies affect the degree to which juveniles can provision themselves, cross-culturally, food provisioning is a recurrent form of benefit transfer from adults to juveniles (e.g., Blurton Jones et al. 1994a, 1994b, 1996; Bogin 1999; Draper and Hames 2000; Hawkes et al. 1997; Kaplan et al. 2000a). Energy intake and its correlates are useful proxies for fitness (e.g., Hagen et al. 2001; Kelly 1995; Kaplan and Hill 1995; Sellen 1999; Winterhalder 1996). Here we use observations of juveniles eating as an index of food provisioning by household, which we think justified because ethnographic observations indicate that the proximate distributors of food eaten in Yora households were household members, predominantly adults (except when juveniles independently acquired foraged items). Because unweaned juveniles' consumption is primarily nursing, and because they are limited in their mobility, we test hypotheses 4-7 with data from weaned juveniles only. We predict that:

Hypothesis 3: Weaned juveniles are more likely to eat at home than elsewhere.

### Hypothesis 4

Alloparental care by close relatives can have positive fitness consequences for the provider (Daly and Wilson 1986; Flinn 1989; Hamilton 1964; Hrdy 1999, Chapter 3 in this volume; Hawkes et al. 1998, 2000). Thus, juveniles may seek investment from potential alloparents in households other than their own. All else equal, alloparental investment is best placed with those most in need. On average, we expect single parents to have fewer resources to give their offspring than two parents, such that:

Hypothesis 4: Weaned juveniles living with 1BP will eat at home relatively less often, and away from home more often, than those living with 2BPs.

### Hypothesis 5

Yora juveniles are free to move about the village. They may therefore increase opportunities to receive alloparental investment both directly (e.g., food provisioning) and indirectly (e.g., protection, precautionary warnings, behavioral models) by spending time in households other than their own. Weaned juveniles living with 1BP may therefore attempt to make up

for missing parental investment by seeking investment from non-parent adults in other households. If so, we predict that:

Hypothesis 5: Weaned juveniles living with 1BP will spend relatively more time in other households than those living with 2BPs.

### Hypothesis 6

Juveniles living with 1BP could compensate for lost parental investment by increasing time spent foraging, by taking over a primary caregiver's work so that he/she can devote more effort to activities directly benefiting the juvenile, or both. When net proceeds from juvenile foraging are higher than net benefits from freeing up time for their adult caregivers, juveniles are expected to increase work effort in foraging or other subsistence tasks directly. Factors that bear on this trade-off include (1) juvenile foraging efficiency; (2) age- or sex-specific base rate of work effort by juveniles with both parents living; (3) efficacy of juvenile work in nonforaging household labor; (4) adult foraging return rate; and (5) degree to which juvenile household labor increases adult caregiver foraging. All else equal, we expect that:

Hypothesis 6: Juveniles living with 1BP will work more than those living with two BPs.

### Hypothesis 7

Ethnographic observation and prior analysis (Sugiyama and Chacon 2000; Walker et al. 1998) show that Yora juveniles do engage in household, horticultural, and foraging work. In contrast to the Hadza (Blurton Jones et al. 1989, 1997), Mikea (Tucker and Young, Chapter 7 in this volume), and Mer (Bliege Bird and Bird 2002b) environments, where children can independently forage in relative safety, the neotropical forest environment of the Yora is potentially dangerous (Sugiyama and Chacon 2000; and see Hill and Hurtado 1996). Adolescent or adolescent/child groups do go on independent fishing trips away from the village, however, and all but the youngest juveniles were seen fishing in the river running through the village. If weaned juveniles can work and forage successfully and have free time available to increase foraging, then we expect that:

Hypothesis 7: Weaned juveniles living with 1BP will spend more time in subsistence work than those living with 2BP.



### Hypothesis 8

Analysis of age-specific hunting success of Ache neotropical bow-hunters suggests that bow hunting takes a long time to master (Walker et al. 2002). This was our impression among the Yora as well. Conversely, we found hook and line, net, and bow fishing to be relatively easier (in that order of difficulty). As Bock (Chapter 5 in this volume) and others (e.g., Bird and Bliege Bird 2002; Bliege Bird and Bird 2002b; Blurton Jones and Marlowe 2002; Bock 2002a; Kaplan 1997; Kaplan et al. 2000a; Walker et al. 2002) have noted, strength, skill, and knowledge may all have effects on juvenile foraging success. Fishing from the bank requires little strength, but traveling by canoe does. If juvenile foraging is primarily practice and knowledge acquisition, and hunting is more knowledge-intensive than fishing, we expect weaned male Yora juveniles to engage in more hunting than fishing because hunting skills must be honed. However, if production is a primary foraging goal—as it appears among the Hadza (Blurton Jones et al. 1997), Mikea (Tucker and Young, Chapter 7 in this volume) and Mer (Bird and Bliege Bird 2002; Bliege Bird and Bird 2002b)—then fishing should predominate, with juvenile hunting seen primarily in association with adults from whom knowledge-based hunting skills can be acquired. Our experience among the Yora and among Shiwiari blowgun/shotgun hunters is that successful adult hunting of large game using traditional weapons requires expert knowledge and a certain amount of strength. And, our ethnographic observations suggest that production was a primary goal of Yora juvenile fishing. We therefore predict that:

- Hypothesis 8: (a) Weaned juveniles will spend more time fishing than hunting.  
(b) Time spent fishing will increase with age during the juvenile period (because long-distance canoe travel requires more size/strength)  
(c) Time spent hunting will increase with age across the lifespan.  
(d) Time allocated to fishing will peak earlier in life than time allocated to hunting.

## V. METHODS

Data were gathered via scan sampling, residence survey, and genealogy. Focal person follows and departure/return records were used to collect ethnographic data on adult and juvenile foraging strategies. During the

59-day study period the population of Putaya varied between 56 and 71 people living in 11 households. From two to six instantaneous scan samples were run on each of 29 days, yielding one hundred scans and 6,448 individual behavioral observations (Hames 1992a, 1992b; Walker et al. 1998). Scans covered all daylight hours. During each scan one of us made a circuit of the village, visited each household, and sought each individual then living in Putaya. For each individual we recorded the time, location of observation, and activity observed. Once people became accustomed to the scans, they altered their behavior very little upon our approach. When someone was not in the village, we asked household members where he/she was, and later cross-checked this information either directly or by confirming the report when we encountered the person later in the day. People kept track of the comings and goings of others, and reports were generally accurate. If someone could not be found, and his/her activity not confirmed, we recorded no behavior for that individual for that scan.

### Demographic Makeup of Sample

During data collection (1990) Yora were living in three locations: 66 persons in the study village of Putaya, 37 persons in Cashpajali (as of 1986; Hill and Kaplan 1989), and a third group in the mission town of Sepahua. The Putaya sample included 38 males and 32 females, of which 27 were adults and 43 were juveniles. Juveniles included 13 unweaned infant/toddlers, 17 children between weaning and puberty, and 13 adolescents between puberty and age of first reproduction. Of these 43 juveniles, 24 had two living parents (55.8 percent), 17 (39.5 percent) had one living parent, and two (4.7 percent) had no living parents. One juvenile, a short-term visitor to Putaya, was excluded from analysis. The household marriage situation of the remaining 42 juveniles consisted of 18 (42.9 percent) living with both biological parents (2BP household), 12 (28.6 percent) living with one biological parent (1BP household), six (14.3 percent) living with a biological parent and a stepparent (stepparent household), and six (14.3 percent) living with alloparents only (alloparent household).

Overall, there was a significant relationship between juvenile lifestage (infant, toddler, child, or adolescent) and primary caregiver composition in the household (1BP, 2BP, alloparents, or biological mother and stepfather) ( $\chi^2 = 14.432$ ,  $df = 6$ ,  $p = .028$ ). Here we focus on those juveniles living in 1BP and 2BP households. From the perspective of individual juveniles, there were ten infants, toddlers, three children, and five adolescents living in 2BP households, while there were two infants/toddlers, seven children, and three adolescents living in 1BP households. Clearly, the number of juveniles in the village is small, and carving the sample into multiple categories reduces the numbers in each. When we compare the chrono-

logical age of juveniles in 1BP and 2BP households, however, the Kruskal-Wallis test shows no significant association between juveniles' ages and household type ( $\chi^2 = 1.82$ ,  $df = 1$ ,  $p = .177$ ).

Between two and 11 people lived in each Yora household. Among juveniles living with either 1BP or 2BP, household size ranged from four to 11 people. Two juveniles lived in 1BP households with seven members, three in households with nine members, and seven in households with 11 members. Three juveniles lived in 2BP households with four members, nine with seven members, three with nine members, and three with 11 members. The Kruskal-Wallis test indicates that juveniles living with 1BP live in larger households than those living with two biological parents ( $\chi^2 = 1.82$ ,  $df = 1$ ,  $p = .177$ ), even though juveniles living with 1BP and 2BP do not differ in number of juvenile coresidents ( $\chi^2 = 0.282$ ,  $df = 1$ ,  $p = .596$ ). The difference is that juveniles living with 1BP tend to live in households with more adults.

## VII. RESULTS

### Household Composition

Hypothesis 1: Does household composition reflect biparental investment?

Of the 23 juveniles with two living biological parents, 18 lived with 2BP (78.3 percent), two (4.9 percent) resided with their mother, and three (7 percent) with their mother and a stepfather. Of the 12 juveniles who resided primarily with one biological parent (1BP household), nine lived with the mother (78.6 percent) while three lived with the father (21.4 percent); in all but two of these cases, the other biological parent was deceased. All six children who lived with one biological parent and one stepparent lived with their biological mother and a stepfather; in three of these cases, the biological father was alive and living in the village (Table 11.1).

Table 11.1 Juveniles' Household Composition and Biological Parent Mortality

Parents living	2BP	1BP		Alloparents	Total
		Mother \ Father	Stepparent Mother \ Father		
0	—	—	—	2	2
1	—	7 \ 3	3 \ 0	3	16
2	18	2 \ 0	3 \ 0	1	24
Total	18	12	6	6	42

In sum, 33 of 36 (91.6 percent) juveniles with biological mother living resided in a household with their biological mother, while only three (8.3 percent)—all of whom resided with alloparents—did not. Twenty of 27 (74 percent) juveniles with biological father living resided in a household with their father, while only seven (26 percent) did not. Again, when father was living, juveniles were more likely to live in a household with him than not ( $\chi^2 = 6.26$ ,  $df = 1$ ,  $p = .012$ ). Twenty-nine of 40 (69 percent) juveniles with at least one biological parent lived with all surviving parents; juveniles were more likely to live with all remaining biological parents than not ( $\chi^2 = 8.1$ ,  $df = 1$ ,  $p = .004$ ). Only six juveniles did not reside with one of their parents who were living, and all of these lived with their mother. Of the six juveniles living with alloparents only, three were living with a father's sister (and father's sister's husband), two were living with mother's sister, and one was living with his mother's father's brother (and mother's father's brother's wife).

Hypothesis 2: Is household composition indicative of cooperative breeding?

Of 11 households, only two included mother, father, and biological offspring. One household included only a married couple. Another included a nuclear family sharing the same roof (condominium style) with a three-generation extended family and two juveniles receiving allomaternal care. Of the seven extended family households (counting the two condo families as one household), two included a stepparental relationship, six included adult alloparental relationships in addition to a stepparent, and two included three generations of individuals. Only three juveniles resided in the same household as a grandparent: two with grandfather and one with grandmother. Overall, 39 juveniles lived in households with extended family members and/or alloparents under the same roof, while only three juveniles lived in nuclear family households.

From the standpoint of individual juveniles, their households had between zero and five potential adult alloparents, and between zero and five potential older juvenile alloparents. On average, juveniles resided with 1.83 potential adult alloparents ( $M = 1.83$ ,  $SD = 1.45$ ), and 2.19 potential older juvenile alloparents ( $M = 2.19$ ,  $SD = 1.53$ ). As noted above, juveniles living with 1BP lived in larger households than those living with 2BP ( $\chi^2 = 1.82$ ,  $df = 1$ ,  $p = .177$ ), because the former tended to have more resident adults.

### Juvenile Time Allocation

An overview of Yora time allocation provides the context for our comparison of juvenile time allocation in 1BP and 2BP households. Of the 6,448

individual scan-sampling observations, 3,626 were of individuals under twenty who had not reached the age of first reproduction, and 2,638 were of children and adolescents. There were 2,537 observations of weaned juveniles living with either 1BPH or 2BPH, and no difference between the relative number of observed and expected observations for weaned juveniles living in 1BP and 2BP households ( $\chi^2 = 0.017$ ,  $df = 1$ ,  $p = .897$ ).

Figure 11.1 shows an overview of time allocation by lifestage for all ages. Overall, 41 percent of time is devoted to leisure, including relaxing/resting, playing, and socializing. Subsistence activities take up 39 percent of time, including gardening, hunting, fishing, and cooking (23.22 percent), consumption (14.56 percent), and distribution (1.6 percent). Household maintenance accounts for 6.65 percent of time allocation, while childcare accounts for 6.26 percent. Note, however, that childcare often co-occurs with other activities; data reported here include only childcare not performed concurrently with another activity. These figures therefore underrepresent time allocated to childcare.

A general comparison of daylight time allocation by lifestage including all infants/toddlers, children, adolescents and adults, indicates that time allocated to leisure is negatively correlated with lifestage ( $R = -0.68$ ,  $p = .000$ ). Among all weaned juveniles, there is a significant association be-

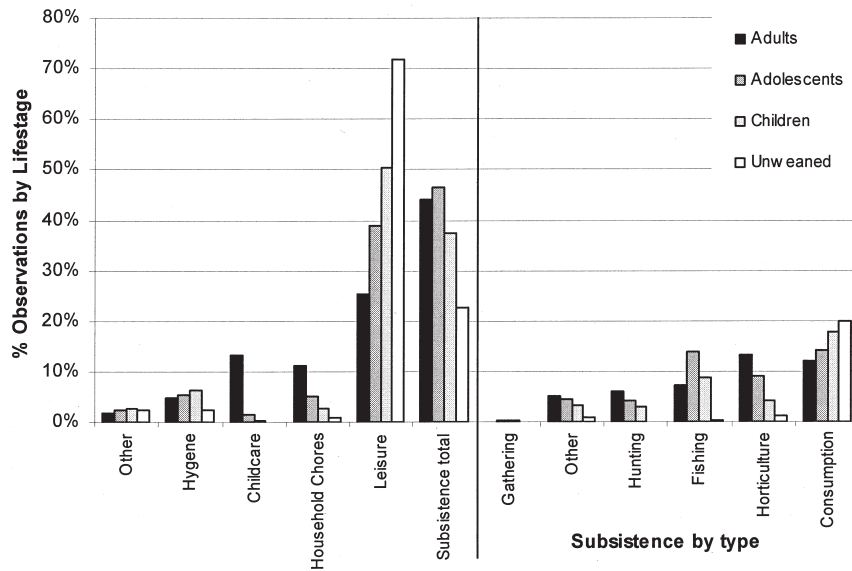


Figure 11.1 General time allocation by lifestage (100%=All observations for each lifestage)

tween lifestage and relative time allocated to work ( $\chi^2 = 287.5$ ,  $df = 1$ ,  $p = .000$ ). Nevertheless, weaned juveniles spent a significant amount of time working (see below). Overall, children spent relatively less time working than adolescents ( $\chi^2 = 51.855$ ,  $df = 1$ ,  $p = .000$ ), and adolescents relatively less time working than adults ( $\chi^2 = 66.404$ ,  $df = 1$ ,  $p = .000$ ). Of the work observed, there is a positive correlation between advancing lifestage and time allocated to household maintenance tasks (e.g., cleaning, hauling water, tending the fire, household repairs) ( $R = 0.593$ ,  $p = .000$ ). Similarly, children spend relatively less time doing subsistence work than do adolescents or adults ( $\chi^2 = 62.946$ ,  $df = 1$ ,  $p < .000$ ), whereas adolescents and adults do not differ in time allocated to subsistence work overall ( $\chi^2 = .584$ ,  $df = 1$ ,  $p = .445$ ), although this obscures important differences (see below).

Hypothesis 3: Is primary residence the main source of food for juveniles?

Hypothesis 1 was based on the assumption that the household was a primary venue for investment. Here we test this assumption with one data source, observations of where juveniles were eating. As predicted, overall, weaned juveniles were observed eating at home more often than elsewhere ( $\chi^2 = 43.90$ ,  $df = 1$ ,  $p = .000$ ).

Hypothesis 4: Do weaned juveniles living in 1BP households eat at home less often, and away from home more often than those in 2BP households?

They do not. Weaned juveniles living with 1BP ate at home more often than away ( $\chi^2 = 4.612$ ,  $df = 1$ ,  $p = .032$ ), while those living with 2BPs did not differ in how often they ate at home vs. away ( $\chi^2 = 49.7825$ ,  $df = 1$ ,  $p = .000$ ). Weaned juveniles living with 1BP ate at home more often than expected compared with those living with 2BP ( $\chi^2 = 6.249$ ,  $df = 1$ ,  $p = .012$ ), but did not differ in the relative frequency with which they ate away from home ( $\chi^2 = 1.632$ ,  $df = 1$ ,  $p = .201$ ) (see Figure 11.2).

Hypothesis 5: Do weaned juveniles in 1BP households spend more time away from home than those in 2BP households?

In general, they do not. Weaned juveniles living with 1BP and 2BPs did not differ in relative time spent away from home ( $\chi^2 = 0.594$ ,  $df = 1$ ,  $p = .44$ ). And, those living with 1BP spent relatively *more* time at home than those living with 2BPs ( $\chi^2 = 9.795$ ,  $df = 1$ ,  $p = .002$ ) (see Figure 11.3).

Hypotheses 6 and 7: Do weaned juveniles living with 1BP work more than those living with 2BPs?

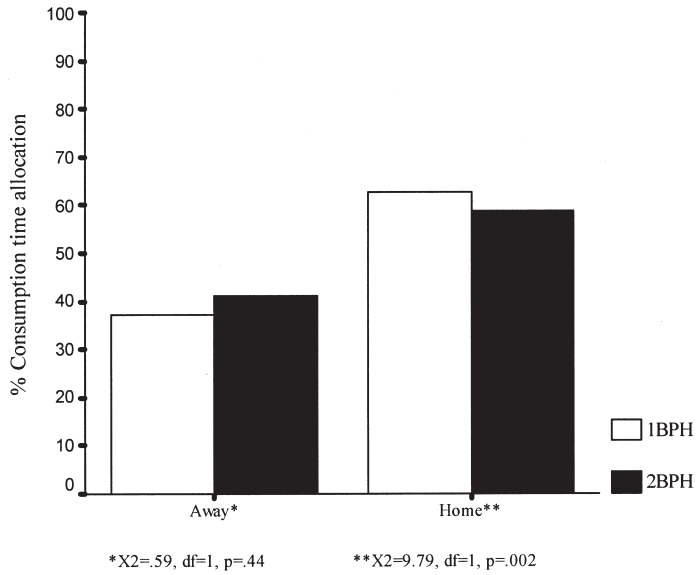


Figure 11.2. Weaned juveniles consumption at home vs. away (100% = all consumption for juveniles of a household type)

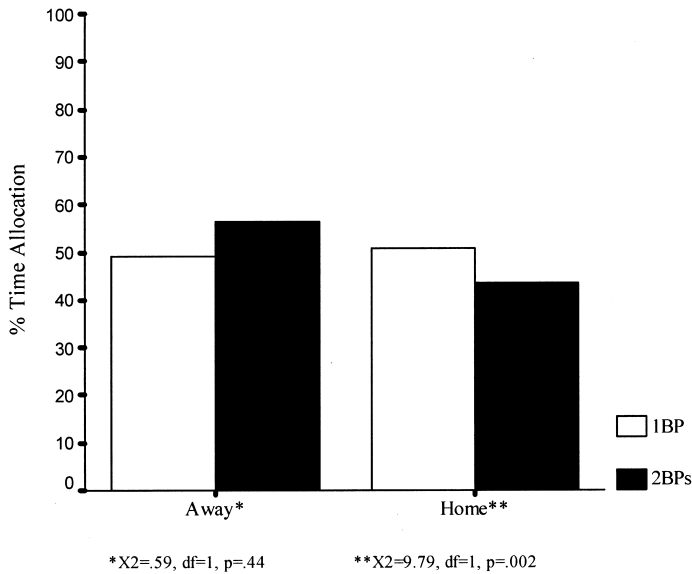


Figure 11.3. Weaned juveniles' time spent at home vs away (100% = all observations for juveniles of a household type)

They do not. Overall, weaned juveniles living with 1BP and 2BPs did not differ in the relative frequency they were observed working overall ( $\chi^2 = 1.1$ ,  $df = 1$ ,  $p = .298$ ), or in subsistence ( $\chi^2 = .812$ ,  $df = 1$ ,  $p = .368$ ). However, those living with 2BPs were observed relatively more often than juveniles living with 1BP doing household maintenance chores (e.g., cleaning, hauling water, washing) ( $\chi^2 = 4.47$ ,  $df = 1$ ,  $p = .034$ ) and hunting work (including processing game) ( $\chi^2 = 7.647$ ,  $df = 1$ ,  $p = .006$ ). No significant differences were found between 1BP and 2BP juveniles for fishing ( $\chi^2 = .006$ ,  $df = 1$ ,  $p = .939$ ) horticulture ( $\chi^2 = .966$ ,  $df = 1$ ,  $p = .326$ ) or gathering ( $\chi^2 = 3.481$ ,  $df = 1$ ,  $p = .062$ ) (see Figure 11.4).

Hypothesis 9. Is juvenile foraging oriented toward skill and knowledge acquisition, or production?

If juveniles forage primarily for knowledge/skill acquisition, then juveniles in 1BP might not be able to make up for investment losses by increasing time allocated to foraging. We can put juvenile foraging goals into perspective by examining them in relation to changes in foraging behavior across the lifespan. Linear regression of age across the entire juvenile period on percentage of time allocated to fishing is significant, with age accounting for 46 percent of the variance in juvenile time allocated to fishing ( $F = 34.02$ ,  $p = .000$ ,  $n = 43$ ,  $R^2 = 46$  percent). Across the lifespan, cubic re-

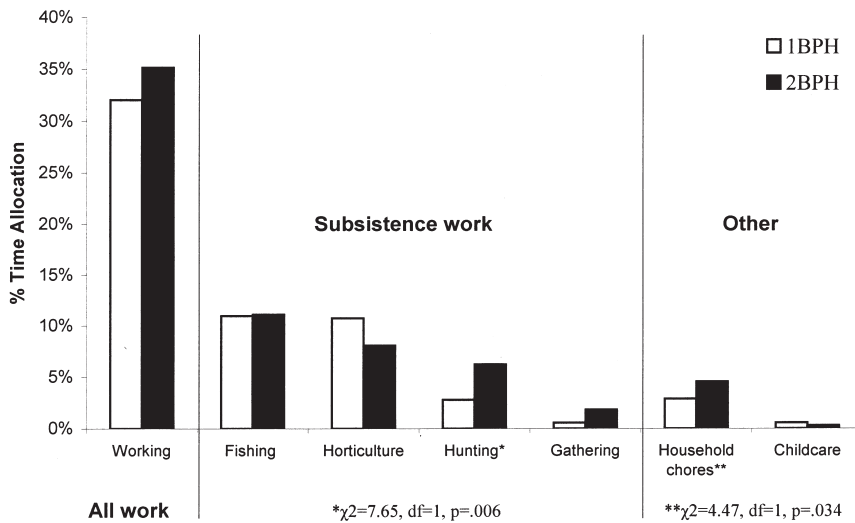


Figure 11.4. Type in legend.



gression indicates a significant inverted-U-shaped relationship between age and percentage of time allocated to fishing: fishing increases with age through the juvenile period but decreases during adulthood until about age 50 ( $F = 7.68, p = .000, n = 75, R^2 = 0.239$ ). The Kruskal-Wallis test shows that males allocate significantly more time to fishing than do females ( $\chi^2 = 20.37, df = 1, p = .000$ ). Also, the relationship between age and fishing time allocation is primarily the product of male behavior: the cubic regression model accounts for 47.5 percent of the variance in male fishing behavior ( $F = 10.25, p = .000, n = 39, R^2 = 47.5$  percent), but for females is not significant at conventional levels ( $F = 2.64, p = .066, n = 37, R^2 = 19.9$  percent). Finally, female fishing time peaks at about age 17, while male time allocation to fishing peaks around age 23 (Figure 11.5).

The Kruskal-Wallis test shows that average male time allocated to hunting was far greater than that for females ( $\chi^2 = 21.351, df = 1, p = .000$ ). While the increase in hunting time with age across the lifespan is generally

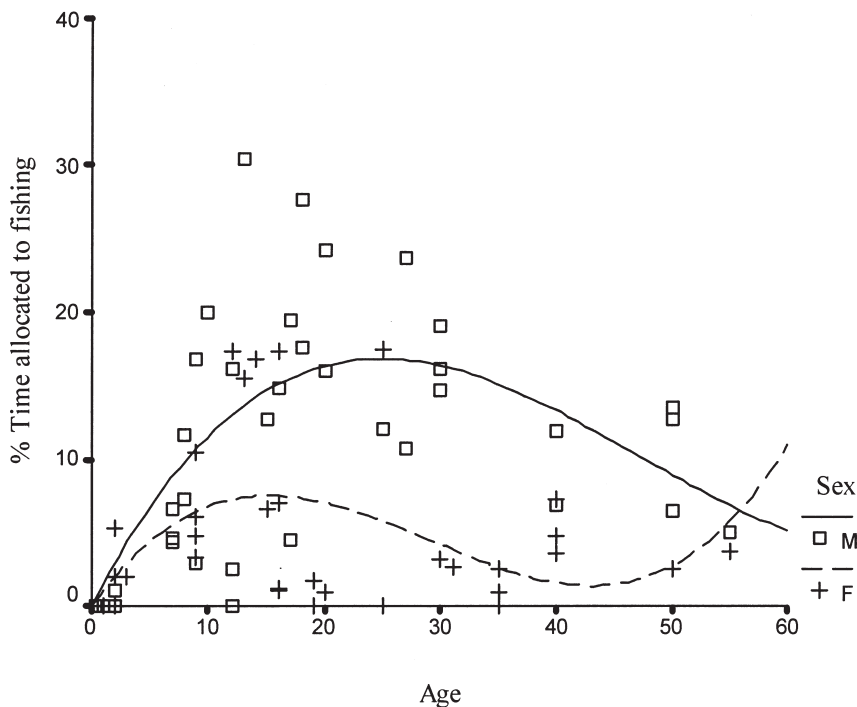


Figure 11.5. Percent male and female time allocation to fishing across the lifespan

linear for both males and females, cubic regression indicates that the increase in female hunting time with age appears to level off between about 20 and 40 years, and then accelerates ( $F = 4.77, p = .001, n = 36, R^2 = 30.9$  percent). Quadratic regression shows male hunting time increasing to at least age 55 but at a slightly decelerating rate after about age 30 ( $F = 12.75, p = .000, n = 38, R^2 = 42.9$  percent) (Figure 11.6).

Among juveniles, the regression model shows significant linear effects of age [ $r = 0.555 (42), p = .000$ ] and sex [ $r = 0.434 (42), p = .002$ ] on time allocated to hunting. Age accounts for 29.1 percent of the variance in time allotted to hunting by juveniles; sex accounts for an additional 11.6 percent. Neither BP status nor the number of coresident juveniles is significantly associated with time allocated to hunting, although they account for 5.6 and 2.7 percent of variance, respectively. Among adults, sex accounted for the greatest proportion of the variance in time spent hunting, 41.6 percent

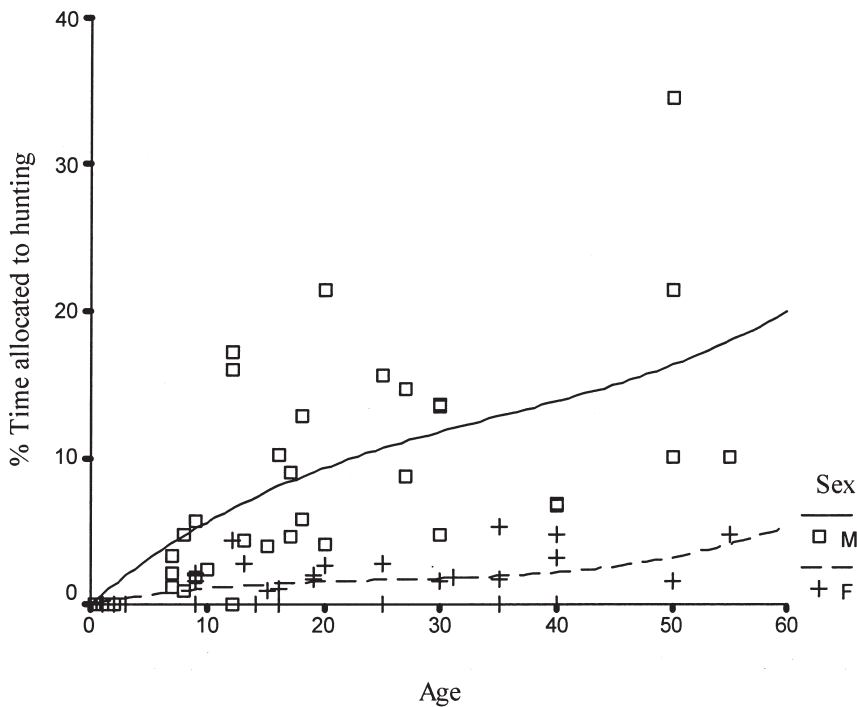


Figure 11.6. Percent male and female time allocated to hunting across the lifespan

( $r = 0.66, p = .000$ ). Age and number of household juveniles accounted for a small percentage of variance in time spent hunting (6.2 and 6.9 percent, respectively), although neither was significantly correlated with hunting time ( $r = 0.316, p = .083$ , and  $r = .305, p = .095$ , respectively).

Finally, juveniles of all ages spent significantly more time fishing than hunting ( $\chi^2 = 80.49, df = 1, p = .000$ ). Although adolescents spent less time hunting ( $\chi^2 = 3.868, df = 1, p = .049$ ), gardening ( $\chi^2 = 6.96, df = 1, p = .008$ ), and gathering ( $\chi^2 = 3.93, df = 1, p = .047$ ) than adults, adolescents spent more time fishing than adults ( $\chi^2 = 41.154, df = 1, p = .000$ ). While juveniles were never observed hunting outside the village without adults, juveniles often went fishing alone or in groups. The Kruskal-Wallis test indicates that, in a sample of 60 person-days fishing, adolescents and adults do not differ in average kilograms of fish taken per hour ( $\chi^2 = 0.65, df = 1, p = .42$ ) (see Figure 11.7).

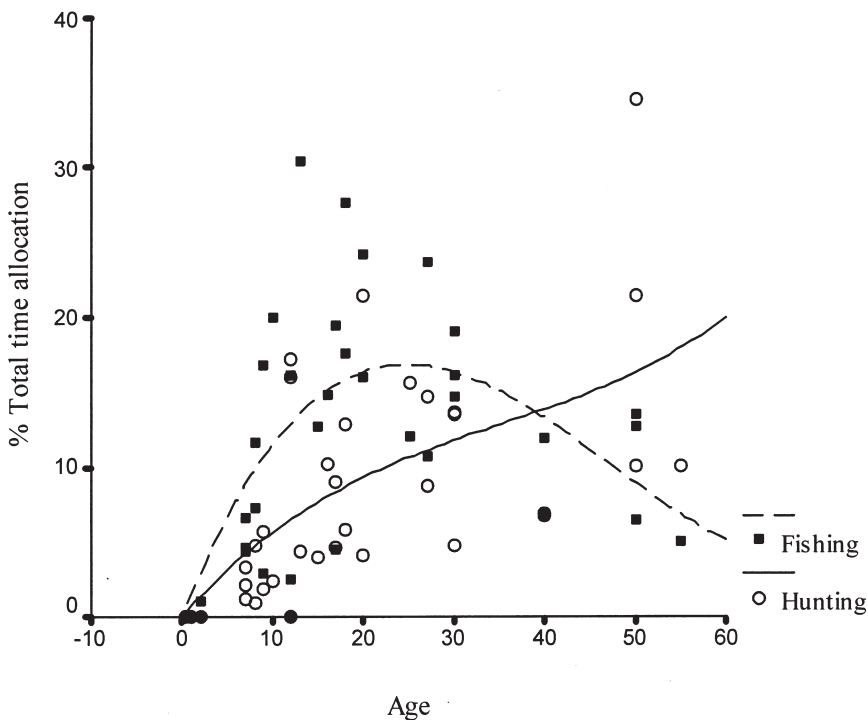


Figure 11.7. Percent male time allocated to fishing and hunting across the lifespan

## VIII. DISCUSSION

As predicted by PI theory, the majority of juveniles (29 of 40) who had a living biological parent resided with all living biological parents, and 20 of 27 juveniles with father living resided in the same household as their father. Infants and toddlers, particularly, spend a large portion of their time at home. And primary residence is linked with at least one important source of investment: food. Overall, weaned juveniles ate at home significantly more often than elsewhere. However, weaned juveniles also received significant alloparental food transfers: approximately 40 percent of their time spent eating was in households other than their own. Hrды's (1999, 2001b, Chapter 3 in this volume) view of humans as cooperative breeders is also supported by household composition patterns. Juveniles were more likely to live in extended and multiple family households than with nuclear family only, and they lived, on average, with several potential adult and juvenile alloparents. Juveniles living with 1BP lived in larger households, with more potential alloparents, than juveniles living with 2BPs. Only three juveniles had grandparents living in the village; all three lived in the same household as the grandparent. Older individuals may have suffered high mortality during postcontact epidemics; thus, that there were few juveniles with grandparents in the village may be a stochastic effect of these epidemics, although in small populations with high mortality such circumstances may be common from juveniles' perspectives (e.g., Chagnon 1997; Hill and Hurtado 1996).

Time allocation data did not support predictions about facultative juvenile responses to living with 1BP versus 2BPs, or about differences in provisioning to juveniles living with 1BP and 2BP. Our assumption that living with 1BP would mean less investment at home was not supported. Weaned juveniles living with 1BP were observed eating at home more, rather than less, often than those living with 2BP. Weaned juveniles living with 1BP did not differ from those living with 2BPs in how often they were observed eating away from home. We also see no evidence that 1BP juveniles seek alloparental support by spending more time in households other than their own. In fact, 1BP juveniles spent more time at home than their 2BP peers. Data on time allocation to work, subsistence, and foraging also showed few differences between 1BP and 2BP juveniles. However, weaned 2BP juveniles spent more time hunting than did 1BP juveniles. Most 1BP juveniles lived with mother; thus, one possible benefit of living in a 2BP household is that one has better access to an adult male model for observational learning of hunting strategies. Alternately, one may be called upon to help out in hunting more often.

Could it be that juveniles do not have adaptations to assess their circumstances and facultatively adjust behavior in response? It is possible,

but other data indicate that this is unlikely to be the case (e.g., Belsky 1997; Betzig et al. 1988; Bliege Bird and Bird 2002b; Chisholm 1993; Blurton Jones et al. 1994a, 1994b; Blurton Jones et al. 1989, 1997; Bock 2002a, Chapter 5 in this volume; Draper and Harpending 1982; Flinn 1988; Konner, Chapter 2 in this volume; Sulloway 1996). It could be that our measures were not sensitive enough to observe strategic differences in behavior based on household ecology, although we did find differences, in the opposite direction than predicted. We believe that what we failed to anticipate was that a significant amount of alloparental care in 1BP households is (apparently) arranged by parental-alloparental household coalitions: the greater number of potential adult alloparents within the households of 1BP juveniles may be the product of mothers' (or other primary caregivers') strategic recruitment or arrangement of multiadult household members, or the result of primary caregivers joining households to produce this effect. We therefore did not see the reduction in household investment we predicted would drive 1BP juveniles to seek resources elsewhere. Juveniles themselves may have had a hand in choosing where to live, based on their assessment of which households could best support them. Indeed, five individuals appear to have done this, but the numbers are too small for us to conclude much from them.

The reason we see few differences in the work strategies of 1BP and 2BP juveniles could be that their work is essentially practice; hence, increasing time allocation to work does not increase juvenile fitness. This seems untenable given the amount of time juveniles spend working, the life-history pattern of this work, and the fact that adolescent fishing return rates are indistinguishable from adult rates. This raises the question of why juveniles forage, and whether differences in time allocated to fishing and hunting indicate that hunting requires more investment in skill and or knowledge than fishing.

Although Yora children had ample leisure time and relatively few household responsibilities, they nevertheless spent significant time foraging. As Konner (Chapter 2 in this volume) notes, reports of children's foraging suggest that there is much play involved, and Yora children's foraging conforms to this observation. However, watching children hungrily devour the proceeds of their foraging gave us the distinct impression that—as with the Mer, Hadza, and others—the goal of Yora children's foraging was, at least in part, production. Our data on fishing support this conclusion. Time allocated to fishing increases across the juvenile period until adolescents are spending more time fishing than adults, with equal hourly returns. As noted earlier, the knowledge and skill necessary for effective hook and line, net, and bow fishing seem to develop rapidly (albeit most Yora juvenile fishing was of the less skill-intensive hook and line or net varieties). One advantage that increases throughout the juvenile

period is strength (e.g., Blurton Jones and Marlowe 2002; Walker et al. 2002). Older Yora children have the strength to pole a canoe greater distances upriver (which opens up a wider territory for exploitation) and to pull in bigger fish. Smaller children, in contrast, tended to request and use smaller hooks.

For adult males, hourly return rates are higher from hunting than fishing (Sugiyama and Chacon 2000), yet, as predicted, time allocated to hunting appears to catch up with time allocated to fishing until well into adulthood. Of course, we would not expect neotropical hunting to completely replace fishing at any time during the lifespan, given that fishing and hunting are complementary strategies that have different payoffs depending on season, water levels, rain, and so on (e.g., Beckerman, 1994). Nevertheless, the trend line (Figure 11.4) regressing male time allocation to fishing on age has a strikingly similar shape and peak to the strength curves reported for Ache (Walker et al. 2002) and Hadza (Blurton Jones and Marlowe 2002) foragers, showing a relatively steep increase during the juvenile years that peaks around age 23. Conversely, the shape of the trend line for male time allocation to hunting is similar to the individual age related return rate curves for neotropical hunting among the Ache (Walker et al. 2002). It accelerates more slowly but continues until relatively late in the lifespan. Further, independent hunting by juveniles was almost exclusively for small prey (e.g., lizards, birds) around the village, or in the company of adult males. Strength does affect accuracy with a bow (Blurton Jones and Marlowe 2002; Walker et al. 2002), but if that is what delays juvenile entry into successful independent hunting, why does the hunting curve not mirror the strength or fishing curves?

Yora bow hunting with dogs requires speed and stamina to corner the animal, strength to jam poles into the ground to secure the prey where it has been cornered, animal knowledge to decide whether it is worth continuing a pursuit, tactical knowledge for extracting the animal, and territorial knowledge to find one's way home after chasing quarry erratically through the forest. Hunting this way entails much higher energy costs per unit time than fishing. When accompanying adults in the chase, older adolescents appear to be effective hunting partners, and younger adolescents and children provide assistance. However, adolescents rarely hunt alone, and children are not physically up to the task of independently cornering and dispatching larger prey without high risk (e.g., Hill and Hurtado 1996). Effective bow hunting by stalking requires extensive knowledge of animal behavior, signs, tracking, calls, strategic approach, and shot positioning. It also requires sufficient skill to handle the bow (something learned fairly early) and strength to shoot arrows high into the canopy (something that takes a period of growth to attain). Even so, the size and strength arguments do not explain the pattern of Yora results. And while

speed, strength, and technical skill with a bow all feature in Yora hunting, all are in place before the hunting time overtakes fishing.

Studies across forager groups suggest that knowledge-based foraging skills may depend on experience, which in turn may be a function of ecology and foraging techniques. For instance, when foraging knowledge was assessed directly, Aka children had knowledge comparable to that of adults (Hewlett 1988). Aka hunt cooperatively in multiage groups using nets; from infancy, then, Aka children have recurrent experience with all aspects of the hunt. In contrast, Ache infants and small children are not normally present on Ache or Yora bow hunts, so opportunities for observational learning are more limited. The greater dangers associated with neotropical hunting may also act to limit Ache and Yora juvenile time allocated to hunting.

The age related tradeoff between time allocated to hunting and fishing superficially appear consistent with the idea that delayed maturity is an evolved life history strategy for reducing risks of entering adult competition before juveniles have a reasonable chance of success (Bogin 1999). On this view hunting is a part of adult male mating competition, but entering this competition before one has the requisite social skills to succeed may lead to irrevocable setbacks. So, juveniles do not enter the competition until nearly adult. On the other hand, Yora males allocate the most time to hunting in their late forties, when they are already adults with dependents. If hunting is primarily mating competition, then it should be most intense in early, rather than late adulthood.

One variable that may explain both the high levels of adolescent fishing and the slow increase in time allocation to hunting is number of dependents. When number of dependents is low, low but consistent fishing return rates may be preferable to higher but more variable hunting return rates. However, if increasing time allocated to fishing is not sufficient to support higher numbers of dependents, then a higher but more variable rate of return from hunting may be preferential. Increase of time allocation to hunting may be motivated by one's parental investment interests rather than constraints upon foraging ability per se (e.g., Bird and Bliege Bird 2002). This hypothesis is not supported by our data: number of household juveniles was negatively correlated with time spent hunting.

Of course, hunting may have fitness benefits beyond its dietary contribution to self and dependents. The view that provision of public goods via hunting is a costly signal of coalitional intent (e.g., Gurven et al. 2000; Hawkes and Bliege Bird 2002; Smith and Bliege Bird 2000; Smith et al. 2003; Sugiyama and Chacon 2000; Sugiyama and Scalise Sugiyama 2003) is more consistent with increased time allocation to hunting with age than is the hunting as (solely) mating competition explanation. If hunting and meat sharing is an honest signal of coalitional intent, then hunting should

increase as reliance upon larger, extra-familial coalitions increases. And, because younger individuals may depend on parents for provisioning during illness and injury, and coalitional support networks in times of conflict, the need to generate and maintain adult alliances might be expected to increase, all else equal, with age (e.g., Sugiyama and Chacon 2000; Sugiyama and Scalise Sugiyama 2003).

Age is correlated with a number of life history variables such that correlation of age and behavior alone is unlikely to settle the question of why juveniles forage (e.g., Bird and Bliege Bird 2002). Behavioral data have been unable to settle the issue of why juveniles take a long time to reach adult levels of hunting efficiency. Experimental data, in contrast, have missed the knowledge hypothesized to be critical for efficient hunting of larger game. We know that not all foraging techniques take a long time to master (e.g., Bird and Bliege Bird 2002), and that different hunting technologies require different levels of knowledge. One possible prediction, then, is that in areas where a mix of hunting technologies is available, younger or more inexperienced hunters will, all else equal, devote more time to technologies that compensate for knowledge-based or other deficits in hunting skills. Among the Yora, for example, the one cast net available in the village was preferentially adopted over bow and arrow fishing by older adolescents, even though their return rates with the net were no different than those of adult males using bow and arrow.

Bock (2002a, Chapter 5 in this volume) presents a punctuated embodied capital model for explaining the life history of foraging competency, with which our Yora data fit fairly well. Less skill-intensive fishing shows age- and probably strength-based increase in time allocation. Very young children fish in the river in front of their homes; older children fish from all points in the village, or go fishing with adults, adolescents, or mixed-age groups. As they gain the strength to pole a canoe upriver, they can fish in pairs or mixed-age groups. Hunting competency, in contrast, is acquired sequentially over a longer period. First, juveniles accompany and assist adults, allowing observational learning of the strategies, animal behavior, and risks involved. Growth allows them to begin hunting independently and, perhaps, to further hone their knowledge and skills. Finally, dependence on adult social alliances may increase hunting because hunting allows one to provision others, thereby providing a costly signal of coalitional intent that may pay off in social support of various kinds (e.g., Gurven et al. 2000; Smith and Bliege Bird 2000; Sugiyama 2004; Sugiyama and Scalise Sugiyama 2003).

Three things seem clear from our analysis. First, Yora juveniles benefit from both biparental and alloparental investment, as predicted from the cooperative breeding hypothesis. Second, predicted patterns of facultative variation in juvenile behavior in response to different household parental



ecologies were not observed. Less clear is why this is the case, but facultative cooperative breeding (alloparenting) alliances may buffer juveniles who have lost a parent, and probably invalidated our expectations about differences between 1BP and 2BP household ecologies. Further analysis of the patterns of adult behavior in relation to the number, age and type of their dependents is clearly called for. A fourth set of findings, addressing why juveniles forage and why they take a long time to reach adult hunting proficiency, suggests that (1) juveniles engage in significant work-related activities, (2) both practice and production are key incentives for Yora juvenile foraging, and (3) time allocated to less skill-intensive foraging (i.e., fishing) reaches adult levels before time allocated to skill-intensive foraging (i.e., hunting) does, in a manner consistent with a punctuated embodied capital model of development, and a social signaling model of hunting.

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