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RESEARCH ARTICLE

Dietary Choices by Four Captive Slender Lorises (*Loris tardigradus*) When Presented With Various Insect Life Stages

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The slender loris (*Loris tardigradus*) is a rare, nocturnal prosimian found only in the tropical rainforest of southern India and Sri Lanka. Little is known about their diet, though it is assumed that insects comprise a majority of their wild diet. Based on this assumption, captive lorises are offered a variety of insects or insect life stages; the species of insect or the life stage is often determined by what is easiest to buy or rear. Captive lorises at the Duke Lemur Center (DLC) were offered the opportunity to choose which life stage of mealworms (*Tenebrio molito*), superworms (*Zophobus morio*), or waxworms (*Galleria mellonella*) they preferred. The DLC captive lorises did not select the largest life stages of any insect offered. They preferred the larvae stage to the adult stage in all three insect species, and males and females had different insect species and life stage preferences. Zoo Biol 30:189–198, 2011. © 2010 Wiley-Liss, Inc.

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INTRODUCTION

The slender loris (*Loris tardigradus*) is a rare, nocturnal prosimian found only in the tropical rainforests and woodlands of southern India and Sri Lanka [Nekaris, 2001, 2002, 2003]. Slender lorises are members of the *Lorisidae*, which includes lorises (*Loris*, *Nycticebus*), bushbabies (*Galago*), angwantibos (*Arctocebus*), and

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pottos (Perodicticus) [Bearder, 1987; Nekaris, 2001, 2003]. Pottos, angwantibos, and bushbabies are all confined to the African continent, whereas lorises are found only in Asia [Bearder, 1987; Nekaris, 2001, 2003].

Owing to the rarity and secretive nature of lorises, little is known of their behavior in the wild [Nekaris, 2001, 2003]. What is known is that slender lorises are omnivorous, with a majority of their wild diet being composed of animal matter: Nekaris and Rasmussen [2003] reported that 96% of all feeding events were animal prey with 62.9% being ants and termites. They also reported that Lorises occasionally consumed spiders, molluscs, and small vertebrates plus gums and legume pods [Nekaris and Rasmussen, 2003]. Lorises have also been observed consuming eggs, small vertebrates, and even plant material [Schulze and Meier, 1995].

Owing to habitat destruction and death of individuals for use in traditional medicine, the wild population of slender lorises has been drastically reduced and the species is currently listed as endangered on the IUCN [2009] red list (http://www.iucnredlist.org/search/details.php/12375/summ).

The slender loris is of interest as a research subject because of the extraordinary assemblage of derived morphological, physiological, and behavioral characteristics [Nekaris, 2003]. Included in these characteristics are *retia mirabilia* of the proximal limb vessels, slenderness of limbs, small hands in comparison with feet that possess reduced second digits, a distinctive nonsaltatory locomotor pattern, the closest orbital approximation among all primates, digestive specializations for toxic prey, and an unusually low basal metabolic rate [Nekaris, 2003]. Slender lorises share characteristics with close relatives, such as the potto, including very short tails, round heads, and eyes with tiny ears covered primarily by fur [Oates, 1984; Schulze and Meier, 1995]. Slender lorises have forelimbs and hindlimbs that are virtually equal in length with exceptionally long fingers and toes that enable them to grasp branches for extended periods of time without movement [Schulze and Meier, 1995].

This article presents the results of feeding trials to determine if captive slender lorises had a preference for a particular insect life stage or insect species, and if there was a difference between males and females in their choices. The trials were designed to test three predictions: (1) captive lorises would preferentially select a life stage with which they are familiar; (2) captive lorises would preferentially select the largest life stages of any insect; and (3) male and female choices would be different.

METHODS

Study Site and Subjects

The study was conducted at the Duke Lemur Center (DLC) located in Durham, North Carolina. Four slender lorises were used to examine food choice (Tables 1, 2). This is the largest collection of captive slender lorises at any world-wide facility and represented 40% of the total captive population at the time of the research. Group 1 individuals were identified from a combination of natural features, including coat color, facial markings, body size, and missing patches of hair. Sex and behavioral patterns were also used to identify Group 1 individuals. A stripe of white-out was placed on the forehead of Group 2 individuals (Fig. 1).

TABLE 1. Description of Individuals in Study Group 1 (NB room 104) and 2 (NB room 113)

Designation	Sex	Age class	Date of birth	Place of birth
Anil	Male	Adult	03/22/1991	Cincinnati Zoo and Botanical Gardens
Samantha	Female	Adult	11/06/1991	Denver Zoological Gardens
Lavoris	Male	Adult	10/17/1992	Zoological Society of San Diego
ABU	Female	Adult	10/10/1997	Duke Lemur Center

TABLE 2. Groups 1 and 2 Enclosure Dimensions

Groups	Length	Width	Height	Area	Volume
1	4.82 m	4.21 m	2.87 m	20.25 m^2	58.24 m^3
2	4.82 m	2.87 m	2.87 m	13.84 m^2	39.70 m^3

Fig. 1. Lavoris (adult male) slender loris marked with white-out for identification purposes at trial apparatus.

The two study groups were housed in indoor enclosures constructed of cinderblocks with a floor of wood shavings (4.8 m $\times$ 4.2 m $\times$ 2.9 m). The enclosures were equipped with branches, buckets, and boxes used for climbing, and other enrichment activities. Each study group contained one male and one female.

Procedure

Data were collected on 14 days in March, April, and May 2008 for 16 hr and 40 min. Lorises were presented with life stages of three insects; mealworm (*Tenebrio molito*), superworm (*Zophobus morio*), and wax worm (*Galleria mellonella*). There were five trials carried out on each individual: (1) three species of insects all in the larvae stage, (2) larvae vs. adult mealworms, (3) larvae vs. adult wax worms, (4) larvae vs. adult superworms, and (5) three species of insects all in the adult stage. For each trial, a total of five repetitions were run on each individual. Each slender loris was subjected to a total of 25 repetitions; therefore, 100 repetitions were conducted. In trials 1 and 5, the total number of insects the lorises had access to per repetition per trial was six, because two lorises were housed together in each room. In trials 1 and 5 with five repetitions, there were a total of 30 insects available for consumption per room; therefore, a total of 60 insects were available per trial. The study was structured so that each loris had access to an assigned trial box; however, on some occasions, the lorises would consume insects from a trial box assigned to his/her cage mate. For this reason, consumption data were collected and scored out of the number of insects available per room ($n = 30$), as opposed to the number of insects available per loris ($n = 15$). When comparing males and females, the numbers of insects available to each loris were used as totals offered. For example, in trials 1 and 5, the males' consumption totals were out of 30 with 15 insects per loris being accounted for as available prey. A second scenario was trials 2–4, where males' consumption totals were out of 40 with 20 insects per loris being accounted for as available prey. Owing to the comparison of males and females, the number of insects available per room could not be used. The procedure used to score the data was exactly the same for males and females. In the trials where the larvae and adult stages were being compared, a total of four insects (two larvae and two adult) were offered per repetition per trial. The total number of insects the lorises had access to per repetition per trial was eight because two lorises were housed together in each room. In a trial with five repetitions, there were a total of 40 insects available for consumption per room; therefore, a total of 80 insects were available per trial. In these three trials, consumption data was collected and scored out of the number of insects available per room ($n = 40$), as opposed to the number of insects available per loris ($n = 20$). The order in which the insects were loaded in the compartments was predetermined for each repetition of each trial before the study began. A different presentation order was used for each repetition of each trial, amounting to five different orders per trial. Each of the four slender lorises was exposed to the same presentation orders. For the 100 repetitions, the order of insect removal was recorded based on the assigned trial box of each loris. Each loris selected insects from his/her individual trial box and the order in which insects were removed was recorded for that trial box exclusively. Insects removed from a cage mate's trial box were not accounted for in the order of removal data, but were scored for the consumption aspect of the study without taking order into account.

Trial sessions lasted 10 min. Two Sony video cameras (Sony Electronics, NY, NY), each focused on a separate feeding apparatus, were used to record observations. Cameras were placed on "nightshot" mode, which activated the infrared feature and allowed two individual lorises to be observed on two television monitors simultaneously.

The trial apparatus was constructed out of lexan glass (SABIC Innovative Plastics, Mount Vernon, IN) (Fig. 1). Each box was covered with green construction paper on the back and bottom to reduce glare. This procedure was presented to the lorises during the initial stages of the study when DLC staff was conditioning the lorises to the boxes. This preliminary procedure helped the lorises to associate the trial apparatuses with food. Each individual slender loris had his/her own trial apparatus assigned to them and only that apparatus was used for each experiment conducted on that individual. The trial apparatuses were constructed so that the slender lorises could only fit their arms and hands into the feeding box. There were a total of four separate chambers in each feeding box, where each individual insect species or life stage was placed.

Analysis

Prediction 1: Larvae stage preference

Mean and standard deviation were calculated for the numbers of mealworms, waxworms, and superworms in the larvae and adult stages the four lorises consumed. Three different chi-square tests were used to examine significance ($P \leq 0.05$): (1) differences in the numbers of larvae and adult mealworms consumed by all lorises, (2) differences in the numbers of larvae and adult waxworms consumed by all lorises, and (3) differences in the numbers of larvae and adult superworms consumed by all lorises.

Prediction 2: Preference for superworms

Mean and standard deviation were calculated for numbers of mealworms, waxworms, and superworms consumed by all lorises. A chi-square test was used to determine if there were significance differences in larval insects consumed. ANOVA (analysis of variance) was used to test for significant differences in more than two means.

Prediction 3: Dietary preference of males and females

Eight different chi-square tests were used to examine significance ($P \leq 0.05$): (1) differences in larval insects consumed by males and females, (2) differences in the numbers of larvae mealworms consumed by males and females, (3) differences in the numbers of adult mealworms consumed by males and females, (4) differences in the numbers of larvae waxworms consumed by males and females, (5) differences in the numbers of adult waxworms consumed by males and females, (6) differences in the numbers of larvae superworms consumed by males and females, (7) differences in the numbers of adult superworms consumed by males and females, and (8) differences in adult insects consumed by males and females.

RESULTS

Prediction ♯1: Slender Lorises Will Show a Preference for Insects Offered in the Larvae Stage

The slender lorises preferred the larvae stage compared with the adult stage in all three insect species presented. They consumed significantly more mealworms offered in the larvae stage ($n = 31$) compared with the adult stage ($n = 9$) (7.8 ± 5.0 vs. 2.3 ± 2.9; $\chi^2 = 26.05$, df = 1, $P \leq 0.05$) (Table 4). They also consumed significantly more waxworms offered in the larvae stage ($n = 39$) compared with the adult stage ($n = 15$) (9.8 ± 3.8 vs. 3.8 ± 4.3; $\chi^2 = 15.65$, df = 1, $P \leq 0.05$) (Table 5). A greater number of superworm larvae ($n = 36$) were consumed than adults ($n = 7$) (9.0 ± 3.74 vs. 1.75 ± 2.87; $\chi^2 = 27.625$, df = 1, $P \leq 0.05$) (Table 6).

Prediction ♯2: Slender Lorises Will Consume More Superworms in the Larvae Stage Than Mealworms and Waxworms Because of Their Larger Size and Energetic Value

The subjects consumed more superworm ($n = 19$) larvae than mealworm ($n = 17$) and waxworm ($n = 15$) larvae (4.75 ± 1.26 vs. 4.25 ± 2.22 vs. 3.75 ± 1.26), but the differences were not significant ($\chi^2 = 1.75$, df = 2, $P \geq 0.05$) (Table 3). ANOVA was also used to show that these means were not significantly different from one another. There was no preference for any larvae over another. In four out of five trails, Lavoris consumed the superworm first, which suggests that this loris had a preference for superworms over the other two insect species. In three out of five repetitions, Lavoris consumed the three insects offered in the same order ((1) superworm, (2) mealworm, (3) wax worm), suggesting his preferences for the three species when offered together. In three out of five repetitions, ABU consumed the

TABLE 3. Trial ♯1: Number of Mealworm, Wax worm, and Superworm Larvae Consumed by Each Loris

	Mealworms	Wax worms	Superworms
Anil (male)	5 (5)	2 (5)	5 (5)
Samantha (female)	3 (5)	4 (5)	5 (5)
Lavoris (male)	7[a]	5 (5)	6[b]
ABU (female)	2 (5)	4 (5)	3 (5)

[a]Lavoris ate five of five from his box and two from ABU's box.
[b]Lavoris ate five of five from his box and one from ABU's box.

TABLE 4. Trial ♯2: Number of Mealworm Larvae and Adults Consumed by Each Loris

	Larvae	Adults
Anil (male)	7 (10)	6 (10)
Samantha (female)	11[a]	0 (10)
Lavoris (male)	12[b]	3 (10)
ABU (female)	1 (10)	0 (10)

[a]Samantha ate 10 of 10 from her box and 1 from Anil's box.
[b]Lavoris ate 10 of 10 from his box and 2 from ABU's box.

TABLE 5. Trial ♯3: Number of Wax worm Larvae and Adults Consumed by Each Loris

	Larvae	Adults
Anil (male)	6 (10)	0 (10)
Samantha (female)	13[a]	7 (10)
Lavoris (male)	13[b]	8 (10)
ABU (female)	7 (10)	0 (10)

[a]Samantha ate 10 of 10 from her box and 3 from Anil's box.
[b]Lavoris ate 10 of 10 from his box and 3 from ABU's box.

TABLE 6. Trial ♯4: Number of Superworm Larvae and Adults Consumed by Each Loris

	Larvae	Adults
Anil (male)	8 (10)	0 (10)
Samantha (female)	9 (10)	6 (10)
Lavoris (male)	14[a]	1 (10)
ABU (female)	5 (10)	0 (10)

[a]Lavoris ate 10 of 10 from his box and 4 from ABU's box.

superworm first, suggesting that if available she preferred superworms to the other two insects' species. In three out of five repetitions, Anil consumed the superworm first. It seems that when given a choice, Anil prefers superworms to mealworms and wax worms. Anil consumed the mealworm second in four out of five repetitions; therefore, a secondary preference exists for mealworms. In this case, Anil's least favorite insects were the wax worms. The order of consumption in Samantha's case varied with each repetition; therefore, order was not a good measure of dietary preference in her case. Out of the three insects offered, Samantha consumed mealworms ($n = 3$) the least and superworms the most ($n = 5$) (Table 3).

Prediction ♯3: Differences will Exist Between Males and Females Regarding Dietary Preference

In trial 1, the lorises were offered three species of insects all in the larvae stage. The males consumed 12 mealworms, 7 wax worms, and 11 superworms, whereas the females consumed 5 mealworms, 8 wax worms, and 8 superworms, but the differences were not significant ($\chi^2 = 4.7$, df = 5, $P \geq 0.05$) (Table 3). The total amount of insects eaten by males ($n = 30$) was greater than females ($n = 21$) (Table 3). In trial 2, the lorises were presented with mealworms in the larvae and adult life stages. The males consumed 19 larvae and the females consumed 12 larvae, but the differences were not significant ($\chi^2 = 3.25$, df = 1, $P \geq 0.05$) (Table 4). The males consumed nine adults, whereas the females consumed zero adults, which led to significant differences ($\chi^2 = 26.05$, df = 1, $P \leq 0.05$) (Table 4). The total amount of insects eaten by males ($n = 28$) was greater than females ($n = 12$) (Table 4). In trial 3, the lorises were presented with wax worms in the larvae and adult life stages. The males consumed 19 larvae and the females consumed 20 larvae, but the differences were not significant ($\chi^2 = 0.05$, df = 1, $P \geq 0.05$) (Table 5). The males consumed eight adults and the females consumed 7 seven adults, which led to a significant difference ($\chi^2 = 15.65$, df = 1, $P \leq 0.05$) (Table 5). Noteworthy is the fact that Samantha consumed seven adult wax worms (moths) and Anil did not consume any, yet these two lorises were housed together (Table 5). Samantha was the only female to consume adult wax worms (moths) (Table 5). Lavoris was the only male and individual housed in room 113 (with an adult female) to consume adult wax worms (moths) (Table 5). The total number of insects eaten by males ($n = 27$) and females ($n = 27$) were equal (Table 5). In trial 4, the lorises were offered superworms in the larvae and adult life stages. Males consumed 22 larvae while females consumed 14 larvae, but the differences were not significant ($\chi^2 = 2.0$, df = 1, $P \geq 0.05$) (Table 6). Males consumed one adult while females consumed six adults, which led to significant differences ($\chi^2 = 27.85$, df = 1, $P \leq 0.05$) (Table 6). Lavoris was the only male to consume an adult superworm and Samantha was the only female to consume adult superworms in this trial (Table 6). Lavoris was housed in room 113 with an adult female and Samantha was housed in room 104 with an adult male; so, these two lorises never came in contact with one another during the course of the study. The total number of insects eaten by males ($n = 23$) was greater than females ($n = 20$) (Table 6). In trial 5, the lorises were offered three species of insects all in the adult stage. Males consumed one mealworm (beetle), two wax worms (moths), and four superworms (beetles), whereas females consumed one mealworm (beetle), four wax worms (moths), and two superworms (beetles), which led to significant differences ($\chi^2 = 36.2$, df = 5, $P \leq 0.05$) (Table 7). The total number of adult insects eaten by males ($n = 7$) and females ($n = 7$) were equivalent (Table 7).

TABLE 7. Trial ♯5: Number of Mealworm, Wax worm, and Superworm Adults Consumed by Each Loris

	Mealworms	Wax worms	Superworms
Anil (male)	1 (5)	0 (5)	4 (5)
Samantha (female)	1 (5)	4 (5)	2 (5)
Lavoris (male)	0 (5)	2 (5)	0 (5)
ABU (female)	0 (5)	0 (5)	0 (5)

DISCUSSION

Prediction 1 was supported as the slender lorises did prefer the larvae life stage over the adult stage; however, they did not prefer a particular insect species over another. A possible explanation for life stage preference is that the larvae stage of the three insect species was a worm, whereas the adult stages varied, with the superworm and mealworm adult stages being beetles and the waxworm adult stage a moth.

It is possible that captive lorises are familiar with the larvae because slender lorises at DLC are offered mealworms (larvae stage) daily as a portion of their captive diet. Similarly, captive slender lorises at Ruhr-University Bochum are readily offered mealworms as a portion of their diet [Fitch-Snyder and Schulze, 2001]. Thus, it may be this familiarity rather than a real preference that results in captive lorises selecting larvae over adult life stages. Furthermore, slender lorises' mode of locomotion may cause them to target slow-moving prey; therefore, prey items in the adult stage may be harder to catch than insects in the larvae stage [Fitch-Snyder and Schulze, 2001].

Prediction 2 was not supported. Lorises consumed all three insect larvae at the same frequency. It was assumed that the larger size of the superworms would entice the lorises to consume them first when offered along with the other two insect species. Larger body-sized lorises must compensate for their larger size by eating prey items that are easily accessible and larger in size [Fitch-Snyder and Schulze, 2001]. This is why the order of consumption was also examined. In all cases except Samantha's, the lorises consumed the superworms first at least three out of five repetitions. Although not a significant result, Samantha did consume superworms more than any of the other insects when offered together. She consumed five superworms, four wax worms, and only three mealworms in trial 1.

Prediction 3 was supported but only in part. In all trials comparing the life stages of an insect species (larvae vs. adult), the males and females did not show a significant difference between the total larvae consumed. Conversely, in all of these same trials, the males and females did show a significant difference between the total adults consumed. Schülke [2003] found that in fork-marked lemurs (*Phaner furcifer*) male foraging efficiency was reduced compared with females. Feeding requires foraging to an extent; therefore, the more efficient foragers are the ones who should consume the most prey. The sex that consumed the most of an insect species or life stage was the one considered to prefer that species or life stage. These trials of feeding preference by gender were also an examination of feeding efficiency, because the numbers of prey items consumed determined the preference.

Males and females were very tolerant of one another during this dietary preference study. Captive lorises partake in more social interactions than other captive nocturnal prosimians, especially bushbabies [Bearder, 1987; Nekaris, 2003; Sussman, 1999]. Cooperative feeding among nocturnal prosimians is an uncommonly seen behavior [Nekaris, 2003]. The slender loris is a highly insectivorous primate, which makes the account of them feeding cooperatively all that more unique [Nekaris, 2003]. Most often, when prosimians of opposite sex are seen feeding together, they are a species whose diet includes nonanimal materials, including gum in fork-marked lemurs and leaves in *Lepilemur mustelinus* [Charles-Dominique and Petter, 1980; Ganzhorn, 1993; Nekaris, 2003]. Although males and females were assigned separate boxes to feed from, they would sometimes venture over to their cage mates trial box and consume insects. Often times when this happened the lorises would switch boxes, where one would leave its assigned box to consume insects from the other lorise's box in the room and vice versa. Other times, males and females would feed from the same trial box simultaneously without any noticeable aggressive interactions. For example, in trial 3, wax worm larvae and adults were offered to Anil and Samantha and Anil consumed 6 larvae and 0 adult wax worms, whereas Samantha consumed 13 larvae, 3 of which were from Anil's trial box. Samantha also consumed one adult from Anil's trial box. In a second scenario (trial 1), Anil and Samantha were offered mealworm larvae and adults. In trial 1, Anil consumed six adult mealworms (beetle), one of which was from Samantha's trial box. On the other hand, Samantha did not consume any adult mealworms (beetle). This is interesting because it seems that these two lorises of opposite sex were allowing one another to feed from each other's trial box willingly. If there was an insect offered that one obviously disliked, it seemed they had no problem with their partner feeding on that disliked insect and vice versa.

This study had some potential problems that could have interfered with the results. The four lorises were in pairs in their home rooms and separating them was not allowed by the DLC. Because they are listed as endangered by IUCN, there is pressure on captive populations to breed in order to protect them from extinction.

The DLC houses one of the largest and most successful captive populations of slender lorises; therefore, they represent a very important component of the captive breeding program [Nekaris, 2003; Izard and Rasmussen, 1985; Rasmussen and Izard, 1988; Schulze and Meier, 1995; Fitch-Snyder and Schulze, 2001].

CONCLUSION

The lack of data available on slender loris' feeding habits in the wild, including the insects they prefer and dislike, is a clear hindrance to their being successfully kept in captivity. Rare and difficult to study in the wild, it is imperative that more information about loris diet preferences be gathered from the few that are in captivity. Presenting captive animals with a preferred diet item would likely improve breeding success, thereby increasing reproductive output. A better understanding of a preferred diet in captive slender lorises is essential to sustaining a healthy captive slender loris population. The DLC slender lorises preferentially selected an insect life stage with which they were familiar, and males and females have different preferences; however, an insect's size does not necessarily make them more attractive to captive slender lorises.

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