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Effects of Radio Transmitter Weight on a Small Nocturnal Primate

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An increasing number of primatologists have begun using radio telemetry to study the behavioral ecology of nocturnal prosimian primates. Radio telemetry has enabled the collection of data on these nocturnal and cryptic prosimians that was previously difficult or impossible to otherwise obtain. A critical assumption of studies employing radio telemetry is that the radio transmitters have no appreciable negative effects on the study animals and the data being collected are not being biased by the presence of radio transmitters. This assumption is made because comparable data from a non-radio-collared control group are impossible to obtain. In an attempt to determine the tolerable weight limit for radio collars for a small nocturnal primate, the spectral tarsier, *Tarsius spectrum,* a comparison of the behavior and body weight of individuals wearing collars of two different weights was conducted. This study was conducted in Tangkoko Dua Saudara Nature Reserve in Sulawesi, Indonesia. A total of 16 individuals from seven groups were trapped in mist nets, radio-collared, and observed using focal follow sampling between April 1994 and June 1995. Each individual was observed for 4–6 months depending on the life span of the radio-collar battery. The two radio-collar weights appeared not to affect spectral tarsiers differentially. Average body masses in neither set of subjects differed between the days collars were attached and 6 months later, when they were removed. No differences in activity patterns, home range size, or prey capture rate were detectable between subjects wearing the different transmitters. These results suggest that the heavier radio collars used in this study did not have any appreciable effects on the behavioral patterns of this primate. Am. J. Primatol. 46:145–155, 1998.

Key words: telemetry; radio tracking; body weight; primate; nocturnal; prosimian

INTRODUCTION

Over the last decade, an increasing number of primatologists have begun using radio telemetry to study the behavioral ecology of the nocturnal prosimian

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primates [*Tarsius bancanus:* Crompton & Andau, 1986, 1987; *Galago zanzibaricus:* Harcourt & Nash, 1986; *Galago senegalensis:* Bearder & Martin, 1979; *Cheirogaleus major:* Wright & Martin, 1995; *Microcebus murinus:* Corbin & Schmid, 1995; *Daubentonia madagascarensis:* Sterling, 1992]. Radio telemetry has enabled the collection of data on these nocturnal and cryptic prosimians that was previously difficult or impossible to otherwise obtain. Because the type, quantity, and quality of the data are near impossible to obtain without radio telemetry, it is difficult to test whether the radio transmitters are affecting the behavior of the study animals. Thus, a critical assumption of all studies employing radio telemetry is that the radio transmitters have no appreciable negative effects on the study animals and the data being collected are not biased by the presence of radio transmitters.

One of the most obvious ways that the radio-transmitter package may affect the study animal's behavior and survival is by adding weight that must be transported. Radio transmitter package weight becomes a critical factor when dealing with small animals. All nocturnal prosimian primates are relatively small, with body weights ranging from 40 g to 3 kg [Fleagle, 1988; Rowe, 1996]. Radio-telemetry studies of nocturnal prosimians have used collars ranging from 5% of body weight in *Galago senegalensis* [Bearder & Martin, 1979] to 5–9% in *Tarsius bancanus* [Crompton & Andau, 1987] to as high as 15% of body weight in *Tarsius dianae* [Tremble et al., 1993]. When dealing with very small radio-transmitter packages, slight reductions in weight become very costly in terms of both transmitter life and transmission range [Brander & Cochran, 1971; Amlaner & MacDonald, 1980; White & Garrott, 1987; Kenward, 1987] because lighter transmitter packages utilize smaller and less powerful batteries. Therefore, it is generally recommended that a transmitter package weight be specified which is not significantly below the study animal's tolerable weight limit. The tolerable weight limit is defined in the literature as the maximum amount of weight an animal can carry in the form of a radio transmitter with no discernible effects on the animal's behavior, survival, and general well-being [White & Garrott, 1987; Kenward, 1987].

In most mammals and birds, 5% of body weight is suggested as the tolerable weight limit [White & Garrott, 1987; Kenward, 1987]. This percentage was determined based on studies of birds and small mammals where comparable data from non-radio-transmittered individuals was obtained [Greenwood & Sargeant, 1973; Amlaner et al., 1979; Warner & Etter, 1983; Garrott et al., 1985; Hines & Zwickel, 1985; Snyder, 1985]. It should be noted, though, that in a few studies where control groups were used and animals wore collars weighing 5% of body weight, significant negative impacts of the radio transmitters on the individuals' behavior and survival have been documented [Hamley & Falls, 1975; Smith & Whitney, 1979; Erikstad, 1979; Webster & Brooks, 1980; Smith, 1980]. For example, radio-harnessed waterfowl experienced substantial weight loss [Greenwood & Sargeant, 1973; Perry, 1981], and decreased survival was noted in radio-collared meadow voles, *Microtus pennsylvanicus* [Webster & Brooks, 1980]. Many more studies of birds and mammals, however, have shown no negative effects of radio-transmitter package weights [Amlaner et al., 1979; Hines & Zwickel, 1985; Snyder, 1985]. In some of these studies, the radio-transmitter package was clearly more than 5% of the animal's body weight.

At present, there have been no studies determining the tolerable weight limit for any of the nocturnal prosimian primates, since comparable data from non-radio-collared controls cannot be obtained. In other mammalian species where data from a non-radio-collared control group are impossible to obtain, mammalogists have tried to ascertain the tolerable weight limit by studying the behavior and survival of animals wearing transmitter packages of different total weights and different attachment methods [Greenwood & Sargeant, 1973; Warner & Etter, 1983]. The goal of this study was to ascertain the tolerable weight limit for the spectral tarsier, *Tarsius spectrum,* by studying the impact of different radio-transmitter package weights on the behavior, body weight, and survival of individuals. Although this method cannot directly determine the absolute maximum weight spectral tarsiers can transport, this roundabout method will aid in the development of tolerable weight limits for radio-transmitter package weights.

This preliminary study will address two interrelated questions: 1) whether there is a difference in the behavior (time budgets, prey capture rates or ranging) or survival of spectral tarsiers wearing transmitter packages greater than 5% of total body weight and those wearing transmitter packages that weigh less than 5% of total body weight, and 2) whether there is any significant difference in the body weight of individual spectral tarsiers wearing transmitter packages after having worn the radio collars for several months.

MATERIALS AND METHODS

Study Site

This study was conducted at Tangkoko-Dua Saudara Nature Reserve on the easternmost tip of the northern arm of the island of Sulawesi (longitude 125 14' east and latitude 1 34'). When the reserve was first formed in 1980, it comprised 8,867 hectares with a sea boundary of 12 km [World Wildlife Fund, 1980]. Based on a vegetation survey conducted by MacKinnon and MacKinnon, the reserve exhibits a full range of floral communities from sea-level coastal communities to lowland forests, submontane forests to mossy cloud forests on the summits of Dua Saudara and the Tangkoko Crater [MacKinnon & MacKinnon, 1980; Kinnaird & O'Brien, unpublished]. The majority of the reserve is clearly disturbed by human influence (old clearing activities and/or selective disturbance). Resource availability, as measured according to insect biomass [Brower et al., 1990] ranged from 6.9–11.1 grams from April 1994 to June 1995 [Gursky, 1997].

Capture and Attachment

The following procedures were used to locate individuals. Prior to dawn, my field assistant and I would stand on the periphery of a 1 hectare plot. Plots were chosen randomly (following a block design) within 1 km^2 of the trail system. As the tarsiers returned to their sleeping site, or at their sleeping site, they gave loud vocal calls for 3–5 min that could be heard from 300–400 m [MacKinnon & MacKinnon, 1980; Niemitz, 1984]. All groups that were heard vocalizing were then followed to their sleeping site. My field assistant and I then returned to the sleeping site prior to dusk to set up several mist nets in the vicinity of the sleeping site. The mist nets were continually monitored for captured tarsiers.

Upon capture, individuals were placed in a cloth bag and weighed with a portable scale providing an accuracy of ±1 g. An SM1 radio collar (manufactured by AVM Instrument Co., Ltd., Livermore, CA) with a groove loop was attached to the tarsier's neck by a simple folding of the thermoplastic band. Two weights of batteries were used in the radio collars (Hg41: 2 g; Hg675: 4 g). The lighter weight battery had a field life span of approximately 4 months vs. 6 months for the heavier battery. Although the heavier radio collar (7 g total collar weight) had a longer transmission range than the lighter one (3.5 g total package weight), this was not relevant in the field due to the relatively small home range used by this species [Gursky, in press]. These two radio collars were chosen because AVM advertised both last at least 6 months in the laboratory and have a transmission range of over 0.5 km. These two radio-transmitter packages were also chosen so that one radio-collar package would weigh less than 5% of adult body weight and the other more than 5% of adult body weight. Table I lists all of the radio-collared individuals on which focal follows were conducted, their group affiliation, their sex, the type of radio collar, the relative weight of the radio-transmitter package (radio-transmitter weight/body weight), the individual's body weight, change in body weight after wearing the radio collar, and the number of months that the radio collar was worn. Capturing individuals did not require immobilization with drugs.

When the battery in the radio collar expired, numerous attempts were made to mist-net individuals a second time in order to remove the radio collars. Out of the 19 individuals captured, three individuals removed their radio collars shortly after they were attached due to configuration problems. Because the loop antenna was opened and not closed, it was not possible to relocate the radio collars, although these three individuals were occasionally observed at their respective sleeping sites. Despite several months of trying to recapture the other 16 individuals, I was able to recapture only nine individuals. The other seven radio-collared individuals that were not retrapped were observed entering and leaving their sleeping sites, indicating that these animals were not dead, just too wary to enter another mist net.

Data Collection

A radio receiver using 151 MHz frequency and a three element collapsible Yagi antenna were used to determine the location of each individual. Each night a single spectral tarsier individual was followed with the aid of moonlight and

TABLE I. Relative Weight of the Transmitter Package for Each Individual*

Individual	Group	Sex	Collar type	Percent body weight	Original body weight measurement (g)	Body weight loss/gain (g)	How long wore collars (months)
864	E650	F	Light	3.07	114	n/a	5
897	G850	F	Light	3.13	112	0	4
226	C600	F	Light	3.18	110	n/a	5
914	J700	F	Light	3.37	104	0	5
008	J700	F_s	Light	4.07	86	n/a	4
046	F600	F	Heavy	6.25	112	+4	5
306	F600	F	Heavy	6.60	106	–4	4
876	G1000	F	Heavy	6.73	104	n/a	4
571	M600	F	Heavy	7.45	94	+10	5
988	G850	M	Light	2.66	132	–4	4
325	E650	M	Light	2.73	126	+6	6
128	F600	M	Light	2.92	120	+4	6
126	M600	M_s	Light	3.88	90	n/a	4
588	C600	M	Heavy	5.55	126	n/a	6
763	J700	M	Heavy	5.74	122	–2	6
038	G1000	M_s	Heavy	7.61	92	n/a	5

*Subscripted s indicates a subadult individual.

flashlights. A total of 16 individuals from seven groups were trapped in mist nets, radio-collared, and observed using focal follows between April 1994 and June 1995. Each individual was observed for 4–6 months depending on the life span of the radio-collar battery (Table 1). As the batteries in the first group of radio collars died, new individuals were mist-netted, radio-collared, and followed. This procedure was repeated several times.

The focal individual's behavior was recorded at 5 min intervals [Altmann, 1974]. The following behaviors were recorded: foraging, feeding, resting, traveling, and socializing (i.e., scent mark, allogrooming, playing, and vocalizing). Definitions of all behaviors recorded are presented in Table II. In addition, all occurrences of insect pursuits and captures were collected continuously *ad libitum*.

Home-range data were collected at 15 min intervals. Each location was marked with flagging tape which noted the time, the individual, and the date. The next day, all flagging tapes were relocated. The actual location was measured with the aid of a compass and tape measure with reference to the 50 m trail system in the study area. Based on these locational data points, the actual home-range size was calculated using minimum concave polygons [White & Garrott, 1987; Kenward, 1987]. To determine the distance each individual tarsier traveled per unit time, I used 15 min step distances [Whitten, 1982; Kinnaird, 1992]. Thus, distance traveled was calculated as the straight line distance between successive 15 min locations. Nightly path length was calculated as the total distance individuals traveled per night, as measured by the 15 min step distances throughout the night.

Data Analysis

It has been noted that behaviors sampled at short time intervals are often autocorrelated [Janson, 1990]. As a result, considering each 5 min sample as independent exaggerates sample size and biases the statistical tests. A chi-square contingency table analysis was performed to determine if the activity-budget data collected in this study were autocorrelated. Successive data points in this study were found to be significantly autocorrelated. Therefore, data points were

TABLE II. Definitions of the Behavioral States Recognized During this Study

Behavior	Definition
Forage	Actively searching the ground or leaves or air for a moving prey item; also involves ears twitching while trying to locate prey, auditorally, but primarily involves active scanning behavior, head is not in the frontal position but is turned from 0–180°
Feed	The animal is actively eating a prey item; includes all handling time of prey, such as putting prey into the mouth
Rest	The animal is motionless; ears and head are not moving; head is not rotated from the frontal position
Travel	Actively moving from one support to another via various locomotor styles such as vertically clinging and leaping, quadrupedalism, and climbing
Social	Involves scent-marking (moving the genital region against a substrate from side to side with the tail in a raised position or urinating), grooming others, vocalizing, and play grappling (running and jumping and tail pulling)
Miscellaneous	Grooming self (scratching with the grooming claw, may include marking own body with scent glands, cleaning body with tongue or hands like a cat)

subsampled until they were no longer autocorrelated at the .05 level of significance [Janson, 1990]. Subsampling began at the first data point and was continued until statistical independence was achieved. All samples for this analysis used 20 min intervals.

The activity budgets of adult males adult and females were calculated using the statistically independent sample and compared to test for statistically significant sex differences using a simple 2 × 4 chi-square goodness-of-fit test [Sokal & Rohlf, 1981]. To eliminate the confounding effects of age, and due to limited sample size, the three subadults in this study were excluded from the analysis. As the activity budgets of the adult spectral tarsiers differed significantly according to sex, it was not possible to pool the data.

Mann-Whitney U tests were conducted to test for differences in the mean distance traveled (meters) per 15 min, the mean nightly path length (meters), the home ranges (hectares), the prey-capture rate, and body weight between adult male and adult female spectral tarsiers.

Since the mobility patterns, prey-capture rate, and the body weight of adult male and adult female spectral tarsiers were also found to differ significantly, it was not possible to pool these data. Therefore, these variables were then calculated separately for each sex wearing each collar type. The Mann-Whitney U test was performed to test for statistically significant differences between adult females wearing the heavier or lighter radio collars and adult males wearing the heavier or lighter radio collars.

The body weight of adult individuals at the time of collaring and their respective weights when the collars were removed (several months later) was then compared using the Wilcoxon matched-pairs signed ranks test [Sokal & Rohlf, 1981].

RESULTS

Weight Loss

The body weights of male and female spectral tarsiers were statistically significant (Mann-Whitney U test: n1 = 5, n2 = 4, U = 20, $P = .014$). The mean body weight for the male spectral tarsiers was 125.8 g (SD ±5.05), whereas the mean body weight for the female spectral tarsiers was 108.2 g (SD ±6.10). There was absolutely no overlap in body weight between the males and the females.

There was no statistically significant change in body mass of spectral tarsiers between the time when individuals were first captured and when the radio collars were removed (Wilcoxon matched-pairs signed rank test Ts = 10, n = 9) (Table I).

Time Budgets

The activity budgets of male and emale spectral tarsiers were statistically different ($\chi^2 = 17.12$; $P = .0001$, df= 3). That is, males and females did not spend equal amounts of time in the four primary behavioral states recorded throughout this study. As a result of the overall statistical difference in the activity budgets of the males and females, all future analyses involving changes in the activity or time budget will be conducted separately for males and females.

The activity budget of the male spectral tarsiers fitted with the heavier transmitter package did not differ significantly from the activity budget of males wearing the lighter transmitter package ($\chi^2= 0.27$; $P = .96$; df= 3). Likewise, the activity budget of females fitted with the heavier transmitter package did not differ significantly from the activity budget of females wearing the lighter transmitter package ($\chi^2 = 0.13$; $P =.98$; df= 3).

Prey-Capture Rates

Adult females captured insects at a slightly faster rate per hour of observation than did adult males (Mann-Whitney U test: n1 = 8, n2 = 5, U = 40, *P* = .003). The mean number of insects consumed per hour of observation by females was 0.96 (SD ±0.06), compared to 0.68 insects per hour of observation (SD ±0.12) by males. Similarly, adult females captured insects at a slightly faster rate per hour observed foraging than did adult males (Mann-Whitney U test: n1 = 8, n2 = 5, U = 40, *P* = .003). The mean number of insects consumed per hour of observed foraging by females was 1.28 (SD ±0.10), compared to 1.98 insects per hour observed foraging (SD ±0.15) by males.

When the effect of collar type (heavy vs. light) was controlled for, the mean rate of capture for insect prey for females wearing the heavy collars was 0.92 insects per hour of observation (SD ±.09). The mean rate of capture for insect prey for females wearing the light collars was 0.98 insects per hour of observation (SD ±.05). There was no statistically significant difference in the prey-capture rate for females wearing the heavy or the light radio transmitter package (Mann-Whitney U test: n1 = 4, n2 = 4, U = 12, *P* = .248).

Similarly, the mean rate of capture for insect prey for males wearing the heavy collars was 0.63 insects per hour of observation (SD ±.06). The mean rate of capture for insect prey for males wearing the light collars was 0.72 insects per hour of observation (SD ±.08). There was also no statistically significant difference in the prey-capture rate for males wearing the heavy or the light radio transmitter package (Mann-Whitney U test: n1 = 3, n2 = 2, U = 4, *P* = .563).

Mobility Patterns

The mobility patterns of the adult male and adult female spectral tarsiers were statistically significant. The mean distance traveled per unit time by adult females was 26.6 m (SD ±8.21), compared to 40.48 m traveled per unit time (SD ±2.31) by adult males. The mean nightly path length by adult females was 447.68 m (SD ±132.16), compared to 790.62 m (SD ±94.38) by adult males. The home range utilized by adult females (n = 304) was 2.32 ha (SD ±0.53), compared to 3.07 ha (SD ±0.72) by adult males (n = 138). Adult females traveled shorter distances per unit time (Mann-Whitney U test: n1 = 8, n2 = 5, U = 38, *P* = .006), traveled shorter nightly path lengths (Mann-Whitney U test: n1 = 8, n2 = 5, U = 39, *P* = .005), and had smaller home ranges (Mann-Whitney U test: n1 = 8, n2 = 5, U = 34, *P* = .047) than did adult males.

The mean distance traveled per unit time by females wearing the heavy collars was 28.9 m (SD ±10.83), compared to 24.3 m traveled per unit time (SD ±5.07) by females wearing the lighter collars. These differences were not statistically significant (Mann-Whitney U test: n1 = 4, n2 = 4, U = 10, *P* = .563). Similarly, the mean distance traveled per unit time by males wearing the heavy collars was 42.3 m (SD ±2.82), compared to only 41.1 m traveled per unit time (SD ±2.40) by males wearing the lighter radio collars. This difference was also not statistically significant (Mann-Whitney U test: n1 = 3, n2 = 2, U = 4, *P* = .563).

The mean nightly path length traveled by females wearing the heavy collars was 489.57 m (SD ±175.31), compared to a nightly path length of only 405.77 m (SD ±73.08) by females wearing the lighter radio collars. These differences were not statistically significant (Mann-Whitney U test: n1 = 4, n2 = 4, U = 10, *P* = .563). The mean nightly path length traveled by males wearing the heavy collars was 797.3 m (SD ±76.01), compared to 786.2 m (SD ±121.88) by males wearing the lighter collars. This difference was also not statistically significant (Mann-Whitney U test: n1 = 3, n2 = 2, U = 3, $P = 1.00$).

The average home range utilized by females wearing the heavier radio collars was 2.31 ha (SD ±.42), compared to 2.34 ha (SD ±.69) utilized by females wearing the lighter radio collars. This difference was not statistically different (Mann-Whitney U test: n1 = 4, n2 = 4, U = 8, $P = 1.00$). Similarly, the average home range utilized by males wearing the heavier radio collars was 3.48 ha (SD ±.80), compared to 2.80 ha (SD ±.66) used by males wearing the lighter radio collars. This analysis was also not statistically significant (Mann-Whitney U test: n1 = 3, n2 = 2, U = 5, $P = .248$).

Survival

Only one of the 16 radio-collared individuals died during this study. The death was the result of avian predation. In addition, one female produced a stillborn infant. All other females (n = 7) produced healthy, vibrant infants that survived to adulthood.

DISCUSSION

If the spectral tarsiers wearing the heavier radio transmitter packages were stressed from transporting more than 5% of their body weight (compared to transporting less than 5% when wearing the lighter radio transmitter), then it might be predicted that these individuals would either 1) increase the amount of time they spent resting or foraging, 2) decrease their mobility (i.e., distance traveled), or 3) decrease the rate at which they captured prey relative to individuals wearing the lighter radio collars. The results of this preliminary study indicate that the spectral tarsiers wearing the heavier radio collars did not significantly modify their behavior (activity budgets, prey-capture rates, or mobility patterns) in any of the predicted ways relative to the behavior of spectral tarsiers wearing the lighter radio collars. This result may reflect the fact that spectral tarsiers, at least spectral tarsier females, are capable of transporting substantial amounts of additional weights. Pregnant females in the last trimester of their pregnancy are carrying a fetus that sometimes weighs more than 25% of their body weight. In contrast, the radio collar in this study was a maximum of 7% of adult body weight.

A quantitative comparison of the body weights of individuals before the radio collar was attached and after wearing the radio collar for several months shows that several individuals experienced changes in their body weight. While a few individuals experienced minor weight loss, several others experienced appreciable weight gains. These observations suggest that the heavier radio collars are probably not affecting the spectral tarsiers' body weight maintenance compared to the lighter radio collars.

The data obtained during this study is inadequate to determine whether the survival of the radio-collared individuals was affected by the presence of the radio collar. It is unclear at this point whether the one predation event and one stillbirth that occurred during this study were due to natural demographic processes or the result of the presence of the radio collar. Additional information on the survival probabilities of non-radio-collared individuals is needed before any additional assessments concerning the impact of the collars on the survival of spectral tarsiers can be made.

These results cannot and should not be interpreted to imply that increasing the weight of the radio collar is presently justified. This preliminary study did not address whether there was any effect from wearing the radio collar, only that wearing the heavier radio transmitter package did not produce any differences in behavior relative to that of the spectral tarsiers wearing the lighter radio collars. Prior to using radio collars weighing more than 5% of body weight, I recommend conducting some short-term captive studies comparing the behavior of non-radio-collared individuals and radio-collared individuals to further clarify whether there is any noticeable effect from wearing radio collars. In addition, a more detailed comparison of a larger range of collar weights may provide a more specific indication of the spectral tarsier's tolerable weight limit. Similarly, it is also important to explore how the length of time the collar is worn may affect the animal's future reproductive behavior (i.e., interbirth interval) and how it may affect other aspects of the animal's foraging behavior.

Thus, although it is not clear whether or not the behavior of individuals is affected by the presence of the radio collar, it can be tentatively stated that the heavier radio collar did not negatively affect the behavior, weight, or survival of these animals relative to the lighter weight radio collar. Indirect tests (such as the one presented in this paper) of the effect of radio-collar weight are very important, as more and more primatologists are using radio tracking in their studies. In addition, future studies should also begin to take into account the effect of different radio-package attachment methods. While some studies have attached collars around the animal's neck, others have used belts or harnesses [Harcourt & Nash, 1986; Crompton & Andau, 1987]. The effect of these different techniques on the behavior and survival of different prosimian species also needs to be reviewed.

CONCLUSIONS

1. Radio-collaring is a very valuable technique for studying the behavior of small nocturnal cryptic primates. Comparing the behavior and survival of animals wearing radio-transmitter packages with varying total package weights is a particularly useful method for identifying a species' tolerable weight limit.

2. The radio collars used in this study did not have a statistically significant effect on the animal's body weight after the collar was worn for several months, regardless of the radio collar's weight. There were also no significant differences in the activity budgets, prey-capture rates, or mobility depending on radio-collar weight for either males or females.

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