

SPOOL-AND-LINE TRACKING OF THE NEW GUINEA SPINY
BANDICOOT, *ECHYMIPERA KALUBU* (MARSUPIALIA, PERAMELIDAE)

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ABSTRACT.—We describe the construction of an improved spool-and-line mammal-tracking device with a range of 1,550 m that we used in a short-term tracking study of the previously unstudied New Guinea spiny bandicoot, *Echymipera kalubu*. We tracked 12 males a total of 18 times. Individuals tracked more than once were active in the same area on each night and often used the same pathways in the forest, but ranges were not exclusive and individuals used several different refuges within their ranges. Grid-cell analysis indicated that the nightly range size may reach 1.2 ha. For the five occasions on which an animal was followed all night, the mean nightly distance traveled was 344 m. We describe three types of nest or refuge and demonstrate that *E. kalubu* forages for invertebrates and fallen fruit. Weighing revealed that males are heavier than females. We discuss ways of refining the spool-and-line technique and compare its potential with radio-tracking.

The New Guinea spiny bandicoot, *Echymipera kalubu* (Fischer), is locally abundant and easily trapped, but, because it is nocturnal and is found in forest areas, no information exists on its behavior and ecology. Together, these features made it a suitable animal on which to test a recently developed method of mammal tracking which uses a "spool-and-line" device. Tracking animals by means of a thread trail is not a new idea; Ariadne was its originator. Breder (1927) and Stickel (1950) developed "trailing" techniques to study the activities of turtles (*Terrapene c. carolina*), and Greeger (1980) was able to gauge the extent of the home range of the armadillo, *Chaetophractus vellerosus*, by attaching rolls of polyester thread to individuals. The spool-and-line mammal-tracking technique that we used follows that developed by Miles et al. (1981) in their parasitological study of Amazonian mammals. Our main aim was to assess the efficacy of spool-and-line tracking in ecological work, and evaluate its usefulness as an alternative or complementary technique to radio-tracking. Although information on Australian Peramelidae (bandicoots) comes from studies of both wild (Gordon, 1974; Heinsohn, 1966; Stoddart and Braithwaite, 1979) and captive (Stodart, 1966) animals, no study of the biology of any of the three species of *Echymipera* (*E. kalubu*, *E. clara*, and *E. rufescens*) has been made. We describe a short-term study of a population of *Echymipera kalubu* in which we investigated nightly distances traveled, its habitat choice, foraging and nesting behavior, and home range exclusivity.

METHODS

The study was conducted 3 August–29 September 1985 in the Baiyer River Wildlife Sanctuary (144.10°E, 5.35°S) near Mount Hagen, Western Highlands Province, Papua New Guinea. The study area (170 ha), 1,200 m above sea level, consisted of lowland and lower montane rainforest. Regions of tree fall were taken over by dense secondary vegetation, whereas areas around the edge of the forest consisted of dense stands of "pit-pit" canegrass (*Miscanthus* and *Saccharum* sp.). A cleared-garden area (4 ha) with banana trees and sweet potatoes under cultivation also was included in the study area. We placed 100 box-style collapsible galvanized wire-mesh mammal traps (55 by 20 by 20 cm) in groups of five at random locations. Trap groups were relocated once every 2 weeks. Fresh papaya bait was changed each evening, and traps were examined daily at dawn. Animals were anaesthetized for 5–10 min by means of an intramuscular injection of *Hypnorm* (Crown Chemical Company Ltd., Lamberhurst, Kent), which allows rapid and complete recovery from anaesthesia. All animals were marked individually using a combination of a toe and an ear clip, and weighed and sexed.

Tracking technique.—The spool-and-line tracking method followed that of Miles et al. (1981) and consisted of attaching a spool of thread to an animal and tracing its subsequent movements by following the trail of thread that paid out as the animal moved. The spool devices, which we manufactured ourselves, consisted of a fixed spool with 1,550 m of thread enclosed in a plastic sheath.

Conical polypropylene "King Spools" wound with 1,550 m of double-stranded terylene thread (2/70 Decitex) were specially supplied by James Pearsall and Co. Ltd., Taunton. We tried using single-stranded terylene thread (1/70 Decitex) that is lighter and may be packed more compactly to allow a greater length of thread on the spool, but this proved too fine for easy tracking in forest. Polypropylene centrifuge tubes (35 mm external diameter), manufactured by Kartell Ltd. and distributed by Baird and Tatlock Ltd., London, formed the plastic sheath enclosing the "King Spool." Polypropylene is a lighter and cheaper material than the polycarbonate used by Miles et al. (1981). The tube length was reduced to approximately 80 mm and a 10-mm diameter hole drilled in the rounded end. The edges of the exit hole were filed smooth. The free end of the thread was passed through the hole and the plastic base of the "King Spool" fused to the open end of the tube with a soldering iron. The remaining part of the base of the "King Spool" then was removed on a lathe. This construction overcame two design weaknesses of the spools used by Miles et al. (1981). The larger exit hole allowed freer passage of thread from the spool, thus reducing breakage from thread fray. In addition, melting rather than gluing the spool and sheath together meant that we did not experience their problems of thread breakage brought about by the spool shifting within the tube. A complete device weighed about 38 g.

Radio-tracking devices generally are used only when they weigh less than 5% of an animal's bodyweight (Macdonald, 1978); we followed the same rule and attached spool devices only to *E. kalubu* weighing more than 800 g. The spool device was attached, using a belt of sticky tape (Advance Tapes, Ltd.), around both the animal and the device, in a lateral position just behind the rib cage. In this position, the spool device did not interfere with movements or inhibit breathing in any way; animals moved naturally and appeared unencumbered when observed on release. Furthermore, this position put the spool device beyond the reach of the bandicoot's powerful back limbs that easily could have torn apart the tape belt. No tracks were obtained for female bandicoots because the tape belt irritated the sensitive skin around the marsupium and no alternative means of attachment could be found. The adhesive of the tape used was ineffective in extreme wet; this accounted for several of the occasions on which spool devices were "shed" but also meant that the belt eventually came off animals that we failed to relocate. The spool device was attached during the morning and the animal left during the day in the trap in a canvas bag. Bandicoots were released at dusk and the loose end of thread tied to nearby vegetation. Every attempt was made to avoid unnecessarily alarming the animal on release in such a way that might affect its behavior.

The animal's track was traced the day after its release by following the thread trail. Its course was plotted by taking compass bearings at points along the thread 5 m apart in the forest. Retrieving the thread from the forest for measurement was laborious and often impossible because the thread became inextricably entangled around the undergrowth. Miles et al. (1981) weighed the retrieved spools and indirectly calculated the length of thread dispelled. Because we required information about the distances traveled in different habitat types, we used the 5-m map distances used in plotting the path of the animal as estimates of the distances traveled. The plots obtained gave a precise topological map of the thread trails, but provided no information about the pattern of thread within each 5-m section. As such our calculated distances were underestimates. Analysis of tracking movements was conducted by superimposing a 12.5- by 12.5-m grid over the plotted tracks (Voigt and Tinline, 1980); 12.5 m is a distance easily covered by these highly mobile animals and, also, the area enclosed in such a square in our study site normally consisted of homogeneous habitat-type, so it is reasonable to take the co-occurrence of two tracks in one grid cell as indicating activity in the same "patch." Areas of activity were calculated from linear tracks by scoring the number of different cells entered by an animal and multiplying the total by the area of a single cell (0.16 ha). We recorded details of habitat, evidence of foraging (e.g., "rootings" in the soil beside the trail), and the construction of nests or refuges located. The pattern of thread deposition was used to gauge whether the animal was active in one spot (concentrated jumble of thread), moving slowly (slack loops), or traveling fast (taut). A trail ended when the animal was relocated, the thread was broken and no continuation could be found, the spool device was found "shed," or the thread in the spool ran out. When an animal was relocated, it was either captured and its tracking device replaced or, if over half the thread remained on its spool device, it was not handled.

In general, the only difficulties of tracking in this way were those associated with forcing a human being through spaces more suited to bandicoot-sized animals. Usually, if a break in the thread occurred, the thread flowed sufficiently freely from the spool device for its continuation to be found within the next 2–3 m. Disruption of the trail once it had been laid could be a problem, especially in the garden area with its high

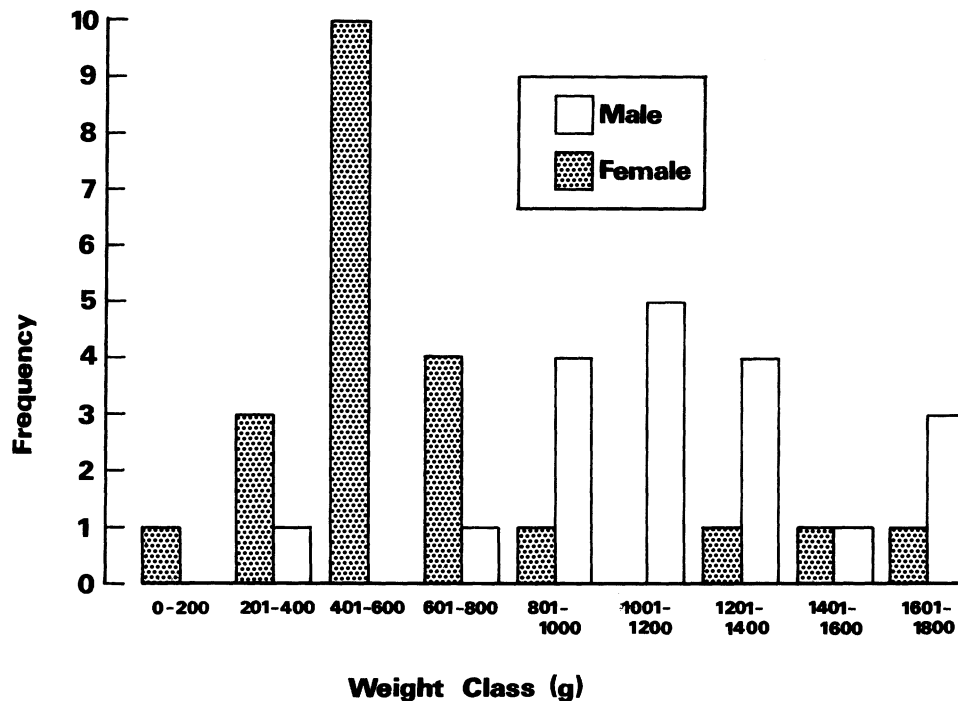


FIG. 1.—Distribution of body masses of male and female bandicoots (*Echymipera kalubu*).

levels of human activity. On one occasion, like Miles et al. (1981), we found that a colony of ants had broken up about 3 m of thread and removed parts of it. Means are presented with ± 1 SD.

RESULTS AND DISCUSSION

Body mass.—We caught 44 *E. kalubu* (24 females and 20 males) over approximately 4,000 trap nights. Animals were captured both in the forest (36) and in the cleared garden area (8). For the 41 animals weighed (22 females and 19 males), males were heavier than females (Fig. 1): mean weights were 685 ± 397 g for females and $1,173 \pm 343$ g for males ($t = -4.174$, $d.f. = 39$; $P < 0.0001$). However, the largest individual caught (1,800 g) was female, which demonstrated that female size is not constrained, relative to males, by growth.

Tracks and habitat use.—We obtained 18 tracks for 12 male *E. kalubu* at Baiyer River (Fig. 2). Five individuals (males 1, 3, 5, 11, and 12) were relocated by following their overnight trails; we have a precise record of their movements over a complete night. For the other 13 tracks, bandicoots were not relocated because of thread breakage (4) or “shedding” (9) of the tracking device; these trails reflected the animal’s movements over an undefined portion of the night. Two animals (3 and 11) were trapped on more than one occasion. Male 3 was trapped and tracked on two separate occasions (15 and 18–19 August) and male 11 on three separate occasions (14, 18, and 21 September). Both animals were active in the same area each time we followed them. On the 2nd and 3rd nights (18 and 19 August) of tracking, 46.2% and 48.9%, respectively, of the grid cells entered by male 3 coincided with those entered on the 1st night of tracking (15 August), and 27.0% and 36.4%, respectively, of the cells entered by male 11 on the 2nd and 3rd nights of tracking (18 and 21 September) also were entered on the 1st night (14 September). These observations indicate that nightly ranges over the short period of study overlapped. The extent of these ranges varied; male 9, tracked for only part of a night, covered 1.2 ha, and two animals tracked over a total of 3 nights (males 3 and 11) covered a total of 2.1 and 1.0 ha, respectively. The five males tracked through an entire night (i.e., they were relocated the following

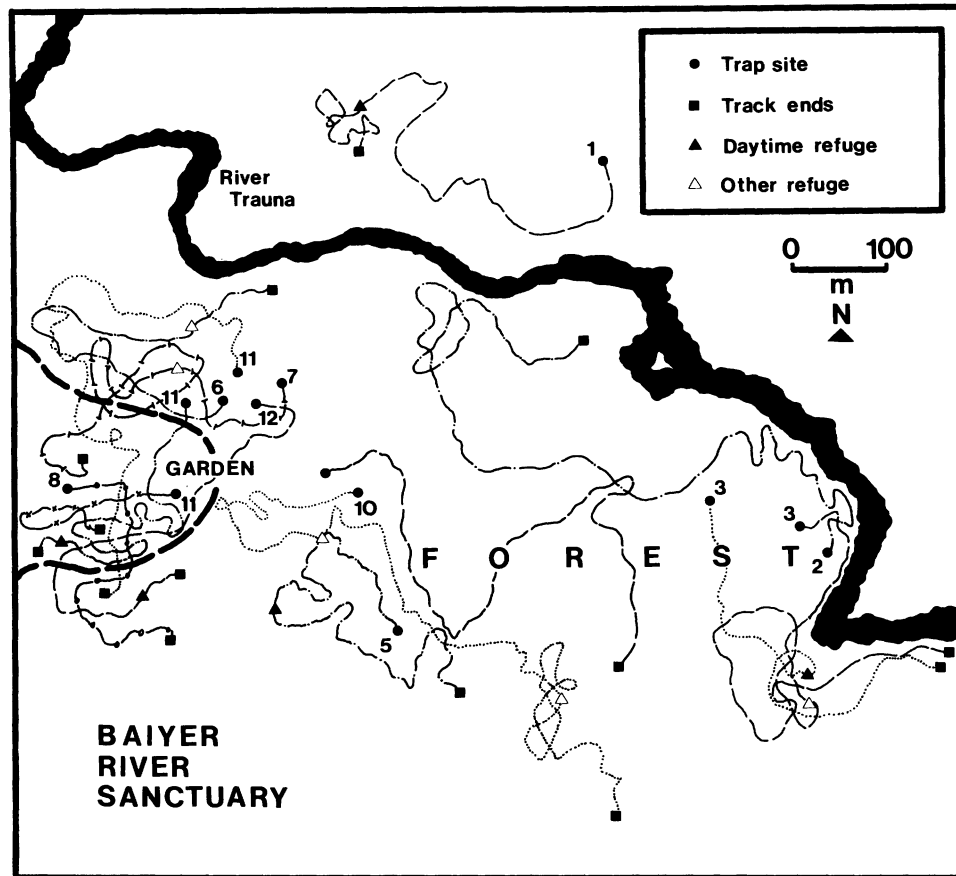


FIG. 2.—Map of bandicoot (*Echymipera kalubu*) tracks in the Baiyer River Sanctuary. Numbers refer to individual males. All tracks obtained are shown, except that of male 4 which was active approximately 200 m N of the area shown.

morning) covered areas ranging from 0.34 (male 5) to 0.64 ha (male 1) with a mean of 0.48 ± 0.13 ha. The limited area covered by most individuals probably reflected the rich foraging within their ranges.

Echymipera kalubu seemed principally to be a forest species. However, some animals were active both in the cleared garden area (males 8, 11, and 12) and in the dense stands of "pit-pit" canegrass common at our study site. Most tracks (10 of 18) went into pit-pit with some animals traveling further than 100 m (200 m in the case of male 2) in it. On four occasions, bandicoots tunneled underneath the false floor of rotting vegetation in a pit-pit stand. Within the forest, intensive activity (from evidence of foraging and the extent of movement within one small area) was associated with recent tree fall and subsequent dense growth of secondary vegetation. When moving across the rainforest floor, with its characteristically sparse vegetation, the trail lacked the loops and jumbles of thread characteristic of searching and foraging activity, and the thread was taut, indicating fast movement. When moving in this way, a bandicoot always used a route along the top of a fallen log if one was available. Presumably such a runway provided the quickest way of moving through the forest. We predict that a radio-tracking analysis would reveal that, in terms of an animal's time budget, these commuting movements would be of minor importance and that most time would be spent foraging in areas of tree and fruit fall.

For the five animals tracked for a whole night, the mean distance traveled per night was

344.0 $\pm$ 71.7 m, and for all tracks it was 506.1 $\pm$ 334.1 m. These figures were underestimates because of the method used to approximate distances traveled. On both occasions on which we recorded an animal traveling more than 1,000 m (1,220 m for male 3; 1,025 m for male 4), the trail ended with a cleanly cut rather than frayed end to the thread that suggests that they had traveled to the end of the 1,550 m of line on the spool. Our method of calculating the length of the thread trail was unsatisfactory. We suggest that marking the thread at regular intervals during the spool winding process would permit the collection of reliable data on both the total distances traveled and distances traveled within each habitat type. A special mark at the end of the thread also would be useful.

Ranges of males overlapped (Fig. 2). For example, on 8 September, 50% of the 20 grid cells entered by male 6 were entered by male 7, and 31% of the 32 cells entered by male 7 were entered by male 6. The garden area formed a focus for activity of several individuals (males 8, 11, and 12) over a period of 16 days (10–26 September). Our information was not sufficient to assess whether or not *E. kalubu* males, like Australian bandicoots (Russell, 1984), maintain an exclusive core area in their ranges. However, the fact that, in an enclosed area in captivity, both male and female *E. kalubu* were aggressive towards each other (Roy Mackay, pers. comm.), as are other bandicoot species (Stodart, 1977), suggested that this is likely.

Foraging.—In the forest, decaying logs formed the foci for bandicoot activity, with the thread trail showing numerous twists, turns, and doublebacks, strongly indicative of searching behavior; bandicoots presumably forage for the invertebrates, especially beetle grubs, plentiful in such wood. There were freshly-dug shallow pits close to loops of thread, suggesting that the animals root, probably for earthworms and insect grubs. Dietary information also came from a post-mortem examination of two bandicoots in which adult flukes (*Echinostoma* sp.) were found. The infective metacercariae of these parasites occur in molluscs (Muller, 1975), indicating that *E. kalubu* feed on snails or slugs. The success of the papaya bait and observations of thread trails suggested that bandicoots also feed on fruit; concentrated activity was evident from the number of trails in the garden area, especially around fallen bunches of bananas. Male 3 visited a large fruiting tree on 2 consecutive nights. *E. kalubu* is apparently a true omnivore, taking both invertebrates and fruit. No additional information is available on the diet of *E. kalubu*, but Heinsohn (1966) noted similar generalist feeding habits in his study of Tasmanian bandicoots (*Perameles gunni* and *Isodon obesulus*).

Nesting behavior.—Five animals were relocated in their daytime nests. Other refuges were easily identified because the thread was tangled round the dried grass and leaves used as bedding. Samples of this material from four of the seven refuges sampled contained bandicoot fleas (e.g., *Parastivalius novaeguineae*), further indicating that the animals spent time at rest at these sites. The existence of these refuges indicated that *E. kalubu* males were not constantly active throughout the night and occupied temporary refuges. Australian bandicoots show the same pattern of temporary bivouacking (Strahan, 1983). In our study, two males (5 and 10) used the same refuge in a hollow log on 2 nights 4 days apart. We found three types of nest construction: i) shallow burrows ($n = 3$) had two entrances and were up to 4 m long, running just beneath the forest floor; a central nesting section of 50 cm was filled with dried leaves and grass. ii) hollow logs ($n = 3$) with part of the interior filled with leaves and grass; and iii) leaf piles ($n = 6$).

Evaluation of spool-and-line tracking.—Spool-and-line tracking provides information about mammal movements over the first night after release. The following observations suggested that our results were a genuine reflection of bandicoot behavior and not merely artifacts brought about by stresses associated with capture and tracking. First, our results were consistent with existing information on bandicoot behavior (Strahan, 1983). Second, animals tracked more than once showed similar patterns of behavior on each occasion, whereas a more random, less repeatable pattern might be expected for a stressed animal. Furthermore, animals traveled along paths which showed evidence of wear from regular usage, and they carried out foraging and nesting behavior.

Problems associated with spool-and-line methods are related mainly to the short-term scope

of each device: an animal can only carry a certain amount of thread, and, in the case of bandicoots, that was used up within 1–2 nights. To conduct a long-term tracking study (e.g., to determine an animal's home range), it, therefore, would be necessary to change the spool device both frequently and regularly, and this would be difficult without significantly disturbing the animal on each occasion. Spool-and-line tracking, unlike radio-tracking, does not provide a time component in its analysis of an animal's movements, although it is possible to compare distances traveled in different parts of an animal's range and an indication of the time spent in each area is provided by the pattern of thread deposition. However, as Miles et al. (1981) pointed out, spool-and-line tracking has several advantages over radio-tracking: i) It reveals the precise path of an animal. Spatial resolution in radio-tracking is poor (Macdonald and Amlaner, 1980) and in a mosaic of ecological "patches" it often is impossible to identify which one the subject is in (D. Macdonald, pers. comm.). The smaller the size of an animal, the smaller the absolute size of those patches, so the inadequacy of radio-tracking increases as the size of the animal decreases. Spool-and-line tracking effectively has perfect spatial resolution, and, therefore, is ideal for fine-grained behavioral and ecological study. ii) Radio-tracking, despite modifications (Montgomery et al., 1973), is difficult to use in dense forest and is not effective in three-dimensional location. Spool-and-line tracking, in comparison, provides precise three-dimensional information and is useful for work in forests where many animals are either scansorial or fully arboreal (Berry et al., 1987; Miles et al., 1981). iii) Spool-and-line tracking is both cheap and easy to use. This feature makes spool-and-line tracking particularly suitable for use in short-term preliminary surveys such as this one.

Our study has demonstrated the applicability and versatility of spool-and-line tracking in field studies of mammal behavior and ecology. Possibly a combination of spool-and-line tracking, for spatial information, and radio-tracking, for temporal information, will prove a useful way to track mammals.

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