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Total Activity Rhythms of Three Soricine Species in Hokkaido

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Abstract. Daily activity rhythms of three sympatric soricine shrews in Hokkaido were investigated. Nineteen *Sorex unguiculatus*, 13 *S. caecutiens*, and 11 *S. gracillimus* were captured, and their total activities were studied using an infrared sensor system under two different laboratory regimes (16L8D, 20°C and 10L14D, 5−15°C). All the three shrew species were more active during periods of darkness than during light periods; however, during the light periods most of *S. gracillimus* and some of *S. unguiculatus* and *S. caecutiens* exhibited short intermittent activity. Activity during periods of darkness was polymodal for all the three species under the 10L14D, 5−15°C regime, but was bimodal in *S. unguiculatus* under the 16L8D, 20°C regime. The actogram pattern of *S. caecutiens* proved to be intermediate between *S. unguiculatus* and *S. gracillimus*. Interspecific differences in activity pattern seem to be related to body size in the genus *Sorex*.

Key words: *Sorex*; Total activity; Daily rhythm; Infrared sensor system; Nocturnal

Four species of soricine shrews, *Sorex unguiculatus*, *S. caecutiens*, *S. gracillimus*, and *S. minutissimus*, inhabit Hokkaido, and the former three are common (Ohdachi and Maekawa 1990a). Yoshino and Abe (1984) described the daily activity rhythms of *S. unguiculatus* and *S. caecutiens*, after observing the behavior of shrews in cages that contained soil and litter. The index of activity which they used, however, does not reflect the total activity of *S. unguiculatus*, since this species is subterranean (Ohdachi, in preparation) and the authors did not observe its underground activities. Furthermore, they observed shrew activity only during summer. Since some shrew species change their activity patterns from season to season (e.g., Lardet 1988), seasonal variation in activity should also be investigated.

In this study, I recorded the total activity pattern of *S. unguiculatus*, *S. caecutiens*, and *S. gracillimus* using an infrared sensor system under two different experimental regimes (16L8D, 20°C and 10L14D, 5−15°C). Then, the results were compared with those of the previous study for *S. unguiculatus* and *S. caecutiens* (Yoshino and Abe 1984) and those of other soricine shrew species.

Materials and Methods

Nineteen *S. unguiculatus* Dobson (8 young females, 9 young males, 1 sex-unknown juvenile, 1 adult female), 13 *S. caecutiens* Laxmann (3 young females, 7 young males, 2 sex-unknown juveniles, 1 adult male), and 11 *S. gracillimus* Thomas (5 young females, 6 young males) were studied. Of the 43 animals, four *S. unguiculatus* and seven *S. caecutiens* were captured from Yufutsu moor (Tomakomai) between 14 and 18 June 1992, and 15 *S. unguiculatus*, six *S. caecutiens*, and 11 *S. gracillimus* were captured from a wind-shelter belt near the Teshio Experimental Forest of Hokkaido University, between 25 June and 27 August 1992, and between 9 and 26 August 1993.

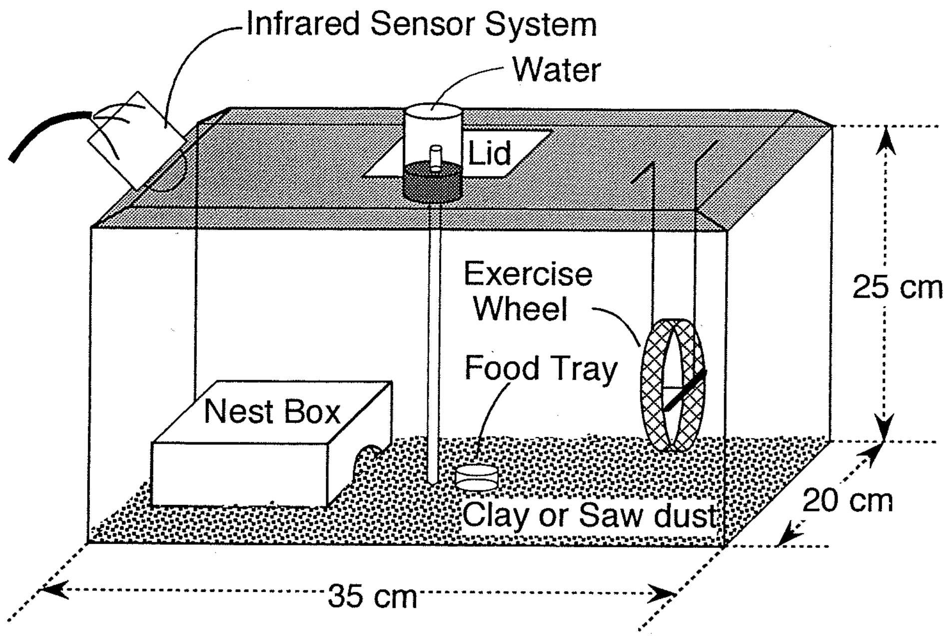

Fig. 1. A shrew cage used for the experiments. The diameter of the exercise wheel for *Sorex unguiculatus* and *S. caecutiens* was 10cm and that for *S. gracillimus* was 7.5 cm. Infrared sensors were detached from the cages when experiments were not conducted.

Plastic pitfall traps (16-cm diameter and 24-cm deep) were used for trapping shrews. The trapping procedure was basically the same that described in Ohdachi (1992). The captive animals were kept individually in plastic cages (Fig. 1) under a 16-hr light and 8-hr dark photoperiodic cycle (16L8D) at 20± 2°C (summer-simulated condition) on the Sapporo campus of Hokkaido University. The light intensity during the light period was 1420 lux and that during the dark period was 8 lux as measured on the center of the laboratory floor. Shrew activity, under the 16L8D, 20°C regime, was studied from August to November or December. Then, the photoperiod and temperature conditions were adjusted to meet a regime of 10L14D, 5−15°C (winter-simulated condition), and the shrew activity was studied until January.

Mixed paste diets were supplied every day. The ingredients of the paste were as follows in the proportions; 400g pork meat, 800g pork liver, 680g canned tuna for cats (Mimy tuna, Nihon Pet Food K.K., Tokyo), 430g canned dog food (Vita-One ration with dietary fibers, Nihon Pet Food K.K.), 100g rabbit pellets (Eko Trading K.K., Nishinomiya, Hyogo) steeped in water, and with vitamins added. The mixture was put into ice cube trays and frozen, and the frozen cubes were preserved in a freezer (-15°C). Occasionally, some living earthworms (*Pheretima* sp.) and mealworms (*Tenebrio* sp.) or frozen silkworm pupae (*Bombyx mori*) were given in addition.

The device for measuring animal activity was fundamentally the same as used by Honma *et al.* (1992) and Shirakawa and Oikawa (1988). Pyroelectric infrared sensors (Elekit PS-393S, Kahomusen K.K., Fukuoka) were installed in the device. This sensor reacts to any movement of substances radiating light of 5−20 μm wavelengths. Ten sensors were connected to an 8-bit computer (NEC PC-8801) and the activities of ten animals were measured simultaneously. The counts of reactions of each sensor were recorded every 15 min onto 1-MB floppy disk for four consecutive days. Because this device counts any movement of a shrew outside its nest box and because a shrew is usually resting or sleeping while it is in the nest box, the counts of the reactions by the device represent a measure of the total activity of the shrew. The four-day session of measuring activity was repeated 1−6 times (usually five times) for each individual. For statistical analysis of the activity patterns, only one result (actograms of four consecutive days) out of the series of sessions recorded for an individual was used as a representative of that individual's behavior.

Actograms of 10 *S. unguiculatus*, 10 *S. caecutiens*, and 10 *S. gracillimus* under the 16L8D, 20°C regime, and those of 11 *S. unguiculatus*, eight *S. caecutiens*, and one *S. gracillimus* under the 10L14D, 5−15°C regime were obtained and used for analysis.

Results

The three species of shrews were fundamentally nocturnal. Most actograms revealed that the shrews exhibited intensive active phases during the dark periods and persistent inactive phases were observed during the light periods, in both of the two experimental regimes (Figs. 2−4). Some actograms revealed, however, that the beginning and ending of intensive activity deviated greatly from the times of light on/off. Mean counts of activity per 15 min was obviously greater during the dark periods than during the light periods for all the three species under both regimes (Table 1).

Table 1. Mean activity counts per 15 min (± *SD*) during light (L) and dark (D) periods and the mean total counts over 24 hr (±*SD*) under the 16L8D, 20°C and 10L14D, 5−15°C regimes for three species of shrews in Hokkaido. Letters on the upper right of means indicate the result of Mann-Whitney's *U*-test (compare the values between the two experimental regimes within species). When the same letters are included, the difference is not significant (α=0.05).

		S. unguiculatus	*S. caecutiens*	*S. gracillimus*
16L8D, 20°C				
Counts per 15 min	L	$13.3^{a}\pm10.6$	$23.6^{a}\pm16.9$	26.0 ± 15.7
	D	$298.5^{a}\pm76.3$	$287.1^{a}\pm99.8$	154.6 ± 42.5
Total counts		$10374.3^{a}\pm2548.6$ (n=10)	$10693.3^{a}\pm3269.6$ (n=9)	6785.1 ± 1616.1 (n=9)
10L14D, 5-15°C				
Counts per 15 min	L	$14.3^{a}\pm13.9$	$36.7^{a}\pm27.8$	14.5
	D	$145.8^{b}\pm94.2$	$259.2^{a}\pm112.2$	80.4
Total counts		$8738.0^{a}\pm5163.2$ (n=10)	$15984.4^{a}\pm6588.7$ (n=8)	5083.3 (n=1)

Table 2. Mean numbers of completely inactive periods per dark period (±*SD*) and their mean duration (±*SD*) under the 16L8D, 20°C and 10L14D, 5−15°C regimes for three species of shrews in Hokkaido. Numbers in brackets are the numbers of completely inactive periods per hour during the dark periods. Numbers in parentheses are those of samples averaged and individuals examined, respectively. Letters on the upper right of means indicate the result of Mann-Whitney's *U*-test (compare the values between species within laboratory regime, or between regimes within species). When the same letters are included, the difference is not significant (α=0.05). When needed, the sequential Bonferroni correction was applied (see Rice 1989).

		S. unguiculatus	*S. caecutiens*	*S. gracillimus*
16L8D, 20°C	No. of inactive periods per dark period [per hr]	$1.00^{a}\pm0.93$ [0.13^{a}] (40,10)	$1.78^{b}\pm1.25$ [0.22^{b}] (36,9)	$3.00^{c}\pm1.81$ [0.38^{c}] (40,10)
	Mean duration (min)	$33.5^{a}\pm16.6$ (51,10)	$33.8^{a}\pm14.6$ (64,9)	$24.7^{b}\pm13.0$ (119,10)
10L14D, 5-15°C	No. of inactive periods per dark period [per hr]	$5.58^{d}\pm1.91$ [0.40^{d}] (40,10)	$4.81^{d}\pm1.86$ [0.34^{d}] (36,9)	3.50 ± 0.58 [0.25] (4,1)
	Mean duration (min)	$48.5^{c}\pm20.1$ (195,10)	$33.5^{a}\pm14.8$ (155,8)	46.1 ± 16.1 (14,1)

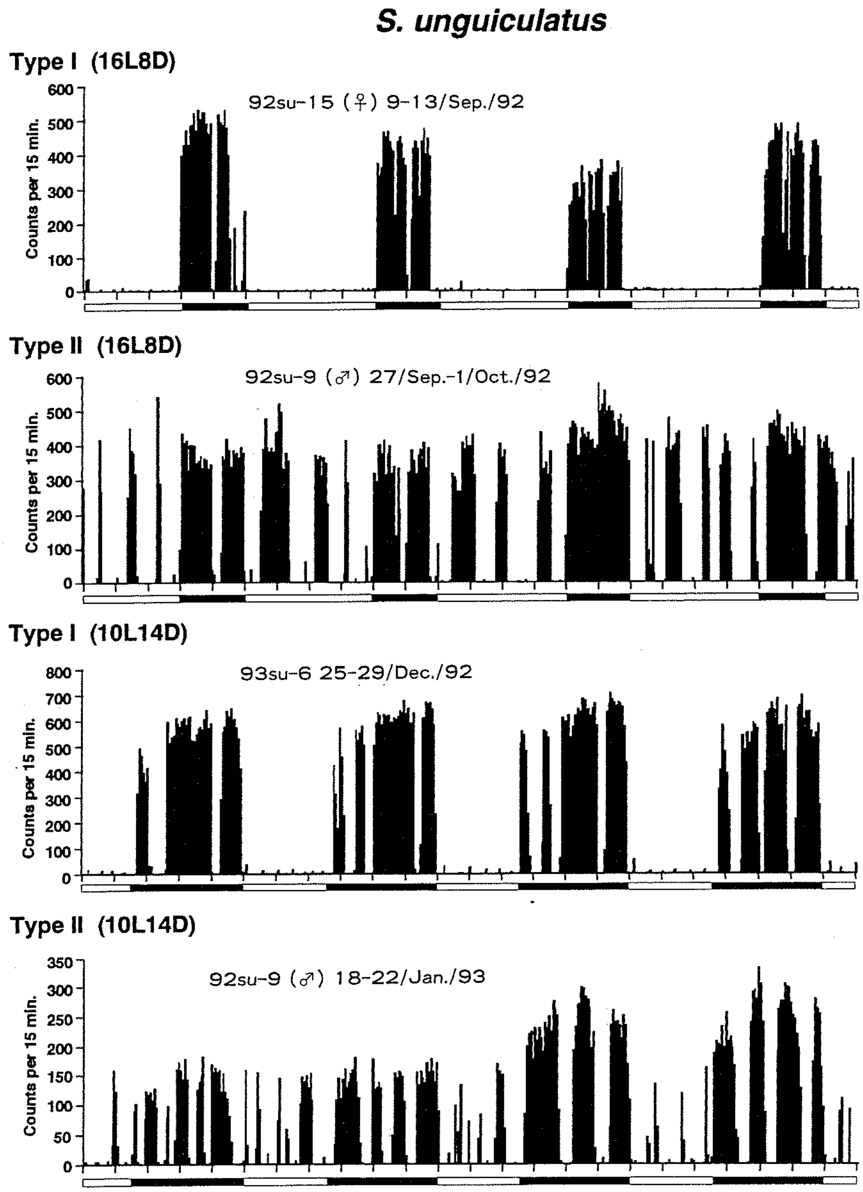

Fig. 2. Typical actograms of *Sorex unguiculatus* under the two laboratory regimes. White and black bars indicate the light and dark periods, respectively. The unit of the time axis is four hr.

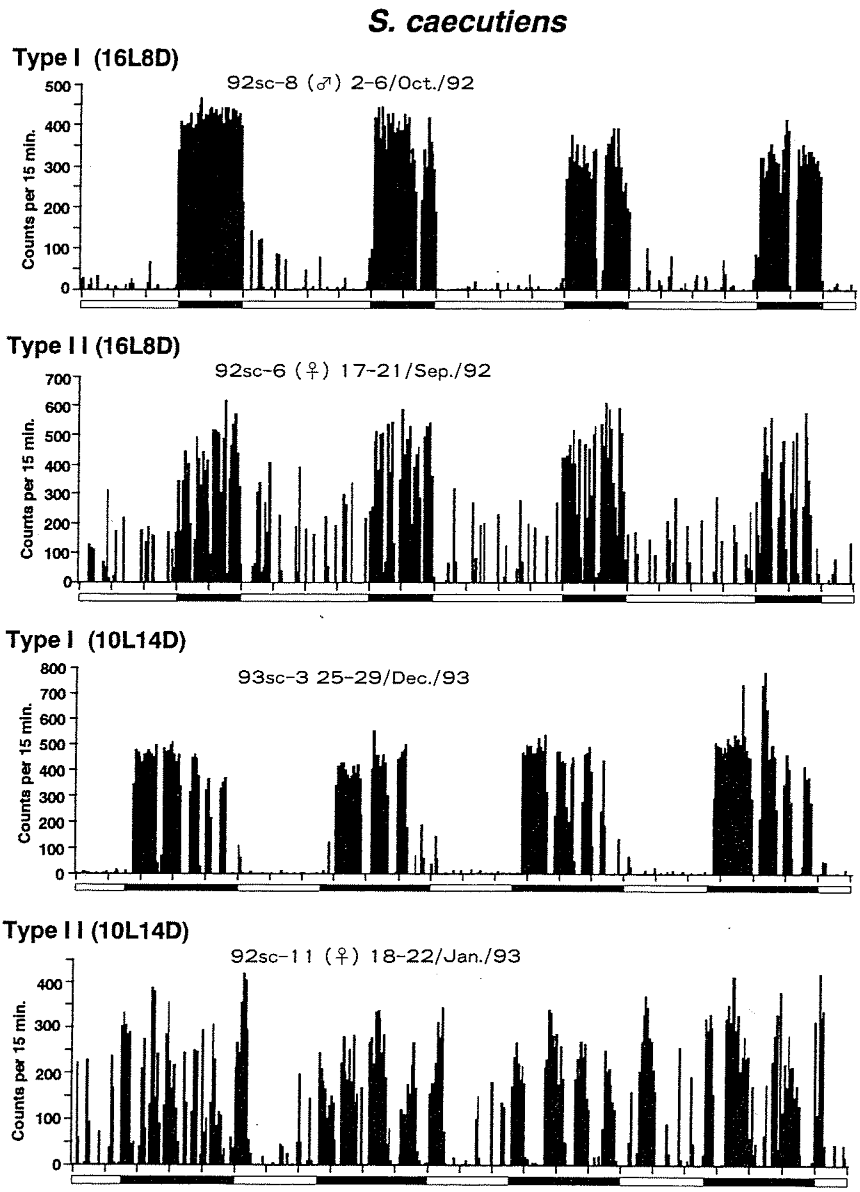

Fig. 3. Typical actograms of *Sorex caecutiens*. See Fig. 2 for explanations.

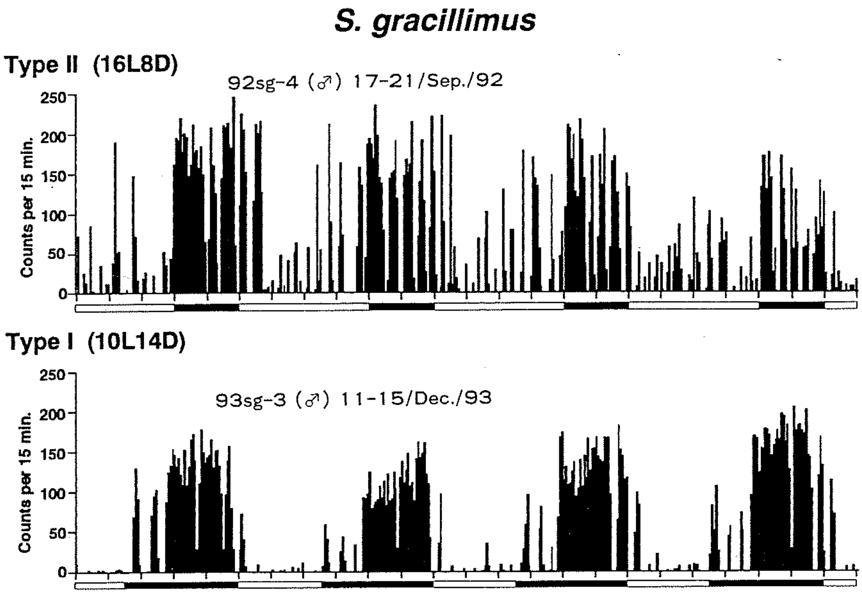

Fig. 4. Actograms of *Sorex gracillimus*. See Fig. 2 for explanations.

During the dark periods, completely inactive periods (the periods when no count was recorded for more than 15 min) were observed in each species (Figs. 2-4). The mean number of completely inactive periods per dark period was smallest in *S. unguiculatus* and greatest in *S. gracillimus* under the 16L8D, 20°C regime (Table 2). The mean duration of the completely inactive period was significantly shorter in *S. gracillimus* than in the other two species under the 16L8D, 20°C regime. Under the 10L14D, 5−15°C regime, the number of inactive periods did not differ significantly between *S. unguiculatus* and *S. caecutiens*, although the mean duration of inactivity was significantly longer in *S. unguiculatus* (Table 2); *S. gracillimus* was omitted from this analysis, since results were obtained from only one individual.

During the light periods, completely inactive periods were frequently observed. The number of inactive periods per light period tended to be constant among species under the 16L8D, 20°C regime, while it was significantly greater in *S. caecutiens* than *S. unguiculatus* under the 10L14D, 5−15°C regime (Table 3). The mean duration of the completely inactive period was significantly longer in *S. unguiculatus* than in the other two species under the 16L8D, 20°C regime and was also greater in *S. unguiculatus* than *S. caecutiens* under the 10L14D, 5−15°C regime (Table 3).

Table 3. Mean numbers of completely inactive periods per light period (±*SD*) and their mean duration (±*SD*) under the 16L8D, 20°C and 10L14D, 5−15°C regimes for three species of shrews in Hokkaido. Numbers in brackets are the numbers of completely inactive periods per hour during the light periods. See Table 2 for explanations.

		S. unguiculatus	*S. caecutiens*	*S. gracillimus*
16L8D, 20°C				
	No. of inactive periods per light period [per hr]	11.37[a]±2.71 [0.71[a]] (30, 10)	12.48[a]±3.11 [0.78[a]] (27, 9)	12.17[a]±2.26 [0.76[a]] (30, 10)
	Mean duration (min)	57.5[a]±35.3 (342, 10)	46.1[b]±24.7 (337, 9)	44.3[bc]±29.8 (363, 10)
10L14D, 5−15°C	No. of inactive periods per light period [per hr]	7.47[b]±1.38 [0.74[a]] (30, 10)	9.09[c]±1.98 [0.91[b]] (27, 9)	7.67±1.16 [0.77] (4, 1)
	Mean duration (min)	56.0[a]±27.2 (224, 10)	35.6[d]±16.4 (217, 8)	48.9±21.8 (23, 1)

The numbers of inactive periods per dark period increased from the 16L8D, 20°C to 10L14D, 5−15°C regimes for *S. unguiculatus* and *S. caecutiens* (Table 2), while the mean duration of the inactive period during the dark periods lengthened only for the former species. Conversely, the number of inactive periods per light period decreased from the 16L8D, 20°C to 10L14D, 5−15°C regimes for *S. unguiculatus* and *S. caecutiens* (Table 3), and the duration of the inactive periods shortened only for the latter species. The numbers of inactive periods per hour during both the dark and light periods tended to increase for both species (Tables 2 and 3). The counts of reactions per 15 min during the dark periods of *S. unguiculatus* decreased from the 16L8D, 20°C to 10L14D, 5−15°C regimes (Table 1), but those during the light periods and those of *S. caecutiens* did not differ between the two regimes. The total counts during 24 hr did not change between the two regimes for both species (Table 1).

Activity rhythm patterns were classified into two types (Figs. 2-4): Type I, activity during the light period was much less than during darkness; Type II, short but intensive active phases were also observed during the light periods although the duration was obviously less than that during the dark periods. Usually, each individual showed the same type of activity pattern among the different experimental sessions, though some individuals did show different types. If an individual showed different types among the sessions, the actogram type of the individual was determined so as to be proportional to the numbers of the sessions of each type. The ratios of Types I to II (Type I/II) were 8 individuals/2 individuals for *S. unguiculatus*, 6.5/3.5 for *S. caecutiens*, and 0/10 for *S. gracillimus* under the 16L8D, 20°C regime. Under the 10L14D, 5−15°C regime, the ratios of the activity types were 9/2 for *S. unguiculatus*, 5.7/2.3 for *S. caecutiens*, and 1/0 for *S. gracillimus*.

Discussion

Many soricine species are known to be either nocturnal or at least more active at night than during the day (e.g., Buchalczyk 1972, Buckner 1964, Genoud 1984, Jânsky and Hanâk 1960, Mann and Stinson 1957, Shillito 1963, Voesenek and Van Bemmel 1984), although there are some exceptions. *Neomys fodiens*, for example, does not show a clear difference in activity between night and day (Lardet 1988, Voesenek and Van Bemmel 1984). In the present study, three of the four shrew species found in Hokkaido were explicitly proven to be nocturnal, both in summer- and winter-simulated conditions (Figs. 2−4). Some soricids have been reported as having two peaks of activity, at dawn and at dusk (Crowcroft 1957, Jânsky and Hanâk 1960). Such a bimodal activity pattern was observed only for *S. unguiculatus* under the 16L8D, 20°C regime, whereas the activity patterns of this species under the 10L14D, 5−15°C regime and other species were polymodal (Figs. 2−4 and Table 2).

Yoshino and Abe (1984) reported from direct observations that *S. unguiculatus* and *S. caecutiens* were more active at night than during the daytime, which has been confirmed by the present study. They also stated that *S. caecutiens* was more nocturnal than *S. unguiculatus*, though such a tendency was not observed in the present study. On the contrary, *S. caecutiens* were found to be more active during the light periods than *S. unguiculatus* (Table 1). Yoshino and Abe (1984) were unable to observe shrew activity while shrews were underground, although *S. unguiculatus* frequently uses underground spaces even during the dark periods (Ohdachi, in preparation). As a result, they were likely to have underestimated the nocturnal activity of *S. unguiculatus*. Another cause for the inconsistency between Yoshino and Abe (1984) and the present study may be related to the types of cages used. In the present study, shrews were unable to make burrows, which might prevent their activity during the light periods.

The ratios of the activity types (I/II), activity counts per 15 min, and the mean numbers of completely inactive periods for *S. caecutiens* were all intermediate between the values for *S. gracillimus* and *S. unguiculatus*. The interspecific differences in these activity patterns appear to be related to differences in body weight. *S. unguiculatus* was the heaviest (ca. 15g for adult male), *S. caecutiens* was intermediate (ca. 7g for adult male), and *S. gracillimus* was the lightest (ca. 4.5g for adult male) (Ohdachi and Maekawa 1990b). The ratios of Types I/II and the ratios of activity counts per 15 min of dark/light periods decreased, and the mean numbers of inactive periods increased in the decreasing order of the body weight under the 16L8D, 20°C regime. It is well known that small shrews have higher basal metabolic rates per unit weight than large ones (Aitchison 1987, Buckner 1964, Genoud 1988, Hanski 1984, McNab 1991). Thus, the metabolic rates are expected to be the highest in *S. gracillimus*, intermediate in *S. caecutiens*, and the lowest in *S. unguiculatus*. It is plausible that species with higher metabolic rates must repeat more frequently the cycle of active/resting, than those with lower metabolic rates.

When laboratory conditions were changed from the summer- to winter-simulated regimes, the numbers of resting periods per hour during the dark periods increased and/or the mean duration of inactive periods increased in both *S. unguiculatus* and *S. caecutiens* (Table 2). On the other hand, the total activity counts over 24 hr did not differ between the two conditions. Therefore, these shrews may conserve energy by taking more resting periods during nights (= active period) in winter than in summer.

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