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Seasonal Variation of the Activity and Range Use Patterns of a Wild Troop of Formosan Macaque in Kenting, Taiwan

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Hai-Yin Wu and Yao-Sung Lin (1993) Seasonal variation of the activity and range use patterns of a wild troop of Formosan macaque in Kenting, Taiwan. *Bull. Inst. Zool., Academia Sinica* **32**(4): 242-252. The activity and range use patterns of a wild troop of Formosan macaque in Kenting were studied from October, 1987 to August, 1990. Whenever possible, troop activity and location were recorded every 15 minutes. Troop activity was divided into five categories (active, inactive, traveling, feeding, and feeding while traveling) and the location of the troop was recorded on a grid map consisting of 0.25 ha quadrates. Inactive and feeding were the two most important troop activities, occupying 40% and 23% of the observation time, respectively. Significant differences in seasonal time budgets were found, and the diurnal patterns of troop activity are described in this paper. The home range of the study troop was 14 ha by quadrate method, or 19.5 ha by the minimum convex polygon method; range areas varied seasonally. The range use pattern of the troop was clumped; they spent 95% of their time in 12 quadrates. We found seasonal differences in the allocation of time by the troop in the core area quadrates; these differences may be related to both the characteristics of each quadrate and weather conditions.

Key words: Activity pattern, Range use pattern, *Macaca cyclopis*

Activity and range use patterns—the ways animals use time and space—reflect the adaptation of animals to their environments. Interspecific comparisons reveal that primate activity and range use patterns are related to body size, food habits, and troop size. Home range size and the amount of time spent feeding and traveling decrease with the amount of foliage in the diet (Clutton-Brock and Harvey 1977, Milton and May 1976). Environmental variables such as food distribution and abundance, weather patterns, habitat structure, and intraspecific interactions may also influence the activity and range use patterns of primates (Bercovitch 1983, Clutton-Brock 1974, Gittins 1982, Harding 1976, Harrison 1983, Isbell 1983, Iwamoto and Dunbar 1983, Post 1981, Rasmussen 1985). Studies have shown that primates have various strategies for adjusting their ranging and foraging patterns to accommodate changing food supplies or weather conditions. During a lean season

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or in a sparse habitat, primates may either increase their investment in foraging to maintain food intake (Homewood 1978, Marsh 1981), or reduce their day range and shift to a less preferred food (Clutton-Brock 1973, Jolly 1985). When conflicting strategies are observed in independent cases, the careful evaluation of variables is advised (Dunbar 1988).

Formosan macaques live in a wide range of elevations and within a variety of habitats. They are good subjects for studies on the adaptation of a species to different environments. However, only a few studies on the ecology of this species have been conducted (Lee 1991). Our studies in the Kenting area (Wu 1986, Wu et al. 1991, Wu and Lin 1992) and one study in the Taipingshan area (Kawamura et al. 1988) are the only long-term studies of the species available. A few surveys have been conducted on the distribution and status of the species (Lee and Lin 1991, Masui et al. 1986, Tanaka 1986) and on populations in some protected areas (Lin and Lu 1989 1990, Lu et al. 1991). However, most of these studies provide little information about the activity and range use patterns of the Formosan macaque.

In this paper, we describe the seasonal variation of activity and range use patterns of a troop of Formosan macaque living in the Kenting area, and explain the observed patterns according to seasonal variation of food supply and weather conditions in the study area.

METHODS

Between October, 1987 and August, 1990 we followed a troop of wild Formosan macaque in the Kenting area. Each month, we spent four to six days in the field to study the activity and range use patterns of the troop. The study troop (S1 troop in Wu and Lin, 1992) consists of one adult male, three or four adult females, and several juveniles of different ages; during our study the troop size ranged from 11 to 16.

The study area, which is 200 to 250 meters in elevation, is situated within Kenting National Park on the southern tip of Taiwan. Scattered throughout the area are many large blocks of uplifted coral reefs. The climate in Kenting is hot and rainy in the summer and cool and windy in the winter. The fruiting season of many plant species in Kenting (subtropical monsoon forest) is in the summer and autumn, and the budding season is in the spring (Ho 1971). A detailed description of the study area and population dynamics of the monkey troop can be found in Wu and Lin (1992).

In activity pattern studies, focal animal sampling and scan sampling are often used for activity data collection (Caldecott 1986, Fa 1986). Both methods need habituation and observability. The topography, dense canopy, and shyness of the monkeys made it difficult for us to follow and approach them. When the monkeys retreated to the top of uplifted coral reefs to rest, it was impossible to approach them without disturbing them; moreover, frequently less than half of the troop members could be observed at any one time. In order to avoid a bias toward the animals and behaviors the most readily seen, the monkey troop was treated as a single sampling unit, and the predominant troop activity or the activity being performed by the majority of visible animals was recorded every 15 minutes (Hall 1962, Chivers 1969). All possible visual and auditory cues were used to determine troop activity. When the cues were insufficient, no record was made. Activity categories were defined as follows:

Inactive (I): most of the animals were resting or stationary, with the whole troop staying at one spot.

Traveling (T): the troop was moving from one place to another.

Active (A): monkeys were playing, moving, grooming, or interacting with others; there might be some individuals taking food in the area, but the animals were not foraging intensively.

Feeding (F): most members of the troop were searching for, collecting, or eating food in one area.

Feeding while traveling (FT): monkeys were feeding while they moved between areas.

The two feeding categories can be combined into a single category: Foraging (FG).

For investigating diurnal variation of troop activity, records for each activity during the four 15-min sessions of each hour were combined (either for the entire study period or for each season) and expressed as a percentage of total observations. Two methods were used to estimate the proportion of time spent for each activity. First, the percentage of the total number of records for each activity was calculated for both the entire study period and the four seasons (method 1, or M1 in Table 1). Second, the mean percentages of each activity during daytime hours were calculated (method 2, or M2 in Table 1) to eliminate the bias resulting from diurnal variation in sample size (Marsh 1981, Post 1981).

In order to analyze range use patterns, troop location was recorded for every observation session on a grid map consisting of 50 m × 50 m (0.25 ha) quadrates. The monkey troop occasionally used more than one quadrate per session. We defined three types of range use patterns for each session: the use of one (type A), two (type B) or more than two (type C) quadrates in one session. For types A and B, each quadrate was scored 1 and 0.5, respectively. The occupational density of each quadrate (Rasmussen 1980), which was used as an index for the time spent in each quadrate, was obtained by summing all the quadrate scores. The proportion of time spent in each quadrate was expressed as the percentage of each quadrate occupational density to the sum of all quadrate scores. Quadrates used in type C were not included in the above calculation since monkeys did not spend much time in these areas. The home range of the troop during the study period or for each season was determined by the total area of quadrates used by the troop (quadrate method) and the minimum convex polygon drawn from the utilized quadrate borders (Southwood 1966). The core area is defined as the quadrates where the troop spent 95% of total observation time. A coefficient of variation of the occupational density in the core area quadrates was used as an index of clumping in range use patterns. A lower value indicates more even quadrate usage (Rasmussen 1980). Spearman's rank correlation coefficient and percentage overlap between seasons were calculated to indicate core area use pattern similarities (or consistency) (Rasmussen 1980). Percentage overlap was computed by adding the percentage values shared in very quadrate used in two seasons (Strushaker 1975).

RESULTS

Troop activity could only be recorded for 1,927 sessions (101 days) out of the 6,025 sessions (138 days) we spent in the field; our activity data are shown in Fig. 1. The troop could only be located in 50% of the time, and activity data were collected for 85% of the observation time.

Diurnal activity pattern

Diurnal variation over the five activity categories is shown in Fig. 2. The hourly percentages of the inactive state and forag-

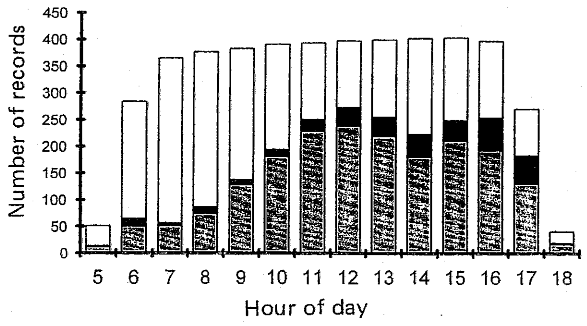

Fig. 1. Diurnal distribution of the number of records for troop activity (shaded area), the number of sessions when the troop was located but no activity recorded (black area), and the number of sessions when the troop was not located (blank area).

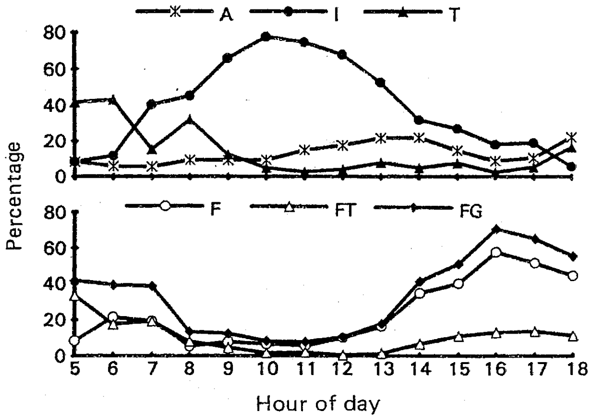

Fig. 2. Diurnal distribution of the percentages of records for each activity category. A:active; I:inactive; T:traveling; F:feeding; FT:feeding while traveling; FG:foraging, F+FT.

ing are negatively correlated ($r_s = -0.88$, $p < 0.01$), indicating that the two activities are distinctly separated in time. The inactive state distribution pattern is monophasic with a peak between 0900 and 1200, which coincides with the timing of the "valley" in the biphasic distribution of the percentages for total foraging time.

We observed two foraging peaks: early morning (0500 ~ 0800) and late afternoon (1600 ~ 1800), with the latter being higher than the former (Fig. 2). The morning foraging peak mainly consists of feeding while traveling, while the afternoon peak consists from feeding only.

Taveling time percentages are higher during the morning periods. "Active" records were made for all time periods, with higher percentages occurring between 1300 and 1500; these were preceded by peaks of inactivity and followed by foraging peaks (Fig. 2).

A troop activity pattern was constructed from the above data. In the early morning, after the monkeys arise from their sleeping site on top of an uplifted reef, they travel some distance for their morning foraging activity. From 0800 to 0900, the troop returns to its day roosting site and rests until 1300. During this time, most of the monkeys sleep or rest. From about 1300, more and more monkeys start playing, grooming, and moving; this is the time when our hourly percentages of active records were higher. After 1600, the monkeys begin feeding near the resting place and gradually move to their sleeping reef.

There are slight seasonal differences in the percentage curve peaks and valleys (Fig. 3). For example, in the summer and autumn, the troop is inactive for more than 50% of time during the periods from 0800 to 1200, but in the spring and winter the same amount of inactive time is from 0900 to 1300. The peak of active time percentage is 1200 in the spring; it shifts to 1300 in the summer and autumn, and again shifts one more hour in the winter.

Time budget

Among the five activity categories, inactive was predominant, comprising 47.4% of the total activity records. After correcting for diurnal variation in sample size, the inactive time percentage was still 40%. Feeding was the second most frequent troop

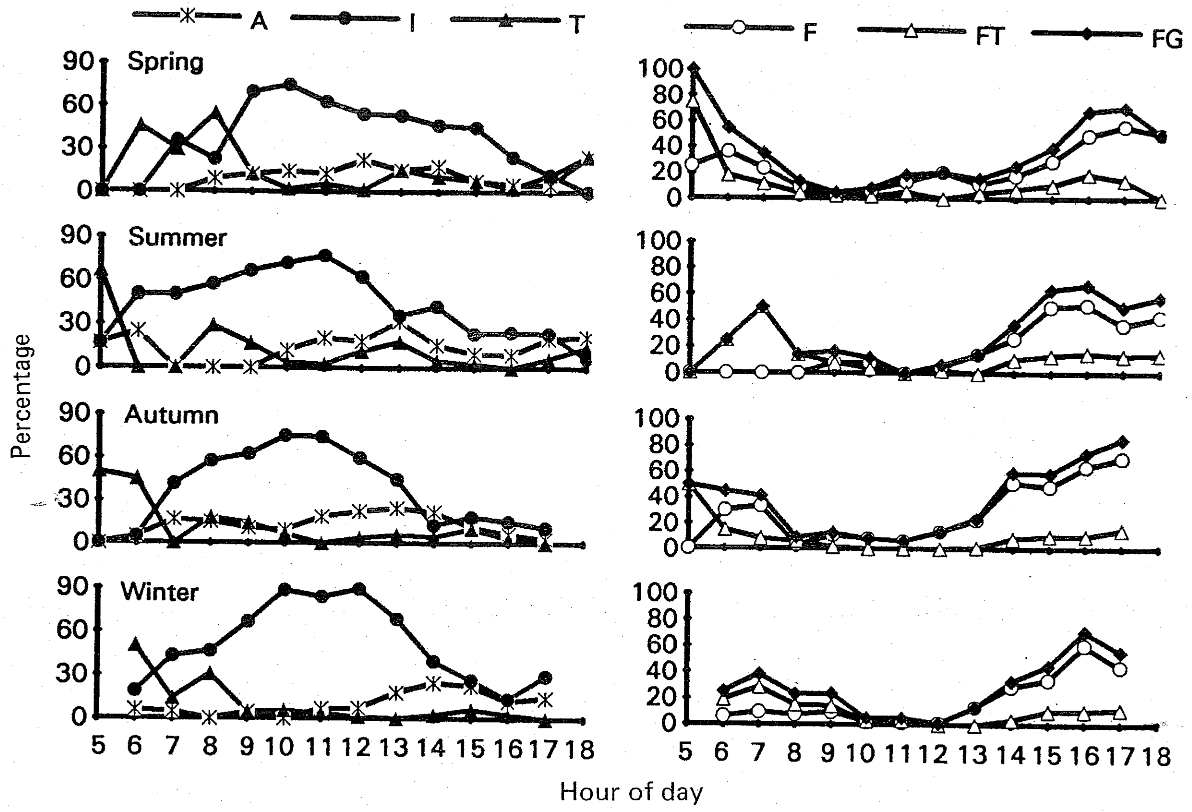

Fig. 3. The diurnal activity patterns of the monkey troop during the four seasons (legends as Fig. 2).

Table 1. Proportion of time the monkey troop spent for each activity during the period from October, 1987 to August, 1990

% / Season	Active		Inactive		Traveling		Feeding		Feeding while traveling	
	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2
Spring	12.0	10.6	46.6	35.8	11.8	16.1	22.0	24.9	7.7	12.5
Summer	16.4	14.4	45.2	43.4	8.9	12.7	21.6	17.3	7.9	12.2
Autumn	15.5	13.0	44.7	37.0	7.6	12.6	27.4	27.8	4.8	9.7
Winter	13.1	10.2	52.4	51.3	5.5	10.2	21.9	18.3	7.1	10.0
Overall	14.2	12.9	47.4	40.0	8.2	14.4	23.7	23.5	6.6	10.3

The percentages were calculated by methods 1 and 2 (M1 & M2), (see text for a full description).
Spring: Mar.-May; Summer: Jun.-Aug.; Autumn: Sept.-Nov.; Winter: Dec.-Feb.

activity (23%), and the time proportions spent on the other three activities were all less than 15% (Table 1).

We found significant seasonal variation in the time budget of the study troop (X^2 test, $p < 0.01$). Significant time budget differences were found between spring and summer, summer and autumn, and summer and winter, when total frequency for each activity was used; moreover, differences were found in all but one paired comparison when a corrected frequency was used (Table 2).

Seasonal differences in the time percentages were found to be significant for inactive, feeding, and foraging (X^2 one-sample test, $p < 0.05$). The monkey troop spent an equal amount of active time during the four seasons. They were more inactive in the winter, traveled more in the spring, and spent more time feeding and less time feeding while traveling in the autumn (Table 1). Total troop foraging time was higher in the spring and autumn.

Range use pattern

Troop location data from 126 days of field work were used to analyze range use pattern. During this period, effective location data were collected 50% of the time (2,822 records in 5,727 sessions); they were unevenly distributed throughout daytime hours (Fig. 4). Less than 10% of the records were made between 0500 and 0900, and 67% were made between 1100 and 1700.

The monkey troop used 56 quadrates, including four quadrates used for type C only (Fig. 5). The total area of the 56 quadrates used is 14 ha, and the area used based on the minimum convex polygon drawn from the borders of the 56 quadrates is 19.5 ha.

The range area used by the troop varied seasonally, and was largest in the spring

Table 2. Comparisons in time budget between different seasons

	Spring	Summer	Autumn	Winter
Spring		NS	S	S
Summer	S		NS	NS
Autumn	S	S		S
Winter	S	NS	S	

S & NS: significant and nonsignificant by X^2 test, $p < 0.05$. Above the diagonal are the results of comparisons using total frequency, and below are the results using corrected frequency.

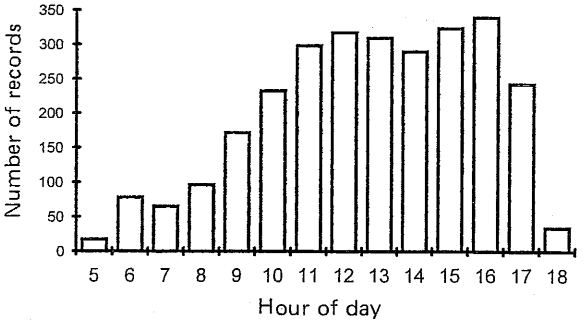

Fig. 4. Diurnal distribution of locality data recorded during the study period.

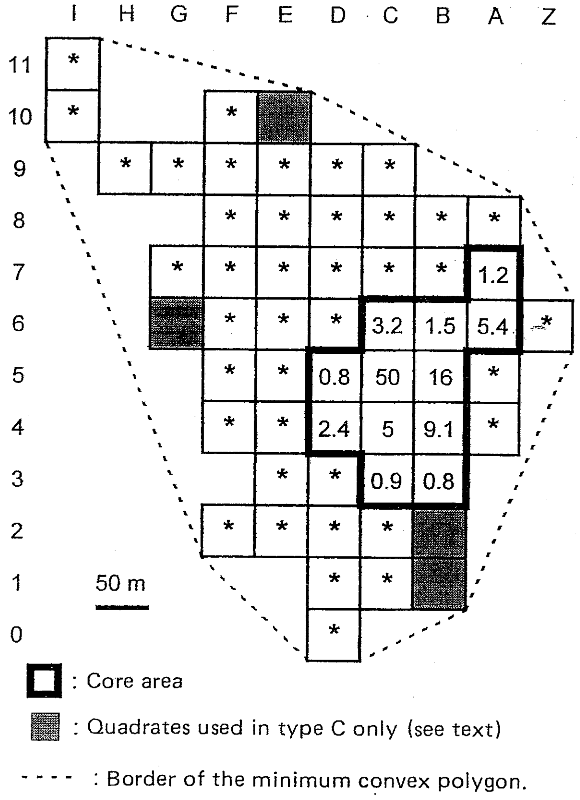

Fig. 5. Proportions of time the monkey troop spent in each quadrate during the study period (*: values less than 0.5%).

(spring: 11.5 ha, summer: 6.3 ha, autumn: 9 ha, winter: 9.5 ha) (Fig. 5). The areas of the minimum convex polygon used throughout the four seasons were found to be larger than the above estimates, but they were of the same order (17.2, 11.1, 12, and 13.5 ha for the four seasons, respectively).

Variation in daily range area was large. In the 34 days when troop location was recorded for more than 30 sessions (7.5 hours), the troop used 2 to 16 quadrates ($\bar{X}=7.5$, $SD=3.3$)—an area of 0.5 to 4 ha. We found no significant seasonal difference in the daily range area used by the troop (Krustal-Wallis test, $p < 0.05$).

The range use pattern was "clumped", as the monkeys spent 50% of the observation time in quadrate C5, 75% in quadrates C5, B5 and B4, for a total of 95% in 12 quadrates (Fig. 5). We found 40 quadrates whose occupational densities were less than 0.5% of the total value.

The twelve most heavily used quadrates constituted the core area of the troop's home range. The coefficients of variation for the quadrate occupational densities over the four seasons show that the monkey troop used core area quadrates more evenly in the summer (134%, compared with 167%, 180%, and 188% in autumn, spring, and winter, respectively). The correlations of quadrate occupational densities between winter and the other seasons were lower; thus, the order of quadrate occupational densities were less similar between winter and the other seasons. However, the percentage overlap of the core area was lower between summer and the other seasons (Table 3).

We found seasonal differences in the time the troop spent in different core area quadrates. Except for the B3, C3, and D5 quadrates, all core area quadrates were used by the troop over four seasons. Area C5 was the most heavily used quadrate; however, in the summer the monkeys spent less time in C5 and more time in B5, B4, and A6 than during the other seasons. In winter, B4 was the second most heavily used quadrate; in other seasons, B5 had the second highest occupational density value (Fig. 6).

Table 3. Indices of consistency in the core area use pattern between seasons

	Spring	Summer	Autumn	Winter
Spring		0.71	0.85	0.68
Summer	61.6%		0.96	0.65
Autumn	79.3%	78.4%		0.60
Winter	83.9%	65.9%	77.0%	

The values above the diagonal are Spearman's rank correlation coefficients, and those below are the percentage overlap of quadrate occupational density between seasons.

DISCUSSION

For this study, we did not provision the monkeys, so it was difficult to approach and follow the troop—especially in areas other than the core area. Evidence exists that if we had tried to locate the monkeys when they were not in the core area, they would have detected us and moved to the core area before we could find them. Close observation in the core area was difficult due to the nature of the uplifted reefs. Owing to the above difficulties, most of the analyzed data were obtained when the monkeys were in the core area. In addition, the data are not evenly distributed throughout the daytime hours; records for the first four hours of a day are far fewer than for other periods. Since the troop's morning foraging was ambiguous, we may have underestimated the home range area of the monkeys, and therefore have a bias in the activity pattern analysis. However, seasonal variation in activity and range use patterns were re-

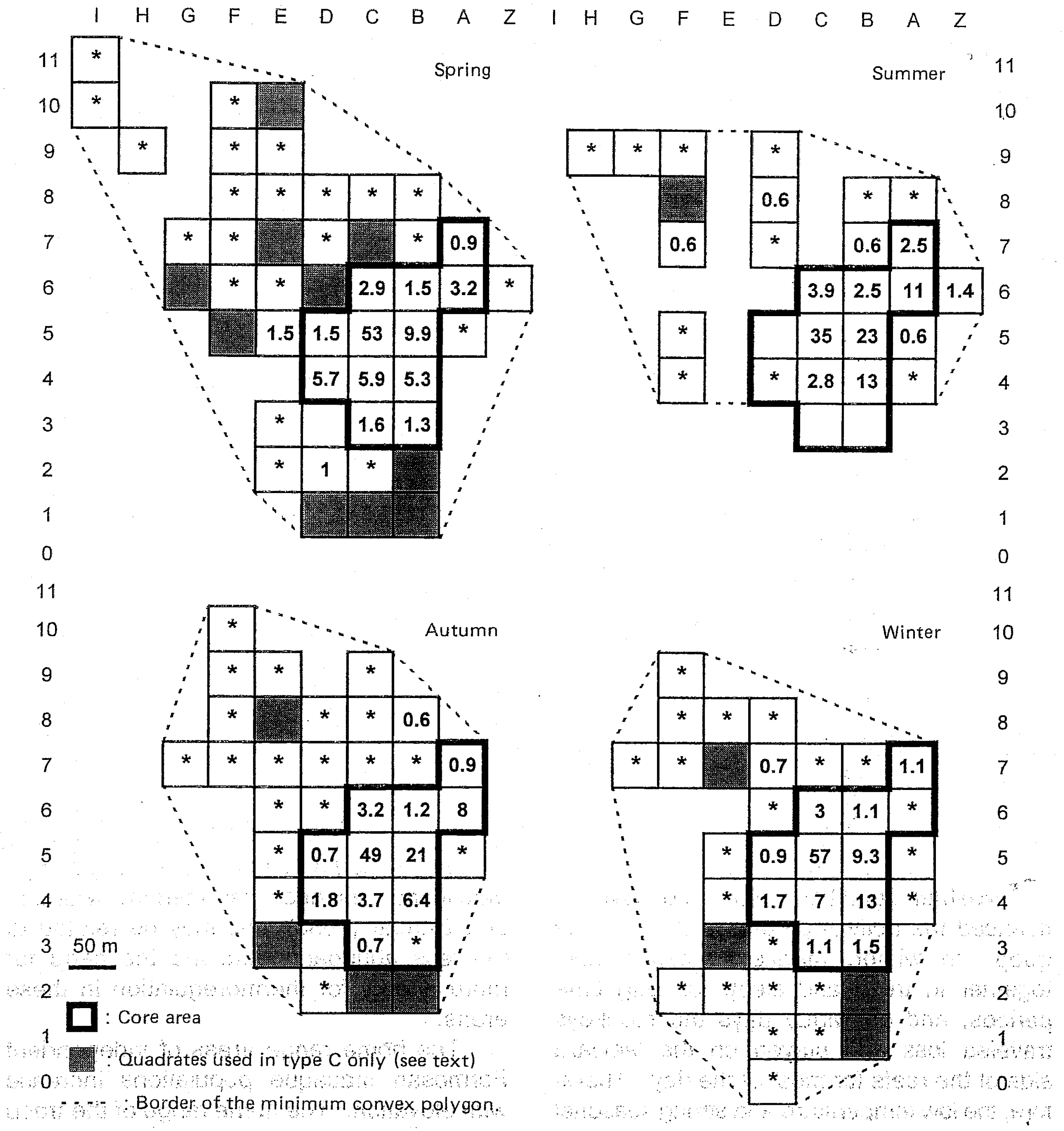

Fig. 6. Proportions of time the monkeys spent in each quadrate during the four seasons (*: values less than 0.5%).

vealed by this study, since we used the same method of data collection throughout the study period.

The Formosan macaque feeds on various kinds of food, including buds, leaves, and fruit. In the Kenting area, there is seasonal fluctuation in the availability of different foodstuffs, and monkeys change their diet in accordance with food availability. They eat more buds and young leaves in the spring, more fruit in the autumn and summer, and they depend mostly on the mature leaves of *Ficus irisana, Diosyros maritima*, and *Pueraria montana* in the winter.

The seasonal variations of activity and range use patterns may be related to food availability. In order to find enough young growth to eat in the spring, the monkeys spent more time traveling and used a wider range. Such behavior is similar to the strategies followed by the mangabey (Homewood 1978) and red colobus (Marsh 1981) in the Tana River area, who may travel farther to find enough food in lean seasons or in poor habitat.

In the winter, the monkeys spent more inactive time; this could be the result of the high foliage content of their diet. Animals that feed on leaves need a relatively large amount of time to rest in order to digest the food (Richard 1985). The strategy of spending less time feeding and traveling, more time resting, and shifting to less preferred food or low quality food (i.e., mature leaves) has been reported in other primate species (Clutton-Brock 1973, Jolly 1985); moreover, this strategy is more likely to be followed by forest-dwelling species than savannah species (Raemakers 1980).

Weather conditions may also have influenced the activity pattern of the monkey troop. In winter, monkeys often huddle together in trees and sleep for long time periods, and on windy days the monkeys traveled less and stayed on the leeward side of the reefs for most of the day. Therefore, the low temperature and strong seasonal wind may be related to the troop's higher proportion of inactive time.

The range use pattern of the monkey troop was highly clumped and consistent over time. The monkeys spent three-fourths of the time in three specific quadrates, and 95% of their time in the core area of 12 quadrates. The core area included the day roosting, afternoon foraging, and the night sleeping site of the troop.

The seasonal differences in spatial use patterns within the core area are related to the characteristics of each quadrate as well as weather conditions. In summer, the troop spent more time on either the windward side or top of the reefs in A4, B4, and B5 quadrates, and less time on the leeward side of C5 than in the other seasons. Sometimes the monkeys went inside a large, cool cave in B4 and rested during the hottest hours of a day. The fact that monkeys hide in cool or shady places may be the reason why it is difficult to find them in summer.

We found differences in activity and range use patterns between monkeys living in Kenting and in other areas of Taiwan. The monkeys in Kenting spent 34% of their day time foraging and 40% inactive. They were usually inactive from 0800 to 1300, and intensive feeding periods seldom exceeded one hour. In the Yushan area, at an altitude of 2,500m, the monkeys might eat for two to three hours—especially when they fed on grasses and clover (Wu unpublished data). In the Nanshi area (1,800 ~ 2,670 m), monkeys spent 35% of their time resting and 55% feeding (Lin et al. 1990). Greater time spent feeding by monkeys living at high elevations has been reported by Iwamoto and Dunbar (1983); this may be related to the less abundant food and the need for more energy for thermoregulation in these areas.

The home range areas of independent Formosan macaque populations increase with elevation. The home range of the troop in this study was less than 20 ha (1.5 ha/individual). It is 140 ha for a troop of 25 individuals (5.6 ha/individual) in the Taipingshan area at an elevation of 800m (Kawamura et al. 1988). The monkey population density in the Nanshi area is 16.4/km^2, which gives an individual range size of 6 ha (Lin et al. 1989). Again, the observed pattern may be related to food availability in different areas, as the same pattern has been reported in other species (Southwick et al. 1991, Wada and Ichiki 1980). More quantitative studies are needed to make comparisons on activity and range use patterns of Formosan macaque populations inhabiting different habitats.

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墾丁地區臺灣獼猴活動模式及活動範圍之季節變化

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1987年10月至1990年 8 月間，在墾丁地區研究一野生臺灣獼猴猴群之活動模式及活動範圍。在野外追踪觀察猴群時，每15分鐘記錄一次猴群的活動及猴群所在的位置。猴群活動共區分爲五種類型：活動中、滯留、移行、攝食及移行中攝食，猴群位置則以其在由0.25公頃方格所組成之地圖上的所在位置記錄之。研究結果顯示，在五項活動中，猴群從事滯留及攝食兩項活動的時間比例最高，分別佔總觀察時間的40％及23％。猴群的活動模式在四季間有顯著的差異，且可能與環境中各類食物的供應情形有關。本研究中猴群的活動範圍爲14公頃，若以最小凸多邊形法估算，則爲19.5公頃。猴群對活動範圍的使用呈現高度集中的現象，牠們在由12個方格所組成之核心區中的時間佔總觀察時間的95％。不同季節中猴群對核心區各方格的使用情形有所差異，而此差異與氣候狀況及各方格內之特色有關。