

## Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan

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**Abstract.** To establish a standard procedure for monitoring wildlife diversity and abundance using camera traps, a three-year camera-trapping study of medium- to large-sized mammals was carried out on Mount Tsukuba, Ibaraki Prefecture, central Japan. A total of 412 photographs of nine target mammal species was obtained. The practical concept of “minimum trapping effort,” defined as the amount of trapping effort required to record a set of target species in a particular area at a certain probability, was proposed. The minimum trapping effort for five major species in the study area was 40 camera-days with a 94% bootstrap probability. In the deciduous forests of Japan, studies should use five cameras for four days (20 camera-days) and be repeated twice between late spring and late summer. By counting a series of conspecific photographs taken repeatedly within a certain period of time as a single appearance, a camera-based encounter rate was calculated and its temporal changes were examined. The results suggest that an intermission length, that is the time required between two consecutive photographs of the same species for them to be counted as independent events, of more than one minute reduces the self-dependence of the data in camera studies.

**Key words:** camera-based encounter rate, infrared motion sensor, mammalian faunal survey, minimum trapping effort, remote camera.

Camera traps, which have been used widely in wildlife studies (Wemmer et al. 1996), are ideal for identifying the species inhabiting a particular area, monitoring relative and absolute abundance of species, and studying activity patterns (Karanth 1995; van Schaik and Griffiths 1996; Miura et al. 1997; Karanth and Nichols 1998; Kawanishi et al. 1999; Koerth and Kroll 2000; McCullough et al. 2000; Martorello et al. 2001; O’Brien et al. 2003). This method has also been used to address a variety of ecological and conservation-related questions relating to, for example, nest predation and frugivory and seed dispersal (Leimgruber et al. 1994; Miura et al. 1997; Yasuda et al. 2000; Otani 2001, 2002).

Recent improvements in technology provide us with various ready-made camera traps with tiny infrared-motion sensors, built-in flash, and data packs at a reasonable price. Potential applications of the method in wildlife studies are increasing. Although demands for monitoring wildlife diversity and abundance in a particular area have been increasing recently, few attempts at

methodological standardization have been made so far. Practical procedures that are applicable to the local environments of Japan need to be established.

The purpose of this study was to provide a practical camera-trapping procedure for monitoring the diversity and abundance of medium- to large-sized terrestrial mammals in Japan. To achieve the purpose, I examined two different types of data set that were extracted from the camera-trapping results: (i) imaging/non-imaging of species, and (ii) the total number of photographs of a species in a census.

Using the first data set, I aimed to standardize a camera-trapping method from the viewpoint of study effort. I discussed the camera-trapping effort required to reveal the mammalian fauna in a forest habitat and proposed the concept of “minimum trapping effort,” defined as the amount of trapping effort required to expose the target species in a given area, based on the results of species imaging/non-imaging. This criterion is necessary for practical applications of camera traps because it serves as

a guide for the amount of study effort required.

Next, using the second data set, I examined the properties of the camera-trapping results by taking into account the number of photographs of each species. Camera-trapping results are often difficult to interpret, especially regarding the treatment of data consisting of a series of photographs of the same species because such a series has strong self-dependence, implying that it is unsuitable for statistical analysis. One way to reduce self-dependence in camera-trapping results is to consider a series of photographs of the same species taken within a certain period of time as a single event (Otani 2002; O'Brien et al. 2003), referred to as a "species-appearance" in this paper. Another way to reduce the self-dependence of the data is to use a camera system with a built-in photographic delay interval that prevents repeated exposures within a certain period of time (Koerth and Kroll 2000). Those settings have varied among studies, and no previous studies that used such treatments have justified why they chose a certain time interval. The same and confirmed time setting should be used in order to compare camera-trapping results from different study sites.

In this paper, I recommend a study period length for a mammalian faunal survey. I specify a suitable intermission length for camera studies that focus on common medium- to large-sized mammals in the forest landscapes of Japan. Finally, I attempt to interpret time series of camera-based encounter rates of the species studied, which might serve as an index of animal abundance (O'Brien et al. 2003).

## Study site and methods

### *Study site*

The study was carried out in a public recreational forest, the Yukiiri Fureainosato Park, in the foothills of Mount Tsukuba, Ibaraki Prefecture, central Japan (lat 36°10'N, long 140°11'E, 120–340 m above sea level; area, 0.144 km<sup>2</sup>). The park was established in 1997 on the site of an abandoned quarry after landscape remediation, and it is now covered with young vegetation consisting of pine and broad-leaved trees (52% of the area), grassland (35%), and ponds (5%). The surrounding area of the park was covered with old regenerating broad-leaved forests and conifer plantations. No obstacles prevent animals from moving freely between the park and the surrounding area.

### *Camera trapping*

The remote cameras used had a built-in infrared motion sensor, a built-in flash, and a data pack that stamped each photograph with the time and date of the event (Sensor Camera Fieldnote, Marif Co., Ltd., Iwakuni, Yamaguchi, Japan). Power was supplied by a CR123A lithium battery, which lasted approximately one month. No photographic delay interval was available for the model used. The cameras were wrapped tightly in a thin transparent polypropylene bag to prevent them from becoming wet and encased in an unsealed plastic box.

A camera-trapping study was carried out every three months from October 2000 to July 2003, for a total of 12 censuses, three censuses for each of the four seasons. A census started in the late afternoon and required seven consecutive days. The total amount of trapping effort during the three-year study period was 200.4 camera-days. Five cameras were installed 1 m above the ground using a camera clip (HCS-23, Hakuba Photo Industry Co., Ltd., Sumida, Tokyo, Japan) at fixed camera stations along animal trails. The camera stations were 50 m or more apart within a radius of 200 m, and they were baited with raw peanuts in the shell (200 g per station). During each census, one roll of color print film (ISO 400; 36 exposures) was used for each camera. The cameras were not inspected during a census.

### *Species identification and data preparation*

After the film was developed, the photographs were examined for images of animals. Species were identified in comparison with Abe et al.'s (1994) guide to Japanese mammals, and the time and date of every photograph were recorded. Then, the data from the five camera stations of each census were merged before further analysis.

The amount of trapping effort required (unit: camera-days) was calculated for each camera from the time the camera was mounted until the camera was retrieved, if the film had remaining exposures, or until the time and date stamped on the final exposure. Total trapping effort in a census was defined as the sum of the camera-days of the five cameras.

### *Minimum trapping effort*

A bootstrap random resampling method was employed to estimate the minimum trapping effort required to obtain a photograph of each major species. For the analysis, the amount of trapping effort, defined as the sum of camera-days from all five cameras, to the first

appearance of a species in a census was used. Two censuses were excluded from the analysis: the autumn 2001 census, because a grass harvest, constituting a considerable human disturbance, had been carried out in the park just before the census, and the winter 2003 census, because the trapping effort during that census was very short (5.2 camera-days). For the other ten censuses, the total amount of trapping effort varied from 10.1 to 33.2 camera-days. To equalize the trapping effort among censuses, the first 10 camera-days of each census were used for the analysis.

The bootstrap random resampling procedure to construct observation periods consisting of a certain amount of trapping effort was as follows: (i) a census was chosen randomly from the ten censuses to be the first observation period of 10 camera-days; (ii) a census was again chosen randomly from the ten censuses, with repeated samplings allowed; this was the second observation period; (iii) the second step was repeated until the total trapping effort reached a certain amount (10–80 camera-days in this study); and (iv) the number of species photographed in the constructed observation periods was examined. This procedure was repeated 5000 times for each amount of trapping effort.

#### *Camera-based encounter rate*

The camera-based encounter rate, after O'Brien (2003), was as follows: Species-appearances were counted independently if the time between two consecutive photographs of the same species (intermission time) was at least a certain length. Various intermission lengths (1 min–2 days) were applied to each roll of film, and the number of species-appearances was summed for each census. Then, the encounter rate of the species was calculated by dividing the number of species-appearances by the total amount of trapping effort (camera-days) in that census. A rank correlation coefficient, Kendall's  $\tau(r_\tau)$ , was used to examine the relationship between time series of the encounter rates obtained by applying different intermission lengths, namely 2, 30, or 720 min. Since any census without a species-appearance (encounter rate = 0) was excluded from the correlation analysis, the sample size as number of censuses treated varied among species.

## Results

### *Species photographed*

Nine species of medium- to large-sized wild mammal (hereafter target species) were recorded in the three-year study period (Table 1A). Six belonged to the order Carnivora.

A total of 1841 photographs was obtained, and of these, 412 included the nine target species (Table 1C). Of the remaining photographs, 480 showed non-target species, predominated by the jungle crow *Corvus macrorhynchos* (74.2%) and the large Japanese field mouse *Apodemus speciosus* (22.2%). The remaining 949 photographs were without any animals (nil photographs).

In this paper, I focus on five major species, the raccoon dog, wild boar, Japanese hare, masked palm civet, and badger, all of which were photographed in at least half of the 12 censuses (Table 1A). These five species accounted for 92.7% of the photographs of target species. The other four target species, the Japanese marten, Japanese weasel, domestic cat, and Japanese squirrel, were photographed only one to five times during the 12 censuses (Table 1A).

Trap rates (number of photographs per camera-day) of the target species were rather constant in the range of 0.58–4.01 (Fig. 1). Those of non-target species ranged from 0.05 to 20.9. A notably high value was observed in winter 2003, when the jungle crow was the predominant subject photographed (Table 1C). As a result, in that census the total trapping effort was only 5.2 camera-days and only three photographs of target species were obtained, so this census was excluded from the analysis. More than five nil photographs per camera-day were usually obtained in winter and spring because in those seasons the sensor was affected by movements of direct sunlight spots through the tree canopy under the sparse vegetation cover.

### *Timing of the first appearance of species*

The first appearance of a target species mostly occurred within 20 camera-traps (Fig. 2). Among the five major species, the first species-appearance usually occurred within 10 camera-days in any census that the species was photographed (Table 1B). The raccoon dog was photographed in all censuses, but the other four species were not always recorded. In those censuses in which a target species was not photographed, this value was unspecified (shown as a blank in Table 1B).

The number of target species photographed in a census

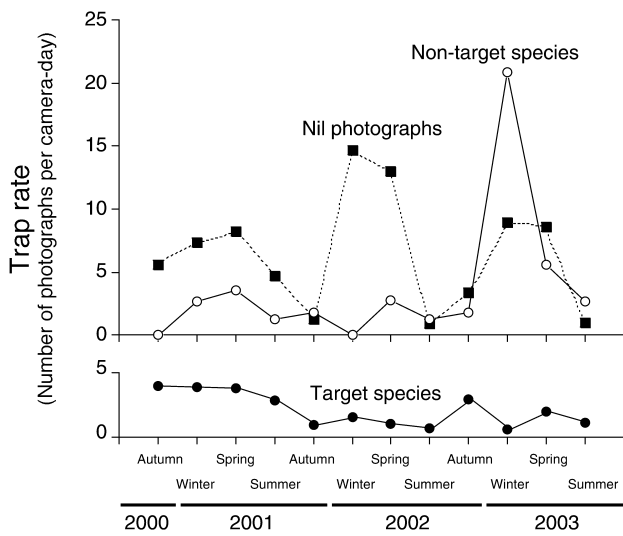
**Table 1.** Results of a 3-year camera-trapping study on Mount Tsukuba, central Japan. The total number of photographs obtained at the five camera stations during a census is shown. Species are sorted according to the total number of photographs. A: Number of photographs obtained of each of nine medium- to large-sized target species. B: Amount of trapping effort to the first appearance of the species in a census. C: Census statistics.

Species	2000						2001						2002						2003						Total	%
	Autumn		Winter		Spring		Summer		Autumn		Winter		Spring		Summer		Autumn		Winter		Spring		Summer			
A. Number of photographs																										
Raccoon dog	46	30	17	14	5	2	2	2	5	36	1	2	2	2	162	39.3										
Wild boar	17	4	13	21	18	10	2	7	23	122	29.6															
Japanese hare	12	8	4	4	4	2	1	3	6	36	8.7															
Masked palm civet	1	4	6	6	2	2	3	7	1	33	8.0															
Badger			12	3			6	5		29	7.0															
Japanese marten				1			1	3		21	5.1															
Japanese weasel				3					1	4	1.0															
Domestic cat		4								4	1.0															
Japanese squirrel					1					1	0.2															
B. Amount of trapping effort to the first appearance of the species (camera-days)																										
Raccoon dog	1.6	1.0	2.7	0.9	23.3	2.8	5.1	0.3	5.3	2.9	0.4	0.5	12													
Wild boar	6.5	1.4	4.2	8.0	17.6	1.7	5.4	3.3	5.4	5.6	3.8	11														
Japanese hare	3.2	3.8	2.9	2.9	1.2	8.3	27.5	17.0	7																	
Masked palm civet	8.2	2.5	5.6	0.6	27.8	1.8	9.6	0.4	8																	
Badger		0.9	6.2	12.4	5.6	2.4	1.6	6																		
Japanese marten				4.2	32.1	6.3	5.2	1.0	5																	
Japanese weasel									2																	
Domestic cat									1																	
Japanese squirrel					20.8				1																	
C. Census statistics																										
Trapping effort (camera-days)	19.0	11.8	12.0	18.1	24.9	10.1	10.3	33.2	23.5	5.2	10.6	21.7	200.4													
Number of target species recorded	4	4	4	7	3	4	4	6	4	2	5	6	9													
Number of photos of target species (a)	76	46	46	52	24	16	11	24	69	3	21	24	412													
Number of photographs of non-target species (b)	1	31	43	22	45	1	28	42	42	108	59	58	480													
i) Jungle crow ( <i>Corvus macrorhynchos</i> )	0	31	19	0	0	0	21	36	34	108	59	48	356													
ii) Large Japanese field mouse ( <i>Apodemus speciosus</i> )	0	0	21	21	41	0	7	5	2	0	0	10	107													
iii) Others	1	0	3	1	4	1	0	1	6	0	0	0	17													
Number of nil photographs (c)	105	87	99	84	29	147	134	28	78	46	91	21	949													
Total number of photographs (d = a + b + c)	182	164	188	158	98	164	173	94	189	157	171	103	1841													
Trap rate (%) (a/d × 100)	41.8	28.0	24.5	32.9	24.5	9.8	6.4	25.5	36.5	1.9	12.3	23.3	22.3 ± 12.3													

Blanks in Tables A and B indicate censuses in which a given species was not photographed.

varied from three to seven (Table 1C), and the number did not always reach a plateau within a census (Fig. 2). A single census was thus inadequate to confirm species presence in the study area even for the five major species.

In autumn 2001, when a grass harvest had been carried out in the park just before the census, a much larger trapping effort was needed to record animals; the first photograph required 17.6 camera-days (Table 1B, Fig. 2). Because this human disturbance considerably affected the results of the autumn 2001 census, this census was excluded from the analysis.



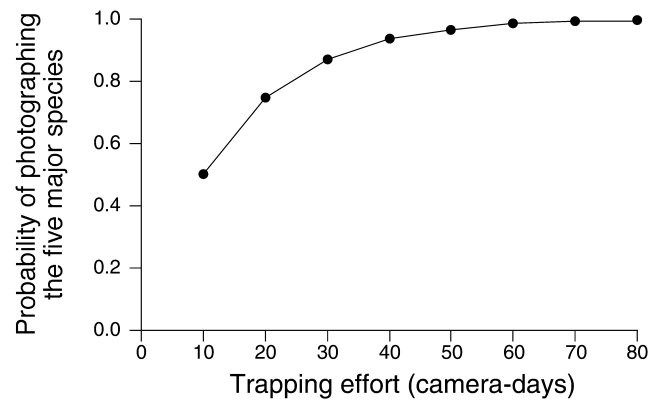
**Fig. 1.** Changes in trap rates with time during the three-year study period. Target species, medium- to large-sized mammals; non-target species, small mammals and birds; nil photographs, photographs without any animals.

*Bootstrap probability of exposure*

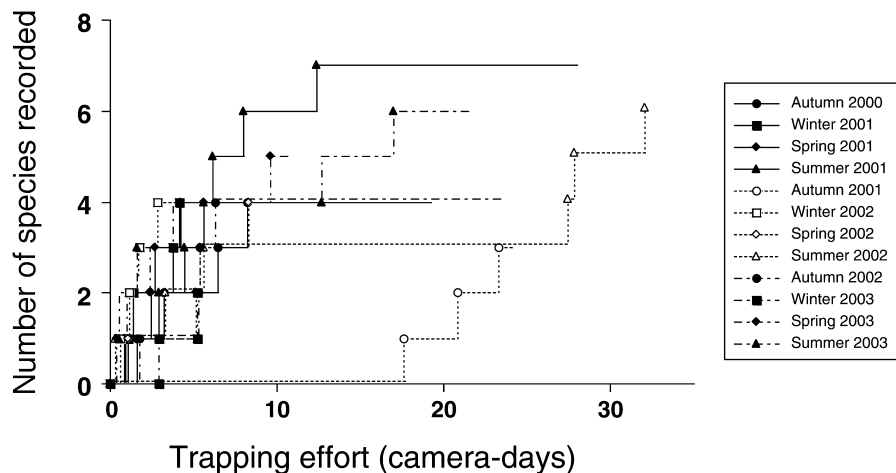
The probability of exposure gradually increased with the amount of trapping effort. The probability was 0.50, 0.75, 0.87, 0.94, 0.97, and 0.99 or more for 10, 20, 30, 40, 50, and 60–80 camera-days of observation, respectively (Fig. 3). This means that, for example, there was a 94% probability that all five major species in this study would be recorded within 40 camera-days.

*Intermission length*

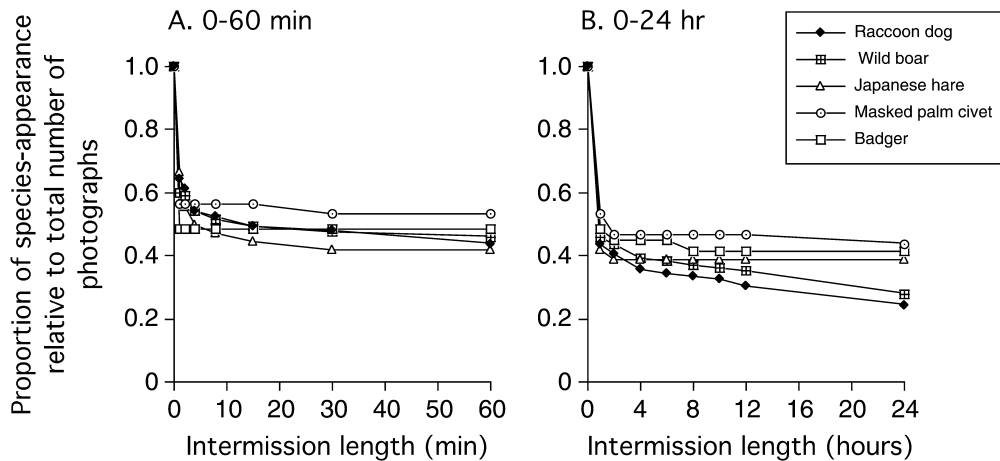
For all five major species, a large proportion of photographs of each species consisted of repeated exposures such that the time stamps on two consecutive photographs of the same species fell within a 1-min interval. Such photographs accounted for 38.9%–51.7% (44.0% on average) of the total number of photographs. The



**Fig. 3.** Relationship between trapping effort and bootstrap probability of photographing the five major species. The first ten camera-days of ten censuses were used for bootstrap resampling ( $n = 5000$ ).



**Fig. 2.** Cumulative number of species recorded by camera traps against trapping effort for each census. The 12 censuses are shown with different symbols and lines. Trapping effort for each census is the sum of the active time of the cameras at the five camera stations.



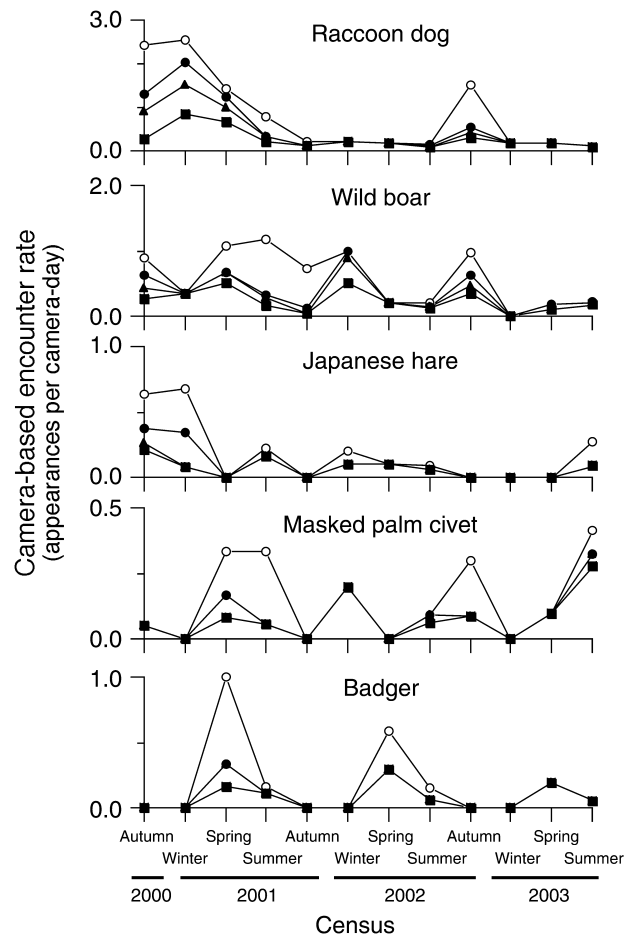
**Fig. 4.** Relationship between intermission length and proportion of species-appearances relative to the total number of photographs for the five major species. A: Intermission length from 0 to 60 min. B: Intermission length from 0 to 24 hr.

proportion of species-appearances relative to the total number of photographs of that species decreased as the intermission length became longer and became nearly constant for sufficiently long intermission lengths (see Fig. 4). For example, the proportion averaged 0.56, 0.48, and 0.39 for 2-, 30-, and 720-min intermission lengths, respectively, for the five major species.

To specify the most suitable settings of intermission length for this case study, the changes of species slopes in Figure 4 were examined. The rate of slope decline per unit intermission length in minutes dropped sharply from 0.41 to 0.0035 on average between intermission lengths of 0–1 min and of 4–8 min. Then the rate gradually decreased to 0.0004 by the intermission length of 30–60 min. The slopes of all the five major species leveled off sufficiently at a 30-min intermission length and three of them had no changes for another half an hour (Fig. 4A).

*Camera-based encounter rates*

Encounter rates (number of species-appearances divided by the total amount of trapping effort in camera-days) for intermission lengths of 2, 30, or 720 min were compared with each other and with untreated camera results (in which every photograph of a species is considered a species-appearance) (Fig. 5). The time trends were similar except for those of the untreated results. In the case of the raccoon dog, the encounter rate declined between the first three censuses and the later censuses, and this decline can be seen at all intermission lengths. With a 30-min intermission length, the encounter rate during the first three censuses ranged from 0.90 to 1.53, but ranged only from 0.09 to 0.42 during the later censuses. In the



**Fig. 5.** Changes in camera-based encounter rates for the five major species over time. The encounter rate for each census was calculated by dividing the number of species-appearances by the total amount of trapping effort in that census. Closed symbols (●, ▲, and ■) represent 2-, 30-, and 720-min intermission lengths, respectively; open circles represent the untreated data set, which includes all photographs of each species.

**Table 2.** Rank correlation coefficients ( $r_r$ ) between the time series of camera-based encounter rates obtained by applying different intermission lengths. The untreated data indicate that every photograph of a species is considered a species-appearance. Since any census without species-appearances was excluded from the correlation analysis, the sample size as number of censuses treated ( $n$ ) varied among species.

Raccoon dog ( $n = 12$ )			
	Untreated	2 min	30 min
2 min	0.818		
30 min	0.788	0.909	
720 min	0.758	0.879	0.970
Wind boar ( $n = 11$ )			
	Untreated	2 min	30 min
2 min	0.527		
30 min	0.527	0.927	
720 min	0.455	0.782	0.855
Japanese hare ( $n = 7$ )			
	Untreated	2 min	30 min
2 min	0.619		
30 min	0.238	0.619	
720 min	0.238	0.619	1.000
Masked palm civet ( $n = 8$ )			
	Untreated	2 min	30 min
2 min	0.400		
30 min	0.182	0.786	
720 min	0.327	0.786	0.857
Badger ( $n = 6$ )			
	Untreated	2 min	30 min
2 min	1.000		
30 min	1.000	1.000	
720 min	0.733	0.733	0.733

case of the wild boar, encounter rates fluctuated greatly, ranging from 0.04 to 0.89, with a 30-min intermission length. The badger had non-zero encounter rates in spring and summer in all censuses during the study period.

Rank correlation coefficients between the time series of these encounter rates were calculated for the whole study period (Table 2). A high correlation ( $r_r = 0.619$ – $1.000$ ) was observed for any combination of encounter rates with intermission lengths of 2, 30, or 720 min. The rank correlation coefficients were always lower if untreated data were included.

## Discussion

### *Mammalian fauna imaged by cameras*

An inventory of the mammal fauna carried out during 1995–1997 confirmed that 23 species of small- to large-

sized wild mammals belonging to six orders inhabited Mount Tsukuba (Ibaraki Animal Study Group 1998). The inventory found ten medium- to large-sized terrestrial species, including the domestic cat, and nine of these were photographed in the present study (Table 1). The red fox *Vulpes vulpes* (Canidae) was the only species that was not recorded by the camera traps during the three-year study period, although that species has been seen in the park by rangers (Tokuya Yano, 2002, personal communication). The reason for failing to record the red fox on camera is uncertain: perhaps it was scarce or its activity may have been low in the study area; it might avoid research equipment or bait with a human smell; or it may have a low preference for the bait used. Four to six medium- to large-sized species were recorded in all but two censuses (mean  $\pm$  *SD*,  $4.8 \pm 1.14$ , Table 1). Other common large mammals in Japan, the Japanese monkey *Macaca fuscata* (Cercopithecidae), Asiatic black bear *Ursus thibetanus* (Ursidae), sika deer *Cervus nippon* (Cervidae), and Japanese serow *Capricornis crispus* (Bovidae), disappeared from Ibaraki Prefecture in the nineteenth or twentieth century (Yamazaki et al. 2001). Thus, the present study successfully photographed most of the medium- to large-sized mammals thought to utilize the study area.

### *Minimum trapping effort and recommended study period*

I considered 40 camera-days to be the minimum trapping effort required in the study area, as the bootstrap probability of species-appearance for the five major species increased with trapping effort and was more than 0.90 at 40 camera-days (Fig. 3). To achieve this trapping effort, three practical procedures can be proposed: one census of 40 camera-days, four censuses of 10 camera-days, and two censuses of 20 camera-days.

The first procedure is rejected, because a single census consisting of 40 camera-days in a period might be inadequate to confirm the presence or absence of even major species (Table 1). The second procedure is rejected, as the first appearance of a species usually occurred within 20 camera-days (Fig. 2). Therefore I conclude that the third procedure is recommendable, for instance, a study using five cameras for four days during two different periods.

The target species were often photographed during the spring and the summer (Table 1). It might be difficult to photograph a species with a strong seasonal activity pattern, such as the badger for example, during a study restricted to the autumn and winter (Table 1). Moreover,

movements of spots of direct sunlight were the most typical cause of nil photographs, which predominately occurred in winter and spring (Fig. 1), when vegetation cover was sparse. Therefore the recommended procedure of camera-trapping study in deciduous forests is as follows: use five cameras for four days in a census and repeat this twice at an interval from late spring to late summer when dense vegetation cover can be expected.

I emphasize that, because the proposed minimum trapping effort of 40 camera-days was derived from a single study and probably depends on animal abundance in a study area, this value should be validated by further studies at various locations for many different species.

#### *Recommended intermission length*

A large proportion of the photographs (41% on average) was taken within a one minute period. The number of species-appearances declined rapidly and practically leveled off at a 30-min intermission length (Fig. 4). Time series of camera-based encounter rates obtained by applying different intermission lengths were highly correlated with each other, but less correlated with those based on untreated data (Table 2, Fig. 5). These results suggest that any intermission length of one minute or longer would greatly reduce the proportion of consecutive photographs likely to have been triggered by the same animal(s) within a short period of time, which is a major factor of the self-dependence in camera-trapping results. On the other hand, it is highly probable that applying an intermission length that is too long eliminates many independent events of species-appearances from the data set. Therefore the suitable settings of intermission length for this case study would be in the range of 8–30 min where on average 50% of conspecific consecutive photographs have been eliminated.

I stress that I cannot specify the recommended intermission length that can be applicable for any camera-trapping study. The most suitable intermission length may depend on many factors, such as the behavior of the target species, the bait used, and the goals of the study. Other studies that have used this technique to reduce the self-dependence of camera-trapping data include a seed dispersal study, in which a one minute intermission length was used (Otani 2002), a deer census for population management (4 min; Koerth and Kroll 2000), and an estimate of the abundance of medium- to large-sized mammals in a tropical forest (30 min; O'Brien et al. 2003). In conclusion, the suitability of any intermission length depends on the purpose of the study, and any

length will probably work at least to some extent. On the basis of the results of this study (Figs. 4 and 5, Table 2) and those of O'Brien et al. (2003) that dealt with various taxa of mammals, I have adopted a 30-min intermission length in the following discussion.

#### *Interpretation of camera-based encounter rates*

Recent theoretical and empirical camera-trapping studies suggest that a camera-based encounter rate can be used as an index of relative abundance of animals (Carbone et al. 2001, 2002; O'Brien et al. 2003). Thus, I attempted to interpret the time series of camera-based encounter rates for the five major species (Fig. 5).

First, the badger was photographed in spring and summer only, never in autumn and winter, which may reflect that this species is inactive in winter (Nowak 1999). This pattern was clearly observed throughout the study period, though the badger was the fifth of the five major species in the number of photographs taken ( $n = 29$  over the study period). This implies that the time series of camera-based encounter rates with a 30-min intermission length is able to illustrate the seasonal activity of species and that the trapping effort in this study was adequate to detect clear seasonal activity patterns of animals.

As a consequence of the above discussion, a camera-based encounter rate could be compared with those in the same season only, not between seasons, even if the rate is certified as an index of relative abundance of animals. For example, we may say that the encounter rate of the raccoon dog in winter showed a decline from the first year of the study period to the following two years (Fig. 5).

For the other species, however, it was difficult to observe changes in the encounter rate over time, with a 30-min intermission length. The sample size in the number of species-appearances was too small for the other species to be able to distinguish the signal from the noise in the data. A larger trapping effort would be needed than in this study in order to examine the relationship between the camera-based encounter rate and the abundance of a particular species in the study area that is given by another independent census method.

A mark-recapture concept is believed to be the best way to obtain a robust estimate of animal abundance. This concept has been also used previously in camera-trapping studies (Karanth 1995; Karanth and Nichols 1998; McCullough et al. 2000; Martorello et al. 2001). In these "mark-resight" studies, individual animals are recognized by their markings or by tags attached to them

before camera trapping began.

However, such conventional mark-resight techniques are not applicable when monitoring a number of wildlife species at landscape-scale. There is a great need for practical indices of animal density in the field of conservation. A camera-trap based index of abundance is one possibility (Carbone *et al.* 2001, 2002). The camera-trapping method is superior to other encounter-based methods that have been commonly used to estimate abundance, for example, counting animals or animal signs, because it allows us to carry out a 24-hour census with fewer resources and leads to fewer inter-observer variations in the results. Recently, O'Brien *et al.* (2003) found a highly positive correlation between camera-based encounter rates and the abundance of animals estimated independently by another method. Jennelle *et al.* (2002) also urged that camera-based encounter rates should be calibrated against an independent measure of density to demonstrate a functional relationship between a species and the locations studied.

#### *Further notes on designing effective camera-trapping studies*

In this study, the bait (raw peanuts) was preferred by all five major species except the Japanese hare. It is likely that baiting introduces a food-preference bias into the frequency of species-appearances, so different baits may alter the results to some extent. Seasonal variation in the availability of alternative foods may also influence the results by altering the bait consumption rate. Moreover, baits that are too attractive are not recommended for camera-trapping studies. When I used a block of krill as bait, visiting animals stayed in the area of the sensor for a long time, until they had consumed the whole bait, which resulted in the entire roll of film containing a series of consecutive photographs of the same individual (Yasuda unpublished data).

However, in my experience, baiting camera traps shortens the minimum trapping effort, and it is therefore a useful technique when time and funding are limited. Baited camera traps have been used widely, for example, to estimate black bear populations (Martorello *et al.* 2001) and sex and age ratios of white-tailed deer (Koerth and Kroll 2000). It is possible to conduct comparable studies using common baits during a fixed period of the year, as recommended previously. Thus, baiting is worth employing, though it may cause some problems. Because of differences in bait preference among species, direct comparisons of abundance between species are

difficult to perform, but monitoring changes in abundance of a particular species over years with camera traps should be possible, after further progress in developing this method, in the future. Camera trapping is potentially, therefore, a powerful, practical method of monitoring wildlife diversity and abundance.

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