DIEL ACTIVITY OF A REMNANT POPULATION OF EUROPEAN BROWN BEARS[1]

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Abstract: The temporal distribution of activity and rest over the 24-hour cycle is characteristic of a species and, to some extent, a function of the environment. Parameters of this distribution could possibly be used to estimate the stress on a given animal population. To measure the diel activity pattern of the last brown bears (*Ursus arctos*) of the Alps, which live in a relatively densely populated area (70 human inhabitants/km^2) in northern Italy, 3 bears were equipped with radio collars. The bears were active about 50% of their time. Pooled hourly data for the proportion of telemetry readings showing bear activity were combined, through an iterative procedure based on a succession of chi-square values, into 5 diel periods showing significant ($P < 0.01$) differences. The basic pattern of diel activity was found to be bimodal with the major activity peak in the evening from 1800 to 2300 hours and a secondary peak in the early morning between 0500 and 0800. The main rest period was in the late morning from 0800 to 1300. However, the variability of the activity schedule, even of the same individual from day to day, was large; bears could be found active at any time of the day.

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The distribution of activity and rest over the 24-hour cycle is thought to be largely characteristic of a given species, i.e., fixed genetically (Aschoff 1962:2). But undoubtedly, animals can modify their activity pattern according to their environment. Once the activity pattern of a species is quantitatively well known under different environmental conditions, certain parameters of this pattern of a given population of wild animals could possibly be interpreted as indicators of the amount of stress the environment (in particular, modern man) is loading on the animals.

Activity data of bears can help to reduce undesirable bear-man encounters and promote better research schedules (e.g., radio fixes are more accurate when the animals are inactive).

Without the hospitality of the late B. Young and G. Kemp, which made it possible for me to learn in 1974 in Alberta how to capture and handle bears, this study could not have been implemented. I would like to thank also the many persons who collaborated in the 24-hour monitoring of the bears. The bulk of this help came from F. Osti (Spormaggiore) and M. Sicheri (Cavedago). I gratefully acknowledge the administrative support given by W. Huber, Bern (concerning the funding), as well as the various administrative and technical assistance offered by the Bureau for State Forests and Nature Parks of the Province of Trento; the Museum of Natural Sciences, Trento; the World Wildlife Fund of Trento; and the Italian Hunters Association, Trento Chapter.

STUDY AREA

The last brown bears of the Alps survive in an area of roughly 1600 km^2 which represents the western quarter of the Province of Trento, also called Trentino, northern Italy (Roth 1973, 1976). After 1965, most of the bear observations were made along the northeast slopes of the Brenta Mountains in an area comprising only about 200 km^2 (Roth 1978). Bears were captured in this subarea (46°15′ N and 11°00′ E), and they spent most of their time during the monitoring periods there. The area is densely settled (70 inhabitants/km^2) and on the valley bottoms, which range in elevation from 200 to 600 m, there are numerous villages with populations of 500 to 2000, only 1.5 to 4 km apart. The steep, forested slopes situated between valley bottoms and high mountain areas, characterized by numerous rock outcroppings, form the bear habitat. Up to 900 m the slopes are covered by pine (*Pinus silvestris*), followed by mixed hardwood forests, reaching up to 1400 m, dominated by beech (*Fagus silvatica*), oak (*Quercus pubescens*), and hophornbeam (*Ostrya carpinifolia*), and offering excellent bushy cover since these areas are clearcut about every 25 years for firewood. Spruce and fir forest (*Picea abies* and *Abies alba*), partly managed for timber production, is found from 1400 to 1800 m, where it is gradually replaced by sparse stands of larch (*Larix decidua*) interspersed with patches of low, bushy mountain

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Table 1. Brown bears radio-monitored in the Province of Trento, Italy, 1976–1979.

Bear No.	Night of capture[a]	Sex	Weight (kg)	Estimated age(years)[b]	Data period[c]
1	12/13 Aug '76 6/7 Nov '79	F	51 86	8-1/2	Aug–Nov '76 Nov '79
2	8/9 Nov '76	M	142	6	Nov '76
3	20/21 Jun '77	M	123	4-1/2	Jun–Nov '77

[a] Bear 1 was captured twice.
[b] Age at date of first capture extimated by analysis of cementum layers of small premolar, made by MATSON's Commercial Microtechnique, Box 308, Milltown, MT 59851. Mention of commercial names is for identification and does not imply endorsment.
[c] Months that yielded the data utilized in this paper.

pines (*Pinus mugo prostrata*). At 1900 to 2200 m they give way to mountain pastures and barrens (peaks up to 3000 m). The areas above timberline are used only infrequently by the bears, but are heavily used by hikers and mountain climbers in summer. The forested slopes, in contrast, are largely undisturbed by tourism and they are in part still inaccessible by vehicles, although the network of forestry roads is expanding rapidly. At 1600 m elevation, the average temperature is 4.8° C (January −4.0; July 13.9); precipitation totals 115 cm per year (maximum in May, minimum in January). Snow cover lasts from late November to late March.

Bounties on bears were paid in the Trentino until the First World War. In 1939, the bears were fully protected by law, but poaching continued (Pedrotti 1972). Recently the attitude of the hunters has seemed to change gradually: they now tend to concede the bears' right to exist. Within the last decade, the number of bears has probably been stable or slightly increasing. Around 10 to 15 wild bears are presently believed to live in the Trentino.

DATA COLLECTION

Three bears were captured 4 times between August 1976 and November 1979 with spring-activated Aldrich foot snares near a baiting station furnished with butcher's refuse (Table 1.) Bear 1 was a small adult female. Bear 2 was (for the Trentino) a large male. Bear 3 was a male, 1 of 2 zoo-bred animals that were released in spring 1974 about 4 km away from the capture site. In late April or early May 1978 this bear was carried by a snow slide (or slid spontaneously) down an extremely steep slope just outside of its den, and was killed.

The bears were fitted with radio collars (manufactured by AVM, USA; second collar of bear 1 by Telonics, USA) without motion sensors. The animals were classified as being active when the strength of the signals fluctuated clearly. Tests and visual observations of collared bears showed that the strength of received signals is uniform only when the collar (the bear) is immobile. Much of the activity data were collected while radiolocating the bears. In addition, bear 1 and 3 were monitored around the clock for their activity pattern on several occasions (bear 1 up to 133.75 hours without interruption). The receiver was turned on every 15 minutes (within the first 5 minutes after the full hour, the full hour and 15 minutes, the full hour and 30 minutes, the full hour and 45 minutes), and at least 40 signals were carefully listened to before deciding on the activity status of the bear. The observations made concurrently with the location fixes were not timed in this rigorous manner, but in order to make their sampling properties similar to those of the data gathered through the systematic activity monitoring, only observations that were at least 10 minutes apart in time were used, and no more than 4 observations of any single hour were accepted for analysis. The systematic and location-fix activity data are treated as one single set in this paper. When reception of signals was poor, the activity status often was unclear. These data and those from the denning and post-denning period (December through April) are omitted. Altogether, 2329 activity readings were accepted for analysis.

DATA ANALYSIS

All data from the same hour of the day were pooled. The smallest time unit for this analysis is 1 hour. The ratio of "active" observations to total number of observations gives an estimate of the fraction of time the bear was active. Generalizing, this can be interpreted as an estimate of the probability of finding a bear active at a particular hour of the day.

I started from the null hypothesis that bears have the same level of activity throughout the day. To test this hypothesis, the 24 chi-square test values ($\hat{X}^2$) which compare the level of activity of all adjacent hours were calculated. The data set is circular: the hour 2300 to 2359 is adjacent to 0000 to 0059. The smallest of the 24 $\hat{X}^2$ values indicated which 2 1-hour periods can be combined with the least probability of losing important information. Then the 2 new $\hat{X}^2$ values for the differences between the newly formed 2-hour period and its 2 adjacent hours were calculated. The smallest of the now 23 $\hat{X}^2$ values was eliminated by combining the corresponding data. This whole procedure was repeated until all $\hat{X}^2$ values were greater than the threshold corresponding to the 1% level of significance.

Let a = number of "active" observations, A = number of all telemetry observations; then a_1/A_1 = level of activity for hour 1 and a_2/A_2 = level of activity for hour 2. If $\hat{X}^2$ is calculated *with* the correction for continuity of Yates, $\hat{X}^2 >$ 0 will be found for identical levels of activity ($a_1/A_1 = a_2/A_2$) if $A_1 \neq A_2$. Furthermore, $\hat{X}^2$ can be smaller, i.e., $\simeq$ 0, for a_1/A_1 not equal (but close) to a_2/A_2. (Example: 50/100 versus 5/10 gives $\hat{X}^2$ = 0.11; 55/100 versus 5/10 gives $\hat{X}^2$ = 0.0009). This is undesirable since adjacent hours with identical activity levels should be combined first. Therefore, $\hat{X}^2$ values were calculated *without* correction for continuity:

$$\hat{X}^2_{(1\,df)} = \frac{(A_1 + A_2)\,[a_1\,(A_2 - a_2) - a_2\,(A_1 - a_1)]^2}{(a_1 + a_2)\,(A_1 + A_2 - a_1 - a_2)\,A_1\,A_2}$$

(which always gives $\hat{X}^2 = 0$ for $a_1/A_1 = (a_2/A_2)$. The correction for continuity makes sense in later runs of the iterative procedure when all $\hat{X}^2$ values have attained a certain size (say, > 1). I used it only in the final run.

The critical value for $\hat{X}^2$ is important. The standard values cannot be used because the same test is applied to the same body of data many times. This increases the probability of finding a significant $\hat{X}^2$ value just by chance. The problem can be resolved by applying the so-called Bonferroni procedure (Sachs 1978:368f): if the test has been performed r times and one wants to work at the significance level P, the critical value of the test statistic to be used is the one corresponding to $\hat{P} = P/r$.

For the activity data, 24 $\hat{X}^2$ values are calculated first. For every $\hat{X}^2$ successively eliminated, 2 additional $\hat{X}^2$ values have to be determined. The elimination of the 3rd to last $\hat{X}^2$ implies the calculation of only 1 additional $\hat{X}^2$ (circular situation), and the elimination of the 2 last $\hat{X}^2$ values (which are identical) implies the calculation of no new $\hat{X}^2$. Therefore, in the worst case, i.e., if the data cannot demonstrate a change of activity level during the 24-hour cycle and all 24 $\hat{X}^2$ values will be eliminated, [24 + (2 × 24) −5] = 67 $\hat{X}^2$ values have to be calculated. To work at the 5% level, the $\hat{X}^2_{(1\,df)}$ for $\hat{P} = 0.05/67 \simeq 0.000746$ must be used as critical value. The corresponding $\hat{X}^2$ value is 11.37. For the 1% level, we have to use the $\hat{X}^2_{(1\,df)}$ for $\hat{P} = 0.01/67 \simeq 0.000149$, which is 14.38. These "worst case" values were applied for all analyses, regardless of how many $\hat{X}^2$ values actually had to be calculated.

A program for a small desk calculator (Texas Instruments TI-59 with printer PC-100 B) was developed to perform these calculations. This program is available from the author.

RESULTS

Fig. 1 illustrates the level of bear activity in relation to the time of the day. All data were combined. This reduces random errors due to small numbers and therefore gives the best estimate of the temporal distribution of bear activity. We lose, however, information on seasonal differences, which are discussed later.

At the 1% level of significance, 5 periods of different probability of finding the bears active can be discerned. Of 2329 telemetry readings, 1037 (45%) were classified as "active". Sample sizes are not equal for all hours. Therefore, the weighted average

$$\left[\sum_{i=1}^{5}\left(\frac{a_i}{A_i}\,T_i\right)\right] \div 24 \qquad (1)$$

(where i designates the 5 discerned time periods, a_i/A_i is the corresponding activity, and T_i the length of the corresponding time period in hours) should give a better estimate of the overall activity level. This value is 47%.

The diel activity pattern is characterized by 2 peaks: a main peak from 1800 to 2300 hours and a secondary peak from 0500 to 0800. The activity is clearly lowered during the night (2300–0500). The main rest period lies between 0800 and 1300 hours. The activity level is intermediate in the afternoon (1300–1800).

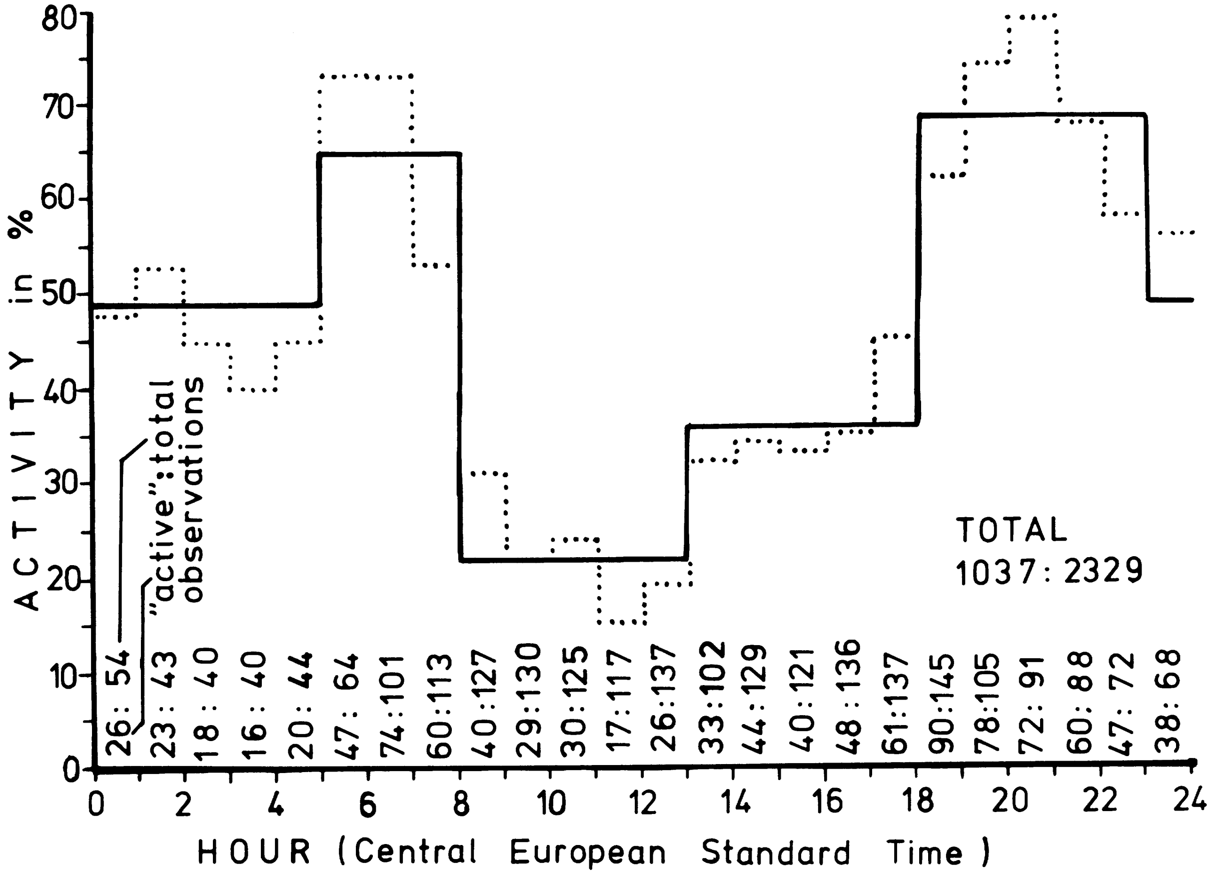

Fig. 1. Activity (%) of brown bears in Trentino, Italy, as a function of the hour of the day (all data combined). The dotted line shows the activity level as measured for every hour. The solid line shows the 5 significant changes in the activity level as determined by an iterative chi-square procedure ($P < 0.01$).

In the Trentino it is very rare—in relation to the frequency of track finds—to see bears. According to interview data (Roth 1972), the average hunter makes a bear sighting about every 30 years. Therefore I presumed the bears to be nocturnal. But telemetry showed that the bears can be active at any time of the day, and even in bright sunlight and hot weather (close to 30 C; bear 3).

Data were grouped by bear and month. The resulting 12 data sets were inspected (bear 1, Aug–Nov 1976 and Nov 1979; bear 2, Nov 1976; bear 3, Jun–Nov 1977). The procedure to define the "significant" time periods of the day (as described in "Data Analysis") was applied to these monthly data, but no essentially different periods or seasonal trends in the periods were discovered. For ease of comparison, I will present the monthly data only in the "period-structure" of the combined data (Fig. 1 and Fig. 2). I shall call the 5 "significant" time periods early morning (0500–0800 hours), late morning (0800–1300), afternoon (1300–1800), evening (1800–2300), and night (2300–0500).

A marked variability in the activity pattern was found. The data are neither numerous nor complete enough to allow an unambiguous separation of possible seasonal trends from individual variations. The most regular feature encountered was the marked decrease of activity from early morning to late morning. Of the 12 data sets only 1, the limited August 1976 data of bear 1, indicated a small and nonsignificant increase in activity from early morning to late morning ("active"/total: 8/14 versus 5/7; $P > 0.2$). Another regularity was the increase of activity from afternoon to evening with only 1 exception (bear 3, Oct 1977: 35/47 versus 7/33; $P < 0.001$). A decreased night activity as compared to the evening and early morning was clearly evident in only 3 data sets (bear 1, Nov 1979; bear 3, Jul and Aug 1977). The August and September 1976 sets of bear 1 indicated a short rest period from 0200 to 0400 hours (instead of 2300–0500). This rest period is blurred by the "time period structure" of Fig. 1 applied here. Five data sets are inconclusive because of too few observations made during the night. The remaining 2 sets strongly suggest that the bear did not rest at night (bear 3, Oct and Nov 1977). In August 1976, bear 1 showed a very high, apparently irregular activity throughout the day (early morning to night: 57%; 71%; 63%; 78%; and 70%), and in June 1977 bear 3 seemed to behave similarly (early morning to evening: 75%; 60%; 42%; 50%; no data from the night). The differences between adjacent time periods were not significant ($P > 0.2$). In 8 of the 12 data sets, an increase in activity from the late morning to the afternoon was evident (significant at $P < 0.01$ in 3 cases: bear 3 in Jul, Aug, and Oct 1977). Four data sets (bear 1 in Aug and Sep 1976, bear 2 in Nov 1976, and bear 3 in Jun 1977) revealed lower activity in the afternoon than in the late morning, but differences were not significant (bear 1, Sep 1976, $P > 0.02$; the other sets, $P > 0.04$). To illustrate the variability, the data combined in 2-month periods are shown in Fig. 2.

The proportion of time bears were active during the 24-hour cycle was estimated for the 12 data sets using formula (1). In 5 data sets (bear 1, Nov 1976; bear 2, Nov 1976; and bear 3, Jun, Aug, and Sep 1977) there are no or very few (<5) telemetry readings from the night. The estimates for the remaining 7 data sets average 53% (SD = 16%, range 22%–69%). If we consider only the 18-hour period from 0500 to 2300, we have usable estimates from all 12 data sets. The average is then 51% activity (SD = 12%, range 25%–69%). The 2 most extreme values came from bear 1, with 69% activity in August 1976 and only 22% in November 1979. (If for ease of testing, one uses the sums instead of the weighted averages derived according to formula (1), the difference between each of these extreme values and the other estimates of the amount of activity is highly significant, $P < 0.001$). Most of the data in November 1979 were collected within a week before bear 1 moved to its winter den. The same animal ahowed a rather

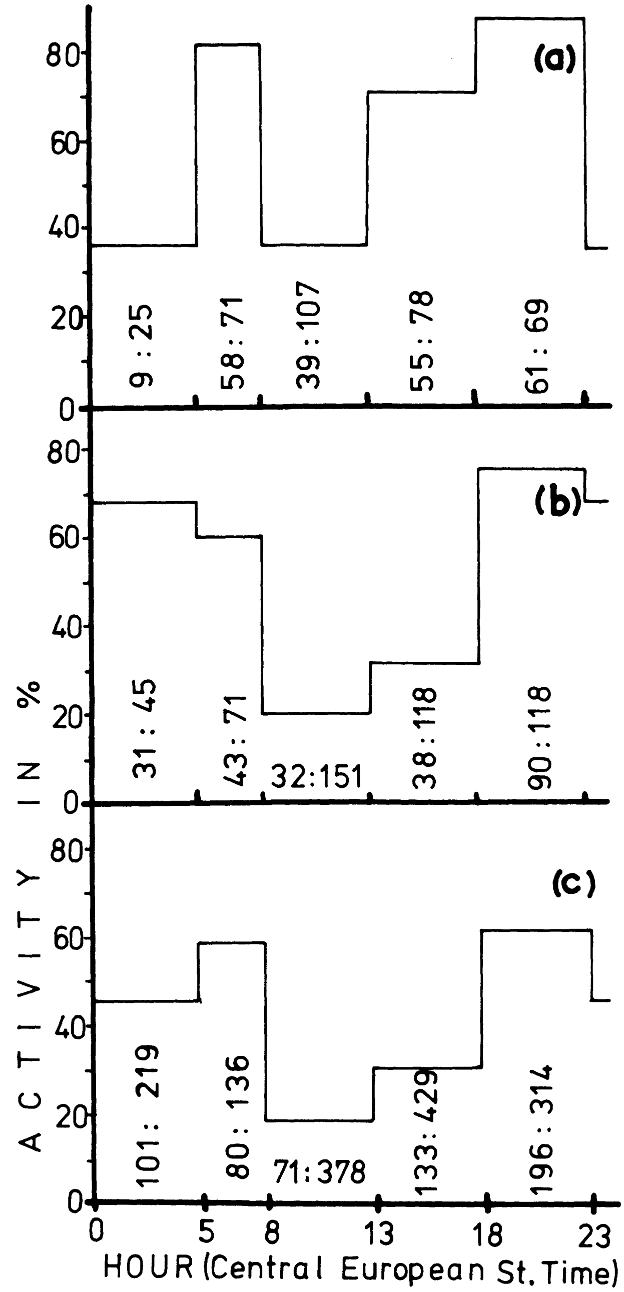

Fig. 2. Activity (%) of brown bears in Trentino, Italy, as a function of the hour of the day and season. (a) June and July 1977, bear 3; (b) August and September 1976 and 1977, bears 1 and 3; (c) October and November 1976, 1977 and 1979, all 3 bears. Number of "active" and total observations, and 5 diel periods, are as shown in Fig. 1.

high activity level of 62% in November 1976. There is considerable variability between the estimates of the amount of activity, and I could not identify significant seasonal trends. The data only weakly suggest a high activity in summer, a slightly lower activity in fall, and a temporary increase in activity in November before denning. After removing the 2 most extreme data sets (bear 1, Aug 1976 and Nov 1979) and combining all the remaining data, formula (1) yields an activity estimate of 57%.

If one examines activity schedules of individual bears on specific days, one is impressed by the variability that seems at first sight to preclude every generalization. This variability may be characteristic for bears, although it may also reflect environmental factors which are difficult to measure and which could make any animal move at any hour of the day, e.g., disturbance by man. Two examples may serve as illustration: on 7 November 1977 bear 3 was already inactive at 0600 when monitoring began. On 8 November he was active till 0915, on 9 November till 1000, and on 10 November till 0900. Bear 1 began her evening activity on consecutive days (12 to 17 Nov 1979) at 1830, 2030, 1845, 1745, 1900, and again 1900. In each 24 hours, there were usually 2 to 3 rather well defined bursts of activity lasting 1 to 13 hours (mean 4 to 5 hours) plus some more scattered activity of short duration (probably in part moving around in the daybed, or a short distance out of it to defecate, according to circumstantial evidence).

DISCUSSION AND CONCLUSIONS

The data support the hypothesis that the bears in the Trentino usually show a bimodal activity pattern (Fig. 1). This is a common pattern among mammals and has been called "bigeminus" (Aschoff 1962:16). But sometimes the bears are active throughout the night, i.e., they adopt a unimodal activity pattern (Fig. 2(b)). There is much variability between months and individual bears. The most constant feature is the low activity (often about 15% to 25%) in the late morning hours from 0800 to 1300. These generalizations are statistical descriptions of the probability of finding the bears active or inactive. The individual pattern is very irregular.

During summer and fall, the bears were active around 45% to 60% of their time (there were not enough data from spring to draw conclusions). The cessation and onset of their activity seemed to be only loosely correlated with sunrise and sunset. This contrasts with the pattern in a number of mammals which are clearly nocturnal such as the European badger (*Meles meles*) (Hainard 1961:271) and rabbit (*Oryctolagus cuniculus*) (Kraft 1978), or diurnal such as the squirrel (*Sciurus vulgaris*) (Zwahlen 1975). The European red deer (*Cervus elaphus*) seems also basically to have a bimodal activity pattern and can also be active at night or day. But deer usually have 7 to 9 bursts of activity of 1/2 to 2 hours duration each in 24 hours (Georgii 1981, Georgii and Schröder 1978). Bears have 2 to 3 bursts of 4 to 5 hours duration. The difference may partly be due to different monitoring techniques (continuous monitoring by Georgii versus 15-minute sampling in this study).

The black bear (*Ursus americanus*) seems to be more active in daylight hours than the brown bears in the Trentino. Data from the western U.S. indicate a predominantely diurnal activity pattern with a tendency to crepuscular activity peaks (Poelker and Hartwell 1973:73, Amstrup and Beecham 1976:341, Lindzey and Meslow 1977:416).

The fragmentary information on activity patterns of brown bears I was able to locate is in general agreement with my data. Where bears are less disturbed by man, they seem to be less nocturnal. Erickson and Siniff (1963) observed, from the air on the Alaska Peninsula, most brown bears in the evening (about 1700–2000), the least around mid-day (1100–1400), and an intermediate number in the morning (0500–0800). Stonorov and Stokes (1972:234) saw about 3 times as many brown bears at an Alaskan salmon stream in the afternoon as in the morning. In the same location Egbert and Stokes (1976:44) found that bear activity was lowest in early and mid-morning hours, increased to an evening peak at 1800 to 1900, decreased sharply between 2200 and 2300, and remained low throughout the night (there was no hunting in the area). Gard (1971:202) stated that on Kodiak Island (where some hunting is done) bear predation on salmon in greatest at night. Pearson (1975:43) found no change of the daily grizzly activity in the Yukon Territory throughout the year (except during the denning period). The activity was low from 1100 to 1500, increased in the late afternoon, and reached a peak at dusk. The activity continued for at least part of the night. The grizzlies in Yellowstone National Park used to visit dump areas in the evenings and at nights, sometimes in the afternoon (Craighead et al. 1960:349). Craighead and Craighead (1972:25) found that bears rested during daylight hours and foraged at night in summer, but were active both day and night in early spring and fall. According to Kistchinski (1972:71), brown bears do not have a clear diel activity pattern in northeast Siberia, but are most often seen in the evening. Ustinov (1974) reported that bears of the maritime Ridge by Lake Baikal feed mostly at night, and Voronov (1974) stated that on the Sakhalin Region Islands the brown bears are active around the clock in spring and summer with diminishing activity during the daylight hours near human settlements.

This review suggests that the diel activity pattern of brown bears varies in relation to environmental conditions, including human activity. The scarcity of systematic and quantitative data precludes a detailed discussion.

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