# DIEL ACTIVITY OF BROWN BEARS IN PLITVICE LAKES NATIONAL PARK, YUGOSLAVIA

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*Abstract:* We obtained 2,757 radiotelemetry activity readings, at 15-min intervals, from 2 brown bears (*Ursus arctos*) in Plitvice Lakes National Park. In late fall, while still with her family group, a yearling female was active during the day, but became nocturnal after her mother disapperared the following year. Her main rest period was from 0800 to 1600 hours, with a secondary rest period around midnight. An adult male followed a similar nocturnal schedule (Jul–Oct 1982 data only). Both bears were active 50%–60% of the time between July and October, 40% of the time in November and December, and 5% of the time in the winter den (Feb 1982, female only).

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Better knowledge and understanding of the 24-hour distribution of activity and rest of wild animals is important from a theoretical and practical viewpoint. Temporal activity patterns are a major component of overall space and time utilization patterns of a population (or species) and thus an important dimension of the ecological niche of the organism.

Because the activity patterns of intelligent, adaptable animals can be modified by environmental conditions, including human activities, detailed and reliable information about "normal" and "actual" activity patterns of a population could become an important wildlife management tool. From knowledge of bears' activity schedules, useful advice can be derived for those who want to encounter bears and those who want to avoid them.

Roth (1983) presented activity data on brown bears from a remnant population surviving in a relatively densely settled area of the Alps of northern Italy. We present data on 2 brown bears from a much larger population living in a less populated area in Yugoslavia.

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## STUDY AREA

Plitvice Lakes National Park (192 km$^2$, 44° 52′ North 15° 34′ East) and the surrounding area used by bears consists of a series of ridges 1,100–1,200 m high that run approximately northwest-southeast and are separated by valleys 500–800 m in elevation. Deciduous forests composed of beech (*Fagus silvatica*) at lower elevations and mature mixed stands of beech and conifers (*Picea abies, Abies alba*) at higher elevations cover 75% of the area. Small agrarian hamlets surrounded by meadows and fields are found in the valleys. The average annual temperature is 8 C. Yearly precipitation is 1,500 mm. For more details see Huber and Roth (this volume).

By European standards, the area is sparsely settled, with only 13 inhabitants/km$^2$. Selective logging is taking place throughout the Park and surrounding area, but it is usually conducted on relatively small (30 ha) areas at a time. Most of the forest is infrequently visited by people. Although there is no hunting within the Park, some bears are taken annually in the immediate surroundings. Because our radiotelemetry data indicate that probably few bears confine their movements to the Park (Huber and Roth, this volume), it is likely that most bears are exposed to some hunting pressure. Hunting, however, causes little harassment of the population because most of the bears are shot from blinds at well-established baiting stations. Thus, we assumed the diel activity pattern of the bears is only minimally influenced by humans.

## METHODS

A female yearling (bear 1) traveling with its mother and sibling and a 4.5-year-old male (bear 2) were captured and radio-collared on 1 November 1981 and 17 June 1982, respectively.

Data collection and analysis closely followed the procedures described by Roth (1983). Whenever possible, we tried to monitor the bears continuously for at least 24 hours. Often, radio contact was lost during the night.

Fluctuations of signal strength indicated that the animal was active. We listened to at least 40 signals before deciding on the activity status of the bear (Roth 1983:224). Systematic tests (monitoring a hidden radiocollar that was moved or laid down at random by a person at 1 min intervals), and visual observations of radio-collared bears showed that even slight movements of the collar (and head) induced clear signal fluctuations, which corresponds to the findings of Lindzey and Meslow (1977:415). To avoid bias toward "active," a reading was repeated if only a few signals were irregular, and the bear was classified as inactive if a 2nd series of 40 signals was regular. We are aware that even with this procedure, "activity" does not always mean feeding or traveling. Strictly speaking we are therefore monitoring more the complete rest periods (bear motionless) than the activity.

Activity readings were made once every 15 min during systematic monitoring sessions. Much of the data for bear 1 from December 1982 was automatically recorded with a tape recorder powered by an automobile battery and connected to an electronic timer. The data collected while routinely locating the bears were also used for activity calculations if the single readings were at least 10 min apart. No more than 4 readings per hour per animal were accepted for analysis. This paper is based on 2,757 readings made from the capture dates through 31 December 1982, corresponding to 689.25 bear-hours of monitoring time (excluding 96 scattered readings from Jan and Mar 1982 for bear 1 and Jun, Nov, and Dec 1982 for bear 2).

The bears were usually > 500 m from the observer, and we could see the animals only rarely. After suspected disturbances by observers, the data for the rest of the day were discarded for activity analysis.

The data analysis procedures are only outlined here; for details see Roth (1983). We started with a 24-hour block of activity data and combined step by step the data of those adjacent hours (or several hour time periods in later runs), that showed the least probability (as indicated by the smallest 2 by 2 table chi-square value) of having different (real) levels of activity. Because the same body of data was treated by the same test many times, the usual chi-square thresholds could not be used. For example, instead of 3.84 for the 95% level (df = 1), 11.37 was used, and for the 90%, 99%, and 99.9% levels, 10.09, 14.38, and 18.75 were used respectively (Bonferroni procedure according to Sachs 1978:368f). Because the 1st hour (0000–0059) is adjacent to the last hour (2300–2359) of the day, a circular situation exists. If gaps of > 2 hours existed in the data, a noncircular version of the analysis procedure was used (Fig. 1a, c).

To decrease the sampling variability and simplify the results, the data of 2 consecutive months were combined unless they showed important differences in the activity pattern. For logistic reasons, bear 2 was difficult to locate, which resulted in less data. Therefore we combined all his data from the active

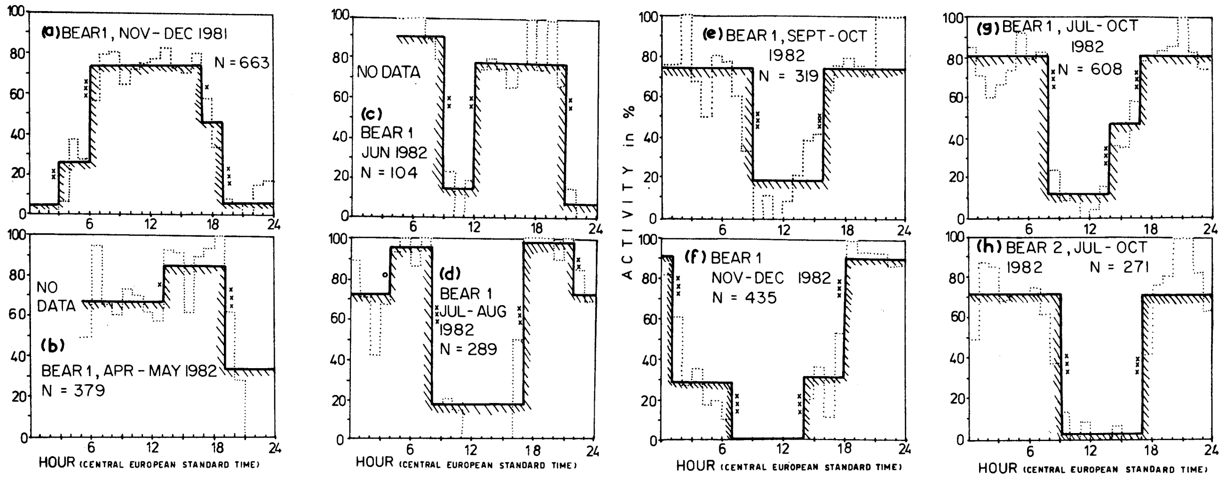


**Fig. 1. Activity (%) of 2 brown bears in the Plitvice Lakes National Park, Yugoslavia, 1981–82, as a function of the hour of the day and the season. The dotted lines show the activity levels as measured for every hour. The solid lines show the significant changes in activity level as determined by the procedure described by Roth (1983). *N* = number of activity measurements. 0 = almost significant, 0.05 < *P* < 0.1; x, significant, 0.01 < *P* < 0.05; xx, highly significant, 0.001 < *P* < 0.01; xxx, very highly significant, *P* < 0.001.**

**Table 1. Level of activity by season and hour of the day of 2 brown bears in the Plitvice Lakes National Park, 1981–82.**

| | 1981 | 1982 | | | | | |
|---|---|---|---|---|---|---|---|
| Hour | Nov–Dec | Feb | Apr–May | Jun | Jul–Aug | Sep–Oct | Nov–Dec |
| Bear 1 | | | | | | | |
| 0[a] | 0/26[b] | 0/12 | — | — | 16/18 | 3/4 | 14/17 |
| 1 | 0/19 | 1/12 | — | — | 10/14 | 3/4 | 11/18 |
| 2 | 0/19 | 1/11 | — | — | 5/12 | 6/6 | 6/22 |
| 3 | 3/19 | 0/9 | — | — | 10/15 | 6/9 | 8/22 |
| 4 | 6/16 | 0/11 | — | 2/2 | 14/15 | 6/12 | 4/22 |
| 5 | 6/22 | 1/12 | 1/2 | 2.2 | 18/18 | 8/10 | 4/20 |
| 6 | 15/27 | 0/12 | 18/19 | 3/3 | 12/14 | 10/13 | 2/18 |
| 7 | 22/28 | 1/12 | 18/27 | 9/10 | 14/14 | 6/10 | 0/16 |
| 8 | 28/35 | 0/13 | 14/23 | 4/5 | 3/16 | 4/12 | 0/20 |
| 9 | 27/42 | 0/16 | 25/34 | 1/4 | 3/14 | 0/16 | 0/20 |
| 10 | 34/48 | 1/16 | 24/34 | 0/3 | 2/13 | 1/9 | 0/27 |
| 11 | 31/42 | 1/14 | 25/40 | 1/5 | 0/5 | 0/9 | 1/33 |
| 12 | 29/38 | 2.12 | 14/24 | 6/8 | 0/4 | 1/13 | 0/18 |
| 13 | 32/39 | 3/13 | 26/28 | 8/10 | 0/3 | 4/19 | 0/20 |
| 14 | 23/32 | 0/13 | 23/25 | 6/8 | — | 5/13 | 3/14 |
| 15 | 22/32 | 0/12 | 20/32 | 4/6 | 0/2 | 7/17 | 3/8 |
| 16 | 23/29 | 0/12 | 19/21 | 7/9 | 4/8 | 17/27 | 1/8 |
| 17 | 13/23 | 0/12 | 16/17 | 3/3 | 6/6 | 18/24 | 7/13 |
| 18 | 7/21 | 0/12 | 13/13 | 3/4 | 4/4 | 19/24 | 17/17 |
| 19 | 1/14 | 0/12 | 10/16 | 5/5 | 17/17 | 18/24 | 16/17 |
| 20 | 1/23 | 3/11 | 4/14 | 4/6 | 17/19 | 17/20 | 15/16 |
| 21 | 0/22 | 0/12 | 0/2 | 1/6 | 20/20 | 10/10 | 15/16 |
| 22 | 3/22 | 2/14 | 0/8 | 0/3 | 16/19 | 8/8 | 14/16 |
| 23 | 4/25 | 0/12 | — | 0/2 | 13/19 | 6/6 | 15/17 |
| Bear 2 | | | | | | | |
| 0 | — | — | — | — | 1/4 | 4/6 | — |
| 1 | — | — | — | — | 3/4 | 4/4 | — |
| 2 | — | — | — | — | 3/4 | 3/3 | — |
| 3 | — | — | — | — | 6/6 | 3/7 | — |
| 4 | — | — | — | — | 7/7 | 4/8 | — |
| 5 | — | — | — | — | 3/3 | 5/8 | — |
| 6 | — | — | — | — | — | 6/8 | — |
| 7 | — | — | — | — | — | 5/8 | — |
| 8 | — | — | — | — | 1/2 | 4/11 | — |
| 9 | — | — | — | — | 0/1 | 1/6 | — |
| 10 | — | — | — | 1/1 | 0/1 | 0/5 | 0/2 |
| 11 | — | — | — | 1/4 | 1/5 | 0/6 | 0/4 |
| 12 | — | — | — | — | 0/4 | 0/7 | 0/3 |
| 13 | — | — | — | — | 0/4 | 0/10 | — |
| 14 | — | — | — | — | 0/7 | 1/7 | 1/1 |
| 15 | — | — | — | — | 0/9 | 0/4 | 3/5 |
| 16 | — | — | — | — | 0/9 | 0/4 | 0/1 |
| 17 | — | — | — | — | 0/8 | 6/6 | — |
| 18 | — | — | — | — | 3/5 | 7/8 | 6/6 |
| 19 | — | — | — | — | 7/8 | 6/8 | 2/2 |
| 20 | — | — | — | — | 2/2 | 12/12 | — |
| 21 | — | — | — | — | 3/3 | 6/6 | — |
| 22 | — | — | — | — | 4/5 | 6/7 | — |
| 23 | — | — | — | — | 1/4 | 6/7 | — |

[a] 0 = 0000–0059 hours; 1 = 0100–0159 hours, and so forth.
[b] Number of "active"/total number of telemetry readings.

period and calculated the activity pattern for bear 1 for the same period for comparison (Fig. 1g, h).

The hour of day is Central European Standard Time (GMT + 1 hour).

## RESULTS

The results are summarized in Tables 1 and 2, and Figure 1. Most data are from bear 1. From November 1981 through May 1982, bear 1 traveled with her family. In November-December 1981, the family group showed a very distinct diurnal activity pattern (Fig. 1a). Even while denning, the activity never reached zero but did not seem to follow a temporal pattern (Table 1). The data from April through May 1982 suggest that in spring 1982, diurnal activity was characteristic—as it was in late fall 1981 (Fig. 1b).

A clear change in the activity pattern of bear 1 became evident for the 1st time after its mother had probably been taken by a hunter (circumstantial evidence), in June 1982, with the insertion of a 3-hour rest period in the morning (Fig. 1c). Both bears had similar summer-fall activity patterns characterized by mostly nocturnal or crepuscular activity and a distinct rest period during the day (Fig. 1e–1h). Bear 1, however, became gradually more active earlier in the afternoon (49% activity 1400–1659 vs. 2.5% of bear 2, $P < 0.001$, $X^2 = 0.26$, df = 1, $N = 41$). In late fall the female decreased her overall activity by resting more often after midnight and through the morning (Fig. 1f).

The percentage of time the animals were active during an average 24-hour period was calculated for the periods for which data were complete (Table 2). Three seasonal activity levels for bear 1 could be discerned: denning period with about 5% activity, summer-fall (Jul–Oct) with about 60% activity, and late fall (Nov–Dec) with about 40% activity (all differences highly significant, $P < 0.0005$). Although strikingly different in pattern, the 24-hour levels of activity for bear 1 in November-December 1981 and 1982 were similar ($X^2 = 0.86$, df = 1, $0.3 < P < 0.4$, $N = 1098$, see Appendix). In summer-fall (Jul–Oct 1982), bear 1 showed a significantly higher activity than bear 2 (61% vs. 49%, Table 2; $X^2 = 10.5$, df = 1, $P < 0.01$, $N = 879$). The data from bear 2 are inadequate to demonstrate seasonal changes in the level of activity.

## DISCUSSION

In general, the activity levels we found are similar to those of northern Italy (Roth 1983). The higher activity level of bear 1 over bear 2 is in accordance with the expectation that younger animals are more active (Aschoff 1962:66ff).

Most of the data (Jul–Dec 1982) indicate a predominantly nocturnal activity pattern with a pro-

**Table 2. Level of activity during an average 24-hour period by season of 2 brown bears in the Plitvice Lakes National Park, 1981–82.**

| Period | Bear (no. of readings) | Activity (% of time)[a] | 95% C. I.[b] | Sig. diff. betw. adj. rows[b,c] |
|---|---|---|---|---|
| Bear 1 seasonal activity | | | | |
| 1981 | | | | |
| Nov–Dec | 1 (663) | 42 | 38–46 | |
| | | | | XXX |
| 1982 | | | | |
| Feb | 1 (297) | 5.4 | 3.1–8.6 | |
| | | | | XXX |
| Jul–Aug | 1 (289) | 61 | 55–67 | |
| | | | | — |
| Sep–Oct | 1 (319) | 58 | 52–63 | |
| | | | | XXX |
| Nov–Dec | 1 (435) | 39 | 34–44 | |
| Bear 1 vs. Bear 2 | | | | |
| Jul–Oct | 1 (608) | 61 | 57–65 | |
| | | | | XX |
| Jul–Oct | 2 (271) | 49 | 43–55 | |

[a] Weighted average of activity levels of periods with significantly different levels (Fig. 1); weights = lengths of periods in hours/24 hours (Roth 1983).
[b] See Appendix.
[c] XX stands for $0.005 < P < 0.01$; XXX stands for $P < 0.005$.

nounced rest period during the day and an occasional 2nd rest period around midnight, which creates a slightly bimodal activity pattern ("bigeminus," Aschoff 1962). Similar activity schedules were found for 3 bears in northern Italy (Roth 1983).

In northern Italy, bears followed a nocturnal or crepuscular activity pattern (Roth 1983). When the 1st data from Yugoslavia (bear 1, Nov–Dec 1981) indicated clearly diurnal activity, we speculated that the much lower human population density in Yugoslavia (13/km$^2$ vs. 70/km$^2$ in Italy) accounted for less disturbance, allowing the bears to live according to their natural diurnal schedule. It came as a suprise when bear 1 switched to a nocturnal pattern in June 1982. Because the change from nocturnal to diurnal activity resulted from insertion and extension of a rest period in the morning hours, not during the hottest hours of the day, the explanation that bear 1 changed to nocturnal activity to escape from high summer temperatures is not convincing. The strikingly contrasting patterns of the November-December data 1981 vs. 1982 (Fig. 1a, f) illustrate how an individual bear can adopt a completely different activity pattern in the same season from 1 year to the next while maintaining the same overall activity level (about 40%). At present, the diurnal pattern of fall-winter 1981 appears to be an exception for European brown bears. To properly interpret and evaluate this phenomenon, more data on family groups and single bears over several years must be accumulated.

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## Appendix: Assigning Confidence Intervals to 24-Hour Activity Levels and Comparing 2 of their Values.

Complications arise because the activity levels are not calculated by simple ratios but by weighted averages (weights = number of hours of time period without significant changes in activity level). For assigning confidence intervals we interpolated from tables giving the intervals for the binomial distribution (Anon. 1968:85ff and 187). Let A be the activity level (expressed as a fraction of time, not as a percentage) calculated by the weighted average. Then the confidence interval for $(A \times N)$ "active" readings out of $N$ readings were interpolated (where $N$ is the total number of readings), i.e., we took the binomial confidence interval for the frequency $f = (A \times N) / \mathrm{N}$. Similarly, for comparing 2 activity levels by a chi-square test, we filled in the quantities $(A_1 \times N_1)$; $(N_1 - (A_1 \times N_1))$ and $(A_2 \times N_2)$; $(N_2 - (A_2 \times N_2))$ respectively in the fields of a 2 by 2 table.