

BROWN BEAR DIURNAL ACTIVITY AND HUMAN USE: A COMPARISON OF TWO SALMON STREAMS

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Abstract: Brown bear (*Ursus arctos*) activity along salmon (*Oncorhynchus* spp.) streams has frequently been characterized as crepuscular. Suggested explanations include: responses to daily changes in salmon abundance, responses to daily cycles of light and temperature, natural feeding schedules, and avoidance of people. We investigated the last hypothesis by comparing bear activity at 2 adjacent streams in Katmai National Park, both spawning habitat for the same run of sockeye salmon (*Oncorhynchus nerka*) but differing in their levels of human use. During 1989 and 1991, bear activity at Margot Creek, where no human activity was observed, was distributed uniformly throughout the day (based on 240 observation hours; $P > 0.90$ both years). This uniform distribution contrasted with the crepuscular pattern of bear activity observed at Brooks River, where human use came from a 60-person lodge, a 60-person campground (20 sites), and substantial day-use. Significant differences ($P < 0.001$) in activity by time of day were found at Brooks River during the autumn salmon spawning period (sampled 1988–92, 905 observation hr). The midday depression in activity was greatest for bears less tolerant of people (>68% of the adult bears seen). As human activity increased over the years of the study, these shier bears shifted their stream use among time periods: midday activity decreased while activity during the 2000–2200 hour time block increased significantly ($P < 0.050$). Our results indicated that avoidance of people cannot be discounted as a factor contributing to observed crepuscular patterns of use in brown bears.

Ursus 10:547–555

Key words: brown bear, diurnal activity, habituation, human impacts, *Oncorhynchus nerka*, salmon, *Ursus arctos*.

Daan (1981) proposed that the daily foraging pattern of an animal originates from an innate species-specific foraging routine that reflects adaptations toward optimizing foraging efficiency. Within this general foraging schedule, individuals adjust their foraging to meet metabolic needs and to respond to changing food abundance, quality, and distribution (Cloudsley-Thompson 1961, Aschoff 1964, Daan 1981). Potential constraints to optimal timing of foraging include environmental conditions that impede foraging ability (e.g., darkness for visually oriented predators) and presence of competitors or potential predators (Aschoff 1964, Daan 1981).

The diurnal activity pattern of brown bears at salmon spawning streams has been characterized as crepuscular (Troyer 1962, Erickson and Siniff 1963, Troyer and Hensel 1969, Warner 1987). Frame (1974) reported a bimodal distribution of activity by black bears (*Ursus americanus*) fishing at Olsen Creek, Alaska. These authors stated that late evening (2000 hr) was consistently the peak daylight time of bear activity. Factors suggested as contributing to the crepuscular patterns included diurnal changes in salmon availability (Frame 1974) and avoidance of human activities (Roth 1983, Warner 1987).

We investigated the role of the latter factor for brown bears using Brooks River in Katmai National Park and Preserve (NPP) between 1988–92. We compared the diurnal activity of bears at Brooks River, a site with high human activity, with bear activity at Margot Creek, a site with no human activity (1989–91). Changes in National Park Service (NPS) management policies for Brooks River resulted in increasing human activity through the years of the study. We therefore compared Brooks River diurnal activity patterns among years to further assess the relationship between human activity and bear diurnal use. Our expectation was that more pronounced crepuscular activity would be seen as human activity increased across years. Because Warner (1987), Mattson et al. (1992), and Olson (1993) found that bears tolerant of human activities showed use patterns that differed from those of less tolerant individuals, we compared Brooks River diurnal patterns among years separately for each of 3 habituation classes.

We thank the staff of Katmai NPP for their field support. C. Garber, M. Buntjer, G. Wilker, B. Holmes, and W. Maier assisted with data collection. S. Fitkin contributed to the design of data collection protocols. Funding was provided by the Alaska Regional Office of the NPS

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through the Utah Cooperative Fish and Wildlife Research Unit, Katmai NPP, and the Utah State University Ecology Center.

STUDY AREA

Our study sites were located in the interior of Katmai NPP (Fig. 1). These streams were within the Naknek drainage, which received annual escapements of >1 million sockeye salmon during the years of this study (Div. Commer. Fish., Alas. Dep. Fish and Game, unpubl. data, 1988–92).

At Margot Creek, salmon spawned in the 5.5-km river below Margot Falls during August (Troyer 1980). We monitored an 800-m section of the river where numerous shallows left salmon vulnerable to bears. This section of river was bordered by alder (*Alnus* spp.), spruce (*Picea* sp.), birch (*Betula* sp.), and willow (*Salix* spp.). The only human activity observed within this study area came from our observation platform 300 m from the river and occasional overflights by small planes.

Bears began fishing for spawning and spawned salmon at Brooks River during the last days of August; bear numbers increased through September and into October (Troyer 1980, Olson et al. 1993). Bears concentrated their activity in the 800-m stretch of river below Brooks Falls. The upper river was bordered by a forest similar to that at Margot Creek. Marshes dominated near the mouth. A developed area north of the river mouth (Fig. 1) provided services for visitors to Brooks River. Brooks Camp included a 60-person lodge, a visitor center, employee housing, and support facilities; 200 m to the north was a 60-person campground. Brooks Camp was accessible only by floatplane or by boat.

Brooks River visitors were permitted relatively unrestricted access throughout the area; however, within 3.2 km of the river, camping was allowed only in the established campground. NPS regulations required: (1) all food be stored in elevated food caches or in bear-proof food containers, (2) anglers immediately bring any fish they intended to keep to facilities in Brooks Camp for cleaning and storage, and (3) visitors refrain from approaching or remaining within 50 m of a single bear or 100 m of a female with young.

During 1988 and 1989, the NPS closed Brooks River below the falls to guided fishing on 10 September; during subsequent years, the entire river was open to guided fishing throughout the fall. Also, the lodge operating period was extended from 10 to 17 September in 1992. During all years, vacating and preparing facilities for winter extended the period of substantial human activity

in Brooks Camp at least 10 days beyond the closing date of the lodge. Between 1988–91, when comparable NPS records were available, September visitation to the Brooks River area increased from 585 to >1,290 visitor days (D.C. Nemeth, U.S. Natl. Park. Serv., King Salmon, Alas., pers. commun., 1991).

METHODS

Data Collection

Bear activity at Margot Creek was monitored between 6–24 August, 1989–91; at Brooks River, data were collected from 26 August–12 October, 1988–92. At Margot Creek we observed bear activity from a platform 6-m high in a tree located on a 70-m high bluff approximately 300 m from the river (Fig. 1). At Brooks, we divided the river from the rapids below Brooks Falls to the mouth on Naknek Lake (approximately 1.15 km in length) into 3 zones (cutbank, oxbow, and river mouth) for data collection (Fig. 1). Observers viewed the cutbank from a 3-m tree stand on the south side of the river atop a 3-m bank. The oxbow and river mouth were monitored simultaneously from a 4-m tower of scaffolding at the pontoon footbridge from 1988 to 1991, and from the new public viewing platform at the footbridge in 1992.

We monitored each river using a sampling schedule that covered all daylight hours in all observation zones within a sample block consisting of 2–4 consecutive days. At Margot Creek, bear activity was sampled between 0600–2200 hours Alaska Standard Time (AST); sample-block length was 3–4 days the first year and 2–3 days thereafter. At Brooks River, 4-day sample blocks were used during all study years; bear activity was sampled, as daylight permitted, between 0800–2200 hours AST.

We were able to identify as individuals most bears seen during sample sessions from records of identifying characteristics; at Brooks River and Margot Creek combined, each year we identified 48–73 independent bears. Each year, 2–3 of the identified bears were seen at both Margot Creek and Brooks River. Because of the distance from which observations were made at Margot Creek, a few individuals seen there were not identified to age–sex class.

We used focal sampling (Altmann 1974) to record bear activity: arrival and departure times and identities were recorded for all bears seen during an observation session. Throughout each session we used scan sampling (Altmann 1974) at 10-minute intervals to record counts of people.

We classified each adult bear seen >2 times at Brooks River as habituated, nonhabituated, or unknown. We defined habituation as consistent tolerance of people at

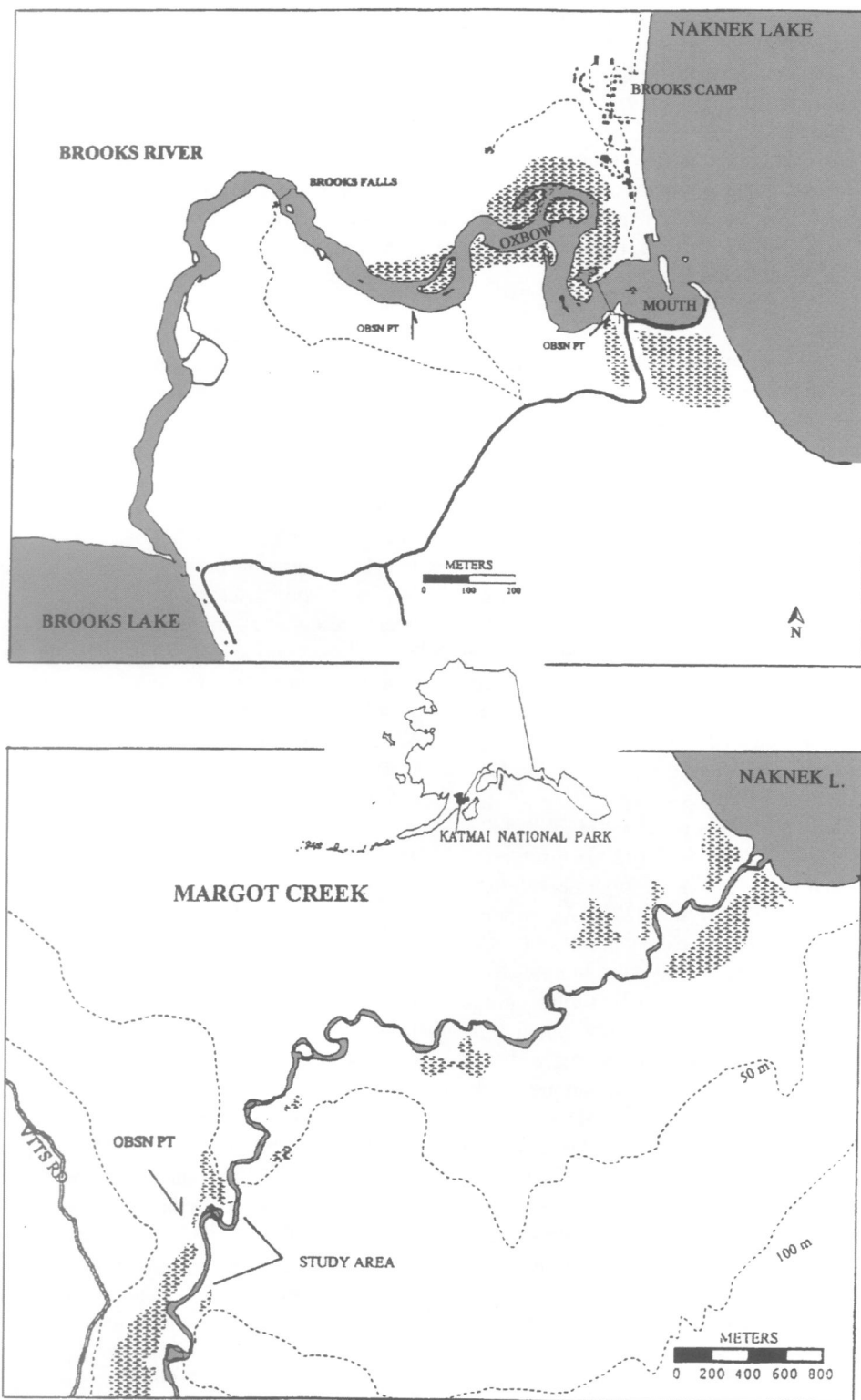


Fig. 1. Location of the study sites in Katmai National Park and Preserve, Alaska, 1988–92.

≤50 m with no noticeable change in behavior. Olson (1993) found that patterns of use and levels of activity did not differ between nonhabituated and unknown adults; therefore, we combined these categories for analyses. Most subadults (bears judged ≤4 yr old) appeared habituated to people; however, Braaten (1988) found that subadults did not show the same degree of human tolerance as habituated adults. We therefore classified subadults as a distinct class to avoid any biases from including most subadults in the habituated category.

Data Analyses

For Brooks River, we limited our analyses to data collected after 10 September because Olson (1993) and Olson et al. (1993) found that most adult bears did not begin fishing at Brooks River until after that date. We also excluded data collected during October because human activity was at minimal levels by October during all years (Olson 1993, Olson et al. 1993).

Few bears were seen within our observation zone at Margot Creek in 1990; observed bear activity was primarily by subadults and females with young. Consequently, the class composition of bear minutes recorded at Margot Creek in 1990 was not comparable to other years. Further, the data showed a marked non-normal distribution, a consequence of the frequency of observation sessions with no bears present. We therefore excluded the 1990 Margot Creek data from analyses.

We analyzed data from 905 hours (1988 = 178, 1989 = 184, 1990 = 167, 1991 = 184, 1992 = 192) of observation time at Brooks River and 240 hours of observation at Margot Creek (1989 = 113, 1991 = 127). We summarized bear activity by sample blocks, with rates of activity expressed as bear minutes/observation minutes (bm/om); rates were calculated as both activity/the sample blocks of consecutive days and as activity/2-hour time periods within the sample blocks. We summarized scan counts of people (people/scans [tp/ts]) by sample block.

Because some single bears seen at Margot Creek were not identified to age–sex class, we were unable to make a detailed comparison of the class composition of bear minutes recorded between our 2 study sites. We did, however, compare the percent of total bear minutes/sample block accounted for by females with young (dependent young were excluded; i.e., 1 family equalled 1 independent bear). Because Cochran's test (Winer 1971) indicated unequal variances ($P < 0.05$), we used an approximate *t*-test on square-root, arcsine transformed data, with Satterthwaite's approximation to estimate the degrees of freedom for the unpooled sample variances (Steel and Torrie 1980:106) for this comparison.

We used 2-way analyses of variance (ANOVA), with year and time period as factors, to compare bear activity among time periods (overall and by habituation class) for Brooks River. Because of insufficient sampling of 2000–2200 hours in 1988, comparisons were limited to data collected between 0800–2000 hours. We compared the proportion of total bear activity that was recorded during 2000–2200 hours (calculated per sample-block for each year) among years for both habituated and nonhabituated bears using 1-way ANOVAs on square-root, arcsine transformed data. The *C* method (modified Cochran's *t*-test; Day and Quinn 1989) was used to make protected unplanned comparisons of means.

For Margot Creek, we used separate 1-way ANOVAs to compare bear activity (bm/om) among time periods within years because the number of days/sample block differed between years. We made these comparisons both including and excluding observations of females with young. We also calculated bear activity rates at Margot Creek for each time period within each sample block during 1989 using scan counts of the number of individual bears present at 10-minute intervals (total no. bears/total scans, br/sc) and using counts of the number of different individuals seen during each observation session (total no. different individuals/observation session min, br/om). We compared these 2 alternative measures of bear activity with the rates derived from continuous sampling (bm/om) using Pearson's correlation coefficients and 1-way ANOVAs. Differences were considered significant at $P \leq 0.05$.

RESULTS

The proportion of bear minutes attributable to females with young was similar between Margot Creek and Brooks River ($T' = 0.754$, 14 df, $P = 0.464$), averaging 29.8% (SE = 4.10) and 26.6% (SE = 1.02), respectively.

At Margot Creek, where no human use occurred, bear activity (bm/om) remained at similar levels through the day during both 1989 and 1991 ($F = 0.37$ and 0.13 ; 7, 32, and 7, 56 df; $P = 0.911$ and 0.996 , respectively, for 1989 and 1991; Fig. 2). Similarly, bear activity (bm/om) excluding females with young did not differ from a uniform distribution through the day ($F = 0.87$ and 0.04 ; 7, 32 and 7, 56 df; $P = 0.972$ and 1.000 , respectively, for 1989 and 1991). Rates calculated for both of the alternative measures of bear activity (br/sc and br/om) showed a positive correlation with those derived from continuous sampling ($r = 0.799$ and 0.718 , 38 df [both coefficients], $P < 0.001$ both tests, respectively, for br/sc and br/om). For both br/sc and br/om, rates were similar among time

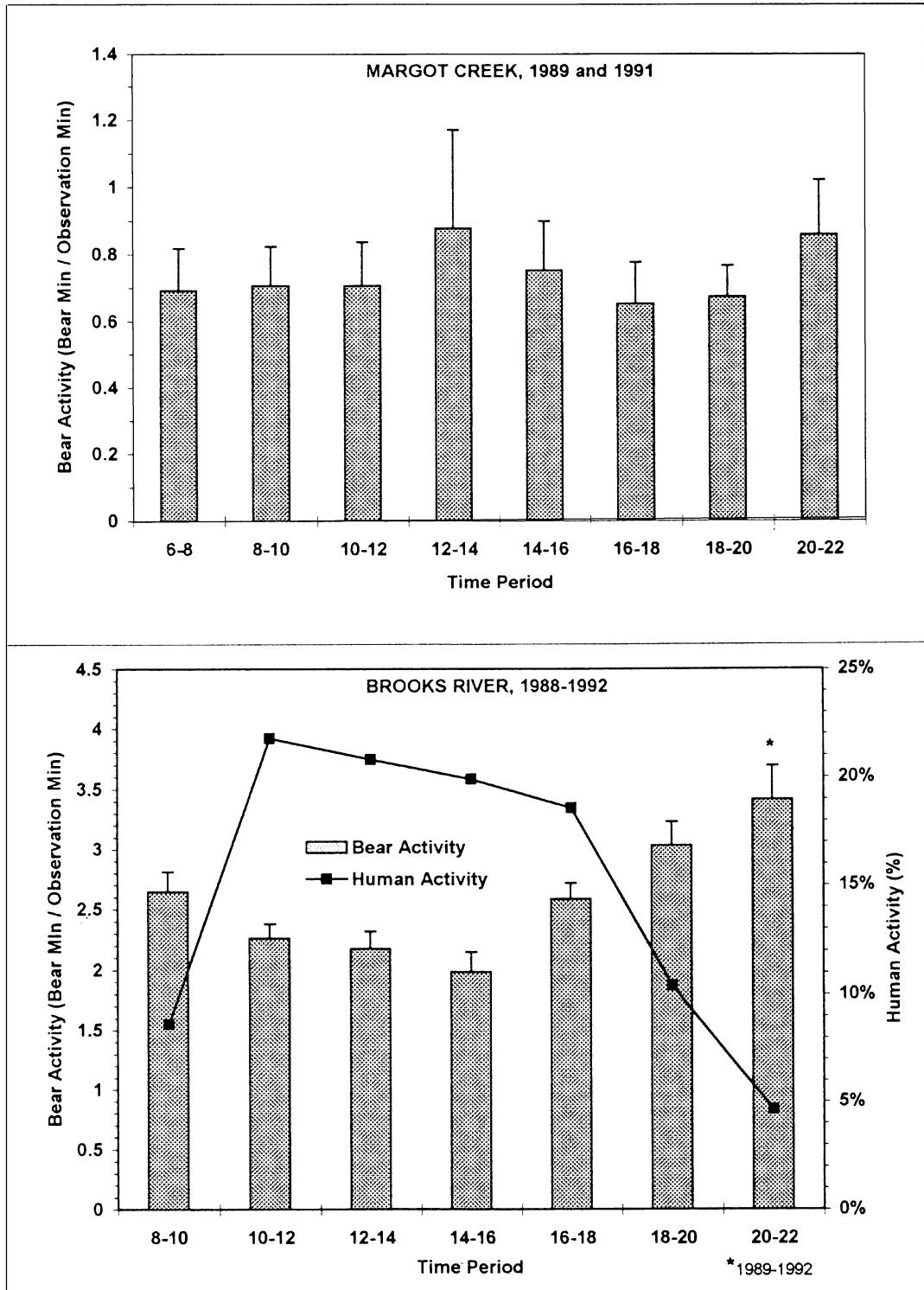


Fig. 2. Bear activity by time period ($\bar{x} \pm SE$) at Brooks River (Sept 1988–92) and Margot Creek (Aug 1989 and 1991) in Katmai National Park and Preserve, Alaska. The distribution of human activity among time periods is also presented for Brooks River. Time period 2000–2200 hr contains data from 1989–92 because of insufficient sampling of those hours in 1988.

periods ($F = 0.28$ and 0.82 ; 7, 32 df [both tests]; $P = 0.958$ and 0.578 , respectively, for br/sc and br/om).

In contrast to Margot Creek, bear activity at Brooks River differed among time periods (Table 1). Highest activity levels were seen at dawn and dusk, coinciding with relatively low human activity (Fig. 2). In most years, habituated adults showed a weak tendency toward lower levels of midday activity; differences in activity among time periods were not significant ($P = 0.061$). Nonhabituated adult bears showed a far more pronounced bimodal pattern of activity, especially after 1989 when the lower river was opened to guided sport fishing (Fig. 3); consequently, activity differed significantly among time periods (Table 1). Subadults showed no differences in activity among time periods (Table 1). Activity differed for all habituation classes among years (Table 1).

Human activity within the Brooks River corridor increased from a mean of 0.58 tp/ts (SE = 0.21) in 1988 to a mean of 3.95 tp/ts (SE = 1.37) in 1992 ($\bar{x} = 0.63$, SE = 0.18; $\bar{x} = 2.77$, SE = 0.28; and $\bar{x} = 1.77$ tp/ts, SE = 0.25, for 1989, 1990, and 1991, respectively).

Whereas the proportion of habituated and subadult bear minutes recorded between 2000–2200 hours remained similar as human activity increased over the years of the study ($F = 0.47$, 1.21; 3, 16 df [both tests]; $P = 0.707$, 0.339, respectively, for habituated and subadult bears), proportional use of this time period by nonhabituated adults differed among years ($F = 5.83$; 3, 16 df; $P = 0.007$). *Post-hoc* comparisons between years indicated that nonhabituated adults were proportionately more active between 2000–2200 hours in 1990 and 1992 than they were in 1989 and 1991 (modified Cochran's *t*-tests $P < 0.05$).

DISCUSSION

Activity of bears at the control site (Margot Creek) was relatively uniform throughout daylight hours, in contrast to the crepuscular patterns of activity that Troyer (1962),

Erickson and Siniff (1963), Troyer and Hensel (1969), Frame (1974), and Warner (1987) reported for bears at other salmon spawning streams. One possible explanation for this disparity relates to sampling methods. Whereas scan counts were the basis for most cited reports of bear diurnal patterns, our study used a continual sampling regime. If bout lengths of river use were shorter during midday than they were during early morning and late evening, these 2 sampling methods could yield different results. Depending on the time interval used between counts, scan sampling could miss some bear activity, while our continuous sampling would record all short-duration use. However, unless bout lengths differed by time period between other study areas and our Margot Creek observations, this explanation seems unlikely, because our comparisons of 10-minute scan counts of bears with activity rates derived from continuous sampling at Margot Creek indicated that the 2 measures were highly correlated.

Reports of the diurnal patterns of different age–sex classes are not consistent. Warner (1987) found that the diurnal activity pattern of predominantly female bears, many with young, seen at Pack Creek, Alaska, was similar to that observed at a control site, where predominantly single, male bears were active. However, several reports of black and grizzly bears in other areas indicated that females with young, and in some cases subadults, were more active during the day than were other bears (e.g., Ayers et al. 1986, Gunther 1990).

Therefore, we examined the Margot Creek data excluding use by females with young. Results of comparisons of activity among time periods for this subset were the same as those for all bears combined: no difference in use among time periods. Further, the proportion of females with young was relatively similar between our study sites. High representation of subadults also seems unlikely at Margot Creek because adults comprised >50% of the activity of single bears that were identified to age–sex class. We concluded

Table 1. Analyses of variation in bear activity at Brooks River in Katmai National Park and Preserve, Alaska, 1988–92.

Source of variation	df	All bears			Habituated			Nonhabituated			Subadults		
		MS ^a	F	P	MS	F	P	MS	F	P	MS	F	P
Year	4	1.887	3.20	0.016	0.812	5.01	0.001	2.934	20.21	0.000	4.074	21.77	0.000
Time period	5	3.588	6.08	0.000	0.353	2.18	0.061	1.491	10.27	0.000	0.290	1.55	0.179
Interaction	20	0.469	0.79	0.715	0.069	0.43	0.985	0.145	1.00	0.467	0.250	1.34	0.169
Error	120	0.590			0.162			0.145			0.187		

^a MS = Mean square.

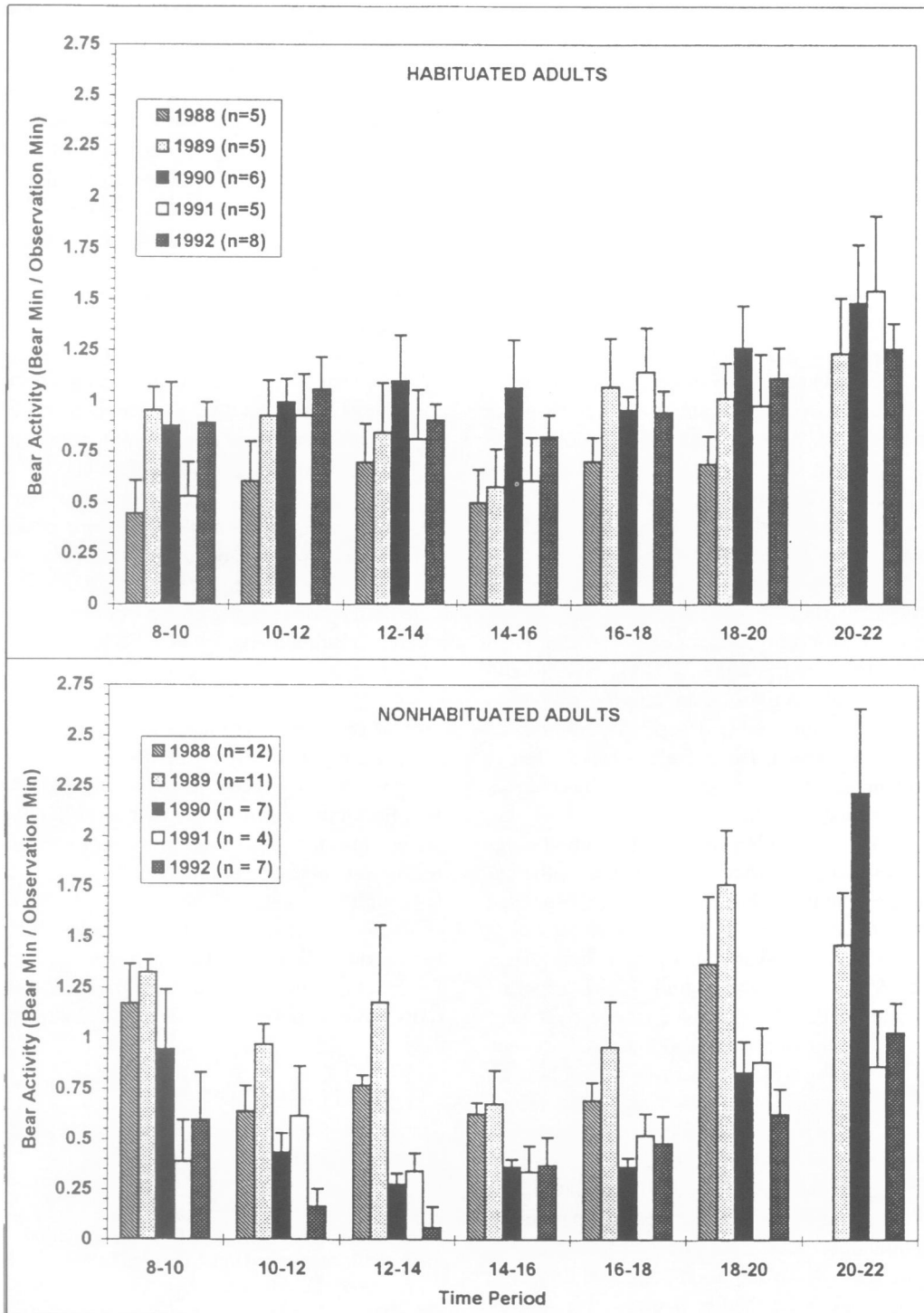


Fig. 3. Adult bear activity by habituation class, year, and time period ($\bar{x} \pm SE$) at Brooks River in Katmai National Park and Preserve, Alaska. September 1988–92. For each year, the number of individual bears is indicated in parentheses.

from these evaluations that differential representation of subadults or females with young was not a viable explanation for the uniform diurnal pattern at Margot Creek.

The diurnal activity seen at Margot Creek may be partly related to bear density. Given the productivity of the food base and the protection from hunting afforded by the National Park, the bear population should be at a relatively high density. We hypothesize that where population density is high relative to the food base, competition should drive some bears to feed during less preferred hours.

The bear activity pattern summarized across habituation classes for Brooks River was generally consistent with those reported from other areas. All adult bears showed some tendency toward higher activity levels late in the day. However, our comparisons of activity patterns by habituation class suggested that human activity was likely related to the relatively low midday activity levels of many bears (i.e., nonhabituated adults). The more pronounced crepuscular patterns of nonhabituated adults relative to those of habituated adults and the apparent increase in proportional activity of nonhabituated adults during late evening (2000–2200 hr) in 1990 and 1992, years with substantial human activity, supported this conclusion. Glenn (1971) described a similar response by bears at McNeil River Falls, Alaska. There, increased human visitation was associated with decreased midday use by bears.

Presumably, if factors other than human activity significantly affected bear diurnal activity patterns, the habituated and nonhabituated groups should have responded similarly to those factors. Nonhabituated bear activity in 1991 was not as skewed toward late evening as was seen in 1990 and 1992. Olson and Squibb (1991) reported that in 1991 many adult bears arrived on the river later than usual, and the number of nonhabituated adults seen was lower than in previous study years. We hypothesized that salmon were available to bears later in the season than usual because of an unusually high escapement in 1991 (3.6 million [Div. Commer. Fish., Alas. Dep. Fish and Game, King Salmon, unpubl. data]) associated with a commercial fishing strike. Consequently, some bears avoided the human activity at Brooks River altogether in favor of feeding at other locations. Thus, the nonhabituated bears that fished at Brooks River during fall of 1991 were likely individuals more tolerant of people or females with young under high nutritional stress, and would be less likely to avoid people.

Although many nonhabituated adults appeared to shift activity toward late evening as human activity increased

through the years, Olson et al. (1993) found that many of these bears also reduced their total daylight use of the river and that several apparently abandoned daylight use of the river completely. It was unknown whether bears that decreased their activity midday concurrent with increasing human activity shifted some of that activity to night-time feeding. With the aid of a light-amplifying scope, Olson et al. (1990) observed bears fishing during the night at Brooks River in 1988; therefore, this time period may already have been occupied by other individuals and consequently not available to displaced bears. The success of fishing in darkness was also unknown, but was presumably lower than that of daylight foraging. Without visual cues, it would have been difficult for bears to catch anything but dead salmon, potentially excluding those bears from the higher fat-content of salmon not yet spawned (Brett 1980, Stalmaster 1981).

We believe that, with the exception of human activity and decreasing autumn daylight, our observations at Brooks River were made under conditions comparable to those found at Margot Creek. We largely avoided the potentially confounding factor of diurnal movements of migrating salmon suggested by Egbert (1978) by limiting our comparisons to bear activity during the salmon spawning period. Activity of females with young was proportionally similar between the creeks that we monitored, averaging nearly 30%; this comparison, along with our previous discussion, led us to conclude that the age-sex class composition was comparable between our 2 study sites. Finally, visibility from our observation platforms was relatively similar between sites: for the most part, our monitoring of bear activity was limited to 50 m of the river corridor at both study sites due to adjacent forest cover. We conclude that human activity at Brooks River was primarily responsible for the difference in activity patterns observed between the 2 streams.

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