The Effects of Salmon Availability, Social Dynamics, and People on Black Bear (Ursus Americanus) Fishing Behavior on an Alaskan Salmon Stream

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THE EFFECTS OF SALMON AVAILABILITY, SOCIAL DYNAMICS, AND PEOPLE ON BLACK BEAR (*URSUS AMERICANUS*) FISHING BEHAVIOR ON AN ALASKAN SALMON STREAM

by

Danielle K. Chi

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Wildlife Biology

UTAH STATE UNIVERSITY
Logan, Utah
1999
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ABSTRACT

The Effects of Salmon Availability, Social Dynamics, and People on Black Bear 
(Ursus americanus) Fishing Behavior on an Alaskan Salmon Stream

by

Danielle K. Chi, Doctor of Philosophy

Utah State University, 1999

Major Professor: Dr. Barrie K. Gilbert
Department: Fisheries and Wildlife

The primary goals of this research were to investigate 3 ecological factors influencing black bear (Ursus americanus) foraging behavior on an Alaskan salmon (Oncorhynchus spp.) stream: fish availability, social dynamics, and human activity. Over 900 observation hours were logged at 2 falls from July 1-September 1 1993-1995; the lower falls were open to public for wildlife viewing, but the upper falls were restricted to research personnel.

In general, black bears responded to differences in fish accessibility on both spatial and temporal scales. All years of the study, 3 indices of bear activity (bear minutes, bear numbers, bout duration) and fish capture rates were significantly higher (all Ps < 0.10) at the upper falls where fishing opportunities were more abundant. Furthermore, seasonal variation in black bear density was indicative of fluctuations in fish accessibility: bear numbers were highest midseason when fish appeared more abundant, but decreased towards the end of the summer.
Although many bears fished within 3 to 5 m of one another, the majority of intra-specific interactions (65-75%) were benign as opposed to agonistic with a preponderance of "passive deferrals" where bears detoured around rather than confronted conspecifics. Only 5.7% of all interactions resulted in reversals or circularity, providing some evidence for a linear dominance hierarchy. The most dominant bears fished where salmon were highly accessible for longer periods of time, therefore capturing more fish than subordinates each year. Of interspecific interactions, black bears were more likely to be displaced when encountering brown bears on the same side rather than opposite sides of the creek.

Of 24 recognized bears, 71% were observed from 75-100% of the time at the upper falls; only 8% (2 females) fished solely at the lower falls. Five of 8 bears that fished exclusively at the upper falls (all large males) appeared wary of researchers upon their arrival. Based on quantile regression analyses, we found that visitor numbers acted as a ceiling on fishing duration of black bears at the lower falls in 1994 and 1995. Furthermore, 2 habituated bears seen frequently at the lower falls spent less time in view (maximum values) as visitor group size increased.
DEDICATION

This dissertation is dedicated to my parents, Ben and Mary Chi. It has been through their sacrifices that I have been able to explore and pursue both my personal and professional goals. Their love, support, and encouragement provided the foundation upon which I was able to conduct and complete this research. I cannot thank them enough.

Danielle K. Chi
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I extend special thanks to my advisor, Barrie K. Gilbert, for giving me the opportunity to become involved in this research that, for me, was a life-altering experience. I will always think of him as a most important mentor in my life because of his enthusiasm, perseverance, integrity, and dedication to the study and preservation of natural systems. Further, I would also like to thank my past and present committee members, Drs. Carl Cheney, Raymond Dueser, Eric Gese, Robert Schmidt, and Michael Wolfe, for their time and patience on this project.

I view this dissertation as the completion of collaborative work of which my friends and family were also an integral part. In particular, Phaedra Budy, Dave Branson, and Scott Barras provided camaraderie in both academic and social endeavors. My parents and sisters never stopped believing in me, which carried me through periods of doubt and frustration. A special thanks goes out to my sister Renee for extending the Chi
family into Logan, Utah; I am so happy you have been here to share the “Utah experience” with me. Lastly, I would like to bestow my sincere gratitude to Michael D. Roberts. My life is richer as a result of his companionship, love, and encouragement these past few years.

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CHAPTER 1
INTRODUCTION

BACKGROUND

Wildlife-viewing programs have gained wide acceptance and have increased in popularity in recent years (Edington and Edington 1986). In particular, opportunities to observe "charismatic megafauna," such as bears (*Ursus* spp.), in their natural environment have captured a great deal of attention (Swanson et al. 1992). Currently, most of the well-known bear-viewing sites are found in Alaska on or near salmon (*Oncorhynchus* spp.) streams where bears concentrate in large numbers during the summer months to feed on migrating and spawning fish. During the past 10 years, these sites have experienced escalating application and visitation rates, some doubling each year (Fagen and Fagen 1994, Olson and Gilbert 1994, Chi and Gilbert 1996). Although some viewing programs (e.g., McNeil River State Game Sanctuary) capped visitor numbers at their inception (Aumiller and Matt 1994), others lacked clearly defined management objectives to address continued growth in visitor use (Titus et al. 1994, Neary unpublished notes).

A prevailing concern to biologists and wildlife managers is the potential negative impacts that unprecedented expansion of viewing programs may have on bears. Wildlife viewing has been categorized as nonconsumptive, implying negligible effects on the resource. This assumption, however, needs evaluation because contrary evidence is well documented in the literature (Gutzwiller 1993, HaySmith and Hunt 1995). Whereas some animals habituate to people and their activities (Frame and Frame 1980,
Jones and Swartz 1984, Aumiller and Matt 1994), others remain wary, avoiding areas of high human use and development (Jope 1985, Nadeau 1989, McCutchen 1990). Furthermore, studies on bear-human interactions at established viewing sites indicate that the mere presence of human observers poses significant disturbance to some bears (Braaten 1988, Olson 1993, Fagen and Fagen 1994, Olson and Gilbert 1994). In Katmai National Park, Alaska, the temporal and spatial distributions of nonhabituated brown bears (Ursus arctos) were better explained by the location, intensity, and timing of human activity than salmon (Oncorhynchus nerka) availability (Olson and Gilbert 1994, Olson et al. 1997). These findings are corroborated by results of Warner (1987) and Reinhart and Mattson (1990). Over-winter survival and reproductive success of bears depend on their ability to build up fat for hibernation (Miller 1994, Noyce and Garshelis 1994). Consequently, displacement of nonhabituated bears from critical foraging areas may invariably affect individual fitness if alternative food sources are unavailable (Archibald et al. 1987, Gilbert 1989, McCutchen 1990, Gilbert and Lanner 1992).

Managers and planners of wildlife viewing programs need a basis for predicting impact thresholds on bears to find a balance between resource protection and public access. Determining such thresholds, however, can be problematic due to the complexity and natural variation inherent to most ecological systems, salmon streams being no exception. On any given day, a bear’s foraging choices could be influenced by numerous ecological variables (i.e., the distribution and availability of primary and alternative food sources, inter- and intra-specific competition), their effects interacting with anthropogenic influences. Furthermore, annual variation in these variables could
mask the impacts of anthropogenic exploitation, resulting in a misinterpretation of human impacts on a resource (Gutzwiller 1993, Krausman and Bolen 1996). In the end, sound management may be obstructed by a lack of understanding of cause and effect relationships (Gutzwiller 1993:528).

Impacts of wildlife viewing on brown bear behavior on salmon streams have been examined in some detail; research on black bears (U. americanus) under similar conditions is quite limited. Frame (1974) studied black bears fishing for salmon on Olsen Creek in southcentral Alaska. However, human activity at this site was very limited. A study conducted in Yellowstone National Park found that overall use of trout (O. clarki) spawning streams near campgrounds and other tourist facilities by both black and grizzly bears (U. artos horribilis) was disproportionately lower than was predicted based on fish densities (Reinhart and Mattson 1990). Although this study did implicate human activity as possibly contributing to the displacement of both species, the indirect methods of data collection employed (scat and paw print analyses) did not allow for more specific conclusions to be made regarding the impacts of anthropogenic disturbance on black bears.

At Anan Creek, host to one of the largest pink salmon (O. gorbuscha) runs in Southeast Alaska, black bears aggregate in large numbers during the summer months to feed on abundant fish. Large boulders constrain the channel at two locations within 2 km of the mouth of the creek. These geomorphological characteristics create a series of small waterfalls, which impede the upstream movement of salmon; consequently, fish accumulate in large numbers along the side-pools of the creek, making them particularly vulnerable to capture. From early July throughout September,
approximately 40-50 different individual black bears and 10-15 brown bears can be observed fishing at the upper and lower falls of Anan Creek (United States Department of Agriculture, Forest Service 1992).

In 1965, the United States Department of Agriculture, Forest Service (USFS), constructed a bear-viewing observatory on the north side of the creek above the lower falls. Visitor numbers at the Anan Creek observatory have rapidly escalated over the last decade from 1,400 people in 1991 to almost 4,000 in 1995 (United States Department of Agriculture, Forest Service 1996). To accommodate the increase in human use, the USFS expanded the observatory in 1993 and built a boardwalk trail leading from the trailhead at Anan Bay to the lower falls. The trail leading from the lower falls to the upper falls has not been maintained for public use. Although USFS personnel were present to provide visitors with information on natural history and safety issues, human behavior has been minimally regulated and there have been few restrictions on visitor numbers. Although rangers attempt to assure that visitors comply with the regulations and safety rules, rapidly escalating visitor numbers have made guidance of human behavior increasingly difficult at Anan Creek. Management became concerned with the effect of the viewing program on the bears that fish at the lower and upper falls of Anan Creek. In 1991, the Wrangell Ranger District (USFS) initiated a preliminary administrative study to monitor visitor numbers and bear activity. Data collected at Anan Creek during 1991 and 1992 indicated the potential for displacement of bears due to high human use and intrusive behavior.

In 1993, we commenced a 3-year cooperative study with the USFS on black bear behavior and ecology at Anan Creek. The primary goals of the research were to
examine the responses of black bears to human activity at Anan Creek and to identify other important biological and ecological variables that influence black bear foraging patterns in this system.

CHAPTERS

This dissertation addresses 3 potential determinants of black bear fishing behavior and activity at Anan Creek: resource distribution, social dynamics, and human activity. In Chapter 2, we examined the spatial and temporal distribution of black bears in relation to fish availability. We determined the differences in salmon accessibility between the lower falls and the upper falls; 3 indices of black bear activity at these two locations were then compared to ascertain whether activity conformed to that expected based on resource differences. Use of particular fishing sites and consumption was documented. We also looked for patterns between seasonal variation in fish abundance and bear activity. Lastly, we documented how bears used rock caves as refuges at both falls where trees were absent.

Chapter 3 investigated intra- and interspecific interactions of black and brown bears and the implications of social status to fishing behavior and resource use. We documented the outcome of encounters between individual black bears. From this data we were able to construct a social hierarchy and assign dominance scores to bears easily identified each year. We explored the relationship between dominance score and several indices of bear activity and fish capture rates. Where different individuals fished (upper falls versus lower falls and micro-sites) was examined with respect to
social status. Finally, we compared diel activity patterns of black and brown bears to

determine whether the latter species might affect foraging behavior of the former.

In Chapter 4, we investigated the impacts of wildlife viewing on the distribution,
diversity, and fishing activity of black bears. Individual spatial activity patterns were
analyzed relative to the location and intensity of human activity. Bear responses to
people were documented at the lower falls (visitors) and the upper falls (research crew)
to determine whether particular bears were more sensitive to human disturbance. To
assess whether black bears at the lower falls fished less when more people were on the
observatory, we examined the relationship between several indices of black bear
activity and visitor numbers at that site.

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CHAPTER 2
BEARS AND SALMON: THE LINK BETWEEN RESOURCE DISTRIBUTION AND BLACK BEAR ACTIVITY

Abstract: We examined black bear (Ursus americanus) distribution patterns in relation to salmon (Oncorhynchus gorbuscha) availability at Anan Creek from early July through August, 1993-1995. Over 900 observation hrs were logged at 2 falls; the lower falls were open to the public for wildlife viewing purposes, whereas the upper falls were restricted to research personnel only. Approximately 16 adult males, 8 single females, and 4 females with dependent young were individually recognized during the study. Our results suggest that, in general, bears responded to differences in fish accessibility on both spatial and temporal scales. First, during all years of the study, 3 indices of black bear activity (bear minutes, bear numbers, bout duration) were significantly higher (0.05 < P < 0.10) at the upper falls where fishing opportunities were more abundant. Second, seasonal variation in black bear density was indicative of fluctuations in fish accessibility, particularly in 1993 and 1995. Bear numbers were highest at each site when fish were most accessible. In 1993 and 1994, bear numbers decreased towards the end of the summer suggesting that some bears abandoned the stream at this time. Those bears remaining into late August took advantage of the decrease in competition by fishing for longer periods of time. At both the lower and upper falls, black bears made extensive use of the crevices and caves formed by large boulders. These caves served as refuges to which bears retreated for feeding, daybedding, and escape purposes. The security that these caves provided black bears
might have been of particular significance for safety from brown bears (*U. arctos*). At Anan Creek, fishing opportunities were clumped in “patches.” Our results suggest that black bears foraged amongst these patches as would be predicted by the “ideal despotic distribution” hypothesis: dominant individuals were first to secure feeding positions in the most productive patches relegating subordinates to less profitable options.

In foraging ecology theory, the Ideal Free Distribution (IFD) suggests that animals should distribute themselves amongst food resources such that their individual consumption rates are maximized (Fretwell 1972). The assumptions of the IFD, as with other optimal foraging models, however, are numerous and easily violated (Alcock 1993). Consequently, how well IFD represents animal distributions observed in natural systems has been questioned (Kennedy and Gray 1993), and field studies testing it are relatively rare (Moody and Houston 1995).

Although the IFD model has not been purposely tested on bears (*Ursus* spp.), studies on movement and distribution patterns of this large omnivore at the landscape scale provide limited support for its premises. Generally, home range size and population density are determined by the degree to which food resources are spatially and temporally distributed (Sandell 1989, Miller et al. 1997). Where food is widely dispersed (Barnes 1990, Hellgren et al. 1991), bears exhibit far-ranging movements, mutual avoidance, and more territorial behavior (Herrero 1983, Rogers 1987). Where high caloric foods are abundant and concentrated [e.g., garbage dumps (Rogers et al. 1976, Herrero 1983), coastal grasslands (Egbert 1978), Pacific salmon (*Onchorhynchus* spp.) streams (Luque and Stokes 1976, Olson 1993)], bears aggregate in large numbers.
and can be observed feeding within close proximity of one another. At such sites, territorial boundaries shrink to the scale of individual feeding position (Rogers 1987). Little research, however, has examined how bears feeding in aggregations distribute themselves between resource microsites that vary in relative profitability.

At Anan Creek, host to one of the largest pink salmon runs in Southeast Alaska, black bears congregate during the summer months to feed on abundant fish. From early July throughout September, approximately 40-50 different individual black bears and 10-15 brown bears can be observed at 2 falls where large boulders constrain the stream channel and create a labyrinth of caves. From an observatory located just above the lower falls, people can view bears fishing for salmon from 10-40 m away. Visitor numbers at this site have been rapidly escalating over the past decade with over 2,500 people frequenting Anan Creek each year since 1991 (United States Department of Agriculture, Forest Service 1992).

We saw Anan Creek as an excellent location to examine black bear foraging choices on a microsite scale as part of a larger study on human-black bear interactions. The objectives of this paper were to 1) test the hypothesis that black bears distribute themselves temporally and spatially based on fish availability, 2) investigate bear use of rock caves as microrefugia, and 3) compare black bear foraging patterns to predictions of an IFD model.

**STUDY SITE**

Anan Creek is located approximately 40 km southeast of Wrangell, southeast Alaska (56°11' N, 131°53' E) on the Tongass National Forest (Fig. 2-1). It is accessible
only by floatplane or boat. Mean annual precipitation is 209.30 cm per year, characteristic of temperate rain forest. Annual temperatures range from \(-2.5^\circ\text{C}\) in winter to \(26.1^\circ\text{C}\) during the summer months. The region is characterized by a closed western hemlock (\textit{Thuja plicata})-Sitka spruce (\textit{Picea sitchensis}) forest with mixed understory of \textit{Vaccinium} spp., \textit{Rubus spectabilis}, and \textit{Oplopanax horridus}. Further inland, riparian areas are interspersed with alder (\textit{Alnus} spp.) and black cottonwood (\textit{Populus trichocarpa}).

All five species of Pacific salmon have been documented in Anan Creek; however, pink salmon dominate the run with as many as 250,000 individuals spawning several kilometers up the north-fork of this river each year [Alaska Department of Fish and Game (ADF&G) unpublished data]. Migrating salmon usually are first observed at the mouth of Anan Creek in early July; peak fish counts occur anywhere from late July to mid-August. Large boulders constrain the channel at 2 locations within a few kilometers of the mouth of the creek. This geomorphological characteristic creates a series of small waterfalls, which impede the upstream movement of salmon. Consequently, fish accumulate in large numbers along the side-pools of the creek making them particularly vulnerable to capture by bears.

In 1965, the United State Department of Agriculture, Forest Service (USFS), constructed a bear-viewing observatory on the north side of the creek overlooking the lower falls. From the observatory, bears can be viewed en route to or fishing for salmon at close range (between 10 and 40 m) with relative ease.

The upper falls, located 0.4 km upstream from the lower falls, has received less use by people. The trail to this site has not been maintained by the USFS. Further, the
upper falls was subject to periodic closures in 1991 and 1992 due to several close encounters between people and brown bear sows with dependent young, resulting in USFS personnel and visitors being charged at close range. This site was closed to the public throughout the duration of the study (1993-1995).

METHODS

Bear Identification

Bears were captured, fitted with radio-collars, ear-tagged with small multi-colored Floy fish tags (Floy Tag, Inc., Seattle, WA), and lip-tattooed by ADF&G personnel from 23-31 July 1993 as part of a larger population study. We differentiated between individual bears with these collars and tags and by using natural markings and morphological characteristics. Sex of individuals was determined from direct observation of genitals, urination posture, or the presence of cubs. Photographs of bears (front view and profiles) were taken and distinguishing physical characteristics were sketched. Both photographs and sketches were used to compile detailed identification records on bears; these records were continuously updated as coat condition changed and new scars were acquired. Binoculars and spotting scopes were used to facilitate bear identification.

Data Collection

We collected data on black bear activity and behavior between 16 July-3 September 1993, 3 July-27 August 1994, and 3 July-3 September 1995. In early July, sampling was conducted between 0600 and 2200 hours with each day divided into 8 2-hr sessions. In mid-July, the last session (2000-2200 hours) was omitted as decreasing
light made observations difficult and return from sites hazardous. For logistic simplicity, we systematically assigned sampling sessions each day to ensure complete coverage of all periods at both sites within a week. Observations were made from the bear observatory at the lower falls and an elevated tree platform/blind on the north bank of the creek at the upper falls.

We used a form of focal animal sampling (Altmann 1974) to collect data on black bear activity. During observation sessions we recorded the following information on all bears seen: species, sex/age class, identification or description, location of bear appearance, and arrival and departure time. In addition, for each bear we documented all fish caught or scavenged and where fish were taken after capture to eat (i.e., stayed in creek, up hill, in cave, surrounding forest).

Data on the relative productivity of fishing spots were obtained during special 2-hr sampling sessions conducted in 1994 only. Streamside topography at the upper and lower falls were hand-drawn to illustrate location of boulders, backwaters/pools, vegetation, caves, and human-made structures in relation to the creek. We overlaid a grid on each map creating cells 2.5 cm$^2$ in dimension that were used to indicate relative positions of caves and fishing spots at each site (Appendices A-1 and A-2). Upon the capture of every fish, we recorded the identity of the bear, cell coordinates containing the location of fish capture, and the eating location (described above).

We used the same maps to collect data on black bear use of rock caves. A cave was defined as any gap between boulders that bears were observed entering. If a cave extended into 2 cells, only 1 was chosen to indicate location. Four categories were used to document cave use by bears: eating location (bear entered with a fish), escape (bear
entered upon being chased or to avoid another bear), fishing spot (bear fished from
cave), and other (bear entered cave without fish). We believe the “other” category
encompassed nursing and resting activity. These categories were mutually exclusive in
that only 1 category was used to describe how a bear used a cave on any given occasion.
The category “escape” was thus used only when a bear was seen actively avoiding
another individual with or without a fish. When a bear entered a cave, the following
information was taken: identity of the bear, cell coordinates containing the cave used,
and category of cave use.

We estimated fish accessibility to black bears for each 2-hr observation session.
Five categories of fish density were used to indicate the percent of side-pool surface
covered by fish: 0 = none to few fish, 1 = <10%, 2 = 10-50%, 3 = 51-90%, and 4 =
>90%. This estimate was validated as a useful measure of fish accessibility for black
bears (Chi and Gilbert 1996). Relative changes in stream depth over the summer were
determined by recording the water level from a graduated staff secured to the fish pass
in 1994 and 1995; in 1993 a yardstick was used.

Analyses

We measured black bear activity with 3 indices of pooled information on
individuals for each 2-hr observation period: bear minutes, bear numbers, and mean
bout duration. These 3 measures identified how bear activity varied: bear minutes
encompassed the total time bears were observed and thus were a function of the number
of bears we saw and how long each bear was present. Per capita fish capture rate (fish
per bear) was calculated for each observation period as well (individuals pooled). We
determined individual fish capture rates (fish per bear minute) for the lower fall and upper falls of bears for which we had >6 observations on at each site.

We used Kruskal-Wallis tests to compare bear activity indices and fish capture rates between 3 years; if significant, Mann-Whitney U tests were used to test for significant differences in these measures between the lower and upper falls for each year (Zar 1984). The units for these comparisons were means calculated for each 2-hr time periods (i.e., 0600-0800 hours, 0800-1000 hours, etc.). Thus we had a total of 7 observations for each site each year. We used a normal approximation to the Wilcoxon paired-sample test to compare between individual fish capture rates at the lower and upper falls (Zar 1984). The unit was an individual bear; these data were pooled across the 3 years of the study. Because the sample sizes in our analyses were small and we suspected confounding effects of other variables not measured, we set critical alpha level at 0.1 rather than 0.5.

Seasonal trends in black bear activity (3 indices), fish capture rates, fish accessibility, and water level were plotted to reveal relationships between these variables; means were calculated for 7-day blocks to ensure that all time periods were represented from both sites in each block.

RESULTS

Age and Sex Class Composition

We logged 305, 258, and 364 observation hrs at the lower and upper falls of Anan Creek in 1993, 1994, and 1995, respectively. The first field season (1993) served to develop a protocol for reliable identification and recognition of individual bears and to
refine data collection methods; consequently, results for this year were restricted to data pooled across individuals. In 1994, we distinguished between 16 adult males, 8 single females, and 4 females with dependent young [2 with cubs of the year (COY), 2 with yearlings]. These numbers were almost identical in 1995: 16 males, 7 single females, and 3 females with dependent young (2 with COY, 1 with yearlings) were identified. Of all bears identified in 1994 and 1995, 24 were recognized during both years.

Male black bears allocated between 84% and 95% of their total fishing time to the upper falls and contributed most as a class to the number of bear hrs sampled at this site (Table 2-1). For female black bears, distribution of activity appeared to depend on reproductive state as well as year. In 1994, single females spent 79% of their time at the upper falls. Females with dependent young, on the other hand, distributed their time equally (lower falls: 53%, upper falls: 47%) between the 2 sites. In 1995, the patterns for females with dependent young and single females were transposed in comparison to 1994. Bears unclassified by sex accounted for <6% of bear activity.

Differences in Fishing Opportunities and Security Between Sites

_Fishing Sites.—_The following results are based on 44 and 22 observation hrs at the lower falls and upper falls, respectively, logged during the 1994 field season only. We recorded 963 fish caught by black bears during this additional sampling and then ranked fishing sites at each falls based on the number of fish captured in each 2.5 cm² cell. At the lower falls, 87% of all fish were captured from only 4 sites. These sites were located within a 23-m stretch of river (Fig. 2-2), predominantly in side-pools and channels where salmon avoided the strong downstream current generated by the falls.
Bears were able to pull fish out of these side-pools from rocks along shore or at very shallow depths (Fig. 2-3).

At the upper falls, fish were consistently caught from 8 sites (Fig. 2-4), the majority located within a 50- to 60-m stretch of river: 7 on the south side of the creek and 2 on the north side. Eighty percent of all fish were caught in the top 3 sites. Most of the productive fishing sites at the lower falls only allowed for 1 bear to fish at a time; several at the upper falls, however, often contained 2 bears fishing simultaneously shoulder to shoulder. Furthermore, the best fishing site at the lower falls only yielded 10% of the fish captured at the best site at the upper falls.

On the north side of Anan Creek, fishing sites were located against a steep embankment rather than amongst large boulders (Figs. 2-2, 2-4). At the lower falls, there were 2 trails leading down to fishing site 2 and only one to fishing site 3. The same was observed at the upper falls. The lack of alternative routes made it difficult for bears to detour around each other as observed on the south side of the creek (see Chapter 3).

**Eating Location.** Of fish caught on the south side of the lower falls \((n = 31)\), most were taken into caves (62%) or the forest (22%) to eat. On the north side \((n = 19)\) where there were no caves (although on occasion 1 adult male and several different sub-adults carried fish under the observatory to eat), most fish were taken into the forest (63%). At the upper falls, we recorded 886 fish caught on the south side and 27 on the north side. Bears catching fish on the south side took their fish into caves (53%) or ate where they caught them (44%). As with the lower falls, bears fishing on the north side
of the upper falls did not have any caves to retreat to upon successfully procuring fish and thus most fish were either taken into the forest (30%) or consumed on site (70%).

*Use of Caves.*—We estimated that there were 19 entrances to caves at the lower falls and 24 at the upper falls (Figure 2-5) and recorded caves used on 211 occasions. Several of the heavily used caves at the upper falls were situated at the water’s edge (see Fig. 2-4 fishing sites 1, 2, 3, and 5) and thus served both as a source of cover as well as a fishing hole. In general, bears most frequently used caves as a secure place in which to consume their fish (Figure 2-6a). Different age/sex classes used caves differently. Most notable, males used caves as primarily eating spots (80%), whereas females with cubs were seen entering caves without fish more than any other age/sex class suggesting use for resting or nursing purposes (Figure 2-6b).

Comparisons in Black Bear Activity and Fish Capture Rates Between Falls

There were significant differences between years in all 3 indices of bear activity and fish capture rates \( (H \geq 5.77, P \leq 0.06) \) (Appendix B-1); consequently, we compared between the upper and lower falls for each year separately. Black bear activity was significantly higher at the upper falls than the lower falls all years \( (U \geq 41, P \leq 0.35) \) (Appendices B-2, B-3, and B-4). Bout lengths at the upper falls were similar for all years (Fig. 2-7c), suggesting that differences in overall bear activity between years (Fig. 2-7a) was due more to the number of bears at Anan Creek (Fig. 2-7b) than how long bears fished during any given visit.

Per capita fish capture rate was significantly lower at the lower falls than the upper falls all years \( (U \geq 49, P \leq 0.002) \) (Appendices B-2, B-3, and B-4). Individual fish
capture rates (fish per bear minute) of 10 bears for which we had >6 observations of at both sites were also significantly higher at the upper falls \((x = 0.26)\) than the lower falls \((x = 0.16)\) \((Z = 1.886, P_{(2),10} = 0.059)\).

Seasonal Trends in Bear Activity Relative to Fish Accessibility

_Bout Duration._—Bout duration increased over the season for all 3 years and at both sites (Figure 2-8), indicating bears were spending more time per visit feeding toward the end of the summer.

_Bear Numbers, Fish Accessibility, and Fish Capture Rates._—In general, bear numbers fluctuated with changes in fish accessibility in 1993 and 1995, but not 1994. In 1993, bear numbers were highest early in the season at both falls but dropped off gradually through August as salmon became less accessible (Fig. 2-9). Fish capture rates at both falls mirrored this pattern declined.

In 1994, fish were more accessible at the lower falls early in the summer (June 26 – July 10), which was reflected in relatively high bear numbers at this site in comparison to other time periods (Fig. 2-10). As salmon migrated upstream during weeks to follow, they became accessible at the upper falls as well. When fish were accessible at both sites, bears seemed to “prefer” the upper falls: bear numbers dropped off at the lower falls (and remained low throughout August), but increased at the upper falls. Lastly, although fish appeared very abundant into August at the upper falls, bear numbers declined following a peak July 25-31.

In 1995, once again, bear numbers tracked fish accessibility at both sites. Due to a sudden increase in water level in early August, fish were more accessible at the upper
falls early in the season and the lower falls later. Variation in fish capture rates at both sites throughout the season reflected changes in fish accessibility and water levels (Figure 2-11). Fish capture rates at the upper falls appeared to be negatively correlated with water levels, whereas the reverse seemed true of the fish capture rates at the lower falls. This inconsistency between falls may have been a function of site-specific channel and geomorphological characteristics. At the upper falls where the channel was more restricted, increases in water level beyond a threshold resulted in most fishing holes being washed out. This did not occur at the lower falls where the channel was wider.

DISCUSSION

Black Bear Distribution in Relation to Fish Accessibility

Our results suggest that, in general, bears responded to differences in fish accessibility on both spatial and temporal scales. First, black bear activity was higher at the upper falls where salmon were easily caught from more locations than at the lower falls. Second, seasonal variation in black bear density was indicative of fluctuations in fish accessibility. This was particularly apparent in late July of 1995 when heavy rain caused water levels to rise >1 m within a few days. During this time, there were only 1 or 2 spots from which fish could be caught at the upper falls due to the torrential conditions (Fig. 2-12); at the lower falls where the channel was wider, salmon became more accessible for several days relative to the rest of the season. We observed several "upper falls" bears transfer their fishing efforts to the lower falls temporarily during this time, but return to the upper falls as water levels subsided. As black bears abandoned
Anan Creek toward the end of the summer, the remaining individuals took advantage of this decrease in competition by fishing for longer periods of time.

Egbert (1978) documented similar findings of brown bears fishing for chum salmon (*O. keta*) on McNeil River. Fish were most accessible from some sites when water levels were high and others when water levels were moderate or relatively low. Bears appeared to be sensitive to these differences in payoff as they were observed switching sites depending on the current river conditions. Furthermore, bear activity mirrored that of fish abundance, being highest at the peak of the run and tapering off at the end of the season. As in our study, individual bears spent more time actively fishing at the end of the summer than midseason, when bear density exceeded the number of available fishing sites. Consequently, some bears had to wait for fishing spots to be vacated or seek out alternatives, such as nearby Mikfik Creek, where salmon were less accessible.

In addition to resource distribution, we suspect that human activity also played a role in where bears concentrated their fishing efforts at Anan Creek. First, Chi and Gilbert (1996) exposed bears at the upper falls to small experimental visitor groups (5-6 people) on a dilapidated viewing platform just below the elevated tree blind. They noted that some large males seen only at the upper falls were consistently displaced to caves or the surrounding forest. Although many reappeared while people were still present, others were not seen again for several days. Similar observations were made each day when researchers arrived at the upper falls (Chi and Gilbert in review). Furthermore, bear activity was consistently lower during the 10 minutes following the arrival of the research team, indicating a more subtle effect of people on bears fishing at this site (Chi and Gilbert 1996).
Second, the north side of the creek at the upper falls was rarely lacking in fish; in fact, live and dead salmon often accumulated in piles along the side pools, particularly in mid-and late August. Bears easily could have feasted on this mass of carcasses or caught fresh salmon with a few seconds of effort. However, only a few bears, typically the same individuals, were observed fishing on this side. We suspect this is related, in part, to an increased chance for close human-bear encounters. From July through August, human activity was restricted completely to the north side of Anan Creek. At the lower falls, bears en route to fish had to pass within 10 m of the observatory. Bears frequently used trails that were used by people (i.e., visitors and research personnel), and thus encounters occurred often at distances of <5 m. This, compounded with the absence of caves and limited access (i.e., trails) to fishing sites, might have deterred bears from fishing on this side.

Other studies similarly have demonstrated that location and timing of human activities can alter resource-determined distribution patterns. For example, based on scat and print analysis, Reinhart and Mattson (1990) found a positive correlation between fish density and bear activity on backcountry cutthroat trout streams located >1 km from campgrounds and visitor facilities in Yellowstone National Park. Although many of the front country streams had higher fish densities, they received less use, particularly by grizzly bear (*U. arctos horribilis*) family groups, suggesting anthropogenic disturbance. Similar human effects have been demonstrated for brown bears feeding on salmon. Along the coast of British Columbia, brown bears fished diurnally where human activity was low and more at night in areas of high human use (MacHutchon et al. in press). In Katmai National Park, numerous anglers and bear-
viewers visit Brooks River every year where large Alaskan brown bears gather in large numbers to fish for migrating sockeye salmon (*O. nerka*) (Troyer 1980). Whereas habituated bears fished where salmon were most abundant near Brooks Camp, nonhabituated individuals were seen most in zones away from people and their activities even though fish capture rates in these areas were lower (Olson and Gilbert 1994).

Low Black Bear Density in 1993

Bear activity at Anan Creek was significantly lower in 1993 compared to 1994 and 1995. This was attributed to fewer individual bears frequenting the area rather than shorter visits per bear. Several factors acting independently or in concert could be responsible for such a low turnout of bears at Anan Creek in 1993. First, the timing and availability of alternate food sources have been shown to affect bear activity at other concentrated feeding sites (Egbert and Stokes 1976, Garshelis 1989). In 1993, relatively abundant berry crops resulting from a dry spring (Martin 1983) may have detained bears at higher elevations early in the season. Second, research has shown that some bears avoid areas disturbed by logging activities or local construction (Archibald et al. 1987, McLellan 1990). In spring of 1993, the USFS initiated logging in Frosty Bay approximately 12.8 km south of Anan Creek. Furthermore, 0.8 km of boardwalk at Anan Creek was constructed by the USFS in late June when bears should have been arriving to fish. The disturbance from timber practices and construction early in the season may have been sufficient to deter bears from fishing at Anan Creek.
Fishing Techniques of Anan Black Bears

Our index of fish accessibility was well suited to the fishing techniques used by Anan black bears, which were different from those described in other studies. Most bears fished by sitting in shallow water or on rocks along the edge of the creek where fish were forced by the falls. Bears captured fish with quick snaps of their mouth or slaps/hooks with their forepaws. Black bears at Olsen Creek, on the other hand, were more active, “plunging into the creek, running through the water, and leaping upon a fish and capturing it with their mouth” (Frame 1974:28). Similar observations have been made of brown bears fishing at Thumb Creek on Kodiak Island (Chi and Gilbert, personal observation). Brown bears fishing in Karluk Lake (Clark 1959) and in Brooks River in Katmai National Park (Barrie Gilbert, personal communication) have been observed pinning fish to the bottom and then retrieving it with their mouths. The multitude of fishing techniques reported in different studies seems to be a consequence of the local fishing conditions specific to particular streams – water depth, stream velocity, and fish abundance (Luque and Stokes 1976) – as well as cultural transmission of distinct individual styles (Gilbert in press).

Black Bear Use of Rock Caves

The lower and upper falls of Anan Creek are surrounded by forest, but lacked vegetation on the south side due to the presence of large boulders whose junctions form a labyrinth of rock caves. Bears were observed squeezing into the smallest possible crevices, a strategy that precluded larger bears from following and possibly stealing recently captured fish. Some individuals, mostly adult males, fished from several caves
situated right along the water’s edge; upon capturing fish, they retreated further back into them and ate in safety (see Chapter 3). Females often deposited their cubs in caves as they might in a tree before proceeding down to fish. After capturing and consuming several salmon, they retrieved their cubs and left the area. From our observation tree blind at the upper falls, we had a direct line of vision into one large crevice where bears, mostly large males, were observed sleeping. This particular cave appeared to have several compartments to it as we witnessed as many as 3 bears using this cave simultaneously on a number of occasions.

We believe these rock caves are of great ecological and behavioral significance to black bears fishing at Anan Creek. They served as micro-refugia to which bears could retreat for feeding, daybedding, and escape purposes, thus reducing the distance bears had to travel where these needs could be met. Other studies have emphasized the importance of cover and security in black bear habitat selection (Mollohan 1987, Mollohan and LeCount 1989), which may be particularly important where ranges are sympatric with those of brown bears (McLellan 1993). For black bears, proximity to forested areas ensures that they will have some means of escape in the event of an encounter with either a larger black bear or a brown bear. Herrero (1983) discussed the use of trees by black bears foraging at the Jasper town dump. Females with cubs, cubs alone, and subadults climbed nearby mature Douglas-fir trees for purposes of escape, protection, play, sleep, and relaxation, all functions similar to those provided by rock caves at Anan Creek.
The Distribution of Foraging Animals

At Anan Creek, fishing opportunities for bears were numerous but concentrated in distinct locations or “patches” varying in payoff. Fretwell (1972) proposed the “Ideal Free Distribution” (IFD) to explain how animals might be distributed where resources are clumped in patches of differing fitness values. This model is based on several assumptions: a) organisms have perfect knowledge of their environment; b) individuals are of equal competitive abilities; c) there are no constraints or costs to movement between patches; and d) per capita intake rates decrease with increasing competitor density within a given patch. Given these assumptions, the IFD predicts that an animal will forage where individual intake rate is maximized. This strategy should produce an equilibrium state whereby individuals cannot increase their intake rates by moving to another patch, and competitor densities within patches reflect the relative fitness values of those patches (Milinski and Parker 1991).

In field studies, the assumptions of the IFD are rarely met, resulting in a model that does not adequately represent foraging behavior of animals in natural systems (Kennedy and Gray 1993, Moody and Houston 1995). Consequently, variants of the IFD model have been developed with different predictions depending on the assumptions violated. The “Ideal Despotic Distribution” model (IDD) was proposed for foraging situations where dominant individuals in a population monopolize the best patches relegating others to less profitable resources (Fretwell 1972, Parker and Sutherland 1986, Newman and Caraco 1987, Milinski and Parker 1991, Van der Meer 1997). In this case, 2 assumptions may be violated. First, through interference by more dominant animals, other individuals do not have “free” access to the resource; furthermore, there may
actually be a cost or risk associated with foraging in the presence of dominants if they are aggressive to subordinates (Janson 1990a,b; Gray 1994). Second, in most field studies, dominant individuals are typically adults that have more foraging experience than members of younger cohorts; consequently, where individuals of all age/sex classes intermingle, the assumption of equal competitors for food may not be met (Monaghan 1980). Based on these foraging conditions, IDD predicts there should be higher per capita intake rates at richer patches due to both lower competitor density (larger individuals displacing subordinates) and possibly better foraging competency of the competitors.

We propose that black bears fishing at Anan Creek dispersed according to the IDD, as our results were consistent with predictions made by this model. First, we found that certain bears—usually the larger, more aggressive individuals—were consistently avoided by other bears, allowing them to occupy the best fishing spots (mostly at the upper falls) unhindered (Chi and Gilbert unpublished data). More subordinate individuals, on the other hand, were relegated to waiting for prime fishing locations to be vacated, or fished at the lower falls. Second, per capita fish capture rates were always higher at the upper falls (the more productive site) than the lower falls, suggesting that bears at the upper falls fished more efficiently and/or excluded other bears from this site.

Our observations at Anan Creek corroborate those made of brown bears at McNeil River, where salmon were accessible similarly in discrete patches (Luque and Stokes 1976). Egbert (1978) found that the most dominant bears, primarily large adult males, occupied the best fishing locations where salmon were easily caught at all water levels;
bears of lower status either waited until prime sites were vacated or used less "preferred" areas characterized by lower fish capture rates.

Despotism amongst foraging animals has been demonstrated in other species as well. In foraging troops of brown capuchin monkeys (Cebus apella), for example, dominant individuals exclude others via aggressive interactions from preferred feeding positions where invertebrate intake rates were highest (Janson 1990a, b). Monaghan (1980) found dominant adult herring gulls (Larus argentatus) to monopolize the most productive refuse area whereas younger subordinate birds were more opportunistic, feeding when and where adults were absent. Similar observations have been made of other foraging birds: mallards (Anas platyrynchos) (Harper 1982), starlings (Sturnus vulgaris) (Inman 1990), common cranes (Grus grus) (Alonso et al. 1997), oystercatchers (Haematopus ostralegus) (Goss-Custard et al. 1984), and turkey vultures (Cathartes aura) (Kirk and Houston 1995).

MANAGEMENT IMPLICATIONS

While black bear activity was typically higher overall at the upper falls than the lower falls, dramatic increases in water level reduced fish accessibility at the former site; conversely, fish accessibility was enhanced under conditions of high water at the latter site. During these periods, bears must either fish at the lower falls in the presence of people or seek out alternative sources of food until conditions improve. This could have energetic consequences for wary bears that typically avoid areas of high human use if alternative food sources are unavailable (McCutchen 1990, Gilbert and Lanner 1992).
Under most conditions, the feeding opportunities at the upper falls were greater than the lower falls as fish were more accessible and the numerous caves provided bears with on-site mechanisms of security and refuge. These characteristics enable more bears to successfully procure and consume fish and, in part, explain the disparity in bear activity between the upper and lower falls. Displacing bears from such an ecologically significant micro-site could have consequences on population-level dynamics (Gilbert and Lanner 1992). To preserve the current population status of Anan black bears, the natural integrity of this site should be maintained and anthropogenic disturbance of any kind kept to a minimum.

The importance of live salmon to black bears in the rain forest is implicated in this study. However, our field season did not extend beyond the point at which live fish were unavailable and spawned out salmon might be utilized highly. We suspect that bears feed on spawned out salmon where dead fish carcasses accumulated during the fall months: in the reach between the falls, on spawning beds several km upstream from the upper falls, and along the lagoon and beach areas. In addition, the dependence of Anan black bears on salmon relative to other food sources (i.e., berries, forbs, other vegetation, and marine invertebrates) is largely unknown. Future efforts should examine bear use of salmon and alternative resources throughout the entire feeding season to better understand the importance of this rich, highly concentrated resource to bears.

LITERATURE CITED


______, and _______. Habitat security for Alaskan black bear at key foraging sites: are there thresholds for human disturbance. Ursus: In review.


Table 2-1. Bear activity by different age and sex classes at each falls and the relative use of both sites within each class.

| Age-sex class | Lower falls | | | Upper falls | | | Both sites | |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|               | Bear min. | Within site (%) | Within class (%) | Bear min. | Within site (%) | Within class (%) | Bear min. | Within site (%) |
| 1993          |           |              |              |           |              |              |           |              |
| Adult male    | 1.53      | 34           | 5            | 28.57     | 94           | 95           | 30.10     | 86           |
| Adult female  | 0.30      | 7            | 43           | 0.40      | 1            | 57           | 0.70      | 2            |
| Female w/yng  | 1.14      | 31           | 78           | 0.41      | 1            | 22           | 1.82      | 5            |
| Subadult      | 1.07      | 22           | 61           | 0.70      | 3            | 39           | 1.77      | 5            |
| Sex unknown   | 0.22      | 06           | 37           | 0.38      | 1            | 63           | 0.60      | 2            |
| Total         | 4.53      | 100          |              | 30.55     | 100          |              | 35.08     | 100          |
| 1994          |           |              |              |           |              |              |           |              |
| Adult male    | 18.86     | 38           | 9            | 185.47    | 70           | 91           | 204.33    | 65           |
| Adult female  | 10.02     | 20           | 21           | 36.98     | 14           | 79           | 47.00     | 15           |
| Female w/yng  | 14.18     | 28           | 53           | 12.75     | 5            | 47           | 26.93     | 8            |
| Subadult      | 4.64      | 09           | 27           | 12.71     | 5            | 73           | 17.35     | 7            |
| Sex unknown   | 2.46      | 05           | 14           | 14.88     | 6            | 86           | 17.34     | 5            |
| Total         | 50.16     | 100          |              | 262.79    | 100          |              | 312.95    | 100          |
| 1995          |           |              |              |           |              |              |           |              |
| Adult male    | 22.48     | 39           | 16           | 117.38    | 65           | 84           | 139.86    | 59           |
| Adult female  | 22.87     | 39           | 53           | 20.27     | 11           | 47           | 43.14     | 18           |
| Female w/yng  | 2.49      | 04           | 20           | 9.66      | 5            | 80           | 12.15     | 5            |
| Subadult      | 8.99      | 15           | 22           | 31.46     | 18           | 78           | 40.45     | 17           |
| Sex unknown   | 1.36      | 02           | 58           | 1.00      | 1            | 42           | 2.36      | 1            |
| Total         | 58.19     | 100          |              | 179.77    | 100          |              | 237.96    | 100          |

*a Bear minutes per 2-hr observation period*
Figure 2-1. A map of the study site, Anan Creek.
Figure 2-2. A sketch of caves and fishing holes at the lower falls of Anan Creek.

Fishing holes are numbered in order of their use by black bears at that site. BT refers to bear trail.
Figure 2.3. Pink salmon concentrated in side pools at Anan Creek.
Figure 2-4. A sketch of caves and fishing holes at the upper falls of Anan Creek.

Fishing holes are numbered in order of their use by black bears at that site. BT refers to bear trail.
Figure 2-5. A female black bear emerging from a rock cave at the upper falls of Anan Creek.
Figure 2-6. Allocation of cave use into 4 functions (a) and the differences in cave use between sex/age classes (b).
Figure 2-7. Differences in bout duration (a), black bear activity (b), and bear numbers (c) between the lower and upper falls of Anan Creek for 1993, 1994, and 1995. All differences are significant at $P < 0.05$. 
Figure 2-8. Mean bout duration at the lower falls (a) and upper falls (b) from July through August.
Figure 2-9. Bear numbers in relation to fish accessibility in 1993 at the lower (a) and upper falls (b).

Fish capture rates at both sites relative to fluctuations in water levels (c).
Figure 2-10. Bear numbers in relation to fish accessibility in 1994 at the lower (a) and upper falls (b) and fish capture rates at both sites relative to fluctuations in water levels (c).
Figure 2-11. Bear numbers in relation to fish accessibility in 1995 at the lower (a) and upper falls (b) and fish capture rates relative to fluctuations in water level (c).
Figure 2.12. The upper falls under conditions of low (a) and high (b) water.
CHAPTER 3
SOCIAL DYNAMICS OF BLACK BEARS \textit{(Ursus americanus)} ON A SALMON STREAM: IMPLICATIONS OF INTRA- AND INTERSPECIFIC INTERACTIONS TO RESOURCE ACQUISITION

\textbf{Abstract:} We studied intra- and interspecific interactions of black bears \textit{(Ursus americanus)} and brown bears \textit{(U. arctos)} fishing at 2 falls on Anan Creek, Alaska, in 1993-1995. Our objectives were to determine the implications of black bear dominance status to pink salmon \textit{(Oncorhynchus gorbuscha)} acquisition and individual foraging strategies and to assess the influence of brown bears on black bear activity patterns. In 1994 and 1995, we identified approximately 16 adult male black bears, 7 single females, and 3 females with dependent young. Although bears fished within close proximity to one another (3-5 m), the majority of interactions (65-75\%) were benign as opposed to agonistic in nature. There was a preponderance of "passive deferrals" where bears detoured around rather than confronted other bears. We found some evidence for a linear dominance hierarchy, but generally relationships between bears were loosely defined and consistent across years, particularly for the most and least dominant individuals. Females with dependent young were involved in the highest percentage of aggressive encounters of all bears. The most dominant bears fished where salmon were highly accessible for longer periods of time, therefore capturing more fish than subordinates each year. Of interspecific interactions, black bears were more likely to be displaced when encountering brown bears on the same side rather than opposite sides of the creek. Whereas black bears were more active during the day, brown bears tended to
be crepuscular. At Anan Creek, we attributed the lack of aggression observed in intra- and interspecific interactions to the surplus of fish and many alternatives for access. Further, we suspect brown bears were crepuscular at Anan Creek to avoid humans, a characteristic that allows black bears more diurnal use of the stream.

Members of the family Ursidae live primarily solitary lives (Gittleman 1989), characterized by a lack of cooperation in parental care, foraging, defense against predators, and mate acquisition (Sandell 1989). The temporal and spatial distribution of their food resources, often patchily dispersed (Barnes 1990, Hellgren et al. 1991), promotes wide-ranging movements of individuals and a tendency toward mutual avoidance and territorial behavior (Herrero 1978, Rogers 1987). Consequently, bears (Ursus spp.) are rarely seen in the company of conspecifics except when mating or accompanied by dependent young (Gittleman 1989).

However, bears have been known to feed in large aggregations where high caloric foods are concentrated locally for several months [e.g., garbage dumps (Herrero 1983, Rogers et al. 1976), coastal grasslands (Egbert 1978, T. Olson personal communication), salmon (Oncorhynchus spp.) streams (Luque and Stokes 1976, Warner 1987)]. Such sites, referred to as "ecocenters" (Craighhead et al. 1995), offer rare opportunities to study the group dynamics of species that, in general, live solitary existences (Herrero 1983). At ecocenters bears appear to form loose dominance hierarchies of which large adult males typically occupy the highest positions (Craighhead et al. 1995, Egbert 1978, Luque and Stokes 1976). In contrast, among black bears gathered at the Jasper town garbage dump, Herrero (1983) noted that females with
young were more frequently dominant over all other age/sex classes, including large males.

Laboratory and field studies on social hierarchies indicate that dominance can confer particular benefits and increased fitness compared to less dominant individuals (Arcese and Smith 1985). For example, in coyote (*Canis latrans*) packs, high-ranking individuals monopolize ungulate carcasses, relegating lower-ranking coyotes to capturing smaller prey or dispersing from the pack (Gese et al. 1996). Amongst common cranes (*Grus grus*), dominant birds (typically large aggressive adults) had the highest food intake rates of all birds as they fed where resources were most concentrated (Bautista et al. 1995, Alonso et al. 1997); subordinate individuals were constantly displaced from the best feeding positions (Bautista et al. 1995). Similar results were reported by Goss-Custard et al. (1984) for oystercatchers (*Haematopus ostralegus*) feeding on mussel (*Mytilus edulis*) beds that differed in prey density.

Research conducted on brown bears on salmon (*Oncorhynchus* spp.) streams suggests that dominant individuals secure the best fishing spots relegating subordinates to forage under less productive conditions (Egbert 1978). However, to date few studies have rigorously explored the implications of social status to resource use of black bears under similar conditions.

As part of a larger study on black bear ecology, we examined social interactions and group dynamics of black bears at Anan Creek. Anan Creek is host to one of the largest runs of pink salmon in Southeast Alaska, attracting an estimated 40-50 different black bears and 10-15 brown bears each summer (United State Department of Agriculture, Forest Service 1992). It is one of the few locations where black bears gather in large
numbers to feed on a natural, highly concentrated food resource. Consequently, Anan Creek provides an unusual opportunity to observe social interactions within this species as well as with its larger congener, the brown bear. We tested 4 null hypotheses: a) there is no social structure to black bears gathered at Anan Creek; b) social status is not a function of aggressiveness; c) there is no relationship between fish acquisition and social status; and d) there is no effect of brown bear activity on black bear foraging patterns.

**STUDY SITE**

Anan Creek is located approximately 40 km southeast of Wrangell, southeast Alaska (56°11’ N, 131°53’ E) on the Tongass National Forest (Fig. 2-1). It is accessible only by floatplane or boat. Mean annual precipitation is 209.3 cm per year, characteristic of temperate rain forest. Annual temperatures range from -2.5°C in winter to 26.1°C during the summer months. The region is characterized by a closed western hemlock (*Thuja plicata*)-Sitka spruce (*Picea sitchensis*) forest and accompanied by an understory consisting of *Vaccinium* spp., *Rubus spectabilis*, and *Oplopanax horridus*. Further inland, riparian areas are interspersed with Alder (*Alnus* spp.) and black cottonwood (*Populus trichocarpa)*.

All five species of Pacific salmon have been documented in Anan Creek; however, pink salmon dominate the run with as many as 250,000 individuals spawning several kilometers up the north-fork of this river each year (Alaska Department of Fish and Game unpublished data). Migrating salmon are first observed at the mouth of Anan Creek in early July; peak fish counts occur anywhere from late July to mid-August.
Large boulders constrain the channel at 2 locations within 2 km of the mouth of the creek. This geomorphological characteristic creates a series of small waterfalls, which impede the upstream movement of salmon. Consequently, fish accumulate in large numbers along the side-pools of the creek, making them particularly vulnerable to capture by bears.

In 1965, the United States Department of Agriculture, Forest Service (USFS), constructed a bear-viewing observatory on the north side of the creek overlooking the lower falls. From the observatory, bears can be viewed en route to or fishing for salmon at close range (between 10 and 40 m) with relative ease.

The upper falls, located about 0.4 km upstream from the lower falls, has been closed to the public since 1992 due to several close encounters between people and brown bear sows with cubs, and for research purposes.

METHODS

Bear Identification

Thirteen black bears were captured, fitted with radio-collars, ear-tagged with small multicolored Floy fish tags (Floy Tag, Inc., Seattle, WA) and lip-tattooed by Alaska Department of Fish and Game (ADF&G) personnel on 23-31 July 1993 as part of a larger population study. We differentiated between individual bears with these collars and tags and by using natural markings and morphological characteristics. Photographs of bears (front view and profiles) were taken and distinguishing physical characteristics were sketched. Sex of individuals was determined from direct observation of genitals, urination posture, or the presence of cubs. Both photographs and sketches were used to
compile detailed identification records on bears; these records were updated continuously throughout each season as coat condition changed and new scars were acquired. Binoculars and spotting scopes were used to facilitate bear identification.

Data Collection

**Sampling Schedule.**—We collected data on black bear activity and behavior between 16 July-3 September 1993, 3 July-27 August 1994, and 3 July-3 September 1995. In early July, sampling was conducted between 0600 and 2200 hours with each day divided into 8 2-hr observation sessions. In mid-July, the last session (2000-2200 hours) was discontinued as decreasing light made observations difficult and return from sites hazardous. For logistic simplicity, we assigned observation sessions systematically each day to assure complete coverage of all sessions at the lower and upper falls within a week. Observations were made from the observatory at the lower falls and an elevated tree platform/blind on the north bank of the creek at the upper falls. We positioned ourselves at both sites to allow for viewing of all bears at relatively close ranges (5-40 m).

**Interactions.**—Focal animal sampling (Altmann 1974) and continuous recording (Martin and Bateson 1986) was used to collect detailed data on interactions between individual bears within 2-hr observation sessions. One focal animal was selected randomly and observed for a 10-min period or until the subject was out of view for longer than 5 min (whichever occurred first). If only 1 bear was in view at the end of the focal period, another focal sample was collected on that same individual. For each focal animal we recorded the identification, start and end time, and number of fish
captured. We operationally defined an interaction as follows: "when one or more bears responds overtly to the presence of another" (Egbert and Stokes 1976:42). For all interactions involving the focal animal, we sequentially noted the behavioral actions leading to the encounter for both participants and the result of all encounters (Appendix C). Interactions were further categorized as aggressive (indicated by jaw-pops, swats, snaps, bites, or chases) or benign (indicated by stares but no aggressive behaviors).

We were interested specifically in documenting incidences of intentional displacement (usually accompanied by an aggressive approach) as well as "passive deferrals" (Egbert 1978), where one individual diverts around another to avoid an interaction. The few studies on social dynamics of bears indicate that dominance relationships between males are determined during the mating season (Craighead et al. 1995). Large males typically incur numerous head and shoulder wounds during these months (May-July), but are seldom observed engaging in serious fights with one another subsequently. Thus passive deferrals are of particular importance to understanding the social structure of bears at feeding aggregations as they reflect the relationships already established during previous months (Egbert 1978).

**Fishing Behavior: Site Selection, Duration, and Eating Location.**—We used a form of focal group sampling (Altmann 1974) and continuous recording (Martin and Bateson 1986) to collect data on individual bear activity and fishing success. During each 2-hr observation session, we recorded the following information for all bears seen: species, sex/age class, identification or description, location of bear appearance, arrival and departure time, fishing attempts, fish caught or scavenged, and where fish were consumed (cave, forest, creek, hillside).
Data on the relative productivity of fishing spots and use by particular individuals were obtained during special sampling conducted in 1994 only. Streamside topography at both the upper and lower falls was hand-drawn to illustrate location of boulders, backwaters/pools, vegetation, caves, and human-made structures in relation to the creek. We overlaid a grid on each map creating cells (2.5 x 2.5 cm squares) that were used to indicate relative positions of caves and fishing spots at each site (Appendices A-1 and A-2). Upon successful capture of every fish, we recorded the identity of the bear, cell coordinates containing the location of fish capture, and the eating location (see above). We hypothesized that dominant individuals would be more likely to secure the most productive fishing locations than subordinate bears.

Analyses

Based on outcomes of interactions between bears, we constructed dominance matrices (see Lehner 1979) illustrating relationships between particular individuals for 1994 and 1995; bears of both sexes were included. When examining social relationships, a reversal refers to an interaction in which an individual succeeds in supplanting another individual to which it loses the majority of encounters (Lehner 1979, Martin and Bateson 1986). A circular relationship is where A dominates B, and B dominates C who, in turn, dominates A, thus resulting in a nonlinear hierarchy (Lehner 1979). We calculated the percentage of total interactions that were reversals or circular to obtain a measure of linearity in social structure (Egbert 1978).

All identified black bears were assigned a dominance score that was calculated as follows: 

$$[(D + 0.5T)/N]$$

where
D = number of encounters where the individual displaced another bear, 
T = number of standoffs (neither bear yields its position), and 
N = total encounters.

Bears with <4 interactions were not included, nor were interactions between adult bears and subadults. We used linear regression to determine relationships between dominance score and total fish captured, fish capture rate (fish per minute fishing), fishing time, mean bout length, total visits to the river, and eating location. We applied Pearson correlation procedures to determine whether bears with higher dominance scores were involved in more aggressive interactions. Because we suspected confounding effects of other variables not measured, and the sample sizes in our analyses were small, we set critical alpha level at 0.1 rather than 0.5.

RESULTS

The first field season in 1993 comprising 305 observation hrs served to develop a protocol for reliable identification and recognition of individual bears and to refine data collection methods. The results reported here are based on the 1994 and 1995 field seasons; 340 and 282 hrs were spent sampling at the lower falls and upper falls, respectively. In 1994, we distinguished between 16 adult males, 8 single females, and 4 females with dependent young [2 with cubs of the year (COY), 2 with yearlings]. These numbers were almost identical in 1995: 16 males, 7 single females, and 3 females with dependent young (2 with COY, 1 with yearlings) were identified. Of all bears observed in 1994 and 1995, 24 were recognized during both years of the study. We distinguished between individual subadults in 1995 (>9) but not 1994. Although we
cannot make quantitative comparisons, there appeared to be more subadults at Anan Creek in 1995 than in 1994, which contributed to more adult-subadult interactions during this year.

Intraspecific Encounters Between Black Bears

The following interaction rates reflect relative differences between sites and years rather than actual rates, because they are based on focal animal sampling rather than total event recording (Martin and Bateson 1986). In 1994, we observed 182 interactions at a rate of 0.19 interactions per observation hr at the lower falls \( (n = 28) \) and 1.4 at the upper falls \( (n = 154) \); 36% were categorized as aggressive (the same proportion for both sites). In 55 (35%) encounters, the outcome was neutral or a stalemate where neither participant deferred to the other; the majority (65%), however, resulted in displacement of 1 bear. The following year, 192 interactions were recorded at rates of 0.34 and 0.73 interactions per observation hr at the lower \( (n = 66) \) and upper falls \( (n = 126) \), respectively. There was a doubling in the interaction rate at the lower falls from 1994 to 1995, probably reflecting the increase in fishing activity at this site particularly by adult males (Chi and Gilbert unpublished data). The percentage of aggressive encounters declined from 35% in 1994 to 25% in 1995, and the proportion of clear displacement was higher in 1995 (71%) compared to 1994 (65%).

All interactions were further classified based on the age/sex of the participants resulting in 5 groups that we labeled "class dyads": male-male, female-female, male-female, male-subadult, and female-subadult. Because of their paucity (3–4 individuals), females with dependent young were grouped together with single females and
categorized as adult females in both years. Each year, the proportions of interactions attributed to different class dyads (not including interactions involving individuals of unknown sex) were similar with male-male encounters being the most frequent (Fig. 3-1). The number of interactions attributed to each dyad did not differ significantly from expected values based on fishing time spent by each sex/age class (i.e., males, females, and subadults) each year (1994: $\chi^2 = 3.91, df = 4, P > 0.5$; 1995: $\chi^2 = 1.28, df = 4, P > 0.75$).

During both years of the study we frequently observed between 10 and 15 bears fishing concurrently within the 40 m of shoreline containing the most productive fishing holes, some only a bear’s length away from another individual. However, the majority of interactions for all class dyads were benign with a clear outcome, indicating a preponderance of “passive deferrals” especially in 1995 (Table 3-1). Interactions consisted mostly of bears moving around each another as if to avoid any possible altercations with other individuals (Fig. 3-2). Of the aggressive interactions recorded, only a few escalated to physical contact between the participants. These were exclusively attributed to males fighting for access to fishing holes when bear activity was exceptionally high (late July-early August). Most chases involved females pursuing other females or subadults: female-female and female-subadult interactions rarely resulted in a standoff between individuals. Males appeared more tolerant of subadults than females (35% of their encounters were stand-offs compared to 13% for female-subadults). In general, females (1994: 40%, 1995: 35%) were involved in more aggressive encounters than males (1994: 35%, 1995: 23%) during both years.
Structure of Dominance Hierarchies

In both years, we found that only 5.7% of interactions were reversals or circular (Fig. 3-3 and Fig. 3-4), indicating relationships between bears for which there were distinct outcomes (one bear displaced another) were linear and transitive. But as reported earlier, approximately 30% of all interactions were stalemates suggesting, the social hierarchy to be loosely structured and asymmetric where some individuals appear to be of the same social status. A note of caution: these diagrams represent relationships between bears rather than distinct social strata, as we were unable to document interactions between all possible pairs of individuals.

Dominance Scores

We calculated dominance scores for 24 and 23 bears in 1994 and 1995, respectively (Table 3-2) for which we had 4 or more interactions. More dominant bears were those that were rarely displaced and frequently avoided by other bears. We did not have a sufficient sample of each sex/age class (e.g., females with dependent young) to test whether more dominant bears were more frequently members of one class than expected. However, there did not appear to be any obvious bias toward class as much as particular individuals. The most dominant individual for both years was a large female, GRE, who arrived with cubs of the year in 1994, and was accompanied by them in 1995.

We determined that dominance score in 1994 was a strong predictor of dominance score in 1995 for 18 bears that were present and ranked during both years \( r^2 = 0.44, F = 12.682, P = 0.003 \) (Appendix B-5). The consistency lay primarily at the extremes of
the social hierarchy: the most dominant bears (GRE, PAP, PAT) in 1994 were so in 1995, and similarly so for subordinate bears (JUA, CYC, WIS). More fluidity occurred between ranks for bears falling between the extremes (Fig. 3-5).

Dominant individuals were involved in more aggressive interactions than subordinate individuals \((r = 0.58, P_{(r)} = 0.002)\) in 1994, but not in 1995. The highest proportion of aggressive encounters both years, however, was displayed by the only 2 females with dependent young (1994: GRE, 62%; DEU, 51%; 1995: GRE, 75%; WIS, 67%).

Social Status and Fishing Success

Data on 3 dependent variables (fishing time, total fish captured, and bout length) were transformed using the natural logarithm of \(y\). In 1994, there was a significant positive relationship between dominance score and fishing time \((r^2 = 0.14, P_{(r)} = 0.031, \text{Fig. 3-6a})\) and total fish captured by bears \((r^2 = 0.25, P_{(r)} = 0.007)\) (Appendix B-6). There were no significant relationships between dominance score and fish capture rate, total visits to the river, or bout length. In 1995, we found a significant positive relationship between dominance score and fishing time \((r^2 = 0.20, P_{(r)} = 0.016, \text{Fig. 3-6b})\), total fish captured \((r^2 = 0.12, P_{(r)} = 0.05)\), total visits to the river \((r^2 = 0.16, P_{(r)} = 0.03)\), and bout length \((r^2 = 0.16, P_{(r)} = 0.03)\), but not fish capture rate (Appendix B-7).

Social Status and Use of the Lower and Upper Falls

We posited that bears with higher dominance scores would feed exclusively at the upper falls where fish are more accessible and visitation by people is limited (see Chapter 2). However, this was not the case (Fig. 3-7). Some dominant bears fished at
both sites, while others were observed only at the upper falls. This same pattern was noted for the most subordinate bears. These individual "preferences" were consistent between years.

The 2 anomalies across years were attributed to 2 females whose reproductive status changed from one year to the next. SMA (not scored) was accompanied by 1 yearling for most of the 1994 field season; she allocated the majority of her fishing efforts (70%) to the lower falls. Similarly, WIS utilized the upper falls more in 1994 as a single female, but the lower falls in 1995 when accompanied by 1 spring cub.

Social Status and Microsite Selection

Microsite selection refers to use of specific fishing holes at the falls. The following results are based on 44 observation hrs at the lower falls and 22 at the upper falls, sampling which was conducted especially for this study in 1994. Fishing spots were coded as cells using maps sketched of each site. Black bears were observed capturing fish consistently from 8 sites at the upper falls (Fig. 2-3) and 4 at the lower falls (Fig. 2-2). On the south side of the upper falls, there was a zone of high fish capture rate (containing fishing sites 1-5, and 8) along a 40-m stretch of river shoreline.

Using dominance scores assigned in 1994, we used cluster analysis to group individuals into social categories: dominant \((n = 7)\), intermediate \((n = 7)\), and subordinate \((n = 6)\). We investigated the relationship between microsite and social category to determine whether dominant bears monopolized the most lucrative fishing holes (Fig. 3-8). Based on this limited sample of data, several patterns were discerned. First, in 1994, 5 of the 7 most dominant bears caught over 50% of their fish in best
fishing site at the upper falls resulting in 41.14 fish captured per bear. Second, almost all bears of intermediate status (82%) captured a higher proportion of their fish at 1 of the next 4 most productive spots at the upper falls resulting in 41.37 fish captured per bear. Third, 3 of the 5 most subordinate bears captured the majority of their fish at the most productive spot at the upper falls. These subordinate bears always waited on the rocks above the sites until vacated before proceeding down to fish and only caught 23 fish per bear. Fourth, for 2 unranked females, all fish were caught in 2 spots both located on the north side of the river where few bears fished. Finally, use of fishing sites by subadult bears was the most evenly distributed of all social classes. These data, although limited, illustrate regularities in foraging and the numerous foraging opportunities available to bears of varying social dominance.

Social Status and Eating Location

Data on proportions of fish eaten in various locations (on the rocks, water, and taken into the forest) were log-transformed to normalize distributions. In 1994, dominance scores were positively correlated with the proportion of fish eaten at the water’s edge ($r = 0.40$, $df = 24$, $P_{(2)} < 0.10$) and negatively correlated with fish taken into the forest ($r = 0.38$, $df = 24$, $P_{(2)} < 0.10$). In 1995, dominant bears also were less likely to take their fish into the forest for consumption ($r = 0.53$, $df = 23$, $P_{(2)} < 0.10$).

Brown Bear–Black Bear Dynamics

*Interspecific Interactions.*—In 1994 and 1995, we documented 57 encounters between black bears and brown bears (lower falls:35; upper falls:22). At the lower falls, black bears avoided brown bears 62% of the time when encounters occurred on
the same side, and 44% if brown bears were on the opposite side of the river. At the upper falls, black bears were displaced in 89% of interactions occurring on the same side and 31% of encounters on the opposite sides. At the lower falls, 88% (30 of 34) of interactions involved 1 young habituated female brown bear. Only 23% (5 of 22) of encounters at the upper falls were attributed to this same bear, the rest involving at least 6 other brown bears. Aggressive interactions constituted only 5% of all brown bear-black bear interactions. Two entailed a brown bear chasing a black bear. The other involved a small black bear female with 1 spring cub that directed a series of charges toward the young female brown bear “regular” (Fig. 3-9).

The few observations we made of brown bears being displaced by black bears involved GALL, the young female responsible for most of the brown bear activity at the lower falls. Because documentation of inter-specific encounters in bears is rare, we describe these interactions in some detail in Appendix D.

*Brown Bear Activity at Anan Creek*—Total observation time of brown bears was about 10% and 1% of black bear activity at the lower and upper falls, respectively. Brown bears were most frequently seen in the early morning and late evening; this pattern was particularly pronounced at the upper falls (Fig. 3-10b). Conversely, black bear activity dropped off after 2000 hrs (Fig. 3-10).

**DISCUSSION**

**Social Dynamics in Black Bears at Anan Creek**

In this study, we investigated whether black bears formed dominance hierarchies when aggregated on a salmon stream and, if so, how social status might affect foraging
behavior. The most striking feature of this study was that interactions between bears at Anan Creek were benign, of low intensity, and subtle in nature. The majority of large adult males as well as some females arrived at Anan Creek in early July with fresh wounds (mostly head, shoulder, and leg), attesting to recent aggressive encounters, a likely consequence of breeding activities (Craighead et al. 1995). However, throughout the fishing season (July-September) these same individuals exhibited a tolerance of one another that we found remarkable given the local bear density. Bears at the lower and upper falls used the same network of trails arriving and departing and thus encountered each other en route regularly. The prime fishing sites at the upper falls were within a 20-30 m zone of shoreline. It was not uncommon to see 10-14 black bears fishing concurrently at this site, with 4-5 individuals about 1 m from one another. In spite of this, the proportion of encounters with overt aggression was low (<40%) and contact fights were rare. Most individuals detoured around other bears rather than challenging them especially when alternative routes and/or fishing holes were available. Furthermore, these "passive deferrals" (Egbert 1978) were exhibited by all bears, even by the dominant individuals on occasion.

This tendency in black bears toward accommodation rather than aggression at salmon streams was also reported at Olsen Creek where territorial fishing borders appeared absent (Frame 1974). At McNeil River, as many as 25-30 brown bears fish simultaneously for chum salmon (Oncorhyncus keta), many within a few meters from one another (Luque and Stokes 1976). For bears foraging in garbage dumps, individual boundaries were reduced (Herrero 1983). Bears obtained feeding positions anywhere from 0.5 – 2 body lengths away from each other, and disputes over food were relatively
infrequent, especially when natural foods were also available (Craighead et al. 1995, Rogers 1987).

Based on a limited sample of interactions observed between particular individuals in which there was an outcome, we found some evidence for a linear dominance hierarchy amongst black bears fishing at Anan Creek within years: circularity and reversals among relationships made up only 5.7% of all interactions. But 30% of encounters were stalemates indicating some asymmetry in the hierarchy as well. Generally, bears seemed to be aligned loosely into 1 of 3 social classes: dominant, intermediate, or subordinate. Social status, particularly for bears of intermediate standing, varied between years suggesting a social structure that is less fixed for this group.

Most studies, including the research presented here, suggest that dominance relationships in bears at feeding aggregations are adaptable and transitory, particularly following the breeding season (Craighead et al. 1995). Egbert (1978) examined relationships between brown bears fishing at McNeil River separately for males and females. He documented a relatively linear hierarchy for adult male brown bears fishing at McNeil River: only 10% of interactions between higher and lower ranking individuals resulted in the latter displacing the former. Relationships between females were more ambiguous. We pooled across sex class because studies on the social interactions of black bears at feeding aggregations suggest females are just as likely to displace males as the reverse (Herrero 1983, Rogers 1987).

Intolerance of Females

Females with cubs have been known to spatially segregate themselves to avoid
confrontations with large males (Wielgus and Bunnell 1994), a strategy that should reduce the chances of infanticide or injury (Miller 1985, Olson 1993, Davis 1996). At Anan Creek, our results suggest that females with dependent young were less tolerant of other bears. In all cases, they constituted the most aggressive individuals each year. We frequently witnessed large males scrambling up rocks to avoid confrontation with GRE, a large, highly aggressive female who had spring cubs in 1994 and these same cubs as yearlings in 1995. This female was never observed yielding her position during intra-specific encounters. GRE alone fished amongst large males while accompanied by dependent young; other females utilized areas that were less used by other bears.

For example, WISH and SMA used the upper falls more as single females but the lower falls and/or north side of the river where large males were rarely seen when they had cubs.

Our results corroborate those of other studies. Herrero (1983) found that black bear females with cubs maintained individual space but consistently prevailed in over 90% of all agonistic encounters including those with large males. Rogers (1987) reported female black bears actively excluding large males from their territories. Female grizzly bears have been observed consistently forcing upper stratum males from productive feeding spots (Craighead et al. 1995, Egbert 1978).

Costs and Benefits of Dominance

The loose social hierarchy in black bears at Anan Creek had consequences for resource acquisition and utilization. As might be expected, dominant bears, in general, secured the most productive fishing spots, and fed on site, decreasing energetic costs
associated with taking fish elsewhere to eat. However, in spite of the advantage dominance bestowed, social status did not impede other bears from obtaining fish. Intermediate bears caught just as many fish (and in some cases more) as dominant bears. Furthermore, despite their having limited access to the best fishing sites as well as retreating to the forest to eat their fish, subordinate bears were still able to procure fish by utilizing other foraging strategies.

Our results and those of other studies indicate that bear ecocenters represent unique foraging circumstances that are possible through mutual tolerance, accommodation, and "reciprocal wariness" (Egbert 1978). This socio-cultural phenomenon facilitates exploitation of a common, highly concentrated resource by many individuals varying in size, age, and social temperament, most of which are able to secure what they require for survival and successful recruitment. While this statement may appear to advocate altruistic behavior, it does not. Rather, by interpreting this phenomenon using the economic framework that underlies foraging theory, we can better understand how such dynamics might exist.

Individual foraging decisions are often examined from a perspective of costs and benefits, the ultimate goal being to maximize return (benefits) and minimize risks (costs) (Alcock 1993). The appearance and intensity of territorial defense behavior seems highly dependent on the abundance and quality of food, the internal state of the animal, and the perception of risk (Erlinge and Sandell 1986). Where food is scarce, the gain obtained from defending a resource from competitors in spite of the cost (energy spent, risk of injury or death) might far outweigh the consequences of not (sure starvation). However, when resources are plentiful, territorial defense incurs a cost to
the animal but confers little or no gain compared to those not defending (Krebs and Kacelnik 1991). Field studies on foraging choices made in various environmental circumstances have provided evidence for these theories. Within a species, for example, small territories or none at all are frequently associated with abundant food resources and larger territories with more meager prey/resource conditions (Gill and Wolf 1975, Craig and Douglas 1986, Temeles 1987, Kruuk 1989, Sandell 1989).

Social conflict over food resources may also be a function of food distribution (Milinski and Parker 1991). For example, in a study of social status and foraging success in dark-eyed juncos (*Junco hyemalis*), Theimer (1987) subjected birds to different foraging conditions of seeds dispersed. When seeds were clumped, dominant and intermediate birds prevailed over subordinates consistently, but when seeds were highly dispersed or clumped in small patches, all birds did equally well. Dominants were unable to monopolize resources that were highly dispersed; food distributed in small patches gave subordinates foraging alternatives to capitalize on. Kirk and Houston (1995) suggested that dominance, recognized as one individual supplanting another, is more likely a consequence of many factors (i.e., body size, satiation level, and costs and benefits associated with challenging conspecifics), all of which can vary with time. It is this variability that is reflected in the flexibility observed in dominance relationships between bears at feeding aggregations.

**Adaptive Foraging in Black Bears**

At Anan Creek, fishing sites were abundant and dispersed as though in small patches (upper falls, south and north side; lower falls, south and north side). On the
south side of the upper falls, at least 6 bears could be accommodated in spots from which fish were easily captured. If the most productive fishing holes were occupied upon arrival, dominant bears often displaced the occupants. Less dominant bears utilized other strategies; some diverted to the less desirable spots located up- or downstream from the productive zone. Others waited on the rocks above or behind good fishing spots until they were vacated, at which time they fished until ousted by another bear or quickly grabbed a fish and retreated to the forest or a rock cave.

Because most bears concentrated on the south side of the upper falls, intraspecific encounters were reduced at the lower falls, where good fishing sites were less abundant. Also, the north side of the upper falls was very rarely lacking in fish. In fact, live and dead salmon often accumulated in piles along the side pools, particularly in mid and late August; bears typically caught fish immediately upon arriving (within the first few seconds) and rarely left unrewarded for their efforts. Thus if bears chose to completely avoid confrontations with other bears, they had alternative locations to fish.

What are the tradeoffs associated with these alternative strategies? First, the lower falls and the trail to it was a hub of human activity as visitors arrived, departed, and accumulated on the observatory up to 40 people at one time. Bears at the lower falls were exposed to far more human disturbance than at the upper falls. In general, sub-adults, single females, females with dependent young, and subordinate males were responsible for the majority of bear activity observed on the north side of Anan Creek, where close encounters with people on the trail and at the observatory were frequent. Very rarely did we witness large adult males on this side.
Because of the surplus of fish and many alternatives for access at Anan Creek, the benefits (i.e., energy gained) of fighting for resources or territorial defense were minimal, whereas the costs (serious injury, death) could have been great. We did not examine changes in rates of agonistic behavior relative to fish abundance at Anan Creek. However, Egbert and Stokes (1976) noted that aggressive interactions increased with decreasing fish capture rates (during years of low escapement). In addition, agonistic behaviors declined over the summer months, as bears became more satiated. These results suggest that resource defense is a function of the cost/benefit ratio as well as internal motivation.

**Black Bears, Brown Bears, and People: A Cascading Effect?**

We examined interspecific interactions between brown and black bears at Anan Creek and compared their diel activity patterns to determine if and how the presence of the former might affect foraging behavior of the latter. Brown bears are known to prey on adult black bears and cubs thus posing a potential danger to the latter (Miller 1985, Ross et al. 1988, Mattson et al. 1992). Consequently, black bears often avoid areas at times when brown bears are active (Miller 1985, Kasworm and Manley 1990, Reinhart and Mattson 1990), resulting in temporal or spatial resource partitioning which can relegate black bears to less desirable foraging conditions (MacHutchon et al. in press).

At Anan Creek, about 10-15 brown bears fished at both falls but did not deter black bears from utilizing these prime locations. Brown bear use was low relative to that by black bears and probably infrequent enough not to warrant complete avoidance by black bears of these areas. Furthermore, black bears did not always leave when brown bears
arrived (particularly when they were on opposite sides), suggesting brown bears were not perceived as enough of a threat under those conditions to abandon fishing.

However, a clear trend for these 2 species to be active at different times of the day was evident. Brown bears were crepuscular, seen mostly in the early morning (0600-0800) and evening (1800-2200); conversely, black bears fished more during the day and were less active at dawn and dusk. MacHutchon et al. (in press) found that where black and brown bear habitat overlapped with human recreational use, the location and timing of human disturbance influenced brown bear use patterns which, in turn, dictated when and where black bears were active. At Anan Creek, we suspect a similar cascading effect. Brown bears, in general, appeared more easily disturbed by people than black bears, most vacating the immediate area when people arrived even at distances of 50-100 m. Only 2 brown bears were sufficiently tolerant of people to fish at the lower falls with little reaction. The rest were seen where visitors were excluded (i.e., the upper falls, along the stretch of river between the lower and upper falls, in the lagoon) and in the early morning or late evening when the observatory was empty. Visitors arrived between 0800 and 1800 hours; brown bears may have concentrated their fishing efforts around this window to avoid people, thus allowing black bears more diurnal use of the stream.

Study Limitations

The primary objectives of this research were aimed primarily at human-bear interactions rather than bear social behavior and group dynamics. Thus the sampling methods used (focal animal) were especially suited for addressing questions concerning
the structure and implications of social status among black bears. Focal animal sampling involves collecting detailed data on 1 individual or a dyad for a pre-specified period of time. All behavioral events are recorded allowing for the identification of important components and sequences (Martin and Bateson 1986). Construction of social hierarchies based on dominance relationships, however, requires multiple observations on numerous dyads (Freeman et al. 1992), a task best accomplished with event sampling (Martin and Bateson 1986).

Our sampling was restricted to the lower and upper falls during daylight hours, limiting our inference space regarding spatial and temporal resource partitioning between black and brown bears on the Anan Creek drainage. To our knowledge, no data on bear use of spawning ground further upstream have been collected. In addition, nighttime observations would have contributed significantly to information on nocturnal activity at both falls, a possible indication of human displacement.

LITERATURE CITED


TABLE 3-1. The aggressiveness and outcome of interactions between sex/age classes in 1994 and 1995. Undetermined refers to stalemates as opposed to one individual displacing another (clear result).

![Table 3-1: Aggressiveness and outcome of interactions between sex/age classes](image)

*a% of interactions within class dyads.

\textsuperscript{M,F,S} Male, female, subadult, respectively
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*aIndicates individuals only identified reliably during that year.
Figure 3-1. The proportion of interactions attributed to 5 class dyads in 1994 and 1995. Expected values, enclosed in parentheses, were calculated based on the relative bear activity observed for males, females, and subadults.
Figure 3-2. Black bears detouring around each other at the upper falls of Anan Creek.
Figure 3-3. Dominance relationships between identified black bears in 1994.

Stalemates were not included. Females, indicated by an asterisk, are in ovals and males in rectangles. Double asterisks refer to females with dependent young.
Figure 3-4. Dominance relationships between identified black bears in 1995.

Stalemates were not included. Females, indicated by an asterisk, are in ovals and males in rectangles. Double asterisks refer to females with dependent young.
Figure 3-5. A comparison between dominance scores of 18 black bears identified in both 1994 and 1995. Females are indicated by an asterisk.
Figure 3-6. The relationship between dominance score and fishing time in 1994 (a) and 1995 (b). Single females are indicated by an asterisk and females with dependent young double asterisks.
Figure 3-7. Allocation of fishing time between the lower falls and the upper falls for 1994 (a) and 1995 (b). Individuals are listed in order from left (highest dominance score) to right (lowest dominance score) with females indicated with an asterisk and those with dependent young a double asterisk.
Figure 3-8. The percentage of fish caught in particular fishing holes by bears assigned to different dominance groups. Numbers designate the relative profitability of fishing holes, the most productive assigned a value of 1.
Figure 3-9. An interaction between a small female black bear (WIS) and a young female grizzly bear (GALL) at the lower falls.
Figure 3-10. Diel activity patterns of black and brown bears at the lower falls (a) and upper falls (b). Data presented here were pooled across 1994 and 1995.
CHAPTER 4

HABITAT SECURITY FOR ALASKAN BLACK BEAR AT KEY FORAGING SITES: ARE THERE THRESHOLDS FOR HUMAN DISTURBANCE

Abstract: We investigated the impacts of wildlife viewing on the distribution, diversity, and fishing activity of black bears (Ursus americanus) at Anan Creek, southeast Alaska. We logged 622 observation hrs at 2 falls in 1994 and 1995. The lower falls was open to the public whereas the upper falls was closed. We identified 14 adult male black bears and 10 adult females at Anan Creek common to both years of the study. Of 24 recognized bears, 71% were observed 75-100% of the time at the upper falls; only 8% (2 females) fished solely at the lower falls. Five of 8 bears that fished exclusively at the upper falls (all large males) appeared wary of researchers upon their arrival. Based on quantile regression analyses, we found that visitor numbers acted as a ceiling on fishing duration of black bears at the lower falls of Anan Creek in 1994 and 1995. Furthermore, 2 habituated bears seen frequently at the lower falls spent less time in view (maximum values) as visitor group size increased. We found no relationship between visitor numbers and other indices of black bear activity and diversity at this site. Whereas the upper falls received more use by bears due to superior fishing opportunities and increased security, we suspect that some bears restricted their fishing effort to this site to avoid high human activity at the lower falls. Bears fishing at the lower falls were more tolerant of people; however, they exhibited sensitivity to larger group sizes as evidenced by shorter fishing bouts. These results are a conservative

1 Coauthored by Danielle K. Chi and Barrie K. Gilbert.
estimate of human impacts on bears as they reflect threshold levels of the most tolerant bears in a population.

Wildlife viewing is rapidly becoming an economically dominant use by the public (Edington and Edington 1986, Flather and Cordell 1995, Larson 1995). In particular, viewing programs that feature “charismatic megafauna” such as bears (*Ursus* spp.), in their natural environment, are in high demand (Swanson et al. 1992). Most of the well-known bear-viewing sites are located in Alaska where bears aggregate on salmon (*Oncorhynchus* spp.) streams to feed on spawning and migrating fish. During the past 10 years, these areas have experienced dramatic increases in visitation, some doubling each year (Aumiller and Matt 1994, Fagen and Fagen 1994, Olson and Gilbert 1994, Chi and Gilbert 1996). Although some viewing programs (e.g., McNeil River State Game Sanctuary) capped visitor numbers at their inception (Aumiller and Matt 1994), others lacked clearly defined management objectives to address continued growth in visitor use (Titus et al. 1994, Neary unpublished notes).

A prevailing concern to biologists and wildlife managers is the potential negative impacts that unprecedented expansion of viewing programs may have on bears. Wildlife viewing has been categorized as nonconsumptive, implying negligible effects on the resource. This assumption, however, requires evaluation because contrary evidence is well documented in the literature (Gutzwiller 1993, HaySmith and Hunt 1995). Whereas some animals habituate to people and their activities (Frame and Frame 1980, Jones and Swartz 1984, Aumiller and Matt 1994), others remain wary, avoiding areas of high human use and development (Jope 1985, Nadeau 1989,
Furthermore, studies on bear-human interactions at established viewing sites indicate that the mere presence of human observers poses significant disturbance to some bears (Warner 1987, Braaten 1988, Olson 1993, Fagen and Fagen 1994, Olson and Gilbert 1994). In Katmai National Park, Alaska, the temporal and spatial distributions of nonhabituated brown bears (*Ursus arctos*) were better explained by the location, intensity, and timing of human activity than salmon availability (Olson and Gilbert 1994, Olson et al. 1997). These findings are corroborated by results of Warner (1987) and Reinhart and Mattson (1990). Over-winter survival and reproductive success of bears depends on their ability to build up fat for hibernation (Miller 1994, Noyce and Garshelis 1994). Consequently, displacement of nonhabituated bears from critical foraging areas may invariably affect individual fitness if alternative food sources are unavailable (Archibald et al. 1987, Gilbert 1989, McCutchen 1990, Gilbert and Lanner 1992).

Moreover, in the absence of restrictions on visitor numbers and permissible human behavior at wildlife viewing sites, disturbance may exceed the thresholds of even the most tolerant individuals. Several studies suggest there are subtle shifts in diel activity patterns of habituated bears in response to peak visitor use during midday hours (Chi and Gilbert in press, Olson and Gilbert 1998). To establish a balance between resource protection and public access at wildlife viewing sites, managers need a basis for predicting impact thresholds on both habituated and nonhabituated bears.

This study investigated the potential impacts of wildlife viewing on black bears at Anan Creek. Anan Creek, rapidly becoming known as an exceptional black bear viewing location, has experienced an upsurge in visitation within the past decade.
(United States Department of Agriculture, Forest Service 1996). This stream is unique as it is one of the few places where both black bears and brown bears (*U. arctos*) can be observed fishing within relatively close distances of one another. The objectives of our research were twofold: 1) to test the hypothesis that visitors do not affect the distribution, diversity, or fishing activity of black bears at Anan Creek; and 2) to recommend appropriate management strategies that maximize bear use of Anan Creek while facilitating recreational viewing.

**STUDY SITE**

Anan Creek is located approximately 40 km southeast of Wrangell, southeast Alaska (56°11' N, 131°53' E) on the Tongass National Forest (Fig. 2-1). The region is characterized by coastal forests of Sitka spruce (*Picea sitchensis*) and western hemlock (*Thuya plicata*) and interspersed with alder (*Alnus spp.*) and black cottonwood (*Populus trichocarpa*) along riparian zones. The left fork of Anan Creek is wide and flat, providing suitable spawning habitat each year for as many as 250,000 pink salmon (*Onchorhynchus gorbuscha*). During summer, both black and brown bears are attracted to Anan Creek to feed on migrating salmon. Two sets of falls impede upstream movement of salmon making them particularly vulnerable to capture by bears.

In 1965, the United States Department of Agriculture, Forest Service (USFS), constructed a bear-viewing observatory on the north side of the creek 12 m above the lower falls. This structure has been modified and expanded since then to accommodate more people; it is currently 15 m long and as wide as 8 m in some spots. A 9-m² section of the observatory is covered, providing viewers with shelter from rain and sun
(Fig. 4-1). From the observatory, bears can be viewed en route to or fishing for salmon at close range (from 10 to 40 m away). Additionally, there is a fish pass located at the bottom of the ledge, 12 m below the observatory and 8 m from the other side of the creek. This pass has a 25-m$^2$ platform that was covered with a tarp in 1994 and 1995 to conceal human observers. Bears have been observed fishing for salmon directly across from this structure as well as beside it.

Anan Creek is accessible only by floatplane or boat. Visitors are dropped off at the trailhead located near the mouth of estuary to follow a boardwalk trail about 0.8 km to the lower falls. USFS interpreters are present at the trailhead and observatory to provide information on natural history and safety issues related to human-bear encounters. However, human behavior is not highly regulated and there are few restrictions on visitor numbers on site.

The upper falls, located 0.4 km upstream from the lower falls, has been closed to the public since 1992 due to several incidences between people and brown bear sows with cubs, and for research purposes. The trail to this area has not been maintained for public use. Due to the limited human activity at the upper falls, it served as an adequate control site.

USFS staff (2-3 people) and the research crew were housed in 2 small administrative cabins located approximately 75 m north of the trailhead. A USFS recreational cabin (capacity 5-6 people) was the only on-site accommodation (located 0.3 km north of the trailhead) available for public use.
METHODS

Bear Identification

Thirteen black bears were captured, fitted with radio-collars, ear-tagged with small multicolored Floy fish tags (Floy Tag, Inc., Seattle, WA), and lip-tattooed by Alaska Department of Fish and Game (ADF&G) personnel from 23-31 July 1993 as part of a larger population study. We differentiated between individual bears by natural markings, morphological characteristics, and remaining ear tags. Photographs of bears (front view and profiles) were taken and distinguishing physical characteristics were sketched. We determined sex of individuals from direct observation of genitals, urination posture, or the presence of cubs. Both photographs and sketches were used to compile detailed identification records on bears; these records were continuously updated as coat condition changed and new scars were acquired. Binoculars and spotting scopes were used to facilitate bear identification.

Data Collection

We collected data on black bear activity and behavior between 16 July-3 September 1993, 3 July-27 August 1994, and 3 July-3 September 1995. In early July, sampling was conducted between 0600 and 2200 hours with each day divided into eight 2-hr periods. In mid-July, the last session (2000-2200 hours) was omitted as decreasing light made observations difficult and return from sites hazardous. For logistic simplicity, we systematically assigned sampling sessions each day to ensure complete coverage of all periods at both sites within a week. Observations were made from the bear observatory
at the lower falls and an elevated tree platform/blind on the north bank of the creek at the upper falls.

We used a form of focal animal sampling (Altmann 1974) to collect data on black bear activity. During observation sessions we recorded the following information on all bears seen: species, sex/age class, identification or description, location of bear appearance, arrival and departure time, fishing attempts, fish caught or scavenged, and where fish were consumed. In addition, we documented all detectable responses exhibited by individual bears to our arrival or to the presence of USFS. Instantaneous scan sampling (Altmann 1974) was used to monitor visitor numbers at the lower falls. Upon the sound of the timer (set at 10-min intervals), the observer visually scanned the designated zone and recorded the number of people present on the observatory. Twelve scans were conducted for each 2-hr observation session.

Lastly, we kept detailed records of all events in which people displaced bears from either the lower or upper falls. We classified the outcome of bear avoidance responses to people as displaced to the surrounding forest or a cave for the entirety of the observation session (DZ), or initially avoided but activity resumed following the episode (RA).

Analyses

We examined how different bears allocated their fishing efforts between the lower and upper falls; activity rates of identified individuals were calculated as the total time each bear was observed at each site divided by the number of observation sessions. As overall measures of black bear activity (individuals pooled), we used 3 indices: bear
minutes, the number of visits, and mean bout length. These 3 different measures identified how bear activity varied as the first index (bear minutes) varied as a function of the latter two (visits and visit duration). In addition, we used individual richness (number of different bears seen) and Simpson's D (a function of richness and evenness) as measures of black bear diversity. Simpson's D was calculated as $H = 1/\sum P_i^2$, where $P_i$ = the number of bear minutes for individual i divided by the total number of bear minutes for that session. Data collected from 10 habituated individuals at the lower falls (classified based on their lack of response to people and extensive use of the lower falls) were separately analyzed.

Visitor activity at the lower falls, represented by people per scan, was calculated by dividing the total number of visitors counted in all scans by the number of instantaneous scans taken (typically 12) for each observation session.

We constructed bivariate scatterplots to examine the relationships between the independent variable (visitor numbers) and several dependent variables (i.e., black bear activity, diversity, and individual fishing time). Our purpose was to determine whether high levels of human activity acted as a constraint on the diversity and activity of bears fishing at the lower falls. When a "ceiling" rather than a "controlling" effect is of interest, ordinary least squares (OLS) estimators, which model the center of data distributions (means) and assume homoscedastic variance (Cade et al. In press), may not accurately portray the nature of the relationship between the independent and dependent variable (Maller et al. 1983, Blackburn et al. 1992, Terrell et al. 1996, Thomson et al. 1996, Scharf et al. 1998, Garvey et al. 1998, Cade et al. in press).
For quantifying the slope of upper bounds in scatterplots, regression quantiles have been proposed as superior models to OLS regression (Koenker and Bassett 1978, Gutenbrunner and Jureckova 1992, Terrell et al. 1996, Scharf et al. 1998). A quantile is defined as “a plane that splits a frequency distribution into parts” (Terrell et al. 1996:109) such that there are Nθ observations below the θth quantile, where N is the number of observations. In quantile regression models the parameters of interest include the intercept (β0) and slope (βp, p≥1) of the θth (0<θ<1) quantile. These models have unbiased medians rather than means, are less sensitive to outlier contamination than OLS models, and accommodate heteroscedasticity in the estimates (Scharf et al. 1998, Cade et al. In press). We fitted the 75th and 90th regression quantiles to model upper limits of bear activity (bear minutes, visits, and mean bout length), diversity (individual richness and diversity of bear activity), and individual fishing time as functions of visitor number. Constraining effects are indicated by 75th or 90th regression quantile slopes (Terrell et al. 1996) being steeper the 50th regression quantile slope. Significance tests of quantile slopes were based on regression rank scores (Gutenbrunner et al. 1993, Koenker 1994) and conducted using an S-Plus program provided by B. C. Cade (S-Plus for Windows Version 3.3).

RESULTS

Individual Black Bear Distribution at Anan Creek

The first field season in 1993 comprising 305 observation hrs served to develop a protocol for reliable identification and recognition of individual bears and to refine data collection methods. Our results are based on the 1994 and 1995 field seasons; 340 and
282 total hrs were spent sampling at the lower falls and upper falls, respectively. Each year we individually identified approximately 19 male and 13 female adult black bears at Anan Creek. However, only 14 male and 10 female black bears were observed both years of the study. These were individuals that were frequently seen and/or had distinguishing markings, thereby making it easier to differentiate them. Consequently, our sample may be biased toward more visible and, possibly, more tolerant individuals. However, time spent on the river by these individuals accounted for 71% and 83% of all adult bear activity observed in 1994 and 1995, respectively. Based on these statistics, we believe this sample to be representative of the majority of bears that consistently fished at the lower and upper falls of Anan Creek.

Within each sex class, there was substantial variation between individuals in the spatial distribution and total amount of fishing time. Of 14 male black bears recognized both years of the study, 7 fished exclusively at the upper falls; an additional 6 bears spent >75% of their time at this site. Of 10 female black bears, 4 were seen only at the upper falls and 2 only at the lower falls. Three females fished at both sites; activity ratios ranged from 50:50 to 30:70/70:30 (lower falls:upper falls). These individual patterns of bear activity were consistent across years with a few exceptions. One large adult male spent 45% of his fishing time at the lower falls in 1994, but was not sighted there in 1995. Two females allocated from 70-75% of their fishing time to the lower falls during the year they were accompanied by dependent young. They reversed this pattern during the year they were single females. In addition, 1 small female exhibited exclusive use of the upper falls as a single female in 1994, but was only seen on 2 occasions the following year when she had cubs of the year.
Black Bear Activity and Diversity at the Lower Falls

Cade and Richards (1996) found that while regression quantiles were not as sensitive to outliers of the dependent variable as OLS regression, they did, however, respond similarly to the effects of leverage points (outliers of the independent variable). For this reason, 1 leverage point was removed from the data set of overall black bear activity and diversity.

We found no constraining effects by people on bear minutes, fishing bouts, individual richness, or diversity of bear activity. However, mean bout length progressively decreased as visitor numbers increased (Fig. 4-2); slope of the 90th quantile was negative, greater in magnitude than that of the 50th quantile, and differed from 0 ($P < 0.10$, Table 4-1). Bout lengths decreased substantially beyond a threshold of 9 people per scan. This threshold value equates to a maximum of 15 people on the observatory at one time (see Chi and Gilbert 1996, p. 102 for calculations). Although not significant, the number of visits bears made increased as visitor numbers increased, a result inconsistent with patterns noted for other indices.

Bout Lengths of Individual Bears (Lower Falls)

Of the 24 bears identified in both 1994 and 1995, 10 (5 males and 5 females) were observed frequently enough at the lower falls to carry out individual analyses. These bears were categorized as habituated because they rarely, if ever, exhibited detectable avoidance of people on the observatory. For 7 of 10 bears, slopes of 75th and 90th quantiles were negative and greater in magnitude than that of the 50th quantile, indicative of a ceiling effect of visitor numbers on duration the bears spent in view.
(Table 4-2). However, for only 2 of these bears were slopes of the 75th (Fig. 4-3a) or 90th (Fig. 4-3b) quantiles significantly different from zero. Interestingly, for 1 bear (Fig. 4-3c) there was a significantly positive relationship between visitor numbers and maximum bout length indicating his visits were longer when larger visitor groups were present.

Human Displacement of Individual Bears

At the lower falls, 10 (53%) bears in 19 instances were completely displaced (DZ) and 9 (47%) avoided (RA); these instances typically involved visitors. The majority of displacements at this site were surprise encounters with females and subadults at close ranges (2-15 m) on the trail near the observatory. At the upper falls, we observed 61 (91%) displacements (DZ) and 6 (9%) cases of temporary avoidance (RA), all due to researcher/USFS personnel arrival or presence. Most displaced bears at the upper falls were adult males (47%) and unknown adults (39%); of the adult males that avoided people at this site, 5 of 8 were almost unknown at the lower falls.

DISCUSSION

We identified almost 50% more adult male than female black bears at Anan Creek both within and across years. This outcome may reflect the relative ease of identifying males; they were typically larger and bore numerous scars, making it easier to distinguish between individuals (Herrero 1983). Adult females were smaller and could more easily have been mistakenly categorized as subadults in the absence of cubs (Olson 1993). However, we believe this bias was minor. The proportion of male bears observed at Anan Creek (≥60%) was well within the range expected based on other

During both years at Anan Creek, most male black bears appeared to “prefer” the upper falls where human activity was minimal; the same generalization could not be made about females. Earlier work by Chi and Gilbert (1996) indicated that the upper falls site provided more ample fishing opportunities and secure locations where bears could retreat to eat fish (i.e., rock caves and crevices). These 2 characteristics in addition to limited human disturbance likely made the upper falls a highly attractive fishing location. Our results are concordant with other bear foraging studies which indicate that adult males typically secure the most productive feeding sites (Egbert and Stokes 1976, Luque & Stokes 1976, Rogers et al. 1976, Rogers 1987, Kearney 1989, Rogers 1989). Further, they are an underrepresented cohort in areas frequented by people (Mattson et al. 1992) and appear more wary of people (Egbert and Stokes 1976, Warner 1987, Aumiller and Matt 1994).

Females and subadult bears, on the other hand, often select less optimal habitat in an effort to avoid the threat and competition presented by large males (Rogers 1989, Wielgus and Bunnell 1994a). Our results provide more evidence for this phenomenon as several females at Anan Creek, when accompanied by dependent young, seemed to segregate themselves from males. Both shifted their fishing efforts from the upper falls to the lower falls when they had cubs. Although seen frequently at the upper falls in 1994, another female completely avoided both falls when accompanied by spring cubs.
It appears that the lower falls functions as an alternative fishing location to the upper falls for females attempting to avoid large males at the upper falls.

The Distribution of Individuals Relative to Human Activity

Based on our results, we rejected the hypothesis that wildlife-viewing activities did not affect where bears fished on Anan Creek. Approximately one-half of all bears within each sex class exclusively fished at the upper falls, which was closed to the visiting public; and >71% spent more than 75% of time there. The composition of individuals fishing at the lower falls overlapped with those at the upper falls, whereas the reverse was not true. Only 8% of our sample of bears (2 females) restricted their use only to the lower falls. Some large males seen only or primarily at the upper falls were consistently displaced by the arrival of research and/or USFS personnel. Although some reappeared after we entered the elevated tree blind, others were not seen again until the next day. However, we acknowledge that any visitor effect was confounded by important differences in fish accessibility and availability of cover between the lower and upper falls of Anan Creek. For this reason, we restricted our inferences to individuals that exhibited obvious avoidance of people at the upper falls.

We offer several possible explanations for why bears at the upper falls might be more sensitive to the human disturbance. First, nonhabituated bears are so categorized based on their tendency to avoid people (Warner 1987, Mattson et al. 1992, Olson 1993, Olson et al. 1998). Olson et al. (1997) found that some nonhabituated family groups delayed their arrival at Brooks River by a week when concessionaire activities (fishing lodge) were extended a week beyond the usual closing date. Grizzly bears in
Yellowstone National Park used front-country streams less during weeks of high visitor use despite it co-occurring with a peak in the trout run (Mattson et al. 1992). At Anan Creek, the upper falls provided an alternative fishing locale for bears less tolerant of people. This behavioral predilection is likely sustained because individuals fishing exclusively at this site have less opportunity for habituation due to limited human access.

Secondly, bears appear to be more tolerant of people and their activities where interactions are expected and innocuous (Craighead and Craighead 1971, Herrero 1983, Jope 1985, Craighead et al. 1995). In a field study on black bear foraging, Rogers and Wilkers (1990) found that their study subjects, habituated to researchers (within 1 m), exhibited wariness and avoidance upon unexpectedly encountering those same researchers. At Anan Creek, human use at the upper falls has traditionally been low; this area was closed to the public from 1993-1995 for research purposes. In addition, there were closures during the 1991 and 1992 field seasons due to encounters with brown bears whereby USFS personnel and visitors were charged at close range on several occasions by a brown bear sow with cubs. Furthermore, access to the upper falls is difficult because the trail is not maintained and hazardous, especially under conditions of heavy rain. Therefore, encounters with people present a relatively novel experience to which bears may be more reactive. Behavioral data collected on a large, relatively wary male (BRU) is consistent with this hypothesis. He tolerated visitors at the lower falls on a few occasions, albeit in a highly vigilant state, in 1994. However, throughout the study he consistently fled to the security of a rock cave or surrounding forest upon detecting our arrival at the upper falls.
Responses of Habituated Bears

Bears habituated to people are characterized by a lack of response to human presence or activity (Jope 1985, Olson 1993, Aumiller and Matt 1994). Where bears and people come into frequent, benign contact with one another, habituation alleviates negative human impacts on some bears (Jope 1985, McLellan 1990) by allowing them to utilize common resources (Gilbert 1989, Gunther 1990). A stable relationship based on mutual recognition of individual boundaries between people and bears can be fostered where human activity is consistent and predictable (e.g., McNeil River State Game Sanctuary). Under such viewing conditions, bears will pass within an arm’s reach of viewers while en route to the falls; brown bear sows have been seen nursing their cubs within 5 m of observers (Aumiller and Matt 1994). A similar adaptive syndrome exists at Anan Creek for a small subset of bears that regularly frequented the lower falls.

We tested several hypotheses concerning the effect of visitor numbers on the fishing activity of habituated bears at the lower falls. We found no declines in several measures of black bear activity (bear minutes, visits, diversity, different individuals) observed at this site in relation to visitor numbers, indicating that these bears are fairly resilient to relatively high levels of human disturbance. Furthermore, due to the placement of the observatory next to bear trails, bears approaching the creek on the north side of the creek passed regularly within 5-10 m of people on this platform. We frequently encountered the same few bears at very close distances (<15 m) on the trail where they slowly detoured around us without sign of distress.

However, we did reject the premise that visitor numbers do not affect overall fishing
duration of bears at the lower falls. We found that as the number of people on the observatory surpassed a threshold 15, bout lengths became progressively shorter, indicating a very subtle change in behavior in response to larger group sizes. Similarly, we found that for 2 habituated bears, they spent less time in view as visitor numbers increased. To maintain total fishing time under high disturbance conditions, bears may be making more visits of shorter duration (incurring an additional energetic cost) to and from the creek.

We attribute the effect of high visitor numbers on fishing duration, in part, to a change in human social behavior we refer to as the "cocktail hour" effect. Small groups of people at the observatory were more engrossed in wildlife viewing when a bear was out fishing or not. As visitor numbers increased, the tendency for humans to interact socially with others also increased. People talking so loudly as to be heard over the roar of the falls resulted in greater disturbance to bears. Furthermore, movement by large groups of people on the observatory probably distracted or disrupted bears attempting to fish while, at the same time, remaining vigilant for other bears. Because time lost fishing equates to lost feeding opportunities, visitor group sizes larger than the threshold may have negative energetic consequences even for very habituated bears.

As visitors were most numerous during midday hours, one might argue that temperature rather large numbers of people was responsible for shorter fishing bouts. The negative correlation between maximum bout lengths and visitor group size might be spurious, possibly a result of temperature. This seems unlikely. First, bout lengths at the upper falls (control site) were not of shorter duration during midday hours (Chi and Gilbert 1996). Second, local weather variation influenced midday temperatures
more than did the time of day. Lastly, we did not find that more people visited Anan Creek on hot days; guided groups were scheduled in advance and arrived as planned unless travel was not possible due to lack of visibility or stormy conditions.

Brown Bear Activity at Anan Creek

While it was not the focus of the research presented in this paper, the impact brown bears have on black bear foraging patterns at Anan Creek deserves mention. Brown bears prey on both cubs and adult black bears and thus pose a potential threat to black bears wherever their ranges are sympatric (Miller 1985, Ross et al. 1988, Kasworm and Manley 1990, Mattson et al. 1992). Habitat use patterns of these two species have been documented under field conditions (Reinhart and Mattson 1990, MacHutchon et al. in press). Black bears avoid areas or periods during which brown bears are active, resulting in a temporal or spatial resource partitioning (MacHutchon et al. in press).

At Anan Creek, we identified 10-15 brown bears each field season. Brown bears fished at both falls and thus did not deter black bears from utilizing these prime locations. However, based on all observations made between 0400-2300 hours, these 2 species appeared to be active at different times of the day. Brown bears were mostly seen in the early morning (0400-0700) and evening (2000-2300), while black bears fished throughout the day (D. Chi unpublished data). MacHutchon et al. (in press) found that where black and brown bear habitat overlapped with recreational use, the location and timing of human disturbance influenced brown bear use patterns which, in turn, dictated when and where black bears were active. At Anan Creek, we suspect a similar cascading effect, as brown bears appeared more easily disturbed by people than
black bears. Most visitors arrived between 0800 and 1800 hours; brown bears may have concentrated their fishing efforts around this window to avoid people, thus allowing black bears more diurnal use of the stream.

Utility of Regression Quantiles

Recent ecological papers have emphasized the need for quantitative methods that model relationships between biological response variables and limiting environmental factors (Blackburn et al. 1992, Kaiser et al. 1994, Terrell et al. 1996, Thomson et al. 1996, Garvey et al. 1998, Scharf et al. 1998, Cade et al. In press). In such relationships, a dependent or response variable may be influenced by any number of factors when it falls below a particular threshold for another factor (Kaiser 1994). As an example, Cade et al. (in press) examined the relationship between species biomass (biological response variable) and habitat conditions (limiting environmental factor). “Changes in species biomass (Y) do not exceed limits imposed by habitat conditions (X) but can be reduced by nonhabitat factors (Z)” (Cade et al. In press). Several methods have been used to quantitatively describe this type of relationship (e.g., partitioned regression, logistic slicing, tests for lopsidedness, regression quantiles, see Thomson et al. 1996). Yet, to date, regression quantile analysis is one of the few techniques with a means by which hypotheses can be statistically tested.

We believe that regression quantile analysis was a valid method for depicting the limiting effect people had on bear activity at Anan Creek. We had some concerns, however, regarding the computations and statistical tests that warrant discussion for future reference and inquiry. First, slopes of 90th regression quantiles for mean bout
length and 3 habituated bears (DEU, WIS, and JUA) were much lower than expected based on a cursory inspection of the patterns. Cade et al. (In press) found that truncating zero counts (which made up 50% of observations) from a data set resulted in more highly negative slopes that differed significantly from zero. Our lack of more attenuated slopes may be due to the large number of zero or low values relative to the range we had for indices of bear activity, especially when fewer people were present. Moreover, it is possible that nonlinear quantile models would have better depicted patterns for a few of the individual data sets (DEU and JUA) as well as for mean bout length (B.C. Cade, United States Geological Survey, personal communication).

Second, for 3 bears (LIM, SHA, and ZIP) the confidence intervals were excessively large and inconsistent with the test statistic and/or the slope of the 90th regression quantile. A resampling permutation test run on one of these data sets revealed that the sampling distribution of the rank score test statistic was bimodal and positively skewed (B.C. Cade, United States Geological Survey, personal communication). This statistical anomaly may be due to discrete data groupings of the independent variable found in all 3 of these data sets. More observations along all values of the independent variable (visitor numbers) is needed to avoid this problem. Caution should be exercised when interpreting such conflicting results as significance tests against the null model under these conditions may be inaccurate. Further experimentation with the rank scores and alternative permutation procedures on a variety of distributions is necessary to identify which approach is most appropriate for particular data sets (Koenker 1994).
Conclusions

Our results indicate that wildlife-viewing activities do impact bears fishing at Anan Creek. We found that although fish were accessible from both sites, some bears never used the lower falls and exhibited avoidance upon encountering people at the upper falls. At the lower falls, the duration of visits by tolerant bears decreased as visitor numbers on the observatory increased. We suggest that these results are a conservative estimate of human disturbance to bears at Anan Creek. Bears intolerant of people may have completely abandoned the area as the popularity of this site increased, leaving a remaining population composed of individuals able to habituate to various degrees of human disturbance. If so, we were relegated to documenting the outcome with no baseline reference for comparison.

MANAGEMENT IMPLICATIONS

Recommendations

Anan Creek harbors one of the largest runs of pink salmon in southeast Alaska, an exceptional source of fat and protein for both black bears and brown bears. As the demand for wildlife-viewing opportunities grows, it becomes increasingly important to monitor and mitigate impacts on wildlife, the resource upon which this activity depends. We discuss the applicability of our findings at 4 scales as proposed by Knight and Temple (1995).

Spatial. – Our data document the importance of having alternate foraging zones where bears can fish in the absence of human disturbance or distraction. At Anan Creek, the upper falls provided a refuge from visitor disturbance as well as superior
fishing opportunities. Displacing bears from such ecologically significant micro-sites such as the upper falls could have negative consequences for population-level impacts (Gilbert and Lanner 1992, Wielgus and Bunnell 1994b). Consequently, the natural integrity of this site should be maintained and anthropogenic disturbances kept to a minimum.

The lower falls may be attractive to subordinates and, more importantly, to females with young as an option to avoid the possible threat large males pose to cubs at the upper falls. We also noted 1 episode in 1995 when high water made fish inaccessible at the upper falls to all but a few bears for several days. During this time, some upper falls users were sighted at the lower falls while others abandoned the stream for the remainder of the season (Chi and Gilbert 1996). Hindering food acquisition by bears, particularly pregnant or lactating females, could contribute to reduced recruitment and impact population growth (Archibald et al. 1987, McCutchen 1990, Gilbert and Lanner 1992). For this reason, managers would do well to set limits on the magnitude and duration of human disturbance that results from wildlife-viewing activities at the lower falls.

Behavioral.—We found that large numbers of visitors on the observatory (>15) affected maximum fishing time of habituated bears. Placing restrictions on group size and providing education on appropriate viewing etiquette could reduce disturbance (Aumiller and Matt 1994, Fagen and Fagen 1994, Neary 1995).

Temporal.—While some bears were quite tolerant of people, we suspect that others did not fish at the lower falls due to the presence of people. Increasing the predictability and consistency of human activity by establishing fixed visitor hours

Visual. Our arrival to the upper falls consistently disrupted the fishing activity of bears, frequently resulting in their immediate displacement from the area. Screening viewers from bears using blinds or hidden platforms and enclosed walkways would reduce the distraction resulting from movement and mask the sound.

Future Research Directions

At Anan Creek, there is a limited understanding of the movement patterns of black bears within and beyond this watershed. We need more information on larger spatial scales. Where do these bears go, what is the availability of other food sources, and how much do they utilize the upstream areas? This lack of information increases in importance as future timber cuts on the Cleveland peninsula near the Anan Creek drainage are proposed and initiated. The degree to which bear populations depend on unique salmon runs like Anan Creek and availability of alternative forage opportunities throughout the season must be determined to better predict human impacts on bears (Titus et al. 1994).

The variation in individual behavior of highly intelligent organisms argues against use of statistical means of activity patterns to provide acceptable predictive capability. Examination of the causes of variation amongst individuals is best understood through long-term studies. Despite the constraints imposed by typical funding cycles, insights will only be revealed through commitment to these studies. Identifying behavioral syndromes could be useful to managers for generating predictions regarding human
effects on population scale dynamics. Future research should address the challenge of
developing models that incorporate individual variation (the range) and the frequency of
behavioral phenotypes in a population to predict population level dynamics. This
undertaking, although complicated with dynamics of habituation as well as the constant
replacement of nonhabituated bears by more tolerant generations (Aumiller & Matt
1994, Stonorov, ADF&G, personal communication), shows promise of developing
realistic models/scenarios for resolving wildlife-human conflicts.

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Table 4-1. Estimated slopes, confidence intervals, and test statistics for 3 quantile regression models of the relationship between indices of bear activity and visitor numbers. Confidence interval boundaries are separated with a comma.

<table>
<thead>
<tr>
<th>Indices</th>
<th>90th quantile</th>
<th>75th quantile</th>
<th>90th quantile</th>
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<tbody>
<tr>
<td></td>
<td>β</td>
<td>90 % CI</td>
<td>χ²</td>
</tr>
<tr>
<td>Bear minutes</td>
<td>1.68</td>
<td>0.84, 3.49</td>
<td>5.61**</td>
</tr>
<tr>
<td>Visits</td>
<td>0.41</td>
<td>0.16, 0.71</td>
<td>8.63**</td>
</tr>
<tr>
<td>Mean bout length</td>
<td>0.09</td>
<td>-0.03, 0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Individual richness</td>
<td>0.23</td>
<td>-0.04, 0.26</td>
<td>8.37**</td>
</tr>
<tr>
<td>Diversity of activity</td>
<td>0.13</td>
<td>0.06, 0.19</td>
<td>8.49**</td>
</tr>
</tbody>
</table>

*P<0.01, df = 1

** P<0.05, df = 1
Table 4-2. Estimated slopes, confidence intervals, and test statistics of 3 quantile regression models of the relationship between bout length and visitor numbers for 10 individual black bears at the lower falls. Confidence interval boundaries are separated by commas.

<table>
<thead>
<tr>
<th>Individual</th>
<th>50th quantile</th>
<th>75th quantile</th>
<th>90th quantile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta_1 )</td>
<td>90% CI</td>
<td>( \chi^2 )</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIM</td>
<td>0.24</td>
<td>-0.41, 0.16</td>
<td>1.95</td>
</tr>
<tr>
<td>T</td>
<td>0.71</td>
<td>0.15, 0.96</td>
<td>2.86*</td>
</tr>
<tr>
<td>PAT</td>
<td>-0.51</td>
<td>-0.57, 0.23</td>
<td>1.83</td>
</tr>
<tr>
<td>SHA</td>
<td>0.53</td>
<td>-1.87, 1.36</td>
<td>0.54</td>
</tr>
<tr>
<td>ZIP</td>
<td>-0.06</td>
<td>-0.18, 0.10</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEU</td>
<td>-0.20</td>
<td>-0.38, -0.11</td>
<td>6.73**</td>
</tr>
<tr>
<td>JUA</td>
<td>-0.13</td>
<td>-0.16, 0.11</td>
<td>0.29</td>
</tr>
<tr>
<td>SHI</td>
<td>-0.10</td>
<td>-0.13, 0.01</td>
<td>1.31</td>
</tr>
<tr>
<td>SMA</td>
<td>-0.01</td>
<td>-0.09, 0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>WIS</td>
<td>0.02</td>
<td>-0.11, 0.22</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*P < 0.10, **P < 0.05
Figure 4-1. People gathered on the lower falls bear observatory.
Figure 4-2. Quantile regression lines (90th, 75th, and 50th) depicting the relationship between visitor activity and mean bout length for bears at the lower falls.
Figure 4-3. Quantile regression lines (90th, 75th, and 50th) depicting significant relationships between visitor numbers and bout duration for 3 habituated black bears at the lower falls.
CHAPTER 5
SUMMARY

This dissertation attempted to tease apart the effects of resource distribution, inter- and intraspecific social dynamics, and wildlife viewing on black bears (*Ursus americanus*) fishing for salmon (*Oncorhynchus gorbuscha*) on Anan Creek. First, results indicated that black bears responded to differences in fish accessibility on spatial and temporal scales as densities were highest at the upper falls where fishing opportunities were more abundant and at midseason during the peak of the salmon run. However, individuals did not appear to be distributed “ideally” between lower and upper falls or fish capture rates should have been similar at these two sites. Rather, bears seemed to be dispersed according to the Ideal Despotic Distribution where more dominant and/or efficient individuals exclude others from the best foraging locations (Fretwell 1972, Milinski and Parker 1991). Black bears used rock caves located near fishing sites as refuges for feeding, daybedding, and escape purposes, all functions typically provided by trees (Herrero 1983), making them of great ecological importance.

Second, we investigated the implications of black bear social dynamics on fishing behavior. Based on the dominance relationships between individuals, we found that black bears at Anan Creek did align loosely in a relatively stable, linear social hierarchy as found by Egbert (1978). This was particularly true for the most and least dominant individuals. The social status of particular animals had consequences to salmon acquisition as more dominant bears fished in the most productive sites. However, the
numerous opportunities for fishing at Anan Creek (i.e., 2 falls) furnished bears of intermediate and subordinate status with sufficient alternatives and conflicts over fishing sites were rare, further attesting to the surplus of fish.

Although individual fishing patterns were determined in part by fish accessibility and social status, we found that human disturbance via wildlife viewing activities at the lower falls and researcher presence at the upper falls were influential in determining where some bears fished. Bears less tolerant of people (as indicated by clear avoidance upon encountering people) fished mostly at the upper falls where the public was excluded. A subset of bears seen at the lower falls appeared exceptionally habituated to people (as indicated by a lack of response). However, even several of these very tolerant bears fished for shorter periods of time when large numbers of people were on the observatory. Based on these results, management should concentrate on maintaining the upper falls as a refuge for less tolerant individuals and reducing disturbance at the lower falls through visitor hours, limits on group sizes, and modification of visitor behavior.

RESEARCH RECOMMENDATIONS

The research objectives of this dissertation did not thoroughly address the ecological relationship between brown bear activity and black bear foraging choices on a larger scale. However, because both species are present in the Anan Creek drainage, there is the opportunity to rigorously investigate resource partitioning between these 2 species. Behavioral research on interspecific interactions between black bears and brown bears has been relatively sparse. To some degree, the paucity of information on this topic
reflects the scarcity of sites at which both species aggregate at high densities. Results of several studies, including this research, and anecdotal reports indicated that black bears avoid areas when and/or where brown bears are active (Reinhart and Mattson 1990, Craighead et al. 1995). Black bear fear of predation by brown bears has been proposed as a mechanism behind such interspecific spacing (Mattson et al. 1992). Consequently, knowledge regarding variables that influence brown bear activity patterns and distribution should contribute to a better understanding of black bear behavior where the species are sympatric.

Anan Creek is a unique location due to its exceptionally dense population of black bears that aggregate during the summer months to feed on spawning salmon. Although the upper and lower falls are clearly important fishing sites for bears, we know little about the vulnerability of fish to capture in spawning areas or the extent of both black bear and brown bear activity further upstream. In addition, information regarding the availability, abundance, and distribution of alternative food sources (i.e. berries, sedges, clams) on the Cleveland Peninsula would contribute to a better understanding of the importance of the salmon resource to bears and how human disturbance affects nutritional needs of bears.

The impacts of timber harvest on black bear movement patterns have been modeled and results indicate that certain timber practices increase the vulnerability of bears to hunting (Mollohan and LeCount 1989). However, clear-cutting patches of forest could also be a detriment to black bears by disrupting tradition travel corridors. As bears have been shown to travel great distances to feed on concentrated food sources like salmon, it
is important to investigate the variation in home ranges of bears that frequent such a site.

Research on human-bear interactions has documented variation in the degree to which both individuals (Warner 1987, Olson 1993) and different age-sex classes habituate to people (Mattson et al. 1992, Aumiller and Matt 1994). However, very little remains understood regarding the mechanisms through which habituation occurs. What learning processes are involved as bears habituate to people and their activities? Why might these processes vary across different age and sex classes? Is there a critical period during which an individual’s behavioral repertoire is more malleable to learning?

Individual experience (McCullough 1982, Gilbert 1989) and cultural transmission of behavior (Gilbert in press) are thought to play a role in the process of habituation, although few studies have attempted to test any hypotheses in the field (Braaten 1988). Long-term research on known individuals is needed to determine what mechanisms are responsible for such adaptation. This knowledge could be especially important for predicting the potential effects of new bear-viewing programs upon individuals present in the resident population.

LITERATURE CITED


Figure A-1. Lower falls.
## APPENDIX B. STATISTICAL RESULTS

Table B-1. Results of Kruskal-Wallis tests comparing between years.

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Rank sum</th>
<th>Test statistic</th>
<th>P-value (2-tailed)</th>
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</thead>
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<tr>
<td><strong>Bear minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>7</td>
<td>28.00</td>
<td>(H = 15.15)</td>
<td>(P &lt; .001)</td>
</tr>
<tr>
<td>1994</td>
<td>7</td>
<td>117.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>7</td>
<td>86.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bears</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>7</td>
<td>28.00</td>
<td>(H = 14.18)</td>
<td>(P &lt; .001)</td>
</tr>
<tr>
<td>1994</td>
<td>7</td>
<td>112.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>7</td>
<td>91.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bout length</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>7</td>
<td>46.00</td>
<td>(H = 5.77)</td>
<td>(P &lt; .056)</td>
</tr>
<tr>
<td>1994</td>
<td>7</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>7</td>
<td>85.00</td>
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<td></td>
</tr>
</tbody>
</table>

Table B-2. Results of Mann-Whitney tests comparing between sites for 1993.

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Rank sum</th>
<th>Test statistic</th>
<th>P-value (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bear minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>(U = 49)</td>
<td>(P = .002)</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bears</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>31.00</td>
<td>(U = 46)</td>
<td>(P = .006)</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>74.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bout length</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>29.00</td>
<td>(U = 48)</td>
<td>(P = .003)</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>76.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fish/bear</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>(U = 49)</td>
<td>(P = .002)</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table B-3. Results of Mann-Whitney tests comparing between sites for 1994.

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Rank sum</th>
<th>Test statistic</th>
<th>P-value (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bear minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>U = 49</td>
<td>P = .002</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bears</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>U = 46</td>
<td>P = .002</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bout length</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>31.00</td>
<td>U = 48</td>
<td>P = .006</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>74.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fish/bear</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>U = 49</td>
<td>P = .002</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table B-4. Results of Mann-Whitney tests comparing between sites for 1995.

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Rank sum</th>
<th>Test statistic</th>
<th>P-value (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bear minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>U = 49</td>
<td>P = .002</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bears</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>31.00</td>
<td>U = 46</td>
<td>P = .006</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>74.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bout length</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>36.00</td>
<td>U = 48</td>
<td>P = .0035</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>69.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fish/bear</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower falls</td>
<td>7</td>
<td>28.00</td>
<td>U = 49</td>
<td>P = .002</td>
</tr>
<tr>
<td>Upper falls</td>
<td>7</td>
<td>77.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table B-5. Regression table for dominance score in 1994 and that in 1995.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>0.247</td>
<td>0.248</td>
<td>12.67</td>
<td>0.003</td>
<td>0.0015</td>
</tr>
<tr>
<td>Residual</td>
<td>16</td>
<td>0.313</td>
<td>0.019</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>0.560</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B-6. Regression table for 1994: dominance score and bear minutes and fish captured.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bear minutes</td>
<td>1</td>
<td>0.723</td>
<td>0.723</td>
<td>3.609</td>
<td>0.071</td>
<td>0.036</td>
</tr>
<tr>
<td>Fish captured</td>
<td>22</td>
<td>4.406</td>
<td>0.200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>5.129</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bear minutes**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>1.503</td>
<td>1.503</td>
<td>7.245</td>
<td>0.013</td>
<td>0.0065</td>
</tr>
<tr>
<td>Residual</td>
<td>22</td>
<td>4.565</td>
<td>0.207</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>5.129</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table B-7. Regression table for 1995: dominance score and bear minutes, fish captured, visits, and bout length.

<table>
<thead>
<tr>
<th></th>
<th>Multiple R</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bear minutes</td>
<td>0.448</td>
<td>0.200</td>
<td>0.162</td>
<td>23</td>
</tr>
<tr>
<td>Fish captured</td>
<td>0.347</td>
<td>0.120</td>
<td>0.078</td>
<td>23</td>
</tr>
<tr>
<td>Bouts</td>
<td>0.397</td>
<td>0.158</td>
<td>0.118</td>
<td>23</td>
</tr>
<tr>
<td>Bout length</td>
<td>0.395</td>
<td>0.156</td>
<td>0.116</td>
<td>23</td>
</tr>
</tbody>
</table>

**Bear minutes (natural log)**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>3.109</td>
<td>3.109</td>
<td>5.265</td>
<td>0.032</td>
<td>0.016</td>
</tr>
<tr>
<td>Residual</td>
<td>21</td>
<td>12.401</td>
<td>0.591</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>15.510</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fish captured (natural log)**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>1.834</td>
<td>1.834</td>
<td>2.873</td>
<td>0.105</td>
<td>0.052</td>
</tr>
<tr>
<td>Residual</td>
<td>21</td>
<td>13.402</td>
<td>0.638</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>15.236</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total bouts**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>2523.886</td>
<td>2523.886</td>
<td>3.93</td>
<td>0.061</td>
<td>0.031</td>
</tr>
<tr>
<td>Residual</td>
<td>21</td>
<td>13481.766</td>
<td>641.989</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>16005.652</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Bout length (natural log)**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$P_{(2)}$</th>
<th>$P_{(1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>0.749</td>
<td>0.749</td>
<td>3.893</td>
<td>0.062</td>
<td>0.031</td>
</tr>
<tr>
<td>Residual</td>
<td>21</td>
<td>4.038</td>
<td>0.192</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>5.536</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C. ETHOGRAM USED FOR DOCUMENTING INTERACTIONS

Operational Definitions of Behaviors Leading to Interactions

Movement - in which an individual approaches, arrives or moves in nonchalant fashion with no apparent intent other than locomotion

Aggressive approach - individual directly approaches another individual with ears laid back

Low aggression - individual directs jawpops or mouthing at another

High aggression - individual directs a swat, snap, chases or bites another

No response - individual acknowledges other with a glance or a stare but does not react

Slow avoidance - individual slowly moves away from another or changes direction of locomotion to avoid another

Quick avoidance - individual trots or runs out of way of another

Results of interactions

Both participants resumed activity (standoff)

Focal animal displaces another bear

Focal animal gets displaced from initial spots but resumes activity elsewhere

Focal animal is displaced and doesn't resume activity

Focal animal is displaced to a cave

Focal animal is displaced and departs the area.
APPENDIX D. DOCUMENTED OBSERVATIONS OF BLACK BEARS

DISPLACING BROWN BEARS

July 24, 1994 - DEU was fishing at the lower falls with her two yearlings; upon seeing GALL approaching from downstream, she retreated quickly to a rock cave. GALL appeared to detect DEU's scent as she headed directly to the cave where DEU and her two yearlings were and poked her head in. DEU charged out of the cave and bit GALL on the hind leg as she retreated.

July 29, 1995 - A small female black bear with one spring cub (WISH) arrived at the lower falls while GALL was fishing. GALL exhibited no response to WISH's arrival upon which WISH began a series of charges directed towards GALL. Each charge "episode" entailed WISH running at GALL in short bursts from the rocks above with her head low and her ears laid back, followed by a quick retreat up the hill about 10 m where she held her position jawpopping and huffing. Three charge episodes ensued within 20 minutes, between which WISH attempted to fish. She eventually ended up scavenging and eating fish discarded by GALL. On July 30th, 1995 three adult black bears succeeded in displacing GALL at the lower falls.

July 30, 1995 - Three black bears were fishing at the lower falls, all within 10 m of one another, as she approached. When GALL got within 40 m of the fishing area, all three black bears initially responded by moving towards caves or uphill but then stopped and stared at the approaching brown bear. Several exchanged glances with each other and then held their ground in a triangular formation. GALL stared back at
the three black bears, turned slowly around and headed off rather quickly downstream; she was not seen again at the lower falls until the next day.
VITA

DANIELLE K. CHI

Department of Fisheries and Wildlife, Utah State University, Logan, UT 84322-5255
Phone: 435-753-3684, Email: dchi@cache.net

EDUCATION

Ph.D. Wildlife Biology
Utah State University Logan, UT
Dissertation: 'The effects of salmon availability, social dynamics, and people on black bear (Ursus americanus) fishing behavior on an Alaskan salmon stream.'
Barrie K. Gilbert - major advisor.

M.A. Psychology
San Diego State University San Diego, CA
Thesis: 'The conditioning of captive cheetahs (Acinonyx jubatus) to regularly occurring environmental stimuli.'
Patricia A. Scollay - major advisor.

B.S. Psychology
University of California, Davis

PROFESSIONAL EXPERIENCE

Environmental Consultant
KW Brown & Associates, Inc. Logan, UT
• Reviewed, synthesized, and responded to comments on draft Environmental Impact Statement for large ski area expansion projects.

Assistant Program Chair - Ecological Society of America
Utah State University Logan, UT
• Coordinated and produced program for the Ecological Society of America’s 1998 Annual Meeting.
• Reviewed all symposia, presentations, workshops, and roundtable discussions for scientific merit.
• Collaborated extensively with other scientific societies, leading ecologists, the ESA governing board, and local arrangements staff on planning and logistics of joint meetings.

Environmental Consultant
Subcontracted – U.S. Forest Service Logan, UT
• Investigated effects of newly implemented management regulations on bear activity and behavior at a recreational viewing site. Responsible for study design, data collection and analysis, and final write-up of results in a technical report prepared for the U.S. Forest Service.
• Produced site-specific individual identification book, and monitoring protocols for continued bear research.
• Trained Forest Service personnel on identification, monitoring, and guiding procedures.

Environmental Consultant
Partner and Vice President, Natural Resources Research and Consulting, Inc. Logan, UT
• Acquired research funding for, designed, and implemented a field survey of bear activity and sign for the purposes of recreational planning.
• Analyzed data, and presented results and management recommendations in technical report prepared for the U.S. Forest Service.
Graduate Research Assistant – Ph.D.  
Utah State University  
1993 - 1996
Logan, UT
- Conducted doctoral research on the foraging ecology and behavior of black bears in relation to human disturbance.
- Responsibilities included design of research and all data collection protocols, 4 seasons of field-work, data entry and analysis, and write-up of 4 chapters for publication.

Wildlife Specialist  
Pioneer Environmental Services, Inc.  
1992 - 1993
Logan, UT
- Conducted background research and prepared biological evaluations and environmental assessments of anthropogenic impacts on listed species (fish, small and large mammals, aquatic invertebrates) for ski area development/expansion and pipeline projects.
- Designed and implemented pilot field survey for habitat assessment and distribution of a listed aquatic invertebrate. Responsible for hiring and training of personnel, and budgeting for all personnel equipment, resources, and labor.

Graduate Research Assistant  
Utah State University  
1991 - 1992
Logan, UT
- Produced comprehensive behavioral ethogram specific to canid ecology, biology and management.

Graduate Research Assistant – M.A.  
Center for Reproduction of Endangered Species  
1990 - 1991
San Diego, CA
- Examined the effects of captivity on cheetah behavior and reproduction.

VOLUNTEER EXPERIENCE

Stream Technician  
Utah State University  
1997
Logan, UT
- Surveyed geomorphic and topographic characteristics for stream channel longitudinal profiles and channel morphology comparison and analysis.

Field technician  
Utah State University  
1996
Logan, UT
- Conducted radio-telemetry on collared swans, monitored hunter check-station, and took physical measurement of harvested swans.
- Clipped and collected aquatic vegetation in experimental study on the effects of disturbance on wetland plant communities.

TEACHING EXPERIENCE

Graduate Instructor - Biostatistics  
Utah State University  
1997
Logan, UT
- Lectured on statistical methods, programming using SAS, and interpretation of biological/ecological data to undergraduate natural resource majors.
- Prepared and graded all practice sets, lab practicals, and exams, assigned grades, and held office hours.

Graduate Teaching Assistant and Grader  
Utah State University  
1995 - 1997
Logan, UT
- Teaching assistant and/or grader for the following courses:
  - Cons. Biol. (LS 280)
  - Wildl. Diversity and Lab (FW 290, 291)
  - Mgmt. Aspects of Wildl. Behav. (FW 421)
  - Wildl. Law Enforcement (FW 410)
  - Eval. and Mgmt. of Wildl. Habitat and Pops. (FW 431)
  - Ecosystem Concepts in Fisheries and Wildl. (FW 540)
  - General Ecology (BIOL 386).
Graduate Teaching Assistant – Natural Resources and the Future  
*Utah State University*  
- Facilitated in-class panel discussions and debates on current controversial topics in natural resource management and conservation.  
- Graded essays, oral presentations, and exams, assigned grades, and held office hours.

Graduate Instructor - Psychology  
*San Diego State University*  
- Prepared and delivered all lectures on topics in introductory psychology to undergraduates.  
- Facilitated class discussions and debates on relevant topics.  
- Wrote and graded all exams and homework assignments, assigned grades, and held office hours.

PUBLICATIONS


In Preparation


Technical Reports


SCIENTIFIC PRESENTATIONS


JOB-RELATED SKILLS AND TRAINING

Computer software/hardware experience

- IBM: Microsoft Word, Excel, PowerPoint, Outlook, WordPerfect, SigmaPlot, Psiplot, SYSTAT, S-PLUS, SAS, SPSS-PC, Netscape, Windows 97, ARCVIEW ( cursory exposure only).
- MACINTOSH: Excel, Microsoft Word, WordPerfect, Cricket Graph, Statview,
- VAX computer systems: SAS, SPSS, BMDP

Other skills

- Global Positioning System (GPS) and analysis of GPS field data
- Geomorphic and topographic surveying (Geodetic total station)
- Ground Radio-telemetry

AWARDS

- Terri Lynn Steele Scholarship Endowment – Awarded by the Fisheries and Wildlife Department, Utah State Univ., May, 1995 for dedication to and achievement in the study of wildlife biology.
PROFESSIONAL ACTIVITIES

- Animal Behavior Society
- International Bear Association
- Ecological Society of America
- Expanding Your Horizons – A program designed to expose young girls to careers in science.
- Faculty/Graduate Student Representative – Attended faculty meetings, interviewed potential job candidates, acted as graduate student/faculty mediator, organized and delivered new graduate student