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IMPACTS OF HYDROELECTRIC DEVELOPMENT ON BROWN BEARS, KODIAK ISLAND, ALASKA

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Abstract: We investigated the impacts of the construction and operation of the Terror Lake hydroelectric project on brown bears (*Ursus arctos middendorffi*) on northern Kodiak Island, Alaska, during 1982-86. Radio collars were maintained on a mean of 35.6 bears throughout each year of the study. We relocated these bears an average annual total of 933.3 times during a 3-year construction period (1982-86) and 994.5 times during a 2-year post-construction period (1985-86). Bears that resided near the project used approximately the same areas each year, making only minor shifts to areas with dense cover during construction. In areas near the project, bears used alpine habitat less, and midslope and lowland habitat more than expected, based on availability. Over 90% of the bear locations in alpine habitat near the project were made after construction activities ceased, suggesting that bears avoided these open areas during construction. Dense, brushy cover in midslope and lowland habitats gave bears secure cover, so they continued to use preferred feeding areas near the project both during and after construction. Areas of mean home range polygons for 5 females closely associated, and 8 females unassociated, with the project were not significantly different ($P > 0.1$) during construction and post-construction periods. Individual bears varied widely in their relative associations with the project, but several bears were commonly located near active construction. Impacts on denning were less than predicted because most bears denned in areas remote from and at elevations above project features. Bears exhibited high fidelity to the same denning areas irrespective of the bears' association with project features. Total habitat lost to inundation and removal of vegetation was <0.5% of the study area. Improved vehicular and foot access provided by constructed roads and powerlines, and the increased incentive for development of rural lands provided by surplus electric power, is expected to have long-term impacts on bears through increased disturbance and killing of bears by recreationists and settlers. Mitigation of the project included dedication of adjacent lands for wildlife and creation of a trust fund to support research and habitat maintenance for bears.

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Brown bear populations on the Kodiak archipelago have been little affected by industrial developments, resource extraction activities, and human settlements compared with populations elsewhere in North America. Conflicts with livestock grazing (Eide 1965) and the killing of bears by rural residents, hunters, commercial fishermen, and other visitors to remote areas have been the main problems associated with human settlement and development on Kodiak Island (Smith et al. 1989).

Proposed construction of the Terror Lake hydroelectric project in the Kodiak National Wildlife Refuge (NWR) on northern Kodiak Island encountered opposition from the public and government agencies concerned about potential effects of the project on wildlife, particularly brown bears. A mitigation settlement was negotiated between 3 national conservation organizations and government agencies; construction commenced in 1982. The settlement included provisions for studies to assess impacts of the project on brown bears, mountain goats (*Oreamnos americanus*), raptors, and salmon (*Onchorynchus* spp.). This paper reports on a 5-year (1982-1986) study of the effects of construction and operation of the project on brown bears.

Spencer and Hensel (1980) predicted that the Terror Lake project would displace bears from important feeding and denning areas, possibly resulting in increased intraspecific strife and competition. Miller (1987) also predicted serious habitat losses and displacement from favored habitats for both brown and black bears (*U. americanus*) near the proposed Susitna hydroelectric project in southcentral Alaska. Construction of a hydroelectric project in British Columbia resulted in grizzly bears shifting to feeding areas with higher vulnerability to human activities (Simpson 1986). In light of these concerns, our primary study objective was to assess the impacts of the Terror Lake hydroelectric project on habitat use patterns and population ecology of brown bears during 3 years of construction (1982-84) and 2 years post-construction (1985-86).

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STUDY AREA

Kodiak Island is the largest (9,600 km^2) of a group of islands located in the Gulf of Alaska 400 km southwest of Anchorage. The 1,400-km^2 study area was located on northern Kodiak Island approximately 30 km west of Kodiak city (Fig. 1). Approximately the western half of the study area, including Terror Lake, was in the Kodiak NWR. Kodiak has a maritime climate characterized by frequent rain, fog and wind. Precipitation often exceeds 180 cm annually. Snow may occur any month at higher elevations but snowfall seldom exceeds 0.5-1 m at sea level from November-April. Mean temperatures in Kodiak city from 1982-86 ranged from 11-14 C in July and August to a mean of -4 - +4 C in January-February (National Weather Service, Local Climatological Data Monthly Summaries).

The study area is mountainous with rugged peaks ascending to 1,340 m. The coastline is varied with jagged cliffs, bedrock outcroppings, boulder-strewn beaches, and steep capes exposed to extreme wave action. Tidal flats occur at the termini of the 2 major drainages, Kizhuyak River and Terror River. Foothills and low ridges are interspersed with flat terrain in the northwestern part of the study area. Vegetation is predominantly a shrub/grass/forb complex, dominated by alder (*Alnus crispa*), salmonberry (*Rubus spectabilis*), bluejoint grass (*Calamagrostis canadensis*) and fireweed (*Epilobium angustifolium*). Cottonwood groves (*Populus balsamifera*) occupy valleys and birch (*Betula papyrifera*) is found on lower slopes. Sitka spruce (*Picea sitchensis*) occurs in scattered patches. The shrub complex grades into wet sedge (*Carex* spp.) and willow (*Salix* spp.) meadows and into mixed sedge/heath meadow at higher elevations. Hickock and Wilson (1979) provided a detailed description of the vegetation in the Terror Lake hydroelectric project area. Sitka blacktail deer (*Odocoileus hemionus sitchensis*) are abundant throughout the area and mountain goats are common in precipitous terrain. Pink salmon (*O. gorbuscha*) are abundant and widely distributed in lowland streams throughout the summer. Chum (*O. keta*), coho (*O. kisutch*), and sockeye salmon (*O. nerka*) also spawn in study area steams.

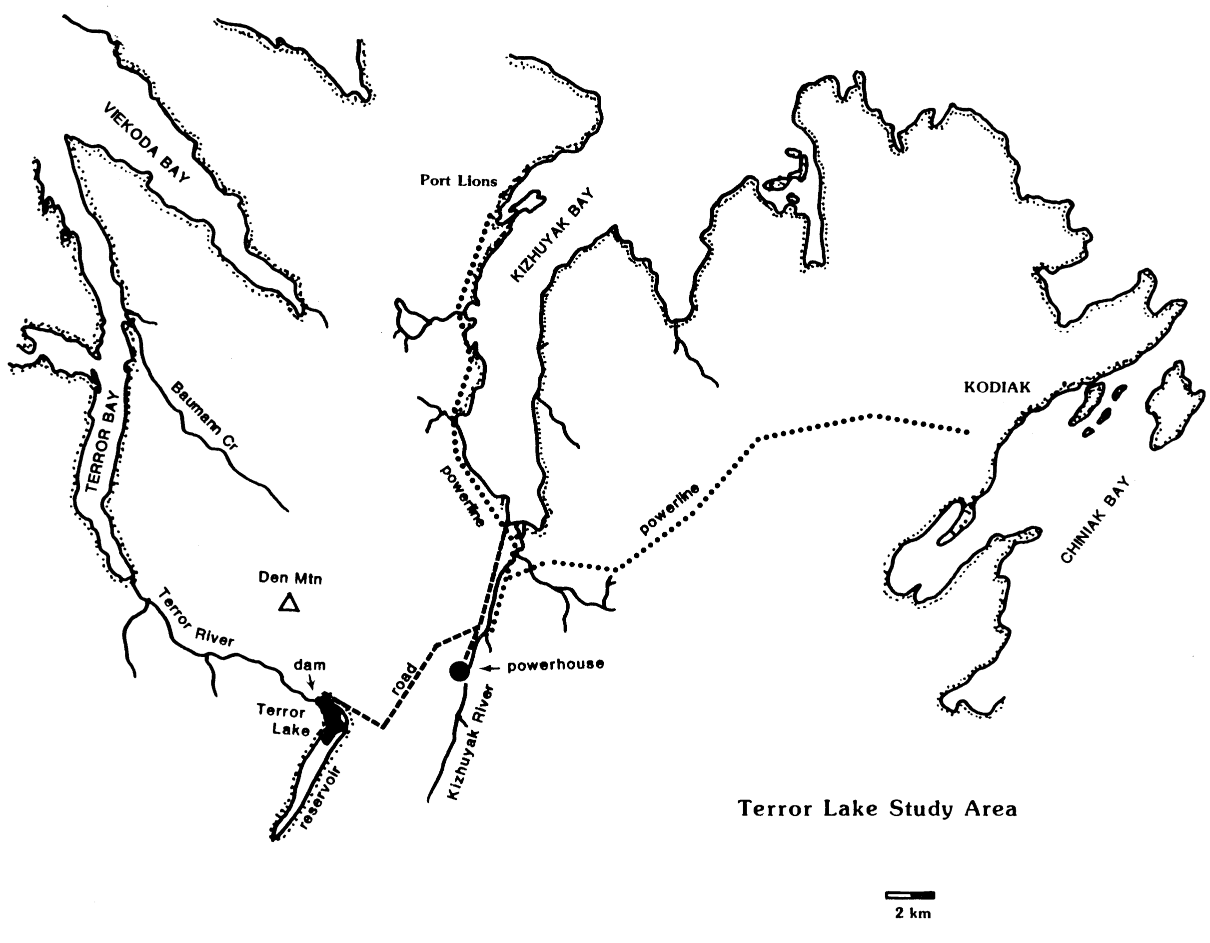

Fig. 1. Location of the Terror Lake hydroelectric project study area, Kodiak Island, Alaska, 1982-86.

Project Features

The Terror Lake project was a 20-MW conventional hydroelectric power source for the city of Kodiak. Terror Lake, a natural lake located in a glaciated valley near the headwaters of Terror River, was raised 52 m with a 747-m long dam. The surface area of the lake was increased from 1.1 km^2 to 3.2 km^2. Three minor drainages were diverted into an underground tunnel, which transports water from Terror Lake to the powerhouse in the Kizhuyak River drainage. A 27-km transmission line transfers electricity to the city of Kodiak and a 21-km distribution line supplies electricity to the village of Port Lions.

Construction of the project occurred from March 1982 to November 1984. A 19-km long gravel access road was built to connect the project sites. Construction camps were established at 3 sites and housed up to 480 workers during the peak of construction. An oil-fired incinerator in a chain-link fenced compound was used for garbage disposal. The project was considered operational by September 1984. Details of construction and operation of the project were provided by Smith and Van Daele (1988).

METHODS

We used helicopters and immobilizing darts to capture study animals (Smith and Van Daele 1988). Bears estimated to be at least 3-years-old were fitted with radio-collars equipped with mortality sensors (Telonics, Inc., Mesa, Ariz.). In 1982, we captured during April and May to locate bears close to their denning areas, and in July to sample bears in other habitats. During the 4 remaining years, capturing was done in June or July. We purposely biased capture efforts toward bears found close to the Terror Lake hydroelectric project, but bears were captured throughout the study area. Instrumented bears were radio-tracked every 7-10 days during April-November and about monthly during December-March. Visual observation and ground radio-tracking were also used occasionally to relocate bears. Bear locations were plotted on U.S. Geological Service maps (1:63,360) and standardized forms were used to record data on habitat, bears' activities, association with other bears, and proximity to project features and construction activities. Maps and relocation points were digitized by computer. Minimum convex home range polygon areas were computed, excluding marine waters.

We analyzed habitat use by comparing the frequency of relocations of radio-collared bears in each of 3 habitat categories to the relative availability (area) of each category. The 3 habitat categories conformed to elevational boundaries: alpine (>450 m), midslope (150-450 m), and, lowland (<150 m). Most bear relocations were made in a 775-km "core" area that included the Kizhuyak, Viekoda, and eastern Terror Bay drainages. Within this "core", 40.3% (312 km^2) was classified as alpine, 33.1% (257 km^2) was midslope, and 26.6% (206 km^2) was lowland. To analyze habitat use by bears near the project, we delineated a 141-km^2 area within a 1,500-m radius of project features. Chi-square and Bonferroni-z statistics were used to analyze habitat use patterns.

Den sites of radio-collared bears were mapped and selected dens were visited after bears emerged to collect data on den site characteristics. We examined fidelity of individual bears to denning areas in successive years as an indicator of construction-related disruption of den site selection. Mortality data were collected by promptly investigating deaths of radio-collared bears or by interviewing hunters who killed marked bears.

Construction activities were monitored by direct observations, from written surveillance reports by the environmental monitor, and from project completion documents furnished by the Alaska Power Authority. Wildlife observation forms were distributed to workers at the construction camps in 1982-84 to collect information on interactions between bears and workers. The project environmental monitor, a USFWS biologist, recorded his own bear observations and known observations by workers.

RESULTS AND DISCUSSION

Captures and Relocations

We captured 140 bears, including 84 adults (≥3 years) and 56 juveniles. Radio-collars were put on 52 females and 30 males. By December of each year an average of 35.6 (range = 32-37) bears were being monitored. No males and 14 females were monitored during all 5 years. Males were usually monitored for shorter periods because of higher mortality and transmitter failure/loss. A total of 4,790 point locations was recorded from April 1982-December 1986, including 1,077 point locations for males and 3,713 point locations for females. For the 3-year construction period (1982-84) the mean annual number of relocations was 933.3, compared with 994.5 for the 2-year post-construction period (1985-86).

Habitat Use

A pre-project impacts assessment by Spencer and Hensel (1980) provided general information on habitat use, but no radio-telemetry data were collected before construction activities started. Comparing movements of bears during construction (1982-84) with their movements after construction (1985-86) enabled us to investigate changes in habitat use. Subjective judgements were unavoidable in attempting to correlate movements of individual bears with construction activity, because of the lack of comparable pre-project data.

Annual Patterns.—Smith and Van Daele (1988) detailed the annual habitat use patterns of bears in the study area and noted significant differences for bears in various reproductive categories (i.e., males, lone females, females with cubs-of-the-year [COY], females with yearling and older offspring). Alpine habitat was generally used for denning. Bears used lowlands and midslopes in late spring when green herbaceous vegetation was developing. They moved higher into midslope areas as vegetation developed at progressively higher elevations. Alpine areas were used extensively from July through mid-August. Most bears then returned to lowlands with the arrival of spawning salmon. By early October bears began moving into midslopes and by late October many bears appeared in alpine habitat before denning.

Effects of Construction Activities.–Habitat use analysis for the 141-km^2 area near project features indicated that bears in all reproductive categories used alpine habitat less, and lowland and midslope habitats more than expected, based on availability. Within this area, 39.7% (55.9 km^2) was alpine, 27.8% (39.1 km^2) was midslope, and 32.5% (45.8 km^2) was lowland. In alpine areas near the project, bears were observed 68.5% less than expected on an annual basis, compared to 24.0% less than expected for the entire core study area. Midslope areas near the project were used 45.0% more than expected, compared to 33.5% more than expected in the core study area. Lowlands near the project were used 45.2% more often than expected, compared to 5.3% less than expected for the core study area.

The paucity of observations in alpine areas near project features suggests that bear use in these open habitats may have been influenced by construction activity. Only 12.5% (71) of the bear locations near project features were in alpine areas. Moreover, 90.1% (64) of these observations in alpine were made in post-construction years (1985-86) compared with only 9.9% (7) during construction (1982-84). Spencer and Hensel (1980) predicted a decline in use of alpine habitat in the Kizhuyak drainage and near Terror Lake during construction. Our results supported that prediction, but alpine use was probably affected in a much smaller area than was predicted.

Although our study was not designed to investigate bears' reactions to specific sources of disturbance, it appeared that intensive, low-level helicopter activity was largely responsible for the avoidance of alpine habitat near project sites during construction activities. Quimby (1974) found that grizzly bears in northeastern Alaska were extremely sensitive to low-level aircraft, but that they displayed the most severe reactions to helicopters. He also noted that some bears were more tolerant than others. Our observations and personal communications with pilots employed on the Terror Lake project suggest that some bears became somewhat accustomed to high-altitude helicopter traffic in regularly used flight corridors. Drilling, blasting, excavation, and other activities probably disturbed bears as well. Harding and Nagy (1980) found that grizzlies appeared to avoid drilling rigs and camps, but it was unclear if noise was a factor.

How much bears avoided construction activities appeared to be related to the density and proximity of secure vegetative cover. Spencer and Hensel (1980) predicted that bears displaced from alpine habitats in the Kizhuyak drainage would move into other alpine areas on northern Kodiak. Our results indicated that affected bears shifted from alpine areas near the project to nearby lowland habitat. Lowland habitat accounted for 60% of the relocations near the project during construction and 38% of the relocations near the project after construction. Lowlands offered dense cover and seasonally abundant food sources, including salmon, berries, and intertidal sedges. Although construction activity was intense in some lowland areas, the combination of available preferred food and security was sufficient to allow continued use by bears.

The importance of cover to habitat use patterns was also evidenced by relatively subtle shifts in movement patterns by some individual bears in lowland areas during the study. Radio-telemetry data suggested that bears avoided the lower sections of salmon spawning tributaries in the Kizhuyak River delta, where streamside cover was relatively sparse, while the Kodiak transmission line was under construction in late summer 1983. However, our data were not sufficient to validate the prediction by Spencer and Hensel (1980) that use of the Kizhuyak River delta would decline during construction. It was not uncommon to see bears feeding on salmon in the lower Kizhuyak tributaries within view of the access road during morning and evening hours. Trails and signs of feeding on salmon suggested that even the most exposed streams continued to be used to some extent during construction. Dense vegetation sufficient to conceal bears was available within 100-300 m of these streams. Limited radio-tracking from the ground suggested that bears were crossing the access road adjacent to salmon spawning streams during the night. We suspect that many bears shifted to more nocturnal use patterns, thereby avoiding the times when helicopter traffic and construction activity were most intense. Because radio-tracking flights recorded daytime locations, we suspect that actual use of the lower Kizhuyak River delta was higher than the data indicated.

Results of recent studies on the effects of roads associated with resource extraction and human developments generally confirmed that brown bears were displaced from preferred habitat near roads (Archibald et al. 1987, Mattson et al. 1987, McLellan and Shackleton 1988, Schoen and Beier 1988). We suspect that similar displacement occurred in the Terror Lake project area, but the access road was apparently not a serious barrier to movements. Archibald et al. (1987) noted that grizzly bears were commonly seen feeding on salmon within 300 m of a logging road both before and after active logging, but that bears were not observed feeding on salmon during the 2 years when the logging road was in use. The closest Kizhuyak River tributary used by bears feeding on salmon was approximately 300 m from the access road, but other heavily used salmon streams were at least 500 m from the road. With reduced disturbance during the post-construction period, bears were more secure in using exposed Kizhuyak delta fishing areas. Continued disturbance in 1985 and 1986, although much reduced, was probably still intensive enough to prevent resumption of normal feeding patterns there.

Bear use of midslope and lowland habitats west of Kizhuyak River, adjacent to the access road and other project sites, was not reduced as greatly during construction as Spencer and Hensel (1980) predicted. The extremely dense vegetative cover in the lower Kizhuyak River was key to providing security that allowed bears to continue using preferred feeding sites despite intensive construction activity. The importance of cover in offsetting the effects of disturbance was cited by Schoen and Beier (1988) to explain continued use of a drainage in coniferous forest during intensive road construction, and by Simpson (1986) who found that grizzlies displaced by a hydroelectric reservoir used areas close to human activities where cover was adequate. In contrast, Harding and Nagy (1980) found that grizzlies in open coastal tundra seldom approached closer than 1 km to oil exploration camps in the Northwest Territories.

Effects of Food Availability.—Disturbance from construction influenced bear habitat use, but was probably a less important factor than annual variations in food availability. Alpine areas were used earlier and for a shorter time during years of relatively early alpine phenology. This was probably because sedges mature more rapidly during years of early snowmelt; hence they are nutritious and palatable to bears for a relatively shorter time (Atwell et al. 1980). Lone females and females with yearling and older offspring exhibited the greatest variation in annual use of alpine areas in the summer. Males never made extensive use of the alpine and females with COY remained in the alpine regardless of vegetative phenology (Smith and Van Daele 1988).

Interannual variation in the availability of other food sources, including grasses and sedges, various berries, and salmon, also occurred during each year of the study. Bears could apparently adjust to shortages in particular food types by using alternate foods. It appeared that bears used salmon less in 1983 than they did in 1982 throughout the study area, because berries were more abundant and herbaceous vegetation developed earlier and more vigorously in 1983 (Smith and Van Daele 1988). In the lower Terror River, an undisturbed area 8-10 km from the Terror Lake dam site, several radio-collared bears that appeared near salmon spawning areas in 1982 were not located near salmon in 1983. Delayed salmon escapement in 1983 that was attributed to unusually low water (ADF&G 1983) may also have affected distribution of bears. In 1985 when green-up was unusually late and berry abundance was low, salmon streams were apparently used more throughout the study area (Smith and Van Daele 1988). Barnes (1986) also attributed increased bear use of salmon in southwestern Kodiak Island in 1985 to failed berry crops.

Although small amounts of food were routinely discarded by workers near worksites and along roads, we doubt that overall habitat use patterns of bears were much affected. From workers' observations and from relocations of study animals it appeared that only a few individual bears visited the worksites where unauthorized trash burning pits were used. Only 1 radio-collared bear, a single female, persistently fed on garbage at the Kizhuyak construction camp.

Home Range

Males had a mean annual home range nearly 5 times larger than that of females (males - 133 km^2, females - 28 km^2) and home range polygons of most males included project features. Females used primarily the same major drainage each year they were monitored and home ranges of several females did not include project features. Females captured in the Terror Bay drainage generally had home ranges remote from project features whereas project features were central to home ranges of many females in the Kizhuyak Bay drainage. Overlap of home ranges for females inhabiting either the Kizhuyak or Terror drainages occurred mainly in summer alpine feeding areas north of Terror Lake and west of Kizhuyak River.

We expected that the size of annual home range areas would be larger during project construction if bears were being displaced by disturbance, but we found no consistent pattern indicating that home range size was affected by project activities. Among 14 females with home ranges encompassing project features, 9 females had their largest annual home ranges after construction and 5 females had their largest annual home ranges during construction. Eleven females had their smallest home ranges during construction compared to 3 bears after construction. Two females had both their largest and their smallest home ranges during construction.

We also compared mean home range size for 2 groups of bears monitored for the entire 5 years of the study. The mean home range sizes of 5 females residing in close proximity to the project were not significantly different ($P > 0.1$) from those of 8 females residing in more remote areas during the construction and post-construction periods (Table 1). We concluded that annual home range size was not a sensitive indicator of bear responses to construction activities in this case.

Movements of Individual Bears

Annual movements of individual bears were examined in detail from sequential relocations (Smith and Van Daele 1988). Females with home ranges in the Kizhuyak Bay drainage resided closest to the construction project features in that drainage. Several males were occasionally located close to project activities, but because their home ranges were so much larger than those of females, it was difficult to correlate the movements of males with construction activity. The immediate environs of the Terror Lake dam site and reservoir were used by relatively few individuals, but we were unable to find bears to capture in that area until after the dam was constructed. We found no evidence that major alterations in movement patterns by bears occurred during construction. Sequential locations of radio-collared bears during construction indicated that traditional interdrainage travel routes were little affected compared to what was predicted by Spencer and Hensel (1980).

Table 1. Annual home range areas for radio-collared female brown bears closely associated and not closely associated with features of the Terror Lake hydroelectric project, Kodiak Island, Alaska, 1982-86.

Home range proximity	n	Mean home range size: Construction (1982-84)	Post-construction (1985-86)	Percent change[a]
Project	5	20.7 km^2	22.6 km^2	+12.6%
Non-project	8	24.4 km^2	22.9 km^2	–6.1%

[a] No significant differences between project and non-project bear home ranges ($P > 0.1$).

Movements of some individual females were considered noteworthy, although correlating changes in annual movements with construction activities was confounded by changing maternal status and by apparent annual variations in food availability. One female regularly found near the Kodiak transmission line corridor in the lower Kizhuyak River in 1982, apparently avoided that area during construction of the line in 1983, but returned after construction. Coincidentally, that female had a litter of 2 COY in 1983 when she apparently shifted her main activity area 5-7 km north of the line. Another female was frequently located near project sites, including the construction camp and the transmission line, during the peak of construction activity in 1983. Her movement patterns changed little after construction, suggesting that construction activity was not a serious deterrent to her normal habitat use patterns.

One female centered her activities around the construction camp and powerhouse site after her capture in 1984, the last year of construction. Workers frequently observed her feeding on garbage at the camp and her 4.2-km^2 home range was the smallest for a female that year. In 1985, she had a litter of COY and was located near the powerhouse only once. She continued to use alpine and midslopes west of the powerhouse in 1986. We suspect that the absence of garbage, reduced disturbance in alpine habitat, and possibly greater need for security when with her COY, caused her post-construction shift in habitat use patterns.

The Terror Lake basin was little used by bears during construction, generally confirming the prediction by Spencer and Hensel (1980) that alpine feeding and denning would be terminated by construction activity. Although the home range polygons of 3 males included Terror Lake, only 1 relocation was made within the impoundment area before flooding. Three females, which were captured after construction, used the slopes surrounding Terror Lake and 2 of the 3 denned within 1 km of the impoundment. We concluded that the Terror Lake impoundment area was relatively lightly used habitat compared to other areas in the Terror Lake drainage.

Denning

Spencer and Hensel (1980) anticipated that denning would be highly sensitive to disturbance during construction of the Terror Lake project. We found that denning was less seriously affected by construction than expected because traditional denning areas were relatively remote from project features. We located 184 den sites used by 64 radio-collared bears. Thirty radio-collared bears (26 females, 4 males) denned at least once within the ecotone between midslope and alpine habitat, described by Spencer and Hensel (1980) as "useable denning area". Dens were commonly located in the alpine zone that they considered unsuitable for denning. Dens used by radio-collared bears were frequently located near peaks and in the uppermost reaches of drainages, 1-6 km from major project features. Among the dens we located, 38% (70) were in the "useable denning area", 49% (91) were at higher elevations, 2% (4) were at lower elevations, and 10% (19) were outside the area studied by Spencer and Hensel.

Most construction activity and project features were located at elevations well below the 665-m mean elevation of dens found in this study. Because denning sites used by bears in the Terror Bay drainage, which had little disturbance attributable to the project, were comparable to those used by bears in the Kizhuyak Bay drainage, where disturbance was much greater, we concluded that the use of higher than predicted den elevations was not related to construction activity.

Thirty-five dens of 17 radio-collared bears (15 females, 2 males) were located in the "primary impact area" of the Terror Lake hydroelectric project described by Spencer and Hensel (1980). Among these dens, 13 (37%) were found in the 1982/83 and 1983/84 denning periods when construction activity was at its peak. Eleven dens of 6 individual bears (5 females, 1 male) were located within 1,500 m of project features. Two of the 11 dens were occupied during the construction period.

Data on successive-year den use were collected for 107 dens used by 42 radio-collared bears in the study area. Successive dens were <1 km apart in 51% (55) of the cases. The mean distance between successive dens was 1.7 km (range = 0-20.0 km). Males exhibited less fidelity to den sites than did females. The mean distance for successive den sites of males was 8.9 km (n = 4; range = 1.3-20.0 km) and for females it was 1.4 km (n = 103; range = 0-9.2 km). High fidelity to den sites was also characteristic of bears on southwestern Kodiak Island during approximately the same period (Van Daele et al. 1990). We interpreted the high fidelity of individual bears to specific denning areas to indicate that disturbance by construction had minor impacts on use of denning habitat.

We concur with Spencer and Hensel (1980) that some potential den sites nearest active construction sites may have been avoided, but we believe the effects were largely temporary and confined to the immediate vicinity, probably within 2 km of construction sites. We did not find that bears denned progressively farther from construction sites as Schoen et al. (1987) found in relation to mining activities on Admiralty Island. The assumption that we initially captured bears near their den sites in April and May 1982 was demonstrated to be correct by the subsequent locations of den sites and the delineation of home ranges.

We found no evidence that potential denning habitat was lost by inundation at Terror Lake or by other impoundments. Dens of 2 radio-collared bears were located in the Terror Lake basin after project construction, but both dens were approximately 270 m above the lake's elevation. Most dens of bears located during the study were in alpine habitat above the 433 m elevation of Terror Lake.

We verified no cases of premature emergence nor abandonment of dens related to disturbance. Some males apparently did not den, not an uncommon occurrence on Kodiak Island (Van Daele et al. 1990). Bears used 2 dens in 1 season in 21 instances, but in most cases the dens were relatively remote from the project site or the incidents occurred after construction. Van Daele et al. (1990) reported use of 2nd dens in a remote area of southwestern Kodiak Island during the same period. Although snowmachine tracks were found within 75 m of a denned bear in the east fork of Kizhuyak River, the bear did not emerge until several days later. However, the potential sensitivity of denned bears to off-road vehicular use was indicated by Reynolds et al. (1983) who reported that a brown bear apparently abandoned its den after too close an approach by a tracked vehicle during seismic surveys. We noted that motion sensors were sometimes tripped by denned bears during close approaches by the radio-tracking aircraft, as was reported by Schoen et al. (1987). We suspect that individual bears vary in their sensitivity to aircraft noise and that the acoustics of different den sites vary considerably. Although we did not confirm that either helicopter or fixed-wing aircraft activity disrupted denning in the Terror Lake project, we agree with Schoen et al. (1987) that high intensity air traffic is a potentially serious source of disturbance.

Population Size and Composition

A pre-project estimate of 200 bears in the eastern Terror Bay and Kizhuyak Bay drainages was based on a projection from actual sightings (Spencer and Hensel 1980). We estimated the population in approximately the same area at 190 bears in 1987 (Smith and Van Daele

1988) by extrapolating from a bear density estimate of 0.35 bears/km^2 done in a 350-km^2 area, which included most of the Terror Lake hydroelectric project (Barnes et al. 1988). Although the techniques used for the pre-project and post-project estimates were different, the comparison supported the conclusion that no decline in bear numbers resulted from construction of the Terror Lake project. The relatively stable home ranges delineated for bears residing closest to the project further indicated that population fluctuation was minimal.

Capture results and observations during radio-tracking flights indicated that bears in all sex, age, and reproductive classes were present during construction, but females with COY may have avoided construction activities disproportionately. Two radio-collared females that were closely associated with project sites when single apparently avoided the project when they had COY litters. Mattson et al. (1987) also found that females with COY showed greater avoidance of human developments in Yellowstone Park than did other classes during summer months.

Reproduction

We found no evidence that project activities were detrimental to production and survivorship of cubs. The percent of eligible females (≥5-years-old) that produced new litters each year varied from 11.1% in 1983 and 1986 to 63.6% in 1984. Mean litter size for a group of 11 radio-collared females with home ranges closest to project activities was 2.13 (31 litters; 66 cubs ≤2.5-years-old), compared to 2.12 (34 litters; 72 cubs ≤2.5-years-old) for 16 radio-collared females with home ranges distant from project activities. Mean litter size for all radio-collared females during construction (1982-84) was 2.06 (48 litters; 99 cubs ≤2.5-years-old), compared to 2.30 (40 litters; 92 cubs ≤2.5-years-old) after construction (1985-86). Overall mortality of COY was 37.5% through the 1st winter, nearly identical to the 37.7% mortality rate found by Miller (1987) in southcentral Alaska. Three of the 4 radio-collared females whose entire litters survived to age 2 resided close to construction sites in the Terror Lake study area.

Mortality

No bear deaths were directly attributed to construction and operation of the Terror Lake hydroelectric project during the study. However, 1 bear was killed in defense of life by a potential contractor during a 1981 visit to the powerhouse site. Improved access created by the project contributed to the deaths of 2 bears. One radio-collared female was killed in 1985 by an unknown party who apparently gained access with an off-road vehicle along the Port Lions distribution line. A deer hunter killed a bear in defense of life approximately 0.5 km west of the access road in the Kizhuyak River drainage in 1986. Hosking (1984) reported that deer hunting activity in the project area was intensive enough that the contractor was concerned about worker safety. Mortalities of radio-collared bears included 17 males and 20 females. Legal hunting was the leading cause of death (16), followed by natural causes (7), capture trauma (7), defense of life or property (4), and unknown causes (3).

Bear Observations by Workers

Workers commonly observed bears near project sites during construction. They reported seeing 262 bears, including 58 in 1982, 175 in 1983, and 29 in 1984. Bears were most often seen crossing the first 3 km of the access road adjacent to the lower Kizhuyak River. Bear sightings were so common, especially during mid-late summer when bears were using salmon in the lower Kizhuyak River, that workers often did not report observations. In contrast, Schoen and Beier (1988) reported that workers building a mining road in coniferous forest near a salmon stream on Admiralty Island seldom saw bears from the ground.

Aggressive behavior was noted in only 2 reports. In September 1982, a female with 3 COY charged to within 50 m of a bus on the road in alpine habitat east of Terror Lake. In July 1983, a female with 3 cubs of unknown age approached a surveying crew near the Port Lions distribution line, prompting the crew to climb trees.

Long-term Impacts

We estimate that approximately 500 ha of brown bear habitat was permanently altered by the Terror Lake hydroelectric project through inundation and removal of vegetation. An unquantified loss of habitat quality also resulted from the continued presence of a permanent work force at the powerhouse and periodic maintenance activities throughout the project area. This loss of habitat quality resulted in less than optimal use of available resources by bears. Project operations pre-determine continued bear-human interactions for the 50-year estimated life of the project.

McLellan and Shackleton (1988) reported that roads increased the vulnerability of grizzly bears to legal and illegal killing. Two bears were killed as an indirect result of improved access to the Terror Lake project area. Those incidents validate the concern of Miller (1987), who recommended minimizing road construction and other access improvements to reduce conflicts between recreationists and bears in the proposed Susitna hydroelectric project area. The access improvements of the Terror Lake project, including the road, jetty, and the cleared powerline rights-of-way will continue to attract increased recreational use, mainly by deer hunters. The access improvements will likely have little effect on bear and mountain goat hunters whose numbers are controlled with strict permit systems.

Construction of the Terror Lake project provided incentives for developing coastal lands. This will undoubtedly have serious future impacts on the brown bear population on northern Kodiak Island. During the study several cabins were built west of Kizhuyak Bay on coastal lands recently transferred into private ownership by the Alaska Native Claims Settlement Act of 1972. Electrical power is expected to be available to those landowners via the Port Lions distribution line, thereby providing incentive for year-round human occupancy, with accompanying conflicts between bears and humans. Surplus electrical power from the Terror Lake hydroelectric project stimulated the local electric cooperative to build an additional 77-km long distribution line in 1986 to service scattered residences along the road system south of Kodiak city. Providing electrical power to rural lands will likely stimulate additional human settlement and produce increased use of brown bear habitat in remote areas. As demands for electrical power increase, presently shelved plans for expanding the Terror Lake project into adjacent drainages with important brown bear habitat are expected to be re-activated. None of these secondary impacts was considered in the original environmental assessment.

Loss of salmon production or changes in distribution of spawning salmon could result in less available food for brown bears. Changes in the hydrologic regimes of the Terror and Kizhuyak Rivers were predicted to result in both minor losses and gains in salmon spawning habitat, which would be mutually compensatory (Federal Energy Regulatory Commission 1981). We suspected that heavy siltation resulting from excavation at the Terror Lake dam site may have caused bears to leave salmon feeding areas in lower Terror River prematurely in 1982, but there was no evidence that the project had permanent effects on salmon availability.

Project Mitigation

Important precedents were set in the Terror Lake hydroelectric project mitigation settlement negotiated between national conservation organizations and government regulatory agencies. Hosking (1984) discussed application of the "Habitat Evaluation Procedures" process in selecting mitigation lands. A 280-km^2 area of comparable brown bear habitat adjacent to the project area, owned by the State of Alaska and the Kodiak Island Borough, was dedicated to be managed for wildlife during the life of the Terror Lake project. A prohibition on livestock grazing on additional lands was also a part of the mitigation settlement. The mitigation settlement provided for studies of project impacts on affected fish and wildlife populations. One of the most important aspects of the mitigation settlement was the establishment of the Kodiak Brown Bear Research and Habitat Maintenance Trust. The Alaska Power Authority established a $500,000 trust fund to be administered by 4 appointed trustees, including a representative from the national conservation organizations that were instrumental in the mitigation settlement. The Trust has assisted in funding brown bear research done cooperatively by the USFWS and ADF&G since 1987.

The low incidence of bear-human conflicts during this project resulted from vigilant efforts by the government agencies administering construction permits and from reasonable cooperation by the contractor in addressing agency concerns for the welfare of the bears. Publicity generated by the controversial decision to build a hydroelectric project on the Kodiak NWR increased the sensitivity of all parties concerned with the project. The importance of the environmental monitor in enforcing the on-site mitigation procedures specified by the Terror Lake project license was documented by Hosking (1984). Although the environmental monitor, a USFWS biologist, did not have stop-work authority, he documented violations of the mitigation procedures and served as a liaison between the contractor and the agencies responsible for administering various permit provisions. The monitor served a valuable public relations role in providing information to workers on the importance of environmental considerations in project construction. The prohibition of firearms by the major contractor, although not strictly enforced, undoubtedly prevented bears from being killed. Workers were instructed on bear safety during periodic lectures presented by the environmental monitor and other biologists.

Using an oil-fired incinerator for garbage disposal during both construction and operational phases of the project helped minimize problems with bears. Continued use of unauthorized trash burning pits resulted in the contractor's being cited in 1986 for violating a State of Alaska regulation that prohibits leaving garbage so that it attracts bears. The contractor was fined and agreed to implement a set of specific stipulations on storage and handling of garbage (Smith and Van Daele 1988). This was an example of inadequate on-site mitigation procedures which Hosking (1984) pointed out often failed to minimize avoidable adverse impacts of the project.

CONCLUSIONS

Brown bears apparently co-existed with intensive construction activity by making minor shifts to nearby areas with heavy cover. We suspect that bears were displaced from alpine habitat and open lowlands, including salmon streams with little streamside cover. Bears apparently resumed use of open habitats after construction, although continued disturbance may have resulted in diminished use of lowland sedge flats and intertidal salmon spawning areas. We suspect that bears shifted to more nocturnal use of salmon streams near the access road and other construction sites. Disturbance of denning during construction and permanent loss of denning habitat were much less than had been predicted.

Correlating bear movements and habitat use patterns with construction activities was confounded by environmental factors and by the highly individual behavior patterns of brown bears. Annual variations in habitat use by bears were related to the phenology and availability of important food sources. Individual bears varied in their sensitivity to disturbance from construction, thus we stress the importance of monitoring a large sample of bears in all sex and age classes. We recommend that at least 2 years of pre-construction study and 2 years of post-construction study be planned to assess impacts of disturbance from future development projects on brown bears objectively.

Spencer and Hensel (1980) speculated that bears would be displaced from Terror Lake hydroelectric project sites into adjacent drainages where intra-specific strife, competition for food, and selection of unsuitable denning sites could result in increased bear mortalities. We did not observe any dramatic changes in population parameters or habitat use patterns indicating that major displacement of brown bears from the study area occurred. Residents of Port Lions reported an unusually high number of nuisance bears in the village in 1985, which they attributed to disturbance from the Terror Lake hydroelectric project. However, the reduced availability of natural bear foods during that year was considered a more likely reason for the unusually large number of bears that were attracted to the nearby village landfill (Smith and Van Daele 1988).

The long-term impacts of the Terror Lake hydroelectric project are expected to have much more serious implications to brown bear habitat management than the immediate effects of construction. Increased accessibility to high density brown bear habitat provided to deer hunters and other recreationists via the access road and powerlines will continue to result in increased killing of bears in defense of life or property. The availability of electric power to rural areas provided incentives for developing additional lands on northern Kodiak Island, which is expected to result in increased bear human-conflicts in the future (Smith et al. 1989). Demand for electrical power will likely result in expanded hydroelectric developments in areas where impacts on bear habitat could be more serious than occurred with the Terror Lake project. For example, impoundment of the Baumann Creek drainage, which was originally considered as an alternative hydroelectric site, could have disastrous impacts on the high density bear denning habitat discovered there (Van Daele et al. 1990). Future impacts studies should more completely address the secondary effects of hydroelectric projects on brown bear populations.

Intrusive short-term development activity was accommodated without major detrimental effects on brown bears. Abundant and varied food resources, as well as dense cover, allowed bears to continue to inhabit the project area. Adequate management of garbage, firearms restrictions, education of workers and minimizing permanent destruction of important habitat were also key factors. The mitigation settlement negotiated with the national conservation organizations was a good model for future developments in brown bear habitat.

An important product of this study was specific information on brown bear habitat and population ecology that will be useful in guiding future land use decisions and population management on Kodiak Island.

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