Wildlife Research Final Report

BROWN BEAR USE OF RIPARIAN AND BEACH ZONES ON NORTHEAST CHICHAGOF ISLAND: IMPLICATIONS FOR STREAMSIDE MANAGEMENT IN COASTAL ALASKA

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Cover photo by LaVern Beier

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EXECUTIVE SUMMARY

Southeast Alaska provides excellent habitat for brown bears (*Ursus arctos*) and populations are of regional, national, and global significance. Abundant spawning salmon (*Oncorhynchus* spp.) and landscapes which provide for all natural history requirements have allowed bear populations to reach high densities. Streamside habitat management for brown bears has been a major management issue in Southeast Alaska since the coming of industrial-scale clearcut logging in the 1950s. Most experts agree that retaining no-cut forested buffers along salmon spawning streams is important to the maintenance of healthy, productive populations of brown bears in Southeast Alaska. However, the question arises on the size and management of the no-cut buffers.

We studied the ecology of brown bears in relationship to riparian and beach fringe habitats during the late summer from 2001-2003 on northeast Chichagof Island, Alaska to provide better insight into streamside and estuary habitat needs. Using new technologies not available to previous researchers, we explored 3 primary, related research questions: 1) Do brown bears use space differently in an altered watershed compared with a relatively unaltered watershed; 2) Does a watershed with relatively intact streamside vegetation support a greater abundance of brown bears; and 3) Do brown bears, especially females, feed on less salmon in an altered watershed. Additionally, we evaluated a field protocol to determine areas along streams that are especially important for foraging brown bears (i.e., "important foraging areas").

We studied the spatial and habitat use by brown bears during the late summer in 2 watersheds with contrasting streamside management. We captured brown bears along 5-km stretches of 2 productive salmon spawning streams (Freshwater and Spasski creeks) during July 15 to September 15 and attached GPS collars on 14 male and 22 adult female brown bears. Freshwater Creek represented a relatively unaltered watershed with only 3% of the area within 150 m (500 ft) of the stream clearcut. In contrast, about 38% of the 150-m streamside zone along Spasski Creek had been clearcut. We found that males stayed close to the stream regardless of streamside management. On the less-altered Freshwater Creek, the median distance from the salmon spawning stream for males was 51 m (167 ft) and 75% of the locations were within 175 m (575 ft). On the highly altered Spasski Creek, the median distance was 41 m (135 ft) and 75% were within 114 m (374 ft). Female brown bears showed greater variability and significant differences between the watersheds (and thus between degrees of habitat alteration given all other things being similar). Female locations in less altered Freshwater Creek were significantly closer to the stream (median = 147 m, 482 ft) compared with Spasski Creek (median = 713 m, 2,340 ft). In order to include 75% of the use of female bears on Freshwater Creek, a buffer would need to extend 349 m (1,145 ft) on either side of the stream. The current management buffers of 31 m (100 ft) and 150 m (500 ft) would contain only 14% and 52%, respectively, of use by adult females on Freshwater Creek.

Male brown bears selected closed forest or estuary habitats near salmon streams or beach fringe at the study area and home range scales. Habitat selection by female brown bears was more variable and differed from males. Females showed a strong selection for estuary, older clearcuts, closed forest, and avalanche slopes at the study area scale. At the home range scale, females showed selection for the same habitats, but the relative strength was lower.

We estimated the abundance of brown bears along 5-km segments of Freshwater and Spasski creeks during the late summer of 2003 using DNA markers and capture-mark-recapture (CMR)

models. We collected hair for individual identification by DNA analysis from 100 hair-snare sites at approximately 50-m intervals along the study streams. We completed 6 CMR sessions on Freshwater Creek and 5 sessions on Spasski Creek. Male brown bear numbers remained relatively constant throughout the salmon spawning season and did not differ significantly between streams, with session estimates ranging from 18 to 33 bears. In contrast, the number of female bears changed substantially during the season and differed significantly between streams. Female numbers peaked at the beginning of the salmon spawning season during the first recapture session and then decreased linearly throughout the remainder of the recapture sessions. The abundance of females was significantly greater on Freshwater Creek throughout the season compared with Spasski Creek. The peak number of females on Freshwater Creek was 47 compared with 24 female bears on Spasski Creek. Thus, the number of female brown bears using the less altered watershed (i.e., Freshwater Creek) was nearly twice the number of bears on the greatly altered Spasski Creek.

We determined the amount of salmon in brown bear diets during the late summer using stable isotope analysis. We found that male bears fed mostly on salmon regardless of study stream. In contrast, the amount of salmon in the diets of females varied greatly and differed significantly between the watersheds with females on Freshwater Creek consuming significantly more salmon than females on Spasski Creek. We found a strong correlation between the amount of salmon in diets and the median distance from a salmon spawning stream. Thus, females on the altered Spasski Creek spent more time farther from the stream and consumed less salmon. Although some females in Spasski Creek drainage spent considerable time near the stream, they still had low amounts of salmon in the diet.

Current Tongass National Forest (TNF) policy calls for the retention of a 150 m (500 ft) no-cut buffer along important brown bear foraging sites (USDA Forest Service 1997), but does not specify how these sites will be identified. We designed and tested a field protocol to determine the relative amount of bear sign along streams as a means of identifying important brown bear foraging sites. Based on bear relocations obtained with GPS collars, we classified stream reaches into high and low use areas, as well as reaches that could support spawning salmon but for a feature downstream that blocks the fish (i.e., non-salmon reaches). We recorded permanent (perennial trails, beds, rub trees) and short-lived (ephemeral trails, salmon carcasses, and scats) bear sign along transects in each stream reach category (salmon = 52 transects, no salmon = 21 transects; high use = 29 transects, low use = 8 transects). We found 980 signs of bear-use, the most common of which was bear trails (71%; 525 perennial and 169 ephemeral) followed by signs of foraging (15%; of which 95% were diggings for skunk cabbage), beds (7%), scats (4%), salmon remains (3%), and rub-trees (trace). Perennial trails were twice as dense along salmon reaches as non-salmon reaches and ephemeral trails were nearly 5 times as dense where salmon spawning occurred. Within streams with spawning salmon, we found few differences in density of bear sign between high and low use bear areas.

Key findings:

1) Our results confirmed the importance of low-elevation, riparian forests to brown bears on northeast Chichagof Island, and presumably all of Southeast Alaska where brown bears occur. Both sexes of brown bears strongly selected closed-forest habitats along salmon spawning streams and estuaries during mid-to late-summer;

2) Spatial use patterns of browns bears, especially females, differed with increased landscape alteration. In the heavily altered watershed with substantially impacted streamside vegetation, female brown bears spent significantly more time farther from salmon spawning streams and less time within 150-m of salmon streams;

3) Abundance of female brown bears in a watershed with relatively intact forested stream buffers along salmon spawning streams was significantly greater than the more altered watershed. Thus, a watershed with intact forested streamside vegetation should provide for larger brown bear populations compared with more altered watersheds;

4) Female brown bears in the less altered watershed consumed significantly more salmon than females in the highly impacted watershed. A salmon stream with limited forested buffers would provide less cover and security (critical for females) for foraging bears, thus female bears in highly altered landscapes would be less productive with reduced opportunity to feed on salmon.

5) We found the transect method of sampling a stream area to determine if it is important for foraging bears was not a good solution to the problems associated this S&G. In fact, our research suggests that all riparian habitats associated with salmon spawning areas are important for bears;

6) Finally, we recommend that a no-cut buffer of at least 150 m (500 ft) be retained along all stream segments with spawning salmon in forested landscapes where brown bears occur because substantial no-cut buffers provide female brown bears with adequate cover for foraging on spawning salmon. Where management objectives call for abundant, healthy brown bear populations, either complete watershed protection or no-cut buffers of 305 m (1,000 ft) should be applied.

Contents

INTRODUCTION

Background

Brown bears (*Ursus arctos*) have long been considered a wildlife species of high public interest in the north Pacific coast including coastal Alaska (Sidle and Suring 1986, Alaska Department of Fish and Game 2000, Interagency Brown Bear Study Team 2001) and the North Coast of British Columbia (British Columbia Ministry of Environment 1995, Horejsi and Gilbert 2006). Riparian habitats, especially with spawning Pacific salmon (*Oncorhynchus* spp.), provide important habitats for brown bears (Schoen et al. 1994, Titus et al. 1999, Suring et al. 2006). During the late summer, most brown bears concentrate in riparian areas with spawning salmon (Schoen and Beier 1990, MacHutchon et al. 1993, Titus and Beier 1999, Suring et al. 2006). Researchers and managers have long recognized the importance of no-cut buffers along salmon spawning streams in forested environments to maintain access for brown bears to spawning salmon (Schoen and Beier 1990, Swanston et al. 1996, Titus and Beier 1999, Bunnell et al. 2001). No cut, forested riparian buffers may be particularly important to subordinate bears, especially females, so they can avoid or at least minimize conflicts with more dominate bears, particularly adult males (Ben-David et al. 2004).

Besides providing important habitats for brown bears in coastal forests, riparian zones are rich ecological areas (Naiman et al. 1998, Naiman et al. 2000, Schindler et al. 2003). The role of anadromous salmon and the transport of salmon by bears into riparian ecosystems have recently been recognized (Willson and Halupka 1995, Reimchen et al. 2002, Hilderbrand et al. 2004). Hilderbrand et al. (1999*a*) found that brown bears were important vectors of salmon-derived N into riparian systems, and the deposition of salmon-derived nitrogen (N) was highly correlated with bear spatial patterns. Within 500 m of the stream, Hilderbrand et al. (1999*b*) estimated that 15.5-17.0% of the total N in spruce foliage was derived from marine-origin, decaying salmon. This influx of marine nutrients, especially N, can be ecologically significant because many northern freshwater and terrestrial ecosystems are nutrient limited (Chapin et al. 1986, Hilderbrand et al. 2004). Nutrient inputs increase productivity of riparian and adjacent areas (Helfield and Naiman 2001).

In addition to feeding on spawning salmon, brown bears use daybed loafing sites and forage on berries (*Oplopanax horridum*, *Rubus* sp., *Ribes* sp. and *Vaccinium* sp.) and skunk cabbage (*Lysichitum americanum*) within or adjacent the riparian zone (McCarthy 1989, Schoen and Beier 1990). On Admiralty Island, 83 day beds averaged 52 m (SE = 3.1) from streams (Schoen and Beier 1990). Most of these day beds were associated with large diameter, live trees ($\bar{x}$ dbh = 110 cm). The extent of riparian vegetation depends on landform and stream process group (USDA Forest Service 1997). Devil's club and skunk cabbage, important bear foods (McCarthy 1989), are characteristic of flood plain and alluvial fan landforms. Depending on streamside characteristics, flood plain width often exceeds 60 m on each side of a stream.

A healthy ecosystem has been defined as one that is: 1) stable and sustainable, 2) able to maintain its organization and autonomy over time, and 3) resilient to stress (Rapport et al. 1998). We incorporate these concepts in our definition of a healthy population. A healthy brown bear population should be relatively stable and sustainable given desired human use, able to maintain its organization and function over time, and resilient to stressors including human impacts and stochastic environmental and demographic events. In contrast, a viable population infers long-term persistence of a population that maintains its vigor and potential for evolutionary adaptation (Soule 1987). Often thought of as a minimum value, this definition does not allow for significant human uses. The Alaska Constitution and Statutes mandate the management, maintenance, protection, and improvement of game resources in the best interest of the economy and well-being of the people. Thus, the mandates of the State of Alaska require the maintenance of healthy wildlife populations, not just viable ones.

The National Forest Management Act (NFMA; 1976) requires each national forest and grassland to have its own integrated plan. The Tongass National Forest revised its management plan in 1997 under NFMA and the 1982 planning rule (codified at 36 CFR part 219). This planning rule requires that "fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area". On most federal lands in Southeast Alaska, habitat management is guided by the Tongass Land Management Plan (TLMP, USDA Forest Service 1997), and requires maintaining habitat for viable populations of wildlife (Suring et al. 1993, Iverson and Rene 1997, USDA Forest Service 1997) instead of healthy populations. Because current brown bear populations in Southeast Alaska probably exceed viable levels, a plan that provides habitat for the maintenance of only viable populations would eventually lead to the elimination of human use.

Aside from the intrinsic ecosystem values of high brown bear densities, other values encourage managing for naturally high numbers of brown bears and the habitats upon which they depend, including the economic importance of both viewing and hunting to the guiding industry (Titus et al. 1994). In Southeast Alaska, the demand for brown bear hunting exceeds the supply that existing populations could sustain and, thus, is restricted by regulation (Alaska Department of Fish and Game 2000, 2006) and the number of commercial use permits available for guided, nonresident hunting on federal lands (USDA Forest Service 2004). Game Management Unit 4 (GMU 4) in Southeast Alaska, including the islands of Admiralty, Baranof, and Chichagof, is one of the most desirable brown bear hunting and viewing areas in the world (Alaska Department of Fish and Game 1998). The current management strategy for GMU 4, developed by citizen and government stake holders, recommended maintaining at least current human use levels and reducing user conflicts (Alaska Department of Fish and Game 2000).

As part of an overall wildlife conservation strategy, the TLMP allocated a system of reserves of various sizes and spacing along with specific standards and guidelines (S&Gs) for the management of wildlife habitats (USDA Forest Service 1997). The reserves were to be managed to maintain the abundance and distribution of habitats to sustain viable, well-distributed populations of all species through the foreseeable future. In addition to reserves, several forest-wide S&Gs were established to conserve brown bear habitats (USDA Forest Service 1997). For example, riparian management S&Gs must consider the needs of riparian-associated wildlife species, especially brown bears. Based primarily on anadromous fish needs, riparian standards and guidelines prohibit commercial timber harvest within at least 30 m (100 ft) of Class 1 (contain anadromous fish) and some Class 2 streams (contain resident fish, USDA Forest Service 1997). Depending on stream process group, streamside buffers may extend to the entire riparian management area (RMA), i.e. at least 43 m (140 ft) for alluvial fan channel types and at least 40 m (130 ft) for flood plain channels. Along important brown bear foraging sites, Wildlife S&Gs call for the establishment of 150-m (500 ft) forested buffers to provide cover for brown bears (USDA Forest Service 1997). Beach and Estuary Fringe S&Gs restrict timber harvest within 305 m (1,000 ft) of all marine coastline and estuaries to maintain important habitats for wildlife, including brown bears. During the TLMP Revision process, expert panels expressed concern with the long-term viability of brown bear populations unless adequate riparian vegetation was maintained, especially in areas with spawning Pacific salmon (Swanston et al. 1996, USDA Forest Service 1997). These panelists strongly recommended that a no-cut buffer of at least 150 m (500 ft) be maintained along streams considered important for brown bear foraging (Swanston et al. 1996). On the Chugach National Forest, a no-cut buffer of 230 (750 ft) is required along important bear foraging areas (USDA Forest Service 2002) and no new road construction is allowed in this brown bear management zone.

The recent introduction of animal collars containing global positioning system (GPS) receivers presented the opportunity to collect frequent positional data independent of time, weather, and personnel availability (Arthur and Schwartz 1999). Although costly, GPS-equipped collars are capable of collecting data not possible from traditional VHF collars, especially in the frequent poor weather conditions of coastal Alaska. Also, the use of GPS collars may be important to verify assumptions from conventional radiotracking studies (e.g., weather conditions or daylight does not bias sample of animal locations). With an early generation of GPS collars, Arthur and Schwartz (1999) found an overall successful fix rate of about 65%. As GPS receivers have moved to 3rd generation models, performance and storage capacity have increased (S. Tomkiewicz, Telonics, Mesa, AZ, personal communication). Flynn and Beier (2001) found GPS collars performed adequately in the larger-sized, closed forests of Southeast Alaska. With the elimination of Selective Availability for GPS signals, the accuracy of GPS collar locations was adequate to determine use of narrow, linear habitats, like riparian and beach zones.

Current TNF policy includes a process for determining important brown bear foraging sites, but easily implemented field criteria have not been established. The process states that segments of anadromous fish streams classified as moderate gradient/mixed control and flood plain will be examined in the field for bear sign. If the area within 150 m (500 ft) of the stream segment was already in a protected land use designation (LUD), no field visit would be necessary. No specific criteria for distinguishing important foraging sites are provided. Bloom et al. (1998) described an attempt to develop a protocol to determine important bear foraging sites, but more work was needed. That study was neither peer reviewed nor published.

The term "important" bear foraging site leaves much to interpretation. Is it important to the individual or the population? Wielgus and Bunnell (1994) found that female grizzly bears avoided food-rich, male-occupied habitats in Alberta. Because female bears with cubs may avoid large male bears at salmon foraging sites (Ben-David et al. 2004, Rode et al. 2006), foraging sites that receive less use by potentially infanticidal male bears may actually be more important to reproductive females and the bear population (Wielgus and Bunnell 2000). Gende et al. (2001) found that bears consumed more of salmon carcasses and were less selective in body parts eaten when salmon availability was lower. Thus, bears on streams with fewer salmon try to compensate their energy demands by eating more of each salmon carcass. Hilderbrand et al. (1999*b*) reported that access to salmon was important for brown bear productivity. Thus, small streams with less overall use may be quite important to the productivity of brown bear populations. These small streams may be very important to the high-density brown bear populations in GMU 4 and some mainland areas of Southeast Alaska because small streams are dispersed across the landscape. These numerous small streams with small, but easily accessible, salmon runs may distribute a dense brown bear population and provide greater access to salmon than a few larger streams with more salmon. Therefore, the combination of smaller and larger salmon spawning streams dispersed across the landscape, combined with other important late summer bear foods (e.g., berries), leads to a bear social structure and food resource that may combine for relatively high densities.

The development of non-invasive, genetic sampling techniques used in conjunction with capture-mark-recapture (CMR) models has greatly increased our ability to estimate brown bear abundance (Woods et al. 1999, Mowat and Strobeck 2000). Individual bears can be identified from DNA extracted from hair roots (Paetkau 2003). Hair samples from brown bears can be collected at hair traps set at capture sites within study areas. By periodically removing hair samples from hair traps during capture sessions, capture histories of individual brown bears can recorded. By using the appropriate CMR model, the number of bears using an area can be estimated (Mowat and Strobeck 2000, Lukacs and Burnham 2005*a*).

Although density may not always reflect habitat quality completely, the number of individuals in an area is an important indicator of habitat quality (Van Horn 1983) and often used in habitat evaluations (Verner et al. 1986). Increasing fitness is an alternate measure of habitat quality, defined as the product of density, mean individual survival probability, and mean expectation of future offspring (Van Horn 1983). Thus, a measure of bear density, especially density of females, is a first step in accessing habitat quality. Because increased amounts of salmon in diets of female bears increases their productivity (Hilderbrand et al. 1999*c*), habitat quality would be increased by greater salmon in the diets of females. By comparing bear numbers and female diets in our stream systems, we can examine differences in habitat quality and whether management of streamside vegetation affects habitat quality.

In preparation for the TLMP Revision, a habitat capability model was developed for brown bears in Southeast Alaska (Schoen et al. 1994). This model was constructed to evaluate the cumulative effects of forest management alternatives on brown bears. This model assumed that estuary and riparian habitats were of highest value for brown bears. Furthermore, this model assumed a density of bears in each habitat during the late summer. Habitats with the greatest value had the greatest density, and bear densities in all other habitats were assumed to be proportional to habitat selection ratios estimated from radiotelemetry studies (Schoen et al. 1994). The accuracy of these brown bear densities has never been evaluated.

Study Objectives

This study was designed to provide ecological information on brown bear use of riparian and beach zones on Chichagof Island during the salmon-spawning period. These results were used to further evaluate the effectiveness of the TLMP conservation strategy, especially the specific management S&Gs for brown bears pertaining to riparian and beach fringe habitats. Also, information was gathered on criteria to classify stream segments as important bear foraging sites and monitoring protocols for brown bears.

Our research objectives were:

1) To determine spatial use and habitat selection by brown bears during the late summer in 2 watersheds with differing amounts of habitat alteration on Northeast Chichagof Island, Southeast Alaska.

2) To estimate abundance of brown bears on salmon spawning streams with different streamside vegetation management during the late summer on Northeast Chichagof Island, Southeast Alaska.

3) To determine diets of brown bears using riparian habitats during the late summer on Northeast Chichagof Island.

4) To develop a practical field protocol for evaluating bear use of riparian and beach buffer areas when conducting timber sale layout.

Study Design Considerations

Our study design compared several brown bear population parameters between 2 similar watersheds but with substantial differences in the amount of streamside vegetation altered by clearcut logging. We were able to incorporate only 2 watersheds into our study design because of financial and personnel constraints. Because of project scope, we were not able to study how specific buffer distances and configurations would affect brown bear numbers. We purposely selected adjacent watersheds with the greatest differences in streamside management. Although no 2 watersheds are identical, we tried to choose 2 watersheds that were largely similar in physical attributes, except for the amount of clearcut logging. From previous research (Titus et al. 1999), both watersheds were known to have numerous brown bears. Although adjacent, few brown bears used both drainages (Titus et al. 1999, Chapter 1). For the watershed-specific analyses, we used only bears that had been captured in each respective watershed.

Because of financial constraints, we limited the project's scope for the spatial analysis to only adult bears, so no juvenile bears were radiocollared. For most analyses, we used the individual bear as the sample unit and separated the data by sex.

Study Areas

General

Southeast Alaska consists of rugged mountains, numerous islands, and conifer-dominated rain forest. Mountains rise from the sea to over 1,400 m. The maritime climate is cool and moist throughout the year. In the Juneau area, the annual precipitation ranges from 135 cm at the airport to 236 cm in the downtown area. Heavy snow accumulations often occur during winter; higher elevations are snow-covered for 7 to 9 months of the year. The natural vegetation is dominated by temperate rain forest, one of the world's most limited ecosystems, interspersed with muskegs and alpine tundra. Because of the lack of frequent, large-scale, catastrophic natural disturbance, the rain forests of Southeast Alaska are predominantly in an old-growth condition (Alaback and Juday 1989). Sitka spruce (*Picea sitchensis*) or western hemlock (*Tsuga heterophylla*) dominate the overstory of most plant associations on productive sites (Martin 1989, Alaback and Juday 1989, Samson et al. 1989). Poorly drained sites often contain mountain hemlock (*Tsuga mertensiana*), Alaska-yellow cedar (*Chamaecyparis nootkatensis*), or western red cedar (*Thuja plicata*). The forest understory, depending on site conditions, may be dominated by shrubs such as blueberry (*Vaccinium* sp.), rusty menziesia (*Menziesia ferruginea*), or devil's club (*Oplopanax horridum*). Common forbs in the old-growth forest include bunchberry (*Cornus canadensis*), trailing raspberry (*Rubus pedatus*), and skunk cabbage (*Lysichitum americanum*). Riparian, beach fringe, and avalanche slide habitats have additional shrubs that produce berries including salmonberry (*Rubus spectabilis*), highbush-cranberry (*Viburnum edule*), stink current (*Ribes bracteosum*), and trailing current (*Ribes laxiflorum*). Important seasonable bear foods in the estuaries and beach fringe include sedge (*Carex lyngbyei*) and chocolate lily (*Fritillaria lanceolata*).

Most watersheds are quite small and drain directly to saltwater, and many streams support spawning Pacific salmon (*Oncorhynchus* spp.). The salmon species include chinook (*O. tshawytscha)*, chum (*O. keta)*, coho (*O. kisutch*), pink (*O. gorbuscha*), and sockeye (*O. nerka*). Distributions and timings of runs vary within the region (Halupka et al. 2000). Pink and chum salmon are most widespread and abundant, followed by coho. Sockeye are limited to systems containing lakes, and Chinook spawn in only a few locations in Southeast Alaska. Typically, pink and chum salmon first appear in the streams during early July. The peak spawning period for most species is usually during late July through August. By the end of September, most salmon have finished spawning and few carcasses remain in the streams, but some streams have later runs. Typically, coho salmon continue to spawn throughout the autumn. Species-specific spawning periods differ by more than a month in some stream systems example, some pink salmon spawning periods extend into September and some coho salmon spawning takes place in November and only late-denning males seem to take advantage of these late coho runs.

Chichagof Island

Northeast Chichagof Island, Southeast Alaska, has 26 productive salmon-spawning streams and abundant brown bear populations (Miller et al. 1997, Titus et al. 1999). We selected 2 of these watersheds for detailed study (Fig. 1). Each watershed had a productive salmon spawning stream of similar size, channel types, flow, and salmon escapements. We selected a 5-km segment of each stream for intensive study (Fig. 1). Because of different ownership and management objectives, the 2 watersheds represented a contrast of streamside vegetative conditions because of past logging activities (Fig. 2). On Freshwater Creek (U.S. Forest Service lands), only 2.5% of the study area within 150 m had been cut, leaving 81% in open or closed forest (Table 1). On Spasski Creek (private lands), 38% of the study area within 150 m of the stream had been clearcut, leaving 52.7% forest (Table 1).

Because of past research, this area had a large number (>100) of previously radiocollared brown bears with known use patterns (Titus et al. 1999). Because of its relatively close proximity to Juneau, travel time and costs to access the study sites were minimized. The extensive road system of northeast Chichagof provided good access to most areas including study streams. Also, housing and other support facilities were available nearby.

Freshwater Creek.—Freshwater Creek (Fig. 1) represented a productive salmon-spawning stream under Forest Service management with only limited human alteration to the streamside vegetation. In order to include 5-km of productive salmon-spawning stream meeting our criteria, the lower 2.4 km of the North Fork and the lower 2.6 km of the South Fork were combined to create the study stream segment. Freshwater Creek is nearly all flood plain channel types with the North Fork a low-gradient flood plain channel and the South Fork a wide, low-gradient flood plain type (Paustian 1992). During 1997-2001, annual stream counts recorded from 23,000 to 43,000 pink salmon and 0 to 400 chum salmon in the stream, with the peak season occurring mid-August (ADFG, Division of Commercial Fisheries files, Douglas, Alaska).

Spasski Creek.—The Spasski Creek watershed (Fig. 1) was substantially clearcut during the 1980s and 1990s. Some clearcut logging continued into 2003, and prior to analysis we updated the landcover maps with recent low elevation photos taken in 2004. We selected a 5-km section of the lower stream for study. Similar to Freshwater Creek, the study section of stream was mostly a low-gradient flood plain channel type (74%) with a low-gradient contained channel in the upper 26%. During 1997-2001, annual stream counts recorded from 3,000 to 107,000 pink salmon and from 900 to 8,000 chum salmon during the peak season in mid-August (ADFG, Division of Commercial Fisheries files, Douglas).

Freshwater and Spasski creeks each have comparable 5-km section of low-gradient channels where salmon spawn. These study stream segments provided a contrast in streamside vegetation management while containing similar stream characteristics (channel types). Also, we found that patterns of stream flow were similar between streams (Fig. 3). In 2002, stream flows in both streams were quite variable throughout the study period. In 2003, stream flows for both streams were low during the early part of the study period, and then increased rapidly and remained high until the end. Although the channel characteristics of the study sections of the streams are similar, Freshwater Creek has more consistent pink salmon runs while Spasski Creek has a highly variable pink run and consistently more chum salmon (ADFG, Division of Commercial Fisheries files, Douglas).

Although brown bear hunting occurred in each area after September 14, all access for hunting was from saltwater because the use of motorized land vehicles for hunting was prohibited (Alaska Department of Fish and Game Regulations). Because of better saltwater access, Freshwater Creek traditionally receives more hunting pressure compared with Spasski Creek.

FIGURES

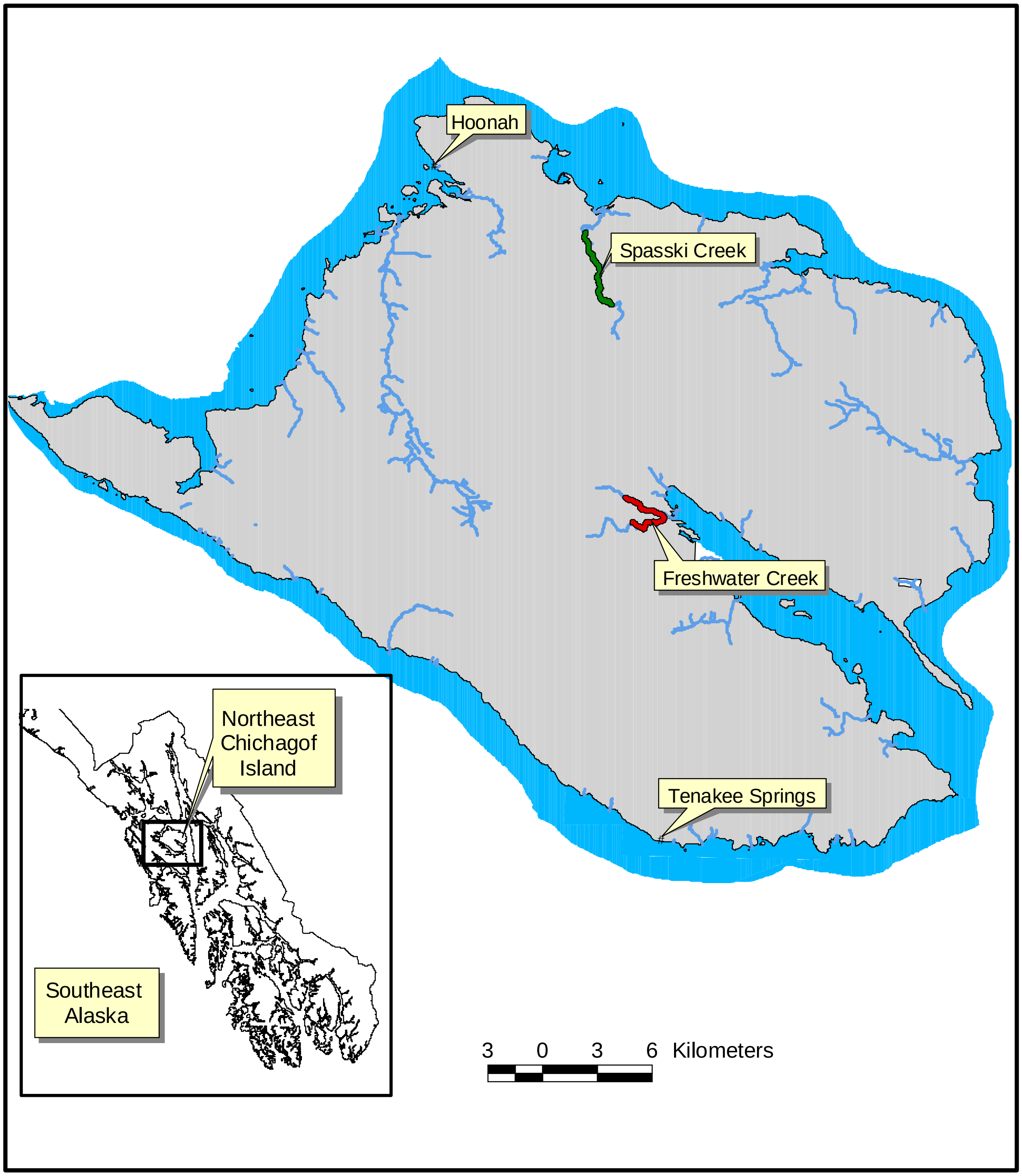

Figure 1. Study streams on northeast Chichagof Island, Southeast Alaska.

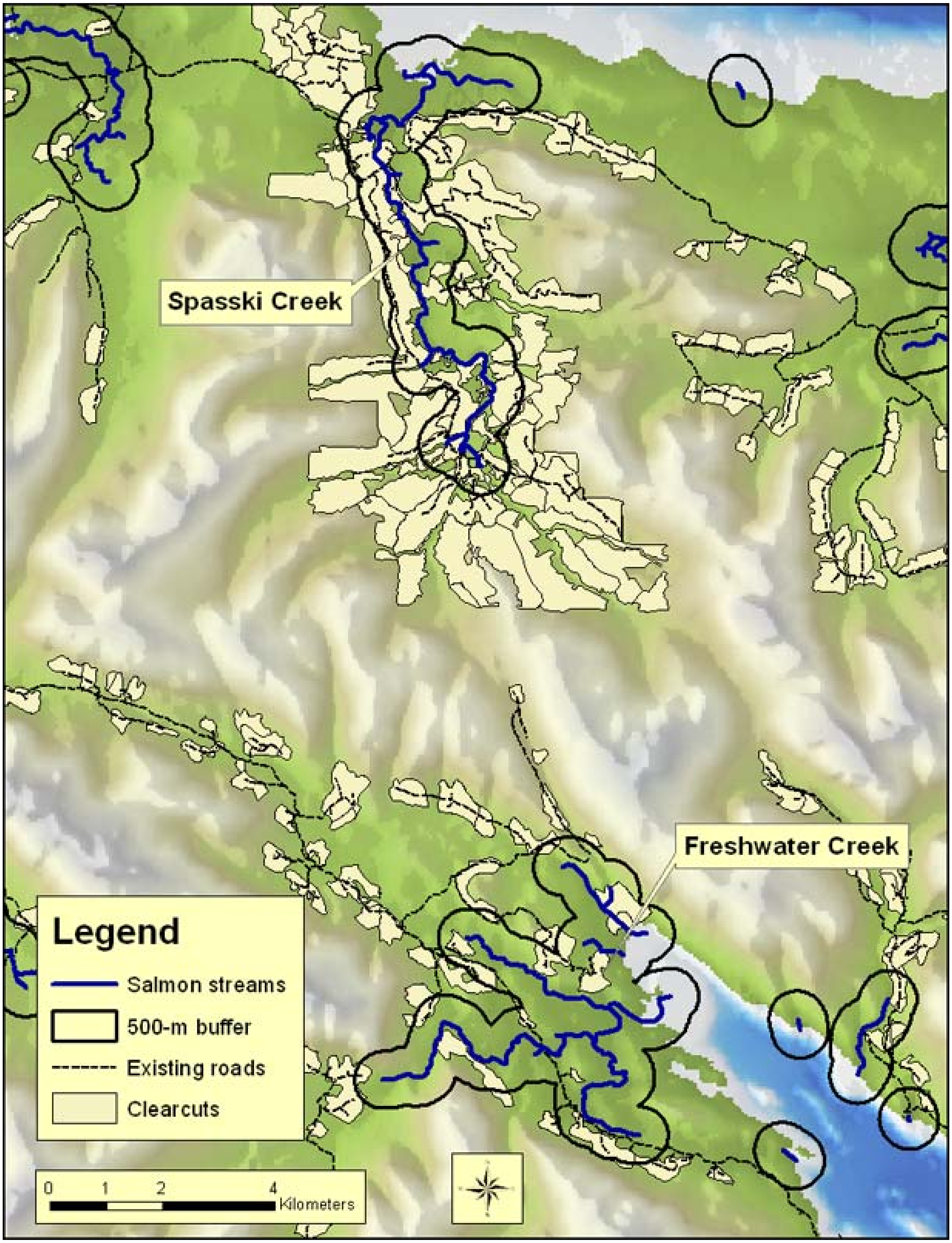

Figure 2. Study streams showing clearcuts and a 500-m buffer along those streams, northeast Chichagof Island, Southeast Alaska.

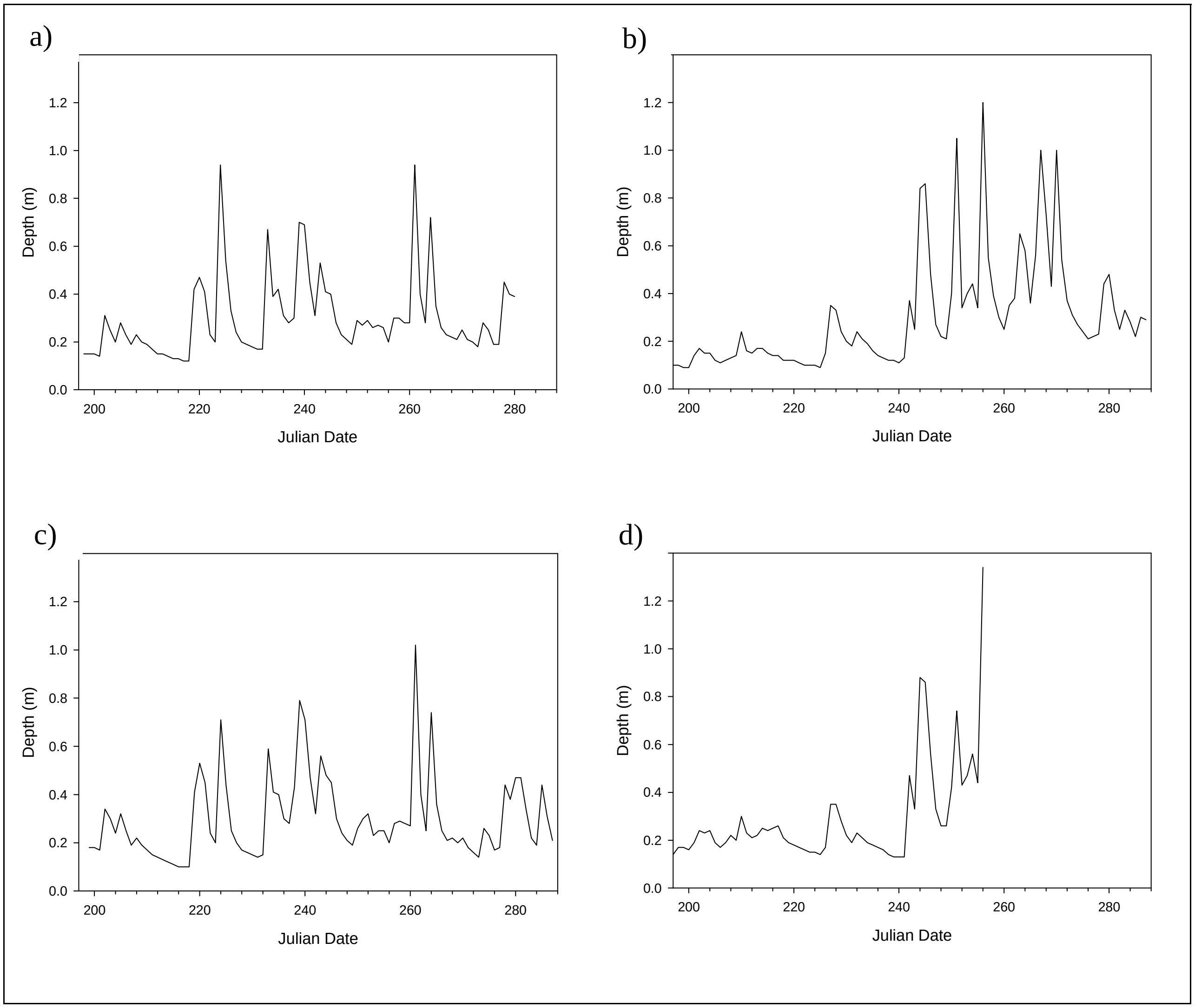

Figure 3. Maximum daily water depth measured on Freshwater and Spasski Creeks from July 16 to October 14 in 2002 and 2003, as an indication of flow. Line represents the maximum daily stream depth measured at a water gauge located within the 5-km study area. Letters denote creek and year: a) Freshwater Creek 2002; b) Freshwater Creek 2003; c) Spasski Creek 2002; d) Spasski Creek 2003.

TABLES

Table 1. Habitat composition of area within 150 m of study sections of Spasski and Freshwater creeks on northeast Chichagof Island, Southeast Alaska. Habitat categories as presented in Chapter 1.

Habitat	Spasski Creek		Freshwater Creek	
category	Area (ha)	Percent	Area (ha)	Percent
Non forest	2.14	1.4	10.29	6.6
Scrub forest	10.24	6.6	15.43	10.0
Open forest	17.96	11.6	70.54	45.6
Closed forest	65.22	42.1	54.84	35.4
Clearcut	59.20	38.3	3.80	2.5

Chapter 1

SPATIAL USE AND HABITAT SELECTION BY BROWN BEARS DURING THE LATE SUMMER ON NORTHEAST CHICHAGOF ISLAND, SOUTHEAST ALASKA

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INTRODUCTION

Brown bears (*Ursus arctos*) have long been recognized as a high profile species with great public interest for hunting and viewing (Titus et al. 1994). The allocation of lands that have a wildlife emphasis has remained a controversial issue in the North Pacific coast of Alaska, especially on the Tongass National Forest (TNF, USDA Forest Service 1997). Previous studies have found that most brown bears were closely associated with salmon spawning streams during late summer (Schoen and Beier 1990, Schoen et al. 1994, Titus and Beier 1999, Titus et al. 1999). Pacific salmon (*Oncorhynchus* spp.) provide an important food source for coastal bears (McCarthy 1989, MacHutchon et al. 1993, Hilderbrand et al. 1999*b*, Ben-David et al. 2004). Boulanger et al. (2004*a*) found a decrease in coastal grizzly bear (*Ursus arctos*) demographic parameters with a decrease in salmon availability. Bear experts have consistently recommended that no-cut buffers be maintained along salmon spawning streams in forested ecosystems to maintain healthy and productive brown bear populations along the north Pacific coast (Swanston et al. 1996, USDA Forest Service 1997, Bunnell et al. 2001). These no-cut stream buffers provide cover for foraging brown bears, especially females and young bears (Ben-David et al. 2004, Rode et al. 2006).

In Southeast Alaska, forested buffers are required along most water bodies based on the needs of multiple wildlife species, water quality, and fish habitat. The size and applicability of buffers depends on landscape features, management priorities, and land ownership (Table 1). Water bodies include salt water, freshwater lakes, and streams. The State Forest Practices Act determines land management on state and private lands and the Tongass Land Management Plan (TLMP) guides management on TNF lands. Because the TNF occupies about 74% of Southeast Alaska's land area, management of TNF lands, or TLMP, has a greater impact on the region's wildlife. In order to maintain adequate habitat to provide for viable brown bear populations across the TNF, the TLMP adopted several habitat conservation measures (USDA Forest Service 1997). Along with a reserve system, these measures required the maintenance of no-cut buffers of various widths along beaches, estuaries, and streams. In particular, no-cut buffers could be up to 150 m (500 ft) along "important" bear foraging sites (e.g., salmon spawning streams) as determined by field review.

For brown bears, information used to develop the prescriptions was based on previous research using standard radiotelemetry (Schoen and Beier 1990, Titus and Beier 1999, Titus et al. 1999). New technologies (i.e., GPS collars) allow a more detailed look at the spatial use of brown bears during the late summer. Frequent, precise locations provide a fine-grained, intensive look at spatial relationships during the period of interest. By describing differences in spatial use patterns within watersheds with contrasting riparian management, we can gain better insight into potential impacts of management actions on brown bear populations. Furthermore, we can gain insight on the efficacy of various buffer sizes by comparing spatial use patterns between a relatively natural watershed and a heavily altered watershed. We expected that spatial use by brown bears would be concentrated near salmon spawning streams during the late summer, and that habitat composition would influence spatial distribution. We hypothesized that spatial use would be similar in the less impacted and heavily altered watersheds regardless of riparian management implementation. In order to test this hypothesis; we measured the spatial use patterns of brown bears captured along 2 salmon spawning streams with different riparian management during the summer on Chichagof Island, Southeast Alaska.

METHODS

Brown Bear Capture

Adult brown bears were captured in the late spring or summer and fitted with GPS radiocollars. Some individuals were captured by darting from a helicopter in alpine habitats near the study streams, and others were captured in Aldrich foot snares set along trails adjacent salmon-spawning streams or within the beach zones. For the helicopter captures, bears were approached within darting range with a Hughes 500 helicopter and injected with Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) for immobilization at a dosage of 7-10 mg/kg estimated body weight (Taylor et al. 1989). We targeted previously radiocollared bears, especially females with young cubs, which were thought to use one of the study streams. During the past 14 years, about 100 brown bears have been captured in the alpine on northeast Chichagof Island (Titus et al. 1999). Although we couldn't predict with complete certainty which salmon-spawning stream would be used by individual bears captured in the alpine, most captured bears choose streams in adjacent watersheds (Schoen and Beier 1990, Titus et al. 1999).

We used Aldrich foot snares to capture adult brown bears within the riparian zones of the specific study streams from mid-July through early September. In each study watershed, we attempted to collar at least 3 adult males and 3 adult females. Although we couldn't predict with complete certainty whether an individual bear would remain on a stream, we assumed that most bears would remain on or near the capture stream. Snared bears were darted and injected with Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) for immobilization at a dosage of 7-10 mg/kg estimated body weight (Taylor et al. 1989). All captured bears were marked with eartags, most instrumented with GPS collars and a few with conventional VHF radiocollars, and then released at the capture site. Blood, tissue, and hair samples were collected for DNA analysis.

The Animal Care and Use Committee of the Alaska Department of Fish and Game (ACUC 03-009) approved all methods of animal handling used in this study.

GPS Location Data

In order to collect frequent, precise bear locations, we deployed GPS-equipped (3rd generation, store-on-board) collars (Telonics Model TGW-3700 - GPS/SOB/D, Telonics, Mesa, AZ) on most of the captured bears. In 2002 and 2003, the GPS receivers were set to collect a location fix every 20 minutes and store the location information in the unit's on-board memory. A temperature sensor was embedded in each collar to record collar temperature with each location. Also, each collar had an activity sensor which recorded the percentage of tip switch events between locations. Each collar was also equipped with a standard VHF transmitter, so the collar could be located in the field. We attached a self-release mechanism to each collar, so the collar could be retrieved in the field without recapturing the bear. An internal clock activated the self-release mechanism. In 2002, the collars were set to self-release on September 10 at 02:00 am which was near the end of the study period. We intended for collar release dates and time to correspond with bears being near the study streams. We were able to retrieve most of the collars by hiking to them. In 2003, we set the collars to release on October 15 at 02:00 am. However, we discovered that by this date many of the bears had moved into denning habitat at higher elevations and a helicopter was needed to access these collars.

After retrieval, location data were downloaded from collars as a text file using software supplied by Telonics. Next, we imported the data file into Microsoft Access for formatting and database management. A visual basic script, obtained from the Internet (http://www.vbrad.com), was used in Microsoft Access to convert UTC time to local time (Alaska Standard Time). We used geographic information system (GIS) software (ArcGIS 9.1, ESRI, Redlands, CA) to convert the Access data files to geographically-referenced geodatabases and project the geographic coordinates (WGS84) to Alaska stateplane (NAD 27, zone 1). All spatial analyses were done using GIS software. We defined the salmon-spawning period as July 15 to September 16 for all future analyses.

Because some of the collars remained attached after their projected release data, we used the activity and temperature sensors in the collar to determine the actual drop date and time. After the activity sensor reading became and remained 0 and the temperature recorded by the collar dropped to ambient air temperature, we assumed that the collar had dropped after the previous location fix.

Spatial Distributions

The spatial distributions of the GPS locations across the landscape were examined and displayed using GIS software. We computed maximum extent home ranges using 100% minimum convex polygons. We used a fixed kernel density estimator to compute utilization distributions (Kernohan et al. 2001) for each animal and groups of animals to estimate spatial use. The utilization distribution is an estimate of the probability of an animal being in a particular grid cell during a specific time period (Worton 1995). DE Solla et al. (1999) found that kernel estimators do not require the removal of serial autocorrelation, a characteristic of frequent GPS locations. For kernel calculations, we estimated the appropriate smoothing factor using likelihood cross-validation (Horne and Garton 2006). We used Hawth's Tools Extension for ArcGIS 9.1 (Version 3.26) to calculate the kernel density estimates. For the output raster, a cell size of 9 m was used to capture fine scale changes in the density probability. In addition to individual animal analyses, we grouped GPS locations by sex and watershed. Thus, all the points for males captured in Freshwater Creek were analyzed together to provide a population-level analysis. The smoothing factor for a group was determined by averaging the estimated factor for individuals across animals in the group. Because of variable sample sizes, we felt that this approach provided the best estimate of the distribution of animals across the landscape.

The distances of the GPS points to important landscape features (nearest salmon spawning stream and beach zone) were computed using the GIS. We computed the distance distributions for each sex by watershed including the mean, median, and 75% cumulative distributions. We examined differences among sex and watershed by comparing the medians of the median distances for each sex and watershed using rank tests. Also, we compared the distance distributions to current TNF management benchmarks, including the 31 m (100 ft) riparian buffer and the 150 m (500 ft) important bear foraging area S&G, as well as a 500-m buffer. In addition, we compared the proportions of locations within these benchmarks for each sex and watershed.

We determined the distance to salmon-spawning stream for each bear during the salmon-spawning season (i.e., 15 July to 15 September) using ArcMap 9.1 GIS software. We created a distance-to-salmon-stream raster coverage, and we sampled that coverage with the point theme of all brown bear relocation points during the salmon-spawning season to generate the distance of each point to the nearest salmon stream. We calculated the median distance to salmon stream for each bear and grouped the distances by sex and stream (i.e., Spasski Creek or Freshwater Creek). We graphically displayed the patterns of bear use by calculating the percentage of each bear's points that fell in categories that increased from 50 – 3,000 m in 50-m increments. We calculated the median of this value (i.e., the proportion of use by distance) for each stream-sex category and graphed it. To examine distances relevant to management guidelines, we calculated the percentage of each bear's points that fell into categories that increased from 10 – 1,000 m in 10-m increments. We calculated the median of this value (i.e., the proportion of use by distance) for each stream-sex category and graphed it. We highlighted distances relevant to current management practices on the TNF, including the 31-m (100-ft) Riparian S&G buffer (primarily for fish habitat and water quality); the 150-m (500-ft) Wildlife S&G buffer (important brown bear foraging sites); and a potential 305-m (1,000-ft) buffer (similar to the buffer for Beach and Estuary Fringe S&Gs; USDA Forest Service 1997).

Habitat Selection

We used both Design II and III sampling protocols for this study (Manly et al. 2002). The resource use by individual brown bears during the salmon-spawning season was compared first with resource availability for the population (i.e., the entire study area, Design II; Manly et al. 2002) and then within each animal's home range area (Design III; Manly et al. 2002). The home range area was defined by a 100% minimum convex polygon drawn around the animal's locations. The salmon-spawning period was defined as from 15 July to 16 September.

Habitat use.—We described habitat use by brown bears by overlaying each GPS location on a GIS map of available habitats. Each point was buffered by a radius of 25 m to account for variability in location precision (95 % utilization distribution radius = 25 m, unpublished data). Habitat composition of the individual use polygons was summed across points for each bear.

We used 3 digital landcover maps to define habitat categories (Appendix A). Because the maps were from multiple sources and the boundaries didn't match exactly, we used a hierarchical approach. First, the National Wetlands Inventory (NWI, Cowardin et al. 1979) database was used to define vegetated and non-vegetated estuary/beach habitats. Because of the limited area of this habitat, the polygon boundaries were edited using the digital orthophotos as the reference. Next, the remaining upland habitats were classified based on the "Existing Vegetation" landcover map from the USDA Forest Service (VEG-MOD; U.S. Forest Service, TNF, Ketchikan, Alaska, USA, metadata available from the Southeast Alaska GIS Library at http://gina.uas.alaska.edu/joomla). This landcover map was developed for timber management purposes at a forest-wide scale (Caouette et al. 2000), but also included lands mapped as nonforest and scrub forest. Along the beaches, the polygon boundaries were adjusted to match the edited NWI database. Finally, the "Managed Stands" layer from the USDA Forest Service was used to identify harvested (clearcut) stands. We classified clearcuts by age of cut with stands harvested since 1996 as new clearcuts, stands harvested from 1970 to 1996 as older clearcuts, and all other harvested stands as second growth. Additionally, we updated the Managed Stands layer for private lands by digitizing cut boundaries from low-elevation photographs taken during September 2004.

We combined the numerous landcover categories to represent habitats that we felt were important distinctions to bears. The final habitat categories were: estuary/beach, alpine, avalanche slope, other shrub, scrub forest, open forest, closed forest, new clearcut, older clearcut, and second growth (Appendix A). Open and closed forest categories were loosely based on Viereck et al. (1992). Forest types were generally defined as follows: scrub forest = nonproductive forest, open forest = volume class 4, and closed forest = volume classes 5, 6, and

7 (see Appendix A for exact definitions). Physiographic variables were sampled from available GIS databases, including elevation, slope (%), distance from salmon-spawning stream, and distance from beach (coastline). We didn't define a "riparian habitat" as in Schoen and Beier (1990) and Titus et al. (1999), but instead evaluated landcover and distance to stream separately.

Habitat availability.—We estimated the amount of each habitat within the study area from 65,000 random points distributed on the habitat map. The study area was defined by a convex polygon with a 1-km buffer drawn around all of the GPS locations. At each random point, the entire suite of habitat and physiographic variables were sampled. For the home range analyses, the habitat attributes were measured at the random points within an animal's home range (100% CP).

Each study stream was divided into 50 segments of 100-m lengths. From late July until October 15, each study stream was surveyed approximately every 10 days for the presence of spawning salmon (Table 2). Biologists walking adjacent to the stream estimated the number of live salmon by species per segment of stream. Observations indicated that the salmon run in 2003 was larger than in 2002, and because of better water conditions the fish moved farther up the streams in 2003. The water levels of each study stream were monitored and recorded hourly by remote instrumentation to help understand the availability of spawning salmon.

Statistical Analyses.—We used a log-linear model to estimate relative selection probabilities among habitat types available to brown bears at 2 geographic scales (Manly et al. 2002). Selection probabilities were estimated relative to selection (i.e., proportion used/ proportion available) for the 'estuary habitat' type. Habitat availabilities were input into the log-linear model as an offset (Littell et al. 1996; offset=base rate of Manly et al. 2002) Bears and bears*habitats were considered to be random effects in the model (Little et al. 1996). Data were analyzed at 2 geographic scales - the study area and home range (100% CP).

RESULTS

Brown Bear Capture

In August 2001, we deployed GPS collars on 2 adult male brown bears captured by Aldrich foot snares along Freshwater Creek and nearby Game Creek on northeast Chichagof Island (Table 3). During July-August 2002, we deployed 15 GPS collars on adult brown bears (7 males and 8 females) captured along Freshwater and Spasski creeks (Table 3). During 2003, we deployed 22 GPS collars on adult brown bears (3 males and 19 females Table 4). In order to collar adult females accompanied with cubs, we darted 6 adult females using a helicopter in nearby alpine during late June. Because females with cubs were difficult to locate within the study watersheds, we searched nearby ridge tops and some of the captures were farther away then planned. Of these 6 females, 5 animals were accompanied by 1-2 cubs (Table 4). Two of the females had been collared previously with VHF radiocollars (#136, 171; Titus et al. 1999). We captured bears using Aldrich foot snares along the study streams from August 1 to 28. We deployed GPS collars on 9 bears (3 males and 6 females) captured along Spasski Creek and 8 female bears at Freshwater Creek (Table 4). Of these female bears, 5 were accompanied with cubs. One of the captured females and one male had been collared previously. The male (#262) carried a GPS collar the previous year.

GPS Location Data

We collected useful location data for 34 brown bears (10 males, 24 females) on northeast Chichagof Island. During 2002, we retrieved 13 of 15 GPS collars by hiking to them, but 2 collars dropped at high elevation and a helicopter was needed to retrieve them. In 2003, 12 of 22 collars dropped in rough terrain and required a helicopter and a substantial effort to retrieve them. By the October 15, 2003 release date, these bears had already moved to denning sites in rugged, mountainous terrain. We failed to retrieve 1 collar (#131) because of the difficult terrain, and 1 collar didn't release properly and remained on the bear (#282). We attempted to capture this bear by darting it from a helicopter, but were unsuccessful. Three collars (#285, 287, and 289) were not initialized correctly and did not collect any useful data.

In 2002, the successful fix rate averaged 35.1%. In contrast, the successful fix rate increased to 67.6% in 2003, probably because of an improvement in antenna design. The number of days a collar was deployed ranged from 25 to 250 with most on for about 48 days. Only 2 bears were monitored for the entire 60 days of the late summer season. The total number of successful GPS fixes for an animal ranged from 429 to 8,202. For the late summer period only, the number of successful fixes ranged from 63 to 4,295.

For the watershed-level analyses, we used only data from bears that had been captured near the stream in the specific watershed. Thus, the male Spasski bears were numbers 224, 250, 262, and 291 and the females were 264, 265, 268, 288, 290, 294, 295, and 296. For Freshwater Creek, the adult male bears were 124, 205, 275, and 278 and the females were 244, 246, 253, 254, 271, 279, 297, 298, 301, 302, and 303.

Spatial Distributions

Home ranges (100% convex polygons) during the late summer (Fig. 2) averaged 13.4 km^2 (SE = 2.3) for males and 21.6 km^2 (SE = 2.1) for females (Table 5). Male #262, the only animal that we monitored for 2 years, had similar home ranges each year with 2003's range overlapping 91.4% with his range in 2002. The maximum distance moved by a bear was 24 km by a young male. He was obviously passing through the capture stream (Freshwater Creek) to another location (the beach near Hoonah). Later, we found the collar at a whale carcass that had washed up on the beach. Otherwise, the greatest distance moved by an adult male was about 11 km. The greatest movement by a female (#268) was about 13 km. This female was the only one that moved between the study streams.

Utilization distributions (UD fixed kernel density) varied greatly by sex (Fig. 3). For adult males, the UDs were focused along the lower portions of the salmon spawning streams. We found the UDs of females to be more variable and spread more widely across the landscape (Fig. 3).

Overall, we used 34,393 points from 28 bears (9 males and 19 females) during 15 July–15 September to describe the distance to salmon streams by brown bears on Spasski and Freshwater Creeks on northeast Chichagof Island (Table 6). Because we started trapping on Spasski Creek first each year, bears were captured sooner there, and thus provided more data points than bears captured at Freshwater Creek (Table 6). We captured more females than males (Table 6).

Across streams, the median distance of male relocations were closer to salmon streams than that of female relocations (Mann-Whitney U Test, $Z = -3.812$, $P < 0.001$; Table 6, Figure 4). Median relocation distances for males were not statistically different between the 2 streams (Mann-Whitney U Test, $Z = -0.490$, $P = 0.730$; Table 6, Figure 4). On Spasski Creek, 41%, 86.5%, and 94.6% of points were located within the management distances from the salmon stream (31-m Riparian S&G Buffer, 150-m Important Foraging Area Buffer, 500-m Bear Foraging Stream Buffer), compared with 41%, 68.9%, and 94.6% for Freshwater Creek (Figure 5). Thus, male relocations in the Spasski Creek watershed were slightly closer to the stream than those in Freshwater Creek, especially at 150 m. The lack of forested riparian buffer along Spasski Creek may have resulted in male bears spending much of their time in or directly next to the stream.

We found the median relocations of females were different between Spasski and Freshwater creeks (Mann-Whitney U Test, $Z = -2.147$, $P = 0.033$; Table 6, Figure 4). On Spasski Creek, where limited riparian forest remains, females had larger median distance from the stream (Table 6, Figure 5). In fact, the mean difference between median distances for Spasski versus Freshwater females was 981 m. On Spasski Creek, 9%, 19%, and 27% of the data points were located within the management distances from the salmon stream, compared with 14%, 52%, and 73% for Freshwater Creek (Fig. 5, Table 7).

Habitat Selection

We found substantial individual variation in patterns of habitat use (Fig. 6), especially between sexes. Because relative selection probabilities differed by sex ($P < 0.001$), all subsequent analyses were performed separately for each sex. At the study area level of availability, estuaries were the most selected habitat type for both sexes and greater than for closed forest (Tables 8, 9). All male brown bears primarily used estuary and closed forest landcover types. All habitats other than estuaries and closed forest showed low selection; no males used alpine or avalanche slopes (Tables 8, 9). Females had a more even pattern of selection and greater individual variation. In addition to estuaries, older clearcuts had higher selection ratios than closed forest (Table 8). The largest differences in relative selection between males and females were for avalanche slopes, open forest, and alpine (Table 8, 9).

Other habitat variables (i.e., distance to salt water, distance to a salmon stream, elevation, and slope) confirmed the pattern based on habitat types (Fig. 7). Relative to availability, males used flat, low elevation areas near salmon streams and the beach. The median average distance of a used data point from a salmon stream was <400m for most males. As with habitat type selection, females show greater variation in other habitat variables than did males (Fig. 7).

At the home range scale, male bears showed even greater relative selection (to estuary habitats) for closed forest (0.70 vs. 0.50, Tables 8, 10). All other habitats had lower relative values. For females, relative selection ratios (to estuary) were higher for all habitats except closed forest and older clearcuts (Tables 9, 11).

DISCUSSION

Spatial use by most adult brown bears during the late summer was strongly influenced by the locations of streams with spawning Pacific salmon. Home ranges of males and females were relatively small and always intersected a salmon stream. We found that adult male brown bears were especially closely associated with salmon streams. In contrast, while all collared females visited salmon streams, they used this habitat much less than males and showed greater variability in use of this habitat compared with males.

Previous researchers in coastal Alaska also found a strong association of adult brown bears with salmon streams during late summer (Schoen and Beier 1990, Titus and Beier 1999, Titus et al. 1999, Suring et al. 2006). Research completed on Admiralty and Chichagof islands showed similar use patterns to those documented here. Using traditional radiotelemetry, Schoen and Beier (1990) found that 61% of all brown bear locations on Admiralty Island and 65% of their locations on Chichagof Island were within 160 m (525 ft) of a stream. An additional 13% and 11% of their locations were between 161 and 483 m (525-1,585 ft) of a stream for cumulative percentages of 74% and 76% of the locations within 483 m. Because Schoen and Beier (1990) did not separate their animals by individual, sex, or landscape, their numbers are not directly comparable with our data. However, the observed patterns were similar. Their Admiralty sample included 44% males while the Chichagof sample included 33% males (Schoen and Beier 1990). The landscape on Admiralty Island was unaltered while their Chichagof site was a mix of logged

(Corner Bay) and unaltered (Kadashan) areas. On northeast Chichagof Island, Titus and Beier (1999) found 36% of all bear locations during August were within 153 m (502 ft) of a salmon spawning stream. Additionally, about 50% of their locations were within 500 m. Although their data were not separated by sex, most of the relocations (79%) were of females. Despite the large number of bears (>200) radiocollared in these two long-term studies (Schoen and Beier 1990, Titus et al. 1999), their use of traditional aerial radiotelemetry, with infrequent relocations, was insensitive to understanding fine scale habitat differences, both in terms in sex-specific differences and forest management.

In the unaltered Khutzeymateen Valley of British Columbia's north coast, MacHutchon et al. 1993 found about 80% of their brown bear locations within 150 m of a salmon stream during the late summer. On the Kenai Peninsula, Southcentral Alaska, average distance from salmon streams for adult females during the summer season was about 2,000 m (Interagency Brown Bear Study Team 2001). However, Suring et al. (2006) reported that human disturbance was a major factor affecting brown habitat selection on the Kenai. This disturbance may have resulted in female bears traveling greater distances from the streams.

In our study, we found nearly 97% of the locations of all adult males within 500 m of a salmon spawning stream. In contrast, 84% of the locations of females on Freshwater and 35% of female locations on Spasski Creek were within 500 m of a salmon stream. Generally, male and female bears along Freshwater Creek spent more or similar amounts of time near or closer to salmon streams than reported by Schoen and Beier (1990) and Titus and Beier (1999), but females along Spasski Creek spent considerable time farther away from salmon streams. Adult males remained near salmon spawning streams regardless of the degree of landscape alteration. In contrast, we found significant differences in spatial use by females depending on landscape composition. In the relatively unaltered Freshwater Creek, female brown bears spent significantly more time closer to salmon spawning streams compared with females in the highly altered Spasski Creek. Assuming that spatial use of Freshwater bears more closely represents patterns of an unaltered landscape, 52% of the relocations were within a management buffer of 150 m (500 ft) and 73% of the relocations were within 305 m (1,000 ft). In contrast, only 19% of the relocations in the highly altered Spasski watershed fell within a management zone of 150 m (500 ft) and 27% of the relocations were within 305 m (1,000 ft). Thus, a management zone of 31 m (100 ft) would capture 41% of the use by adult males, but only 9 to 14% of the use by females.

Schoen et al. (1990) found that brown bears on Admiralty Island strongly selected for riparian old-growth forest along salmon spawning streams during the late summer. Likewise, Titus et al. (1999) reported similar results for male and female brown bears during the late summer on northeast Chichagof Island. In our study, male brown bears consistently selected estuary and closed forest habitats near salmon spawning streams at the landscape and home range scales, even in a significantly human-modified landscape. In the altered Spasski Creek, male brown bears selected the limited closed forest habitats along the stream, seldom visiting the adjacent clearcuts. Additionally, they selected open estuary habitats, but seldom ventured far from the fringe forest. Female brown bears showed great individual variation in habitat selection. Some females primarily used estuary habitats near salmon streams. Other females spent little time on the salmon streams; instead using older clearcuts, closed forest, and avalanche slope habitats, depending on where they lived. At both geographic scales, female bears strongly selected estuary and closed forest habitats. At the home range scale, relative habitat selection was more similar, indicating that bears often used habitats located near their highly preferred foraging habitats (i.e., salmon streams and estuaries).

Many authors have documented the importance of access to salmon to bear populations (Schoen and Beier 1990, Gilbert and Lanner 1997, Hilderbrand et al. 1999*b*, Titus and Beier 1999, Gende and Quinn 2004, and others). Access to salmon plays a key role in the accumulation of lipid stores of female brown bears (Rode et al. 2001), which is especially important during the pre-denning hyperphagia (Gilbert and Lanner 1997). Additionally, populations with access to abundant, spawning salmon were larger and more productive (Hilderbrand et al. 1999*c*). However, female bears with cubs may avoid adult male bears at salmon foraging sites (Ben-David et al. 2004, Rode et al. 2006). This avoidance can result in lower energy intake by females with cubs (Nevin and Gilbert 2005) because subdominant bears may forage in poorer quality fishing sites (Quinn and Kennison 1999, Gende and Quinn 2004), consume poorer quality fish (Hendry and Berg 1999, Gende et al. 2004), and spend less time fishing on the stream (Quinn and Buck 2000, Gende and Quinn 2004). Thus foraging sites that receive less use by potentially infanticidal male bears may actually be more important to reproductive females and the productivity of brown bear population (Swenson et al. 1997, Wielgus and Bunnell 2000).

Besides salmon, other important seasonal food sources are available for coastal brown bears during the salmon-spawning season, especially berries (McCarthy 1989). Riparian habitats often have abundant shrubs (e.g., devil's club and currents) that offer berries during the late summer. Avalanche slide areas also have abundant berries, especially later in the season. Sometimes, clearcuts will have abundant blueberries, depending on the year and site (Alaback 1982, Deal 2001).

Much of the low elevation forest in Spasski Creek has been cut, leaving various aged clearcuts regenerating to second growth forest. Although female bears in the Spasski drainage made substantial use of the extensive young and older clearcuts, most use was on the valley slopes far (i.e., > 500 m) from a salmon stream. Highly-altered landscapes present female brown bears with 3 choices: 1) stay in the riparian closed forests near the stream looking for salmon amongst the numerous adult males; 2) utilize the logged landscape for whatever food resources exist there; or 3) make regular trips to a salmon stream from the nearby slopes, often spending little time on the stream or places in between. Thus, in altered Spasski Creek, female brown bears may avoid spending large amounts of time in the riparian forests because of the concentration of adult male brown bears residing there. However, the option of traveling to adjacent recent clearcuts to supplement diets with berries will soon begin to disappear as the conifers in the clearcuts become reestablished, shade out the understory vegetation, and ultimately eliminate all shrubs that produce berries (i.e., stem-exclusion; Alaback 1982, Deal 2001). Once stem-exclusion occurs, large portions of this landscape will provide no food resources for bears (or much other wildlife) for decades to come (Alaback 1982). Then, female brown bears would need to travel greater distances between salmon streams and alternate foraging sites.

MANAGEMENT IMPLICATIONS

We found that no-cut, closed-forest buffers along salmon spawning streams were highly selected by brown bears. In addition, we observed that mid-to late- summer spatial use patterns of browns bears, especially females, differed with increased landscape alteration. A large forested buffer provides more extensive cover for foraging females near salmon streams. Brown bear populations with access to abundant, spawning salmon are larger and more productive (Hilderbrand et al. 1999*c*), and thus unrestricted access to spawning salmon is important for maintaining healthy, productive brown bear populations in Southeast Alaska. As access to salmon decreases, we expect that cub production and survival would decrease and female mortality rates would increase because of poorer nutrition and conflicts with adult males.

Reduced population productivity would likely result in reduced hunting opportunities through restrictive seasons and/or fewer commercial services permits.

Because all salmon streams are likely important to female brown bears, we recommend that no-cut buffers be applied to all salmon-spawning streams in forested landscapes where brown bears occur. How large and where should no-cut buffers be applied? Our results suggest that a forested, no-cut buffer of 147 m (482 ft) would contain 50% of the use by female bears and a buffer of 305 m (1,000 ft) would contain 73% of female use in a lightly altered landscape. Where management objectives call for abundant, healthy brown bear populations, either complete watershed protection or substantial no-cut buffers should be implemented. Where timber production is the greater management emphasis, we recommend that no-cut stream buffers of at least 150-m (i.e., TLMP Wildlife S&G for Important Foraging Areas) should be applied universally to all salmon spawning streams in all brown bear habitats. A larger no-cut buffer of about 305-m (1,000 ft) should be applied to streams where an interagency team of biologists recommends a larger buffer is more appropriate for maintaining brown bear population objectives for hunting and viewing.

FIGURES

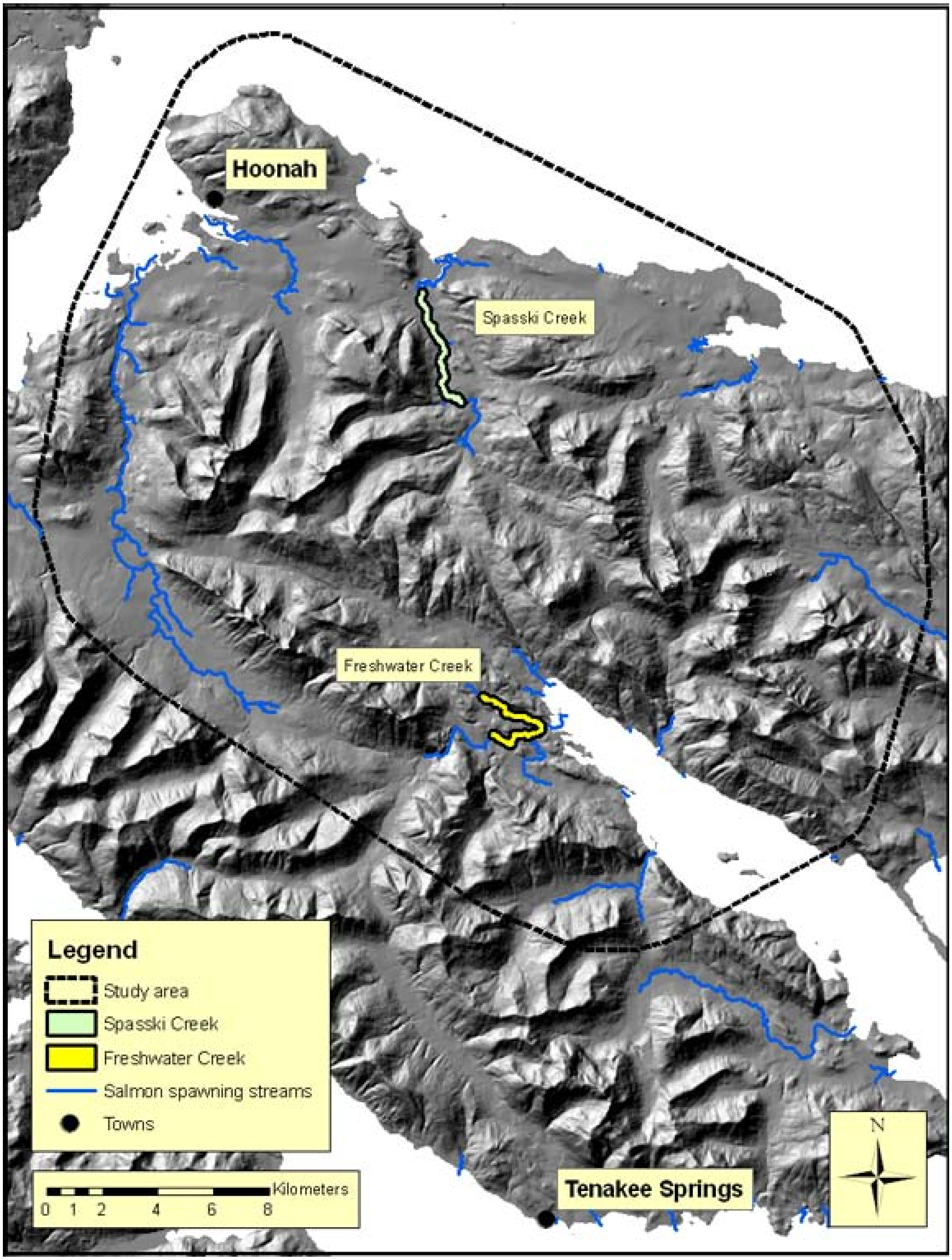


Figure 1. Map of the study area on northeast Chichagof Island, Southeast Alaska. The study area was defined by a 100% convex polygon (plus a 1 km buffer) drawn around all brown bear locations. The streams selected for intensive study, Freshwater and Spasski creeks, are also shown.

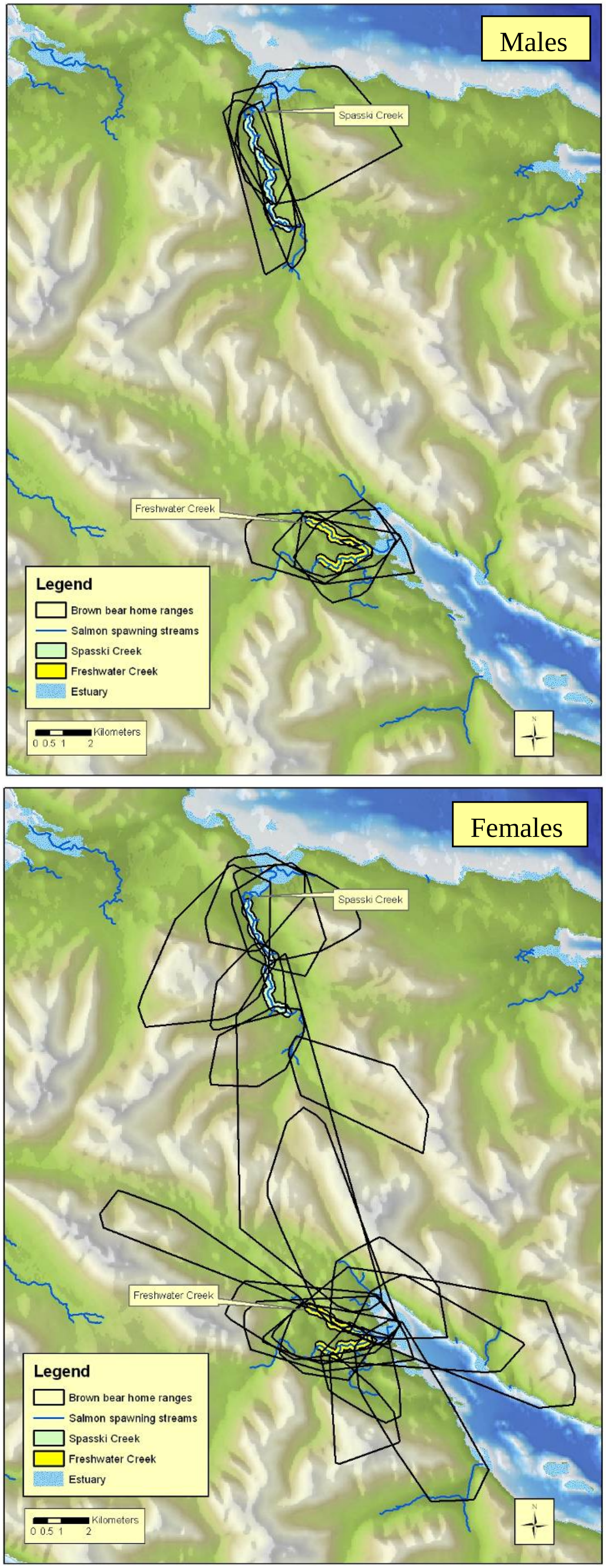


Figure 2. Home ranges (100% CP) of brown bears during late summer on northeast Chichagof Island, Southeast Alaska.

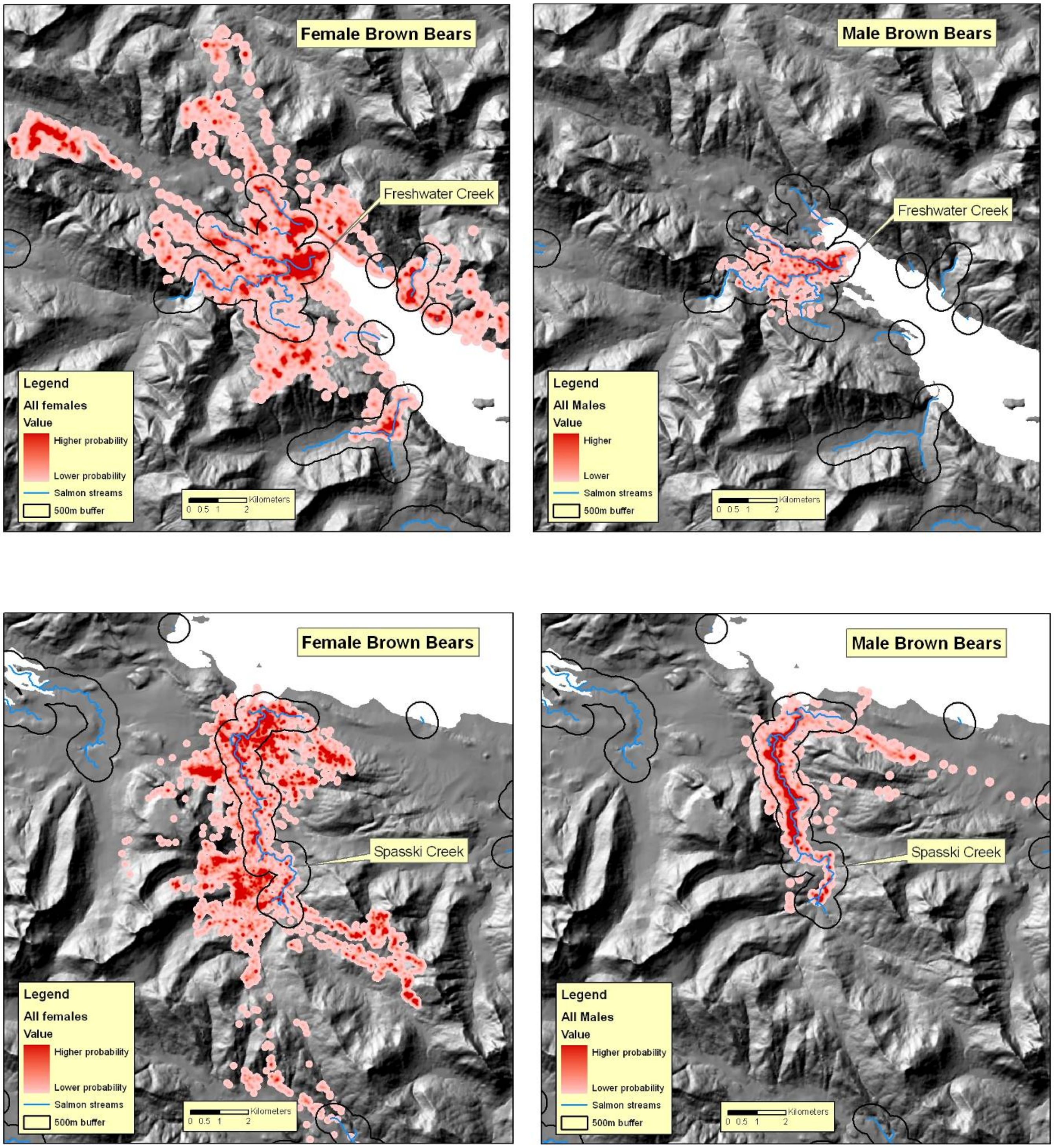


Figure 3. Utilization distributions of brown bears captured on Spasski and Freshwater creeks on Chichagof Island during the late summer, 2001-2003. Distributions were calculated using a fix kernel density estimator for animals grouped by sex and by stream. The smoothing factor was calculated from the data. A 500-m buffer is shown along each salmon spawning stream for reference.

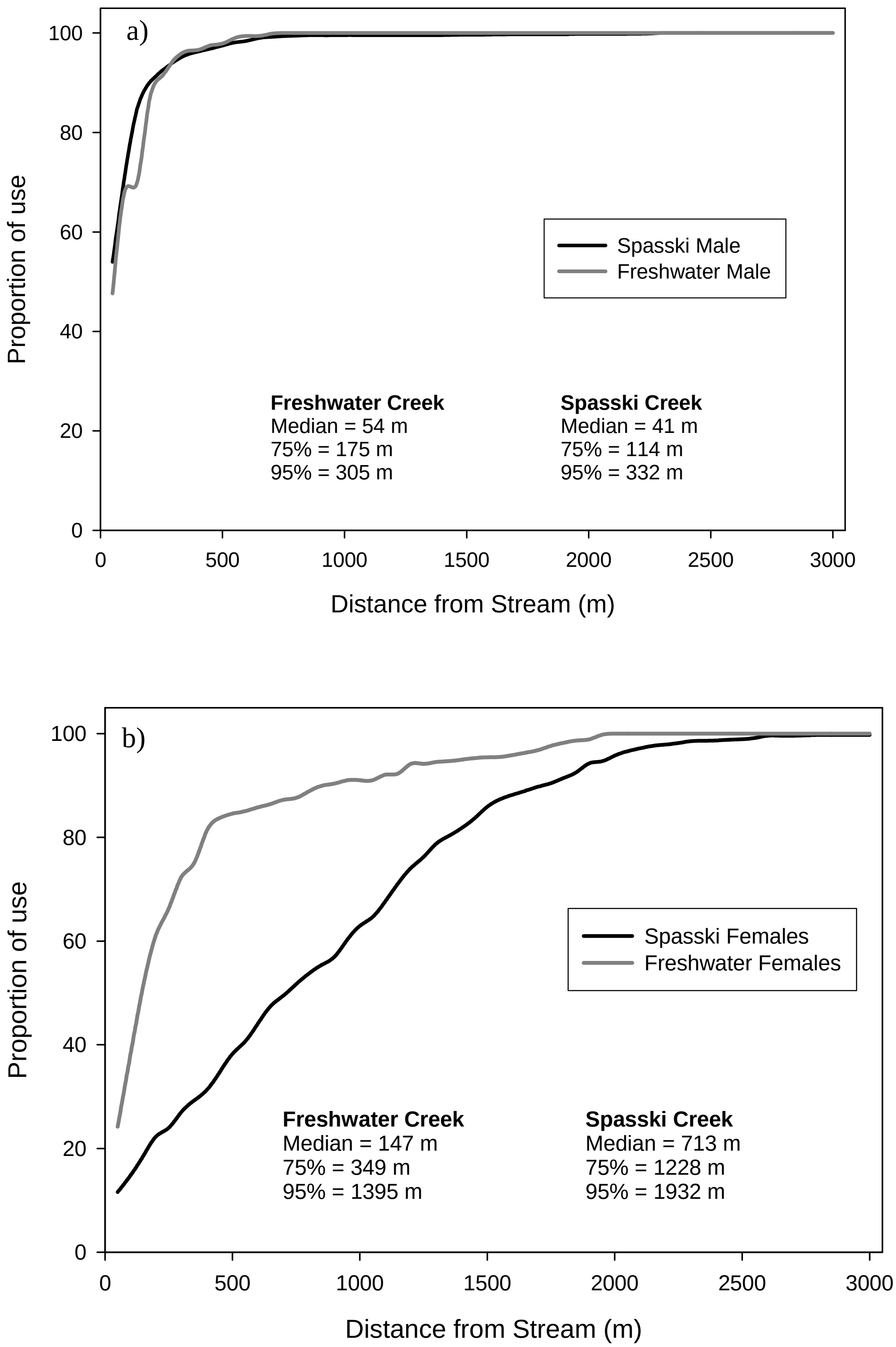
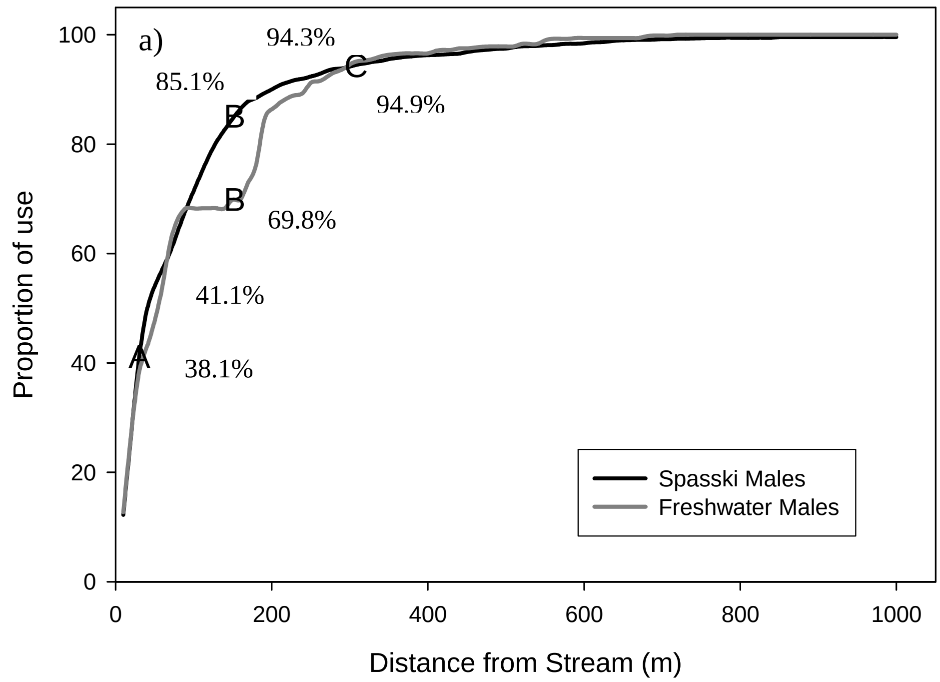


Figure 4. Median proportion of relocations for male (a) and female (b) brown bears at increasing distance from salmon streams on Spasski and Freshwater Creeks on northeast Chichagof Island, 2001 – 2003. Median, (i.e., 50%), 75% and 95% values are included for each stream and sex.



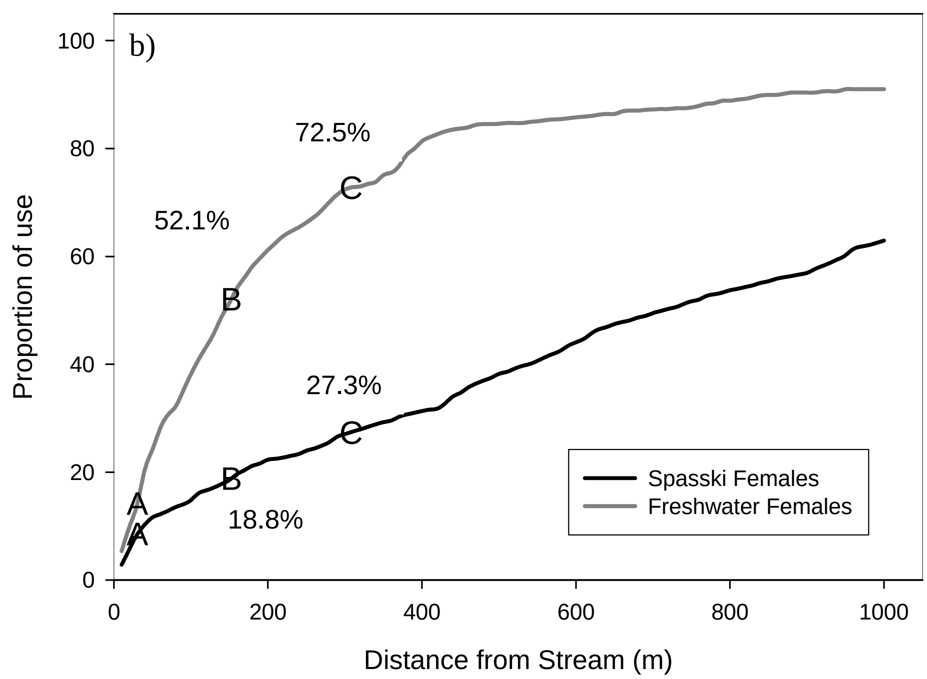
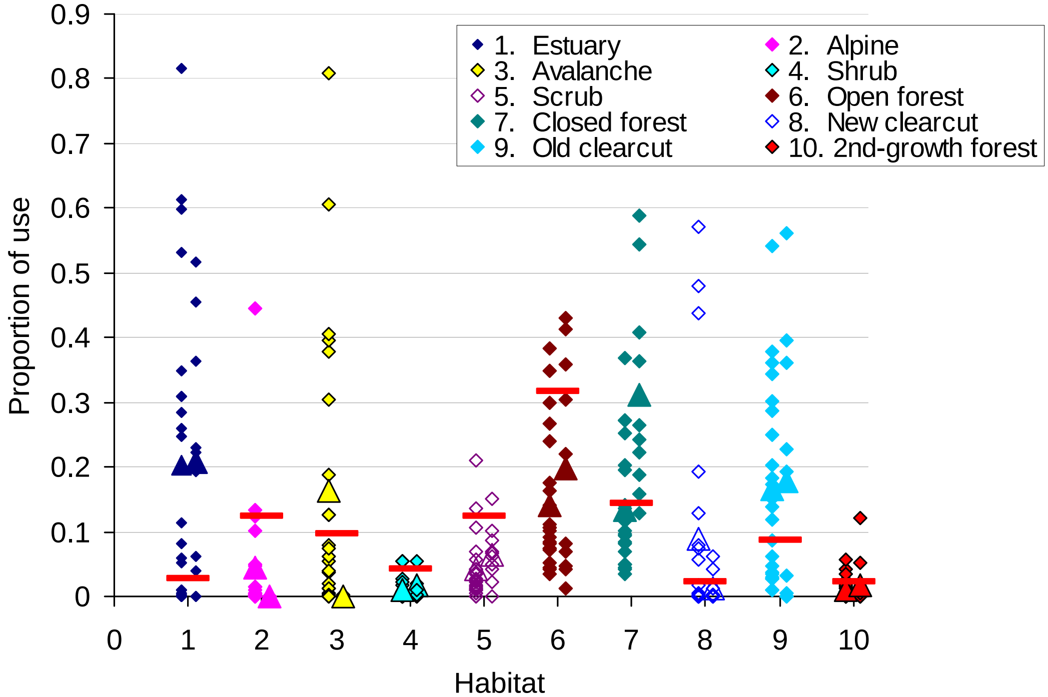


Figure 5. Median proportion of relocations for male (a) and female (b) brown bears at increasing distance from salmon streams up to 1,000 m on Spasski and Freshwater Creeks on northeast Chichagof Island, 2001 – 2003. Letters denote distances significant to management guidelines: (A) 31-m (100-ft) buffer associated with Class 1 streams; (B) 150-m (500-ft) buffer associated with important foraging areas for brown bears; and (C) 305-m (1,000-ft) buffer recommended in this report.



(red bar= available, triangles are mean use proportions; female data are on the left and male on the right for each habitat type)

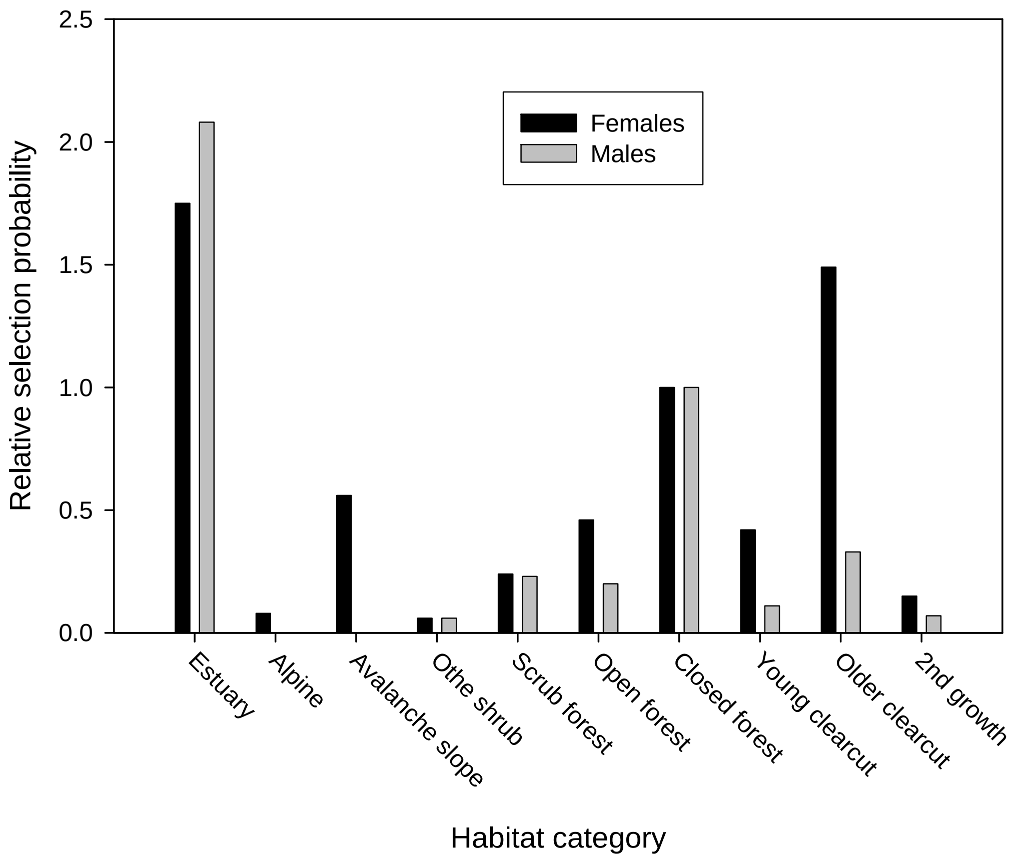
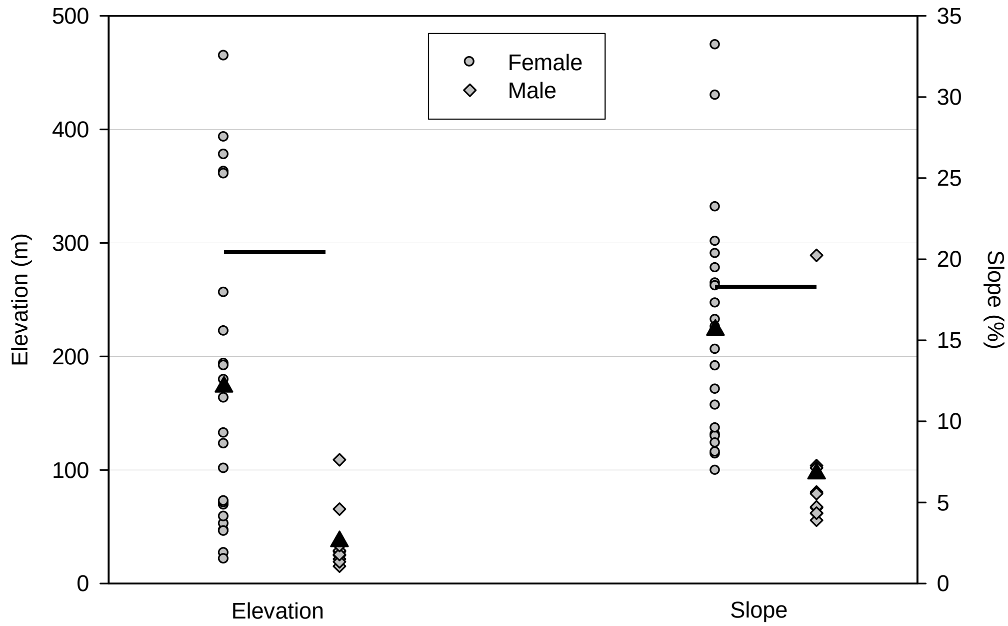


Figure 6. Use and relative selection of habitats during the late summer by brown bears on northeast Chihagof Island, 2001-2003. Data analyzed at the study area scale.



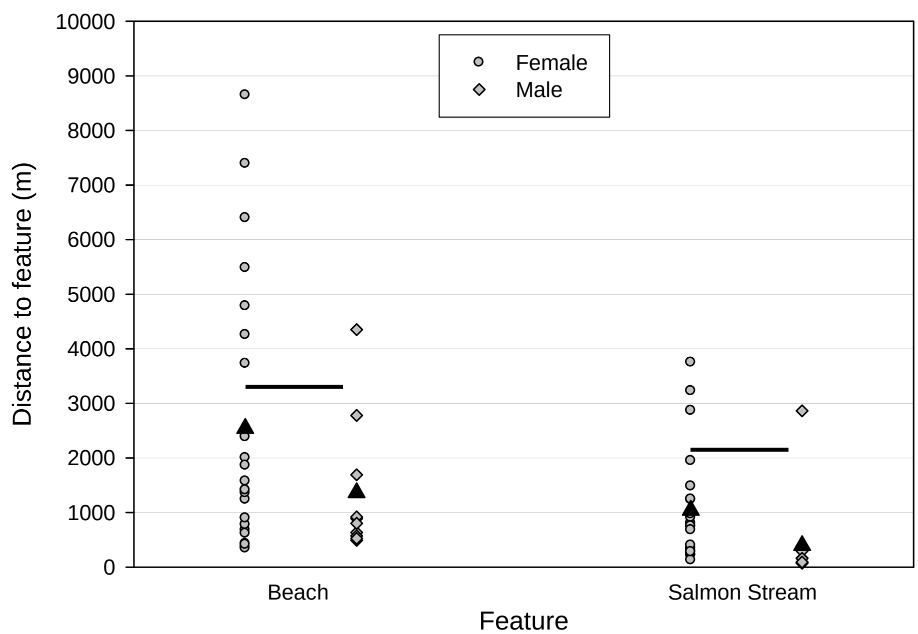


Figure 7. Use of physiographic features by brown bears during the late summer on northeast Chichagof Island, Southeast Alaska, 2001-2003. Circles and diamonds represent values for individual female and male bears. Black triangles represent the median value across each sex and the dark line is the median value of random points.

TABLES

Table 1. Authority, size, and applicability of various buffers along water bodies in Southeast Alaska.

Statute or regulation	Buffer distance m	ft	Applicability
Alaska Forestry Practices Act[a]			
Private	20	66	All anadromous streams
State	30	100	Anadromous streams or streams with high value resident fish
TTRA[b]	30	100	All Class 1 streams and Class 2 streams flowing into Class 1 streams on TNF.
TLMP[c]			
Beach fringe	305	1,000	All lands on TNF
Estuary fringe	305	1,000	All lands on TNF
RMA[d]			
Alluvial fan channel types	43	140	Or entire active fan on TNF
Flood plain channel types	40	130	Or the entire flood plain, riparian vegetation, or wetland fens on TNF
Brown bear important foraging areas	150	500	On TNF as determined by field review.

[a] Alaska Forest Resources & Practices Act 2003.
[b] Tongass Timber Reform Act of 1990, Public Law No: 101-626. Class 1 streams contain anadromous fish and Class 2 streams contain resident fish.
[c] Tongass Land Management Plan 1997.
[d] Riparian management areas in TLMP.

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Table 2. Numbers of pink salmon counted during hair snaring sessions on Freshwater and Spasski Creeks, Chichagof Island, 2002 and 2003.

Year	Session	Stream	End date [a]	Salmon count
2002	1	Freshwater	3 September	5,065
		Spasski	4 September	2,855
	2	Freshwater	10 September	4,635
		Spasski	11 September	3,225
	3	Freshwater	17 September	2,514
	Total	Freshwater	–	12,214
		Spasski	–	6,080
2003	1	Freshwater	30 July	5,790
		Spasski	29 July	18,498
	2	Freshwater	11 August	11,145
		Spasski	10 August	11,870
	3	Freshwater	21 August	10,090
		Spasski	22 August	6,510
	4	Freshwater	11 September	1,664
		Spasski	12 September	1,072
	5	Freshwater	23 September	192
		Spasski	2 October	333
	Total	Freshwater	–	28,814
		Spasski	–	38,283

[a] Date that session ended and the stream was walked to check hair snares and count salmon.

Table 3. GPS collars deployed on brown bears on northeast Chichagof Island, Southeast Alaska 2001-2002.

Collar CTN	Bear number	Sex	Age	Cubs	Capture date	Release date	Fix attempts Total	Successful	%	Study area
496053A	124	M	18	-	08/25/2002	10/10/2002	3,334	532	16.0	Freshwater
466343	205	M	28	-	09/10/2001	10/15/2001	1,633	493	30.2	Freshwater
496049A	224	M	9	-	07/26/2002	09/10/2002	3,280	1,201	36.6	Spasski
498322A	246	F	6	0	08/04/2002	09/10/2002	2,052	670	32.7	Freshwater
466345	249	M	17	-	09/06/2001	05/15/2002	2,721	1,157	42.5	Game Cr.
496048A	250	M	8	-	07/25/2002	09/10/2002	3,389	1,681	49.6	Spasski
496044A	253	F	12	2	06/13/2002	09/10/2002	6,371	2,378	37.3	Freshwater
496050A	254	F	12	0	06/14/2002	09/10/2002	8,441	4,113	48.7	Freshwater
496054A	262	M	6	-	07/24/2002	09/10/2002	3,416	934	27.3	Spasski
496046A	264	F	11	0	07/26/2002	09/10/2002	3,548	1,486	41.9	Spasski
496043A	265	F	16	0	07/26/2002	09/10/2002	3,311	1,426	43.1	Spasski
496045A	268	F	5	0	07/27/2002	09/10/2002	3,285	1,783	54.3	Spasski
496047A	271	F	8	0	08/01/2002	09/10/2002	2,864	429	15.0	Freshwater
498330A	275	M	8	-	08/05/2002	09/10/2002	4,244	1,052	24.8	Freshwater
496052A	278	M	7	-	08/12/2002	09/10/2002	2,052	670	32.7	Freshwater
498325A	279	F	14	0	08/12/2002	09/10/2002	2,101	653	31.1	Freshwater
498326A	280	M	3	-	08/17/2002	10/10/2002	3,904	1,270	32.5	Freshwater
Totals							59,946	21,928	35.1[1]	

[1] Mean successful fix rate.

Table 4. Brown bears captured and outfitted GPS collars on northeast Chichagof Island, Southeast Alaska during 2003.

Collar CTN	Bear number	Sex	Age	Cubs	Capture date	Release data	Capture method	Fix attempts Total	Successful	%	Study area
496054A[1]	136	F	15	2	6-30-03	10-15-03	Heli	0			Bear Cr.
496046B	171	F	15	0	6-23-03	10-15-03	Heli	8170	6743	82.5	Seal Cr
498325A	244	F	17	0	8-25-03	09-16-03	Foot-snare	1565	1127	72.0	Freshwater
496051A	262	M	7	0	8-09-03	10-01-03	Foot-snare	3744	390	10.4	Spasski
496045B	281	F	9	1	6-23-03	10-15-03	Heli	8202	6600	80.5	Spasski
498324A[2]	282	F	8	1[+]	6-10-03	10-15-03	Foot-snare	0			Freshwater
496044B	283	F	7	1	6-29-03	10-15-03	Heli	7743	6034	77.9	Gartina
496049B	284	F	20	1	6-29-03	10-15-03	Heli	5319	4428	83.2	Spasski
496053A[1]	285	F	10	1	6-30-03	10-15-03	Heli	0			Freshwater
498322A[1]	287	M	6	-	8-04-03	10-15-03	Foot-snare	0			Spasski
496052A	288	F	12	2	8-05-03	10-15-03	Foot-snare	5106	4368	85.5	Spasski
518520A[1]	289	F	8	2	8-05-03	10-15-03	Foot-snare	0			Spasski
498326A	290	F	4(16)	0	8-05-03	10-15-03	Foot-snare	5066	4239	83.7	Spasski
496043B	291	M	21	-	8-06-03	10-15-03	Foot-snare	5020	3639	72.5	Spasski
498321A	294	F	13	0	8-08-03	10-15-03	Foot-snare	5413	4295	79.3	Spasski
518519A	295	F	5	0	8-08-03	10-15-03	Foot-snare	4866	3776	77.6	Spasski
496050A	296	F	10	0	8-08-03	10-15-03	Foot-snare	4870	3532	72.5	Spasski
496048B	297	F	5	0	8-22-03	10-15-03	Foot-snare	3856	2757	71.5	Freshwater
496047B	298	F	13	2	8-15-03	10-15-03	Foot-snare	4363	3127	71.7	Freshwater
498330A	301	F	15	0	8-24-03	10-15-03	Foot-snare	3735	2313	61.9	Freshwater
498327A	302	F	8	0	8-28-03	10-15-03	Foot-snare	3451	928	26.9	Freshwater
498329A	303	F	15	1	8-28-03	10-15-03	Foot-snare	3246	1292	39.8	Freshwater
Totals								83,735	59,588	67.6[3]	

[1] GPS collar was not initialize properly, so no data was collected.
[2] Collar did not release from bear, so data not retrieved.
[3] Mean successful fix rate.

Table 5. Home ranges of brown bears during the late summer (7/15-9/15) on northeast Chichagof Island, 2001-2003, based on a 100% minimum convex polygon.

Bear no	Sex	*n*	100% CP area (mi^2)	100% CP area (km^2)
124	M	235	1.76	4.55
171	F	3677	4.81	12.45
205	M	63	0.04	0.10
224	M	1199	2.56	6.63
244	F	1105	2.80	7.25
246	F	715	4.69	12.14
249	F	189	2.81	7.28
250	M	1657	7.66	19.83
253	F	1473	6.37	16.50
254	F	1355	4.43	11.47
262[a]	M	934	2.00	5.18
262	M	272	3.35	8.67
264	F	1476	7.20	18.65
265	F	1394	2.24	5.80
268	F	1727	14.59	37.79
271	F	429	2.32	6.00
275	M	681	3.23	8.37
278	M	656	2.50	6.47
279	F	654	8.39	21.73
280	F	650	52.34	135.56
281	F	3467	14.09	36.49
283	F	3475	8.89	23.03
284	F	3464	24.43	63.28
288	F	2542	3.53	9.14
290	F	2352	3.26	8.44
291	M	2083	20.13	52.14
294	F	2100	3.70	9.57
295	F	2120	4.28	11.08
296	F	2175	4.21	10.91
297	F	1089	10.35	26.82
298	F	1723	7.97	20.64
301	F	1190	3.15	8.16
302	F	527	2.35	6.08
303	F	467	5.03	13.03
Males mean			5.19	13.44
Female mean			8.33	21.57

[a] Male bear 262 was monitored during 2 summers.

Table 6. Number of brown bears, points, and values of central tendency describing the distance to the stream for brown bear relocations collected during the salmon-spawning season on 2 creeks on northeast Chichagof Island, 2001 – 2003.

			No. points	Distance to stream (m)		
Stream	Sex	n	$\bar{x}$ ± SD	$\bar{x}$ ± SD	Median	Range
Spasski	Male	4	1,536 ± 422	41.8 ± 11.9	41.4	27.9 – 56.6
	Female	8	2,030 ± 539	908.6 ± 933.9	712.7	73.2 – 3094.1
Freshwater	Male	5	432 ± 271	72.6 ± 47.8	54.3	22.6 – 124.9
	Female	11	955 ± 409	730.4 ± 1061.2	147.0	43.9 – 3993.1

Table 7. Median percentage of female brown bear locations from 2 salmon streams by current management buffer distances on northeast Chichagof Island, Southeast Alaska. Two additional distances (305 and 500 m) are shown for reference.

Distance from salmon stream m	ft	Spasski Creek	Freshwater Creek
31[a]	100	9%	14%
150[b]	500	19%	52%
305	1,000	27%	73%
500	1,640	35%	84%

[a] Riparian buffer in Tongass Timber Reform Act.
[b] Important brown bear foraging areas in Tongass Land Management Plan.

Table 8. Estimated relative selection probabilities for habitats by brown bears during the late summer on northeast Chichagof Island, 2001-2003. Selection probabilities area based on study area availability with all measures relative to the selection of estuary by males.

	Relative selection probability	
Habitat	Females	Males
Estuary	0.89	1.00
Alpine	0.04	0.00
Avalanche slope	0.28	0.00
Other shrub	0.03	0.03
Scrub forest	0.12	0.11
Open forest	0.23	0.10
Closed forest	0.50	0.50
Young clearcut	0.21	0.05
Older clearcut	0.75	0.16
Second growth	0.07	0.03

Table 9. Estimated relative selection probabilities for habitats by brown bears during the late summer on northeast Chichagof Island, 2001-2003. Selection probabilities area based on study area availability with all measures relative to the selection of estuary for each sex.

	Relative selection probability	
Habitat	Females	Males
Estuary	1.00	1.00
Alpine	0.05	0.00
Avalanche slope	0.32	0.00
Other shrub	0.04	0.03
Scrub forest	0.14	0.11
Open forest	0.26	0.10
Closed forest	0.57	0.50
Young clearcut	0.24	0.05
Older clearcut	0.86	0.16
Second growth	0.08	0.03

Table 10. Estimated relative selection probabilities for habitats used by brown bears during the late summer on northeast Chichagof Island, 2001-2003. Habitat availabilities were based on the composition of home ranges of individual bears. All selection probabilities were scaled relative to the selection of estuary by males.

	Relative selection probability	
Habitat	Females	Males
Estuary	1.57	1.00
Alpine	0.24	0.00
Avalanche slope	0.84	0.00
Other shrub	0.33	0.09
Scrub forest	0.35	0.23
Open forest	0.44	0.16
Closed forest	0.79	0.68
Young clearcut	0.73	0.07
Older clearcut	0.83	0.23
Second growth	0.40	0.21

Table 11. Estimated relative selection probabilities for habitats used by brown bears during the late summer on northeast Chichagof Island, 2001-2003. Habitat availabilities were based on the composition of home ranges of individual bears. All selection probabilities were scaled relative to the selection of estuary within each sex.

	Relative selection probability	
Habitat	Females	Males
Estuary	1.00	1.00
Alpine	0.16	0.00
Avalanche slope	0.53	0.00
Other shrub	0.21	0.09
Scrub forest	0.22	0.23
Open forest	0.29	0.16
Closed forest	0.50	0.70
Young clearcut	0.47	0.07
Older clearcut	0.52	0.22
Second growth	0.26	0.20

Chapter 2

ABUNDANCE OF BROWN BEARS ON SALMON SPAWNING STREAMS DURING THE LATE SUMMER ON NORTHEAST CHICHAGOF ISLAND, SOUTHEAST ALASKA

Rodney W. Flynn, Stephen B. Lewis, Grey W. Pendleton and LaVern R. Beier

INTRODUCTION

Managers have speculated on the need and appropriate size of forested, no-cut buffers along salmon-spawning streams in the temperate rainforests of the Pacific north coast to maintain healthy brown bear (*Ursus arctos*) populations (Schoen and Beier 1990, USDA Forest Service 1997, Titus and Beier 1999, Bunnell et al. 2001). These no-cut stream buffers provide cover for foraging brown bears, especially females and young bears (Ben-David et al. 2004, Rode et al. 2006). Previous authors have recommended maintaining forested, no-cut buffers along salmon spawning streams based on recording the spatial use of brown bears during the late summer (Schoen and Beier 1990, Titus and Beier 1999, this study). Little information exists on the actual abundance of brown bears using salmon-spawning streams and the effect on abundance of different habitat management scenarios. Previous population estimation efforts have focused on the number of brown bears over large areas (>1,000 km^2) on northeast Chichagof Island and northern Admiralty Island using capture-mark-resight procedures (Schoen and Beier 1990, Titus and Beier 1993, Miller et al. 1997, J. Whitman, ADF&G, personal communication 2002). These estimates assumed that all habitats within a study area, such as alpine, rock/ice, upland forest, riparian forest, beach habitats, etc were sampled. The development of non-invasive, genetic sampling techniques, used in conjunction with mark-recapture models, has greatly increased our ability to estimate brown bear abundance (Woods et al. 1999, Mowat and Strobeck 2000, Boulanger et al. 2002), especially in forested habitats. Using a DNA-based approach, Boulanger et al. (2004*a*) found a decrease in coastal grizzly bear (*Ursus arctos*) demographic parameters with a decrease in salmon availability. We wanted to determine whether the number of brown bears using specific stretches of streams during the salmon spawning season was associated with streamside habitat management.

We estimated the number of brown bears in the forested riparian zones of salmon spawning streams during late summer with a capture-mark-recapture (CMR) experiment using genetic markers (Woods et al. 1999, Mowat and Strobeck 2000, Boulanger et al. 2004*a*). We focused on the abundance of brown bears in these riparian zones because we wanted to better understand the number of bears using these areas, given their significance in forest management issues and brown bear productivity. These areas often contain large trees on flat terrain, making timber harvest efficient and profitable compared with other upland habitats. Also, riparian zones that contain salmon spawning habitat are highly productive areas in an ecological context and highly desirable for fishery habitat management (Helfield and Naiman. 2001, Schindler et al. 2003).

For study, we selected 5-km sections of 2 nearby salmon spawning streams, otherwise similar, but with differing amounts of habitat alteration and riparian management standards. We estimated the number of individual brown bears along each stream segment during several capture sessions throughout the late summer and early autumn of 2003. We compared brown bear densities along these stream segments during each capture session. We hypothesized that streams with a larger and more intact forested buffer would support greater brown bear abundance during the important salmon-spawning season.

STUDY AREA

We selected 2 nearby watersheds on northeast Chichagof Island, Southeast Alaska for study, Spasski and Freshwater creeks (Fig. 1). Northeast Chichagof Island, located about 50 km west of Juneau, Alaska, has 26 productive salmon-spawning streams and abundant brown bear populations (Miller et al. 1997, Titus et al. 1999). Each studied watershed had a productive salmon-spawning stream of similar size, channel types, flow, and salmon escapements. The watersheds differed in the amount of habitat alteration resulting from logging. Because of different ownership and management objectives, the 2 watersheds represented a contrast of streamside vegetative conditions because of past logging activities. On Freshwater Creek (U.S. Forest Service lands), only 2.5% of the study area within 150 m of the stream had been cut, leaving 81% in open or closed forest. On Spasski Creek (private lands), 38% of the study area within 150 m of the stream had been clearcut, leaving 52.7% forest. We selected a 5-km segment of each stream for intensive study (Fig. 1). Because of past research, this area had a large number (>100) of previously radiocollared brown bears with known use patterns (Titus et al. 1999).

METHODS

Collecting Samples and Genetic Identification

Within each watershed, we simultaneously estimated the number of brown bears along 5-km stream segments during several concurrent sampling sessions using a non-invasive, DNA-based, CMR approach. We collected DNA material using single-catch hair traps (Beier et al. 2005) set on trails along stream segments. Given the high density of bears, we used single-catch hair traps to avoid mixed samples. Each hair trap consisted of a modified neck snare with 4 pieces of barbed wire attached to the snare cable. After tightening on a bear's neck, the snare would release, snagging hair in the barbed wire, and then fall to the ground (Beier et al. 2005). In 2002, hair snares were placed at 100-m intervals along the banks of the stream, alternating sides, for 50 sites per stream (Beier et al. 2005). In 2003, we set hair snares at 50-m intervals along the banks of the stream, alternating sides, for 100 sites per stream. The hair snares were set along established bear trails, usually within 10-25 m of the stream. The snares were checked about every 10 days from late August to October. During a field check, tripped snares were collected, placed in individual, 2-gallon plastic bags, labeled with the trap site and date, and brought back to camp or to our office. A new snare was set in the same place. Each day, hairs from each snare were removed and placed in individual paper envelopes, air dried, and then stored in a dry environment. Before returning them to the field, each snare was cleaned by burning the hair with a small lighter. The frequent rain in Southeast Alaska was thought to greatly reduce human odors on the snare.

At the end of the season, the hair samples were sent to a commercial genetics laboratory (Wildlife Genetics International Lab, Nelson, BC) for DNA extraction and individual bear identification (Paetkau 2003) using 7 microsatellite loci (G1A, G1D, G10H, G10J, G10M, MU50, G10X, Paetkau et al. 1998, Paetkau 2003). If values were obtained for all 7 loci, we considered the hair sample to have been successfully genotyped for the purpose of individual identification (Paetkau 2003). Because we assumed that all bears considered identified had been genotyped correctly, we did not modify the analysis to incorporate genotyping error (Lukacs and Burnham 2005*b*).

Because we focused our captures on adult bears, we had only 3 known-aged, DNA-identified young bears (yearlings) using the area. The hair snares sampled one of these yearling bears. Thus, we assumed that bears >1 were sampled by the hair snares. Cubs of the year often walk behind the mother, so they would unlikely be entering the snares. Also, the loop of the snares was set to catch larger bears.

Salmon Abundance and Stream Conditions

From late July until October 15, each study stream was surveyed approximately every 10 days for the presence of spawning salmon (Table 1). Each study stream was divided into 50 segments of 100-m lengths. Biologists walking adjacent to the stream estimated the number of live salmon by species per segment of stream. Observations indicated that the salmon run in 2003 was larger than in 2002, and because of better water conditions the fish moved farther up Freshwater Creek. The water levels of each study stream were monitored and recorded hourly by remote instrumentation to help understand the availability of spawning salmon.

GPS Monitored Bears

We obtained frequent locations of several adult brown bears during the hair-snaring sessions to measure capture probabilities directly. We captured adult brown bears in the late spring and summer to attach global positioning system (GPS) radiocollars (Telonics Model TGW-3700 - GPS/SOB/D, Telonics, Mesa, AZ), primarily for other study objectives (Chapter 1). We used Aldrich foot snares, set along trails adjacent to salmon-spawning streams, to capture adult brown bears within the riparian zones of the specific study streams from mid-July through early September. In each study watershed, we attempted to collar at least 3 adult males and 3 adult females. Snared bears were darted and injected with Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) for immobilization at a dosage of 7-10 mg/kg estimated body weight (Taylor et al. 1989). All captured bears were marked with eartags, most instrumented with GPS collars, and then released at the capture site. Blood, tissue, and hair samples were collected for DNA analysis as previously described. The Animal Care and Use Committee of the Alaska Department of Fish and Game (ACUC 03-009) approved all methods of animal handling used in this study.

The GPS collars were set to collect a location every 20 minutes, store the data in the collar, and then release on October 15. After retrieval of the collar, location data were downloaded as a text file using a computer and software supplied by Telonics. Next, we imported the data file into Microsoft Access for formatting and database management. We used geographic information system (GIS) software (ArcGIS 9.1, ESRI, Redlands, CA) to convert the Access data files to geographically-referenced geodatabases and project the geographic coordinates (WGS84) to Alaska stateplane (NAD 27, zone 1). All spatial analyses were done using GIS software.

Statistical Methods

With the genetic data identifying individual bears, we estimated the number of bears using each study stream using open population mark-recapture models. Because we snagged and identified hair from 1 live-trapped bear known to be 2-years old, we defined a bear as any individual > 1 year of age. Open population models were necessary to avoid the assumption that the same bears were using a stream for the entire 6-week study period. Previous research (extensive radiotelemetry information on >200 radiocollared brown bears) showed dynamic movements of bears to and from salmon spawning streams throughout the late summer (Titus et al. 1999), indicating that an open model was necessary. We used the Cormack-Jolly-Seber (CJS) model (Williams et al. 2001) to estimate recapture probability and population size by capture session. We used a constrained version of the JS model with a constant recapture probability across sessions; we did this largely because of the relatively small numbers of bears captured during any session. We used Crosbie and Manly's (1985) parameterization of the CJS model to estimate the cumulative number of bears that used each stream across the entire sampling period. We performed these analyses for sexes separately and for all bears combined.

The relationships between the numbers of bears on each stream and time were examined using regression analysis. The 95% confidence intervals for the estimated number of brown bears visiting each stream were compared to determine whether the total number of bears differed by stream. Also, the average numbers of bears on each stream were compared using t-tests with observations paired by capture session. Brown bear densities from this study were compared with those in the habitat capability model (Schoen et al. 1994). For this analysis, we assumed that the area sampled was 500 m across by the 5-km length. We compared 90% confidence intervals for density with those assumed by the model.

For collared bears with a genetic identification, we determine which ones had been located within 150 m of the study streams during hair-snaring sessions. Thus, we were able to compute encounter rates and capture probabilities directly (Boulanger et al. 2004*b*), the proportion of bears located within 150 m of hair snares and also recorded at a snare by DNA analysis. Also, we calculated the proportion of the bear's total points located within 150 m of a hair snare. We examined the relationship of capture probability with the number of relocations within the 150-m zone during a session using logistic regression

RESULTS

Brown Bear Abundance

2002.—On Freshwater Creek, we completed 3 surveys (3 Sep 2002, 10 Sep 2002, 17 Sep 2002) and collected 14, 13, and 17 hair samples respectfully (Table 2). From these hair samples, we obtained a successful individual ID for 8, 11, and 13 of the samples, resulting in 6 (4 males, 2 females), 9 (3 males, 6 females), and 11 (3 males, 8 females) unique individual bears. On Spasski Creek, we completed 2 surveys (11 Sep 2002, 25 Sep 2002) and collected 11 and 15 hair samples respectfully (Table 2). From these hair samples, we obtained a successful individual ID for 8 and 3 of the samples respectfully, resulting in 8 (5 males, 2 females, 1 unknown) and 3 (1 male, 2 females) unique individual bears. The second sampling period on Spasski had especially low success for individual identification (20%). The first session at Freshwater Creek had moderately poor success compared with the other 3 sample periods (57% vs. 85% and 76%).

Because of the few hair captures and individual identifications during 2002, sample sizes were too small for the CJS analysis. At Freshwater, 19 individuals (11 F, 8 M) were caught 25 times over the 3 weeks (multiple samples for a bear within the same week only count as 1 'capture'). At Spasski, 10 bears (3 F, 8 M, 1 unknown) were caught 11 times. Based on this data, we concluded that additional hair snares were needed. Thus, we doubled the number of hair snare sites in 2003 to from 50 to 100 sites per stream segment.

2003.—On Freshwater Creek, we completed 7 surveys and collected 197 hair samples (Table 3). From these hair samples, we obtained a successful individual ID for 141 (72%) of the samples, resulting in 59 (25 males, 34 females) unique individual bears. On Spasski Creek, we completed 6 surveys and collected 190 hair samples (Table 3). From these hair samples, we obtained a successful individual ID for 126 (63%) of the samples, resulting in the identification of 53 (36 male, 17 female) unique individual bears. The 4th session on both streams had relatively low success for individual identification (44% and 41%, Table 3). The successful identification rate for the remainder of the sessions varied from 54 to 84%.

At Freshwater Creek, we had evidence of at least 59 individual bears (> 1-year old) visiting the 5-km segment of stream over the sampling period (Table 3). The number of captures for an individual bear ranged from 1 to 9. On a per session basis, individual bears were captured at least once for up to 4 different sessions. At Spasski Creek, we found at least 53 individual bears using the stream (Table 3). Sixteen of these bears had been handled previously. The number of captures for an individual bear ranged from 1 to 17. Except for the 1 bear that was captured every session, individual bears were captured at least once for up to 3 different sessions. Only one bear was hair-snared in both study areas. Capture probabilities were estimated to range from 0.230 for females on Freshwater Creek to 0.469 for females on Spasski Creek.

On Freshwater Creek, we estimated that 87 (95% CI = 75-107) individual brown bears visited the stream during the 2003 sample period (Table 3). Of these bears, females comprised 59.8%. The number of females decreased steadily (r^2 = 0.84, P = 0.006) from 47 (90% CI = 24-70) during the initial sample period (Fig. 3.) in early August to 4 (90% CI = 1-11) during early October. In contrast, the number of males ($\hat{N}$ = 24.4, 90% CI = 21-28) did not decrease significantly (r^2 = 0.01, P = 0.95) during the entire sample period.

On Spasski Creek, we estimated that 77 (95% CI = 65-102) individual brown bears visited the stream during the 2003 sample period. Of these bears, females comprised only 24.7%. The number of females decreased steadily (r^2 = 0.96, P = 0.01) from 24 (90% CI = 12-37) during the initial sample period (Fig. 4.) in early August to 0 by late September. In contrast, the number of males ($\hat{N}_t$ = 22, 90% CI = 21-24) did not decrease significantly (r^2 = 0.11, P = 0.31) during the entire sample period.

The total number of female bears ($\hat{N}_t$ = 52, 95% CI = 43-71) visiting Freshwater Creek was significantly greater than Spasski Creek ($\hat{N}_t$ = 20, 95% CI = 18-31). Although the numbers of female bears on the streams per session were highly correlated (r = 0.80), the mean number of female bears determined by hair snaring sessions on Freshwater Creek was significantly greater than on Spasski Creek ($\bar{x}$ = 30.3 vs. 9.4, t = 5.95, P = 0.002). Thus, Freshwater Creek had consistently more female bears. The total number of males did not differ significantly between Freshwater ($\hat{N}_t$ = 34, 95% CI = 28-47) and Spasski creeks ($\hat{N}_t$ = 55, 95% CI = 45-77). Although inconsistent by session (r = 0.40), we found similar numbers of male brown bears in each of the watersheds across sampling sessions (paired t-test, $t = -0.0615$, $P > 0.28$). Because of the small sample sizes, our estimates of male abundance were quite variable.

Capture Rates of Collared Bears

We found that 10 of 31 collared bears that were located within 150 m of a snare were identified during the hair snaring sessions for a capture probability of 0.24 (Table 4). Capture probability was not related to the number of relocations within the 150-m zone ($P = 0.47$). For example, bear #253 was identified at a snare site during Session F02-1 with only one location within 150 m of a snare. In contrast, bear #291 was not identified during Session S03-4 with 911 relocations within 150 m. Bears may have encountered snares, but not left sufficient or adequate quality of hair to obtain a genetic identification. The capture probability estimated from the data varied from 0.24 for males and females at Freshwater Creek to 0.32 for males at Spasski and 0.47 for females at Spasski Creek.

DISCUSSION

We found peak numbers of brown bears visiting salmon streams during the first trapping session in late July to early August. This period corresponded to the first appearance of substantial numbers of salmon in the streams. Brown bears are well-known to concentrate along salmon streams during the late summer (Schoen and Beier 1990, MacHutchon et al. 1993, Titus and Beier 1999, Rode et al. 2006). Salmon provide a desirable food resource for foraging brown bears because they are often readily available, highly digestible, and provide considerable energy (Hilderbrand et al. 1999*c*). The greatest numbers of bears occurred during the initial flush of salmon in the streams. After the initial surveys, male abundance remained similar throughout the salmon spawning season, indicating a high preference for salmon. Adult males are able to dominate all other sex and age classes and remain near the salmon streams throughout the season (Rode et al. 2006). In contrast, the abundance of female bears declined linearly through the remainder of the salmon spawning season and into the early autumn. We observed similar patterns in both watersheds. Although salmon were still available in the streams, female bears appeared to spend less time on the salmon streams as the season progressed, probably choosing alternative foods and spaces. Ben-David et al. (2004) found that female bears, especially females with cubs, consumed less salmon compared with males, likely avoiding infanticide and possible cannibalism (Rode et al. 2006). After foraging primarily on vegetative matter during the spring and early summer, female brown bears may be highly motivated to forage on salmon early in the season to improve nutrition (Rode and Robbins 2000), but may chose to return to vegetation and berries later in the season to avoid conflicts with other bears (Rode et al. 2006).

Numbers of female brown bears visiting the salmon stream were significantly less in the highly altered watershed of Spasski Creek. Otherwise, the watersheds were similar, including the strength of the salmon run. Because of private ownership, only a 9-m buffer is required by statute on Spasski Creek. Because of blowdown, the intact forested buffer is less in some places. Although some logging has occurred, forested buffers in Freshwater Creek are still mostly intact. In contrast, the abundance of males was similar between watersheds, indicating that males, probably large adults, were able to coexist with the limited buffer. Because the sex ratio on Freshwater Creek was biased toward females, we suspected that the adult males were probably excluding young males from the streams.

Boulanger et al. (2004*a*) found the demographics of coastal grizzly bears in British Columbia decreased during years of reduced salmon availability. They concluded that low salmon availability resulted in low apparent survival rates and negative population growth. Gende et al. (2004) found that dominate brown bears displaced subordinates at salmon streams, reducing the salmon intake of subordinate bears. Forested stream buffers provide more accessibility to salmon, especially for female bears (Chapter 3). Thus, reduced salmon availability, whether from low salmon escapement or increased competition among bears, would decrease population growth.

We found that the numbers of brown bears on either stream were much greater than the density (0.95/km^2) assumed for similar habitats during the late summer in the habitat capability model for Southeast Alaska (Schoen et al. 1994). Although we could not calculate a density estimate because of problems in determining the area sampled, if a riparian habitat width of 500 m was assumed, then we observed average brown bear densities ranging from 22 (Freshwater) to 13 (Spasski) bears/km^2. Additional research and analysis needs to be completed to better understand actual densities.

We illustrated that a DNA-based CMR model can be used successfully to estimate the number of brown bears using salmon streams during the late summer in a high density, coastal population. Most previous studies have been completed in low-density grizzly bear populations in the relatively dry Rocky Mountain region (Wood et al. 1999, Mowat et al. 2005). Boulanger et al. (2004*b*) estimated that 37% of GPS-collared grizzly bears located in close proximity to hair traps were not "captured" in subsequent DNA analyses. Reasons for failing to capture all bears included failure of the bear to enter the trap, the bear entered the trap but hair was not snagged, and hair was snagged but sample was inadequate or somehow contaminated, precluding a positive identification. In contrast, we found that 24% of our GPS-collared bears that were located within 150 m of hair snares during a session were subsequently identified in the DNA sampling. By using a single catch hair snare, we were able to avoid mixed samples. On the negative, the hair stations were no longer functional after being encountered by a bear. The wet environment probably contributed to our lower than expected successful individual identification rate. Beier et al. (2005) reported lower successful identification rates of hair samples collected later in the summer as the weather became wetter. Shorter snaring sessions would decrease the time the hair samples would be exposed to the elements and reduce the time a station was not functional. On the other hand, more frequent sessions would increase the cost of collection and contribute to more human disturbances along the streams. More research is needed to determine the probability of capture for young bears.

MANAGEMENT IMPLICATIONS

This research indicated that a watershed with relatively intact forested stream buffers would have significantly more female brown bears along salmon spawning streams than a watershed with highly altered riparian habitats. In contrast, the numbers of males would be similar. Thus, a watershed with intact forested streamside vegetation would provide for larger brown bear populations compared with more altered watersheds.

Because of difficulties with study design and project scope, we were not able to study how specific buffer distances and configurations would affect brown bear numbers. Our study design reflected one contrast of 2 watersheds with substantial differences in riparian management. In combination with other data on spatial use and habitat selection (Chapter 1), we concluded that a relatively unaltered watershed within the distribution of coastal brown bears would contain more females, and the females would spend more time closer to the stream, providing greater opportunities to forage on salmon during the late summer. With more females feeding on more salmon, the brown bear population would be expected to be larger and more productive.

FIGURES

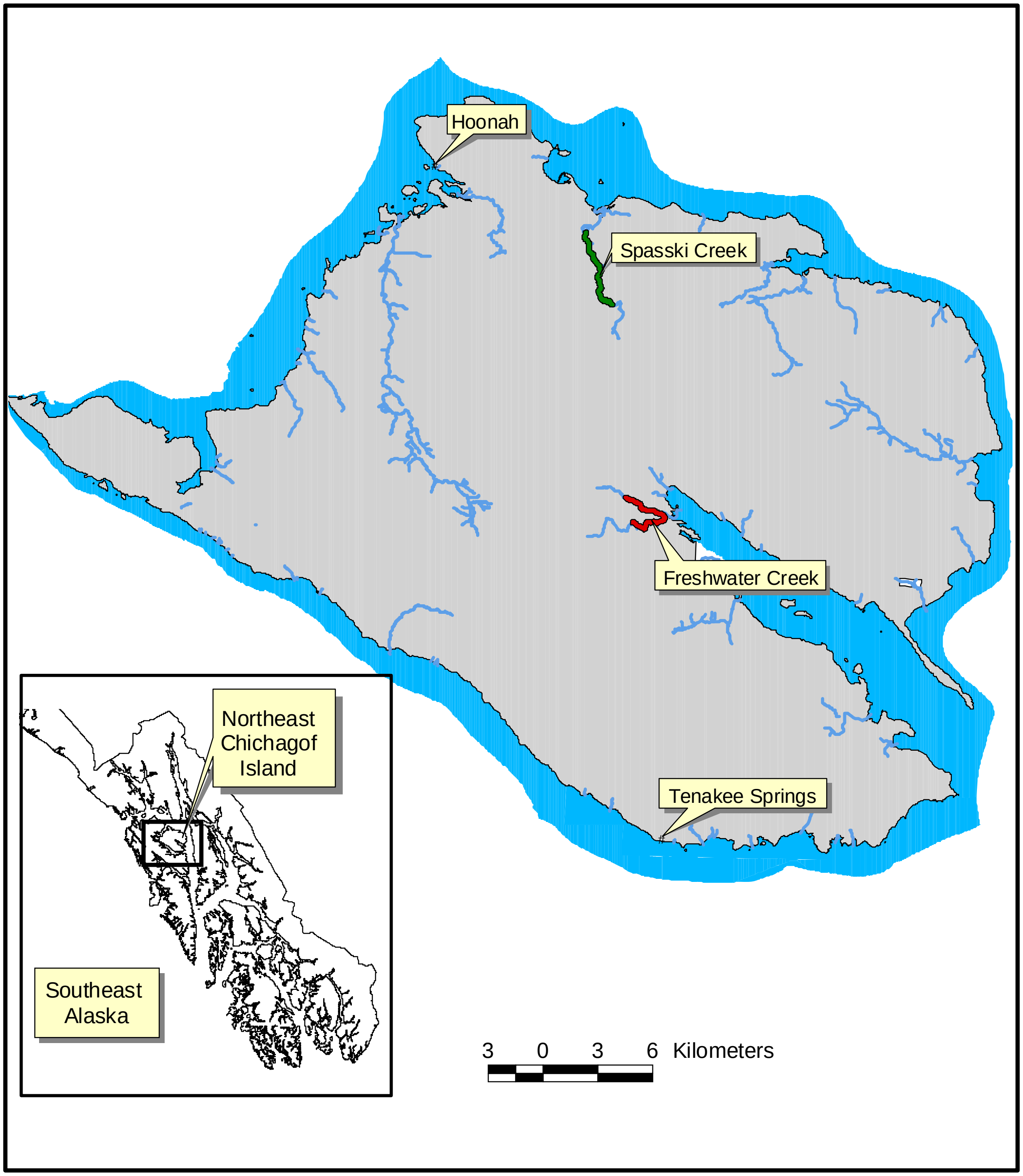

Figure 1. Study streams on northeast Chichagof Island, Southeast Alaska.

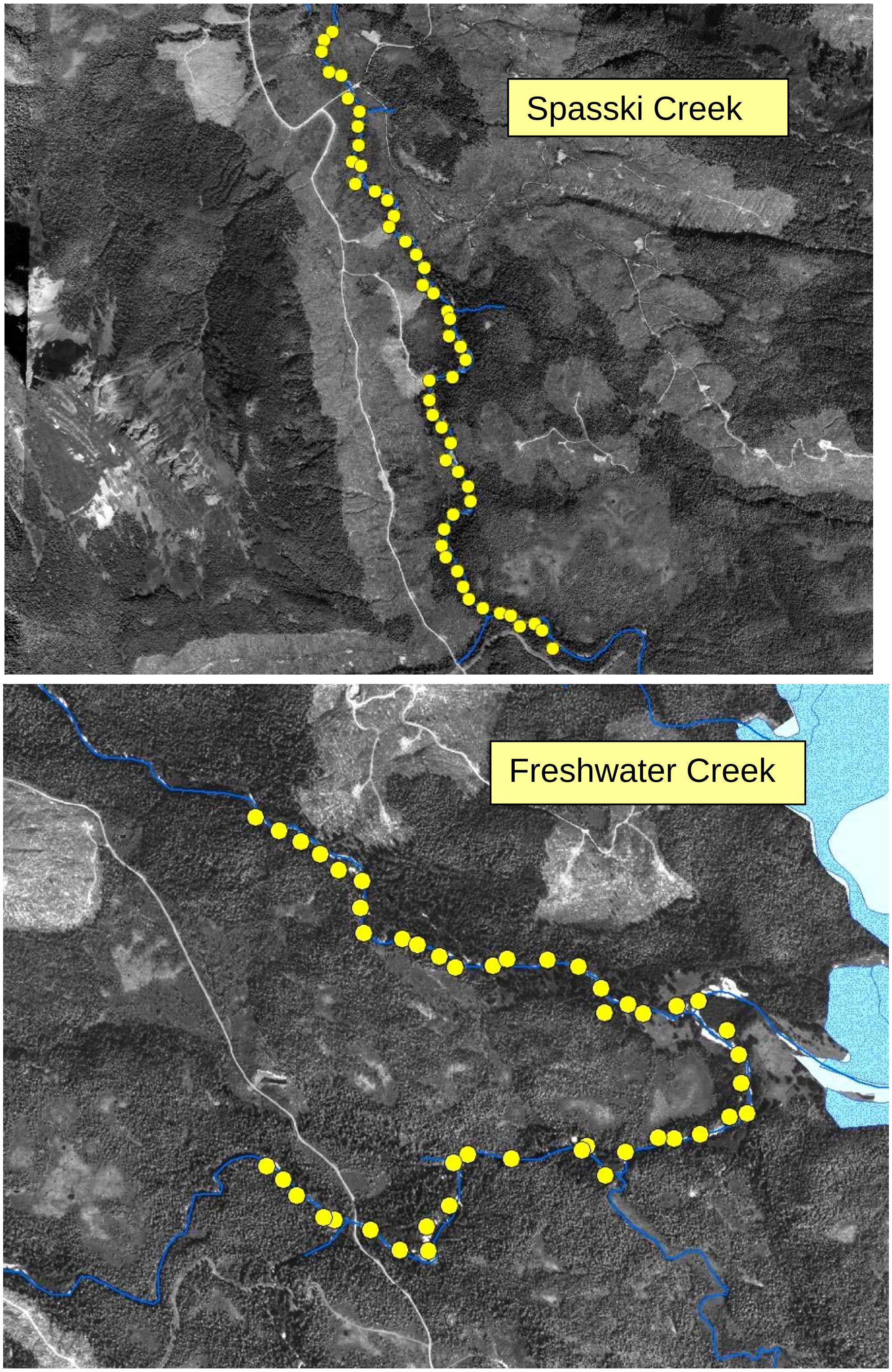

Figure 2. Locations of hair snares on Spasski and Freshwater creeks on northeast Chichagof Island, Southeast Alaska, 2003. Each stream had 100 snares placed about 50 m apart. In 2002, we used every other location or 50 snares per stream.

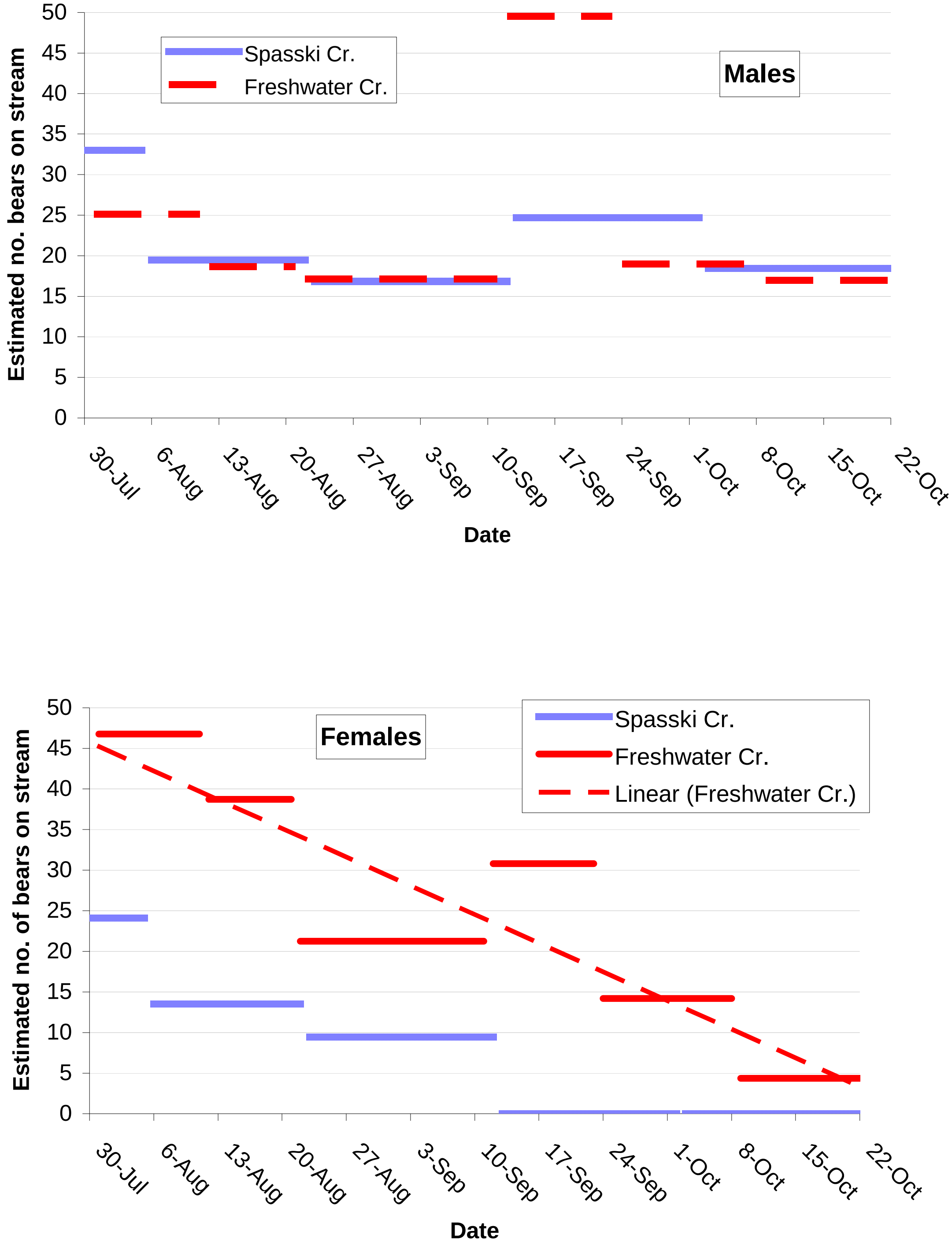

Figure 3. Estimated number of unique male and female brown bears visiting 2 study streams during summer/fall 2003. The timing and duration of capture session shown by a horizontal line. The linear relationship between bear numbers and time for Freshwater Creek is indicated by dashed line.

TABLES

Table 1. Numbers of pink salmon counted during hair snaring sessions on Freshwater and Spasski Creeks, Chichagof Island, 2002 and 2003.

Year	Session	Stream	End date [a]	Salmon count
2002	1	Freshwater	3 September	5,065
		Spasski	4 September	2,855
	2	Freshwater	10 September	4,635
		Spasski	11 September	3,225
	3	Freshwater	17 September	2,514
	Total	Freshwater	–	12,214
		Spasski	–	6,080
2003	1	Freshwater	30 July	5,790
		Spasski	29 July	18,498
	2	Freshwater	11 August	11,145
		Spasski	10 August	11,870
	3	Freshwater	21 August	10,090
		Spasski	22 August	6,510
	4	Freshwater	11 September	1,664
		Spasski	12 September	1,072
	5	Freshwater	23 September	192
		Spasski	2 October	333
	Total	Freshwater	–	28,814
		Spasski	–	38,283

[a] Date that session ended and the stream was walked to check hair snares and count salmon.

Table 2. Brown bear hair-capture results from Spasski and Freshwater Creeks on northeast Chichagof Island, Alaska, 2002–2003. In 2002, 50 snares were set along 5 km of stream at 100 m intervals. In 2003, 100 hair snares were set 50-m intervals on the same stream segments.

Year	Location	Session	Session period	Duration (days)	No. snares with hair	Individual identity *n* (%)
2002						
	Spasski	2	09/03 - 09/11	7	11	8 (73)
		3	09/12 - 09/25	14	14	3 (21)
	Freshwater	1	08/21 - 09/03	12	14	7 (50)
		2	09/04 - 09/10	7	13	11 (85)
		3	09/10 - 09/16	7	17	13 (76)
	Mean			9	14	8 (60)
2003						
	Spasski	1	07/17 - 07/29	13	48	37 (77)
		2	07/30 - 08/05	12	43	32 (74)
		3	08/06 - 08/22	12	29	19 (66)
		4	08/23 - 09/12	21	29	12 (41)
		5	09/13 - 10/02	20	24	13 (54)
		6	10/03 - 10/22	20	17	13 (76)
	Freshwater	1	07/22 - 07/30	9	41	33 (81)
		2	07/31 - 08/11	12	32	26 (81)
		3	08/12 - 08/21	10	34	21 (62)
		4	08/22 - 09/11	21	27	12 (44)
		5	09/12 - 09/23	12	31	26 (84)
		6	09/24 - 10/08	15	21	14 (67)
		7	10/09 -10/23	13	11	9 (82)
	Mean			15	30	21 (70)

Table 3. Brown bear CMR estimates for a 5-km stretch of 2 salmon spawning streams on northeast Chichagof Island during late summer-early fall 2003.

Location	Sex	Capture session	Session period	Captures (hair)	$\hat{N}$	SE	90% CI	Capture probability[a]
Spasski Creek								
	Females	1		7				
		2	07/30 - 08/05	12	24.1	7.56	11.7 - 36.5	0.469
		3	08/06 - 08/22	5	13.5	3.33	08.0 - 19.0	
		4	08/23 - 09/12	6	9.4	3.11	06.0 - 14.6	
		5	09/13 - 10/02	0	0.0			
		6	10/03 - 10/22	0	0.0			
		All		17	20.0		17.6 - 30.6[a]	
	Males	1		20				
		2	07/30 - 08/05	12	33.0	9.05	18.1 - 47.9	0.325
		3	08/06 - 08/22	7	19.5	5.53	10.4 - 28.6	
		4	08/23 - 09/12	4	16.8	5.65	07.5 - 26.1	
		5	09/13 - 10/02	7	24.7	8.38	10.9 - 38.5	
		6	10/03 - 10/22	6	18.4	7.57	06.0 - 30.9	
		All		36	55.1		44.9 - 77.1[b]	
		Both sexes		53	77.0		64.7 - 102.1[b]	
Freshwater Creek								
	Females	1		15				
		2	07/31 - 08/11	11	46.8	14.14	23.5 - 70.0	0.230
		3	08/12 - 08/21	11	38.7	11.97	19.0 - 58.4	
		4	08/22 - 09/11	4	21.2	9.54	05.5 - 36.9	
		5	09/12 - 09/23	7	30.8	12.96	09.5 - 52.1	
		6	09/24 - 10/08	4	14.2	7.77	04.0 - 27.0	
		7	10/09 -10/23	1	4.4	4.21	01.0 - 11.3	
		All		35	52.2		43.1 - 71.4[b]	
	Males	1		7				
		2	07/31 - 08/11	7	25.2	9.45	09.6 - 40.9	0.236
		3	08/12 - 08/21	2	18.7	6.6	07.8 - 31.5	
		4	08/22 - 09/11	6	17.1	5.44	08.2 - 30.6	
		5	09/12 - 09/23	12	49.5	8.17	19.6 - 81.8	
		6	09/24 - 10/08	5	19.0	7.19	07.2 - 30.8	
		7	10/09 -10/23	4	17.0	8.45	04.0 - 30.9	
		All		24	34.1		28.4 - 47.0[b]	
		Both sexes		59	86.9		75.2 - 107.3[b]	

[a] Mean capture probability across capture sessions.
[b] 95% C.I.

Table 4. GPS-collared brown bears with DNA signatures located within 150 m of 2 streams during hair snaring sessions on northeast Chichagof Island during 2002-2003.

Session	Bear number	No. GPS points	No. times hair snared
Freshwater Creek			
F02-1	246	29	0
	253	1	1
	271	15	0
	275	92	1
F02-2	246	3	0
	253	2	0
	271	1	0
	275	90	0
F02-3	275	62	0
F03-3	298	53	3
F03-4	244	248	0
	297	13	0
	298	32	0
	301	11	0
	302	9	0
	303	16	1
F03-5	244	14	0
	298	7	0
	303	36	0
F03-6	303	3	0
Spasski Creek			
S02-1	224	29	0
	250	51	0
	262	83	1
	264	21	0
	265	26	0
S03-3	262	48	0
	288	116	1
	290	1	0
	291	473	1
	294	169	0
	295	91	0
S03-4	262	84	0
	288	33	0
	290	43	1
	291	911	0
	294	136	1
	295	60	0
S03-5	262	110	2
	288	10	0
	290	4	0
	294	29	0

Chapter 3

DIETS OF BROWN BEARS USING RIPARIAN HABITATS DURING THE LATE SUMMER IN RELATION TO FOREST MANAGEMENT ON CHICHAGOF ISLAND, SOUTHEAST ALASKA

Rodney W. Flynn, Stephen B. Lewis, and LaVern R. Beier

INTRODUCTION

Meat resources provide important nutrients for coastal brown bears (*Ursus arctos*; Hilderbrand et al. 1999*b*). Spawning Pacific salmon (*Oncorhynchus* spp.) provide a desirable food resource for foraging brown bears because they are often readily available, highly digestible, and provide high energy (Hilderbrand et al. 1999*b*). Brown bear populations with access to abundant, spawning salmon were more numerous, larger, and more productive (Miller et al. 1997, Hilderbrand et al. 1999*c*). Southeast Alaska has numerous salmon spawning streams (Halupka et al. 2000) and brown bears frequent them during the late summer (Schoen and Beier 1990, Titus and Beier 1999; Chapter 1). Intraspecfic competition may limit salmon availability to certain segments of the population, especially more subordinate bears (Ben-David et al. 2004, Gende et al. 2004, Rode et al. 2006). Ben-David et al. (2004) reported that the proportions of salmon in the diets of female brown bears on Chichagof Island were less than for males. Also, Ben-David et al. (2004) found that females accompanied by cubs had even less salmon in their diets than lone females. In the forested north Pacific coast, the amount and quality of streamside vegetation may accentuate competition for salmon among bears. The dense forests in this area allow for greater numbers of bears to utilize streams without potentially detrimental interactions. However, if these forests are removed or altered by management activities (e.g., logging operations), a greater potential for competition and interactions between bears exists. The added competition may result in less salmon in the diet of subordinate bears, especially females.

We used stable isotope analysis (Ben-David et al. 2004, Mowat and Heard 2006) to investigate diets of brown bears visiting salmon spawning streams during the late summer in Southeast Alaska. We collected hair samples along salmon spawning streams using hair snares (Beier et al. 2005) deployed for a DNA-based mark-recapture population estimate (Chapter 2, this report). We analyzed hair samples for the stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$; Ben-David et al. 2004). Although not part of the original study, the opportunity arose to examine late summer diets through the assistance of Garth Mowat (personal communication) as part of his study of brown bear diets across Alaska and British Columbia (Mowat and Heard 2006). Each hair sample was genotyped (Chapter 2), so we could determine diets of individual, known bears. In addition, we had location data from GPS-collared bears using the area (Chapter 1). Thus for some marked bears, we had diet and movement data. We hypothesized that female brown bears in a watershed with relatively unaltered riparian habitat would consume more salmon during the late summer compared with a heavily altered watershed.

STUDY AREA

We selected 2 nearby watersheds on northeast Chichagof Island, Southeast Alaska for study, Spasski and Freshwater creeks (Fig. 1). Northeast Chichagof Island, located about 50 km west of Juneau, Alaska, has 26 productive salmon-spawning streams and abundant brown bear populations (Miller et al. 1997, Titus et al. 1999). Each studied watershed had a productive salmon-spawning stream of similar size, channel types, flow, and salmon escapements. The watersheds differed in the amount of habitat alteration resulting from logging. Because of different ownership and management objectives, the 2 watersheds represented a contrast of streamside vegetative conditions because of past logging activities. On Freshwater Creek (U.S. Forest Service lands), only 2.5% of the study area within 150 m of the stream had been cut, leaving 81% in open or closed forest. On Spasski Creek (private lands), 38% of the study area within 150 m of the stream had been clearcut, leaving 52.7% forest. We selected a 5-km segment of each stream for intensive study (Fig. 1). Because of past research, this area had a large number (>100) of previously radiocollared brown bears with known use patterns (Titus et al. 1999).

METHODS

We evaluated brown bears diets using stable isotope analysis of guard hairs. We used hair from individual-genotyped bears collected along the heavily altered Spasski Creek (5 males, 18 females) and the relatively unaltered Freshwater Creek (2 males, 22 females) during July 29 - October 10, 2003 (Chapter 2). The hair was collected at snare sites located on 5-km sections of the streams during several hair-snaring sessions (Chapter 2). Most hair samples (86.5%) were collected during the late summer period (August 15 to September 15) according to methods described in Beier et al. (2005). Hair samples were dried, and then placed in paper envelops for storage (Chapter 2).

Genotyping Bears

Hair samples were sent to a commercial genetics laboratory (Wildlife Genetics International Lab, Nelson, BC) for DNA extraction and individual bear identification (Paetkau 2003, Chapter 2) using 7 microsatellite loci (G1A, G1D, G10H, G10J, G10M, MU50, G10X, Paetkau et al. 1998, Paetkau 2003). If values were obtained for all 7 loci, we considered the hair sample to have been successfully genotyped for the purpose of individual identification (Paetkau 2003).

Stable Isotope Analysis

Stable isotope analysis of guard hair samples was completed as described by Mowat and Heard (2006) as part of a larger study of brown bear diets. For bears with multiple samples, we used the hair sample collected latest in the year. Although Fortin et al. (2007) found that isotope signatures of guard hairs did not vary during the summer, we felt that samples collected later in the year would better reflect summer diets because hair would be activity growing during the summer. Jones et al. (2006) found that guardhair values differed from underfur because the guardhair better reflected annual diets and underfur better represented autumn diets. After the roots were removed for DNA analysis, the hair was cleaned by soaking it for 2 h in a 2:1 chloroform–methanol solution, and then it was rinsed in distilled water and air dried. One or more hairs totaling 1 mg (0.8–1.2 mg) were put into a tin cup and analyzed at University of California, Davis for the stable isotopes of carbon ($\delta\ ^{13}C$) and nitrogen ($\delta\ ^{15}N$). Measurement error, variation among repeated measures of hairs from within the same sample, and variation among hairs taken from different areas of the body were not large enough to mask variation among bears. Two control samples were analyzed after every 12 hair samples, and measurement error was 0.05 (SD) for $\delta\ ^{13}C$ and 0.12 for $\delta\ ^{15}N$ (n = 103), which was lower than the variation among repeated samples (Mowat and Heard 2006).

We assumed that increasing ratios of $\delta^{15}N$ and decreasing ratios of $\delta^{13}C$ reflected a greater proportion of salmon in bear diets (Ben-David et al. 2004). Diet variability by sex was described by the coefficient of variation (CV) of the sample. We compared means of $\delta^{15}N$ ratios for males and females with *t*-tests to look for sexual differences. In order to examine differences in salmon consumption by bears visiting the study steams, we compared $\delta^{15}N$ ratios of males and female bears found at Spasski and Freshwater creeks using *t*-tests.

GPS-collared Bears

Of the genotyped bears, 14 bears had been outfitted with GPS telemetry collars (Chapter 1). Thus, we obtained hair samples from known bears with known movements. We compared utilization distributions (see Chapter 1) of 14 bears (3 male, 11 females) that had been radiocollared and then had their hair snagged in hair traps placed along salmon streams during late summer. We used linear regression to examine the relationship between mean distance from salmon spawning streams for individual bears and $\delta^{15}N$ in their diet during late summer.

RESULTS

Brown bears on Chichagof Island showed substantial individual variation in diet as indicated by stable isotope ratios (Fig. 2). We found $\delta^{15}N$ ratios of females (CV = 28.6%) to be more variable than those of males (CV = 13.4%). Based on $\delta^{15}N$ ratios, male bears ($\bar{x}$ = 11.3, SE = 0.69) consumed significantly more salmon than females ($\bar{x}$ = 8.8, SE = 0.41; t = 2.3, P < 0.03). Female brown bears on Freshwater Creek consumed significantly more salmon compared with those on Spasski Creek ($\bar{x}$ = 9.7 vs. 7.7, t = 2.56, P = 0.02; Table 1). We found no significant difference in the mean values of $\delta^{15}N$ for males between the two creeks (Freshwater $\bar{x}$ = 12.3 vs. 10.8, t = 0.88, P = 0.38).

For the collared bears, we found $\delta^{15}N$ ratios strongly correlated with mean distance from salmon spawning stream (r^2 = 0.57, P < 0.01; Fig. 3). On Spasski Creek, the utilization distributions of all 4 GPS collared brown bears (1 male, 3 females) overlapped Spasski Creek. The males spent most of their time near the stream and had a large proportion of salmon in their diets (Fig. 5). The amount of salmon in the diets of females varied substantially. Some females that spent substantial time near the salmon streams actually fed little on salmon (Fig. 4).

DISCUSSION

We found that male brown bears along salmon spawning streams foraged primarily on salmon, even in the highly altered watershed. In contrast, female bears generally ate less salmon and their use of salmon was more variable. Females in the less altered watershed (Freshwater Creek) consumed significantly more salmon than females in the highly altered watershed (Spasski Creek). Our observations were consistent with the predictions of Ben-David et al. (2004) that female bears, especially females accompanied with cubs, would choose to avoid conflicts with male bears along salmon streams to reduce the risks of infanticide and cannibalism (Rode et al.

2006). Consequently, a salmon stream with limited forested buffers would provide less cover for foraging bears and provide less security for foraging females. Female brown bears in the altered Spasski Creek spent less time along salmon spawning streams and moved greater distances away from the streams (Chapter 1), probably resulting in a reduced amount of energy intake for these bears (Nevin and Gilbert 2005). We found that amounts of salmon in diets of individual bears were correlated with mean distance from salmon streams. Because female brown bears in altered Spasski Creek traveled greater mean distances from salmon streams and spent less time near salmon streams (Chapter 1), they had less opportunity to forage on salmon and thus consumed less salmon.

No-cut, forested buffers along all salmon-spawning streams would provide more opportunities for brown bears to foraging on salmon, especially females and other more subordinate bears. Previous recommendations for a no-cut buffer width of about 160 m (Schoen and Beier 1990, Swanston et al. 1996, Titus and Beier 1999) probably represent a minimum needed for maximum access. In order to ensure long-term sustainable brown bear populations in altered landscapes, no-cut buffers should probably be larger, more like 305 m (Chapter 1). These no-cut buffers should be applied to all salmon-spawning stream segments, not just streams with the greatest salmon escapements. Because small salmon streams may receive less use by more dominant bears (Gende et al. 2004, Rode et al. 2006; Chapter 1), small salmon streams provide important foraging areas for less dominate females and subadults. Also, small salmon streams are scattered across the landscape, providing a broader dispersion of foraging areas.

Although we considered Freshwater Creek as relatively unaltered, the watershed has been roaded and a significant portion of the area clearcut. Although we found greater use of salmon in less altered Freshwater Creek than highly altered Spasski Creek, we do not know whether salmon use would be even greater in completely unaltered watersheds. Completely intact watersheds provide all the needs of brown bears in coastal environments (Schoen and Beier 1990) and would ensure healthy future populations (Audubon Alaska 2007).

We did not have an opportunity to investigate other timber harvesting techniques besides clearcutting. Partial cutting of buffers, and the landscape in general, could leave substantial cover, depending on the amount of retention, and maintain berry-producing understory plants. Unfortunately, little partial cutting is done currently or anticipated into the future (USDA Forest Service 1997).

MANAGEMENT IMPLICATIONS

Our results support maintaining no-cut, forested buffers along all salmon-spawning streams in areas where brown bear occur to provide salmon for foraging bears, especially females and more subordinate bears. Because female brown bears with more salmon in their diet are more productive (Hilderbrand et al. 1999*c*), we expect that female bears foraging in highly altered landscapes would be less productive because they have more restricted access to salmon than those in less altered settings. A less productive brown bear population would decrease over time, even with constant mortality. With more social conflict along streams and restricted access to salmon, mortality rates may increase. Also increased development and human activities, associated with highly altered landscapes, would lead to higher mortality rates for brown bears (Titus et al. 1999). Furthermore, forest succession in clearcuts will eliminate important berry producing habitats over time (25-30 years), reducing alternate foods in altered watersheds.

This combination of decreased productivity and increased morality could have long-term detrimental effects on a brown bear population. Because brown bears are long-lived, a measurable population response may take several years to detect. Currently, brown bear hunting provides substantial economic benefits to local economies. Because of high current demand, hunting regulations and land-use permits restrict brown bear hunting in all areas of the north Pacific coast (Alaska Department of Fish and Game 2006, USDA Forest Service 2004, British Columbia Ministry of Environment 2006). A further reduction in population productivity and survival would result in reductions in hunting and viewing opportunities.

FIGURES

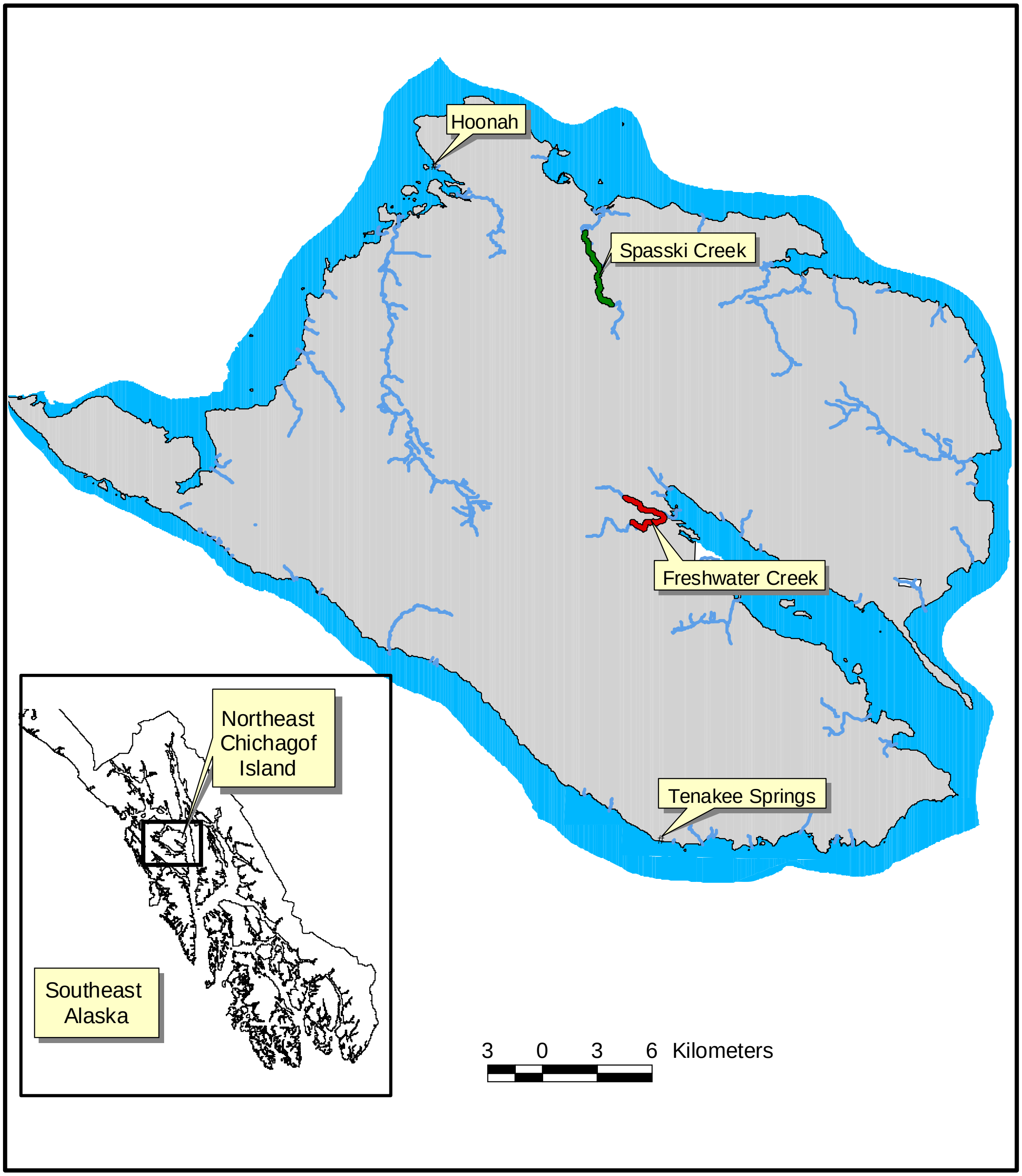

Figure 1. Study streams on northeast Chichagof Island, Southeast Alaska, including the highly altered Spasski Creek and the relatively unaltered Freshwater Creek.

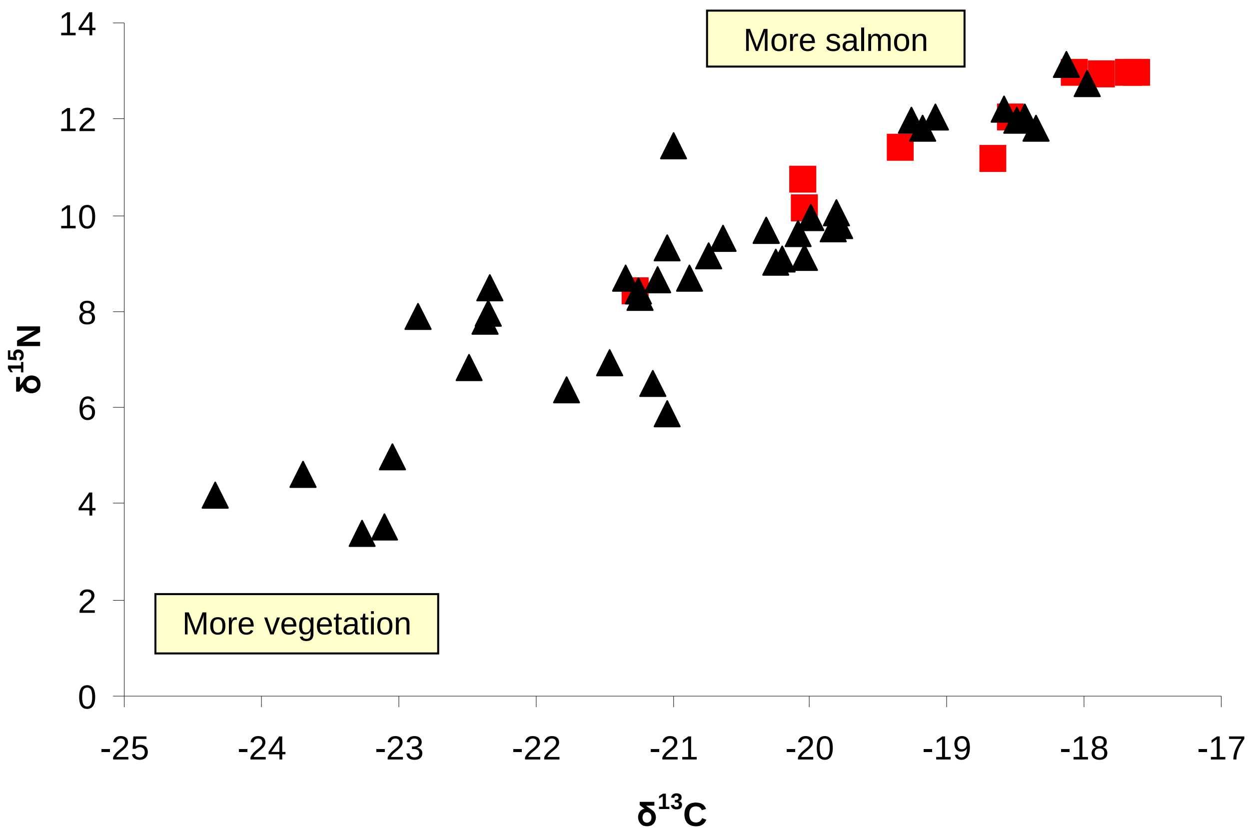

Figure 2. Stable isotope values ($\delta^{15}N$) for brown bear hair collected along 2 study streams on northeast Chichagof Island during early fall 2003 (males = squares and female = triangles).

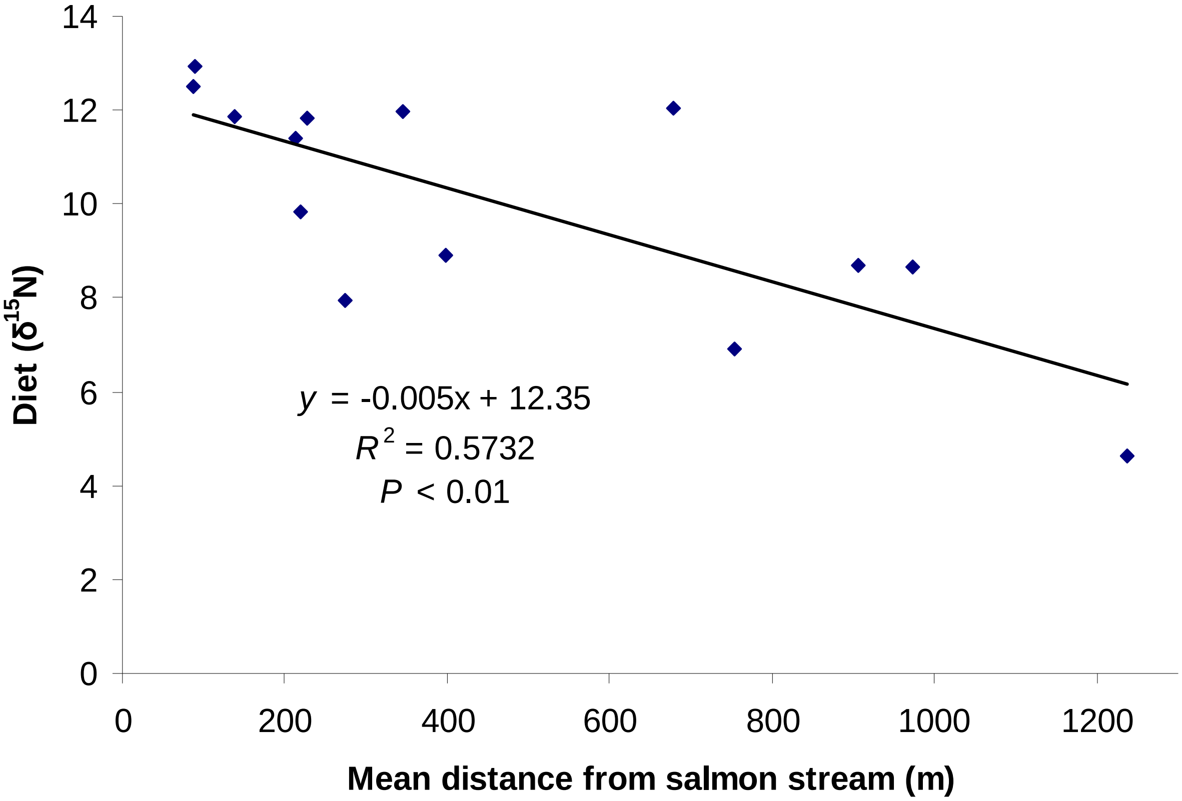

Figure 3. Relationship between the mean distance from salmon stream and $\delta^{15}N$ in diet for brown bears on Chichagof Island, 2003.

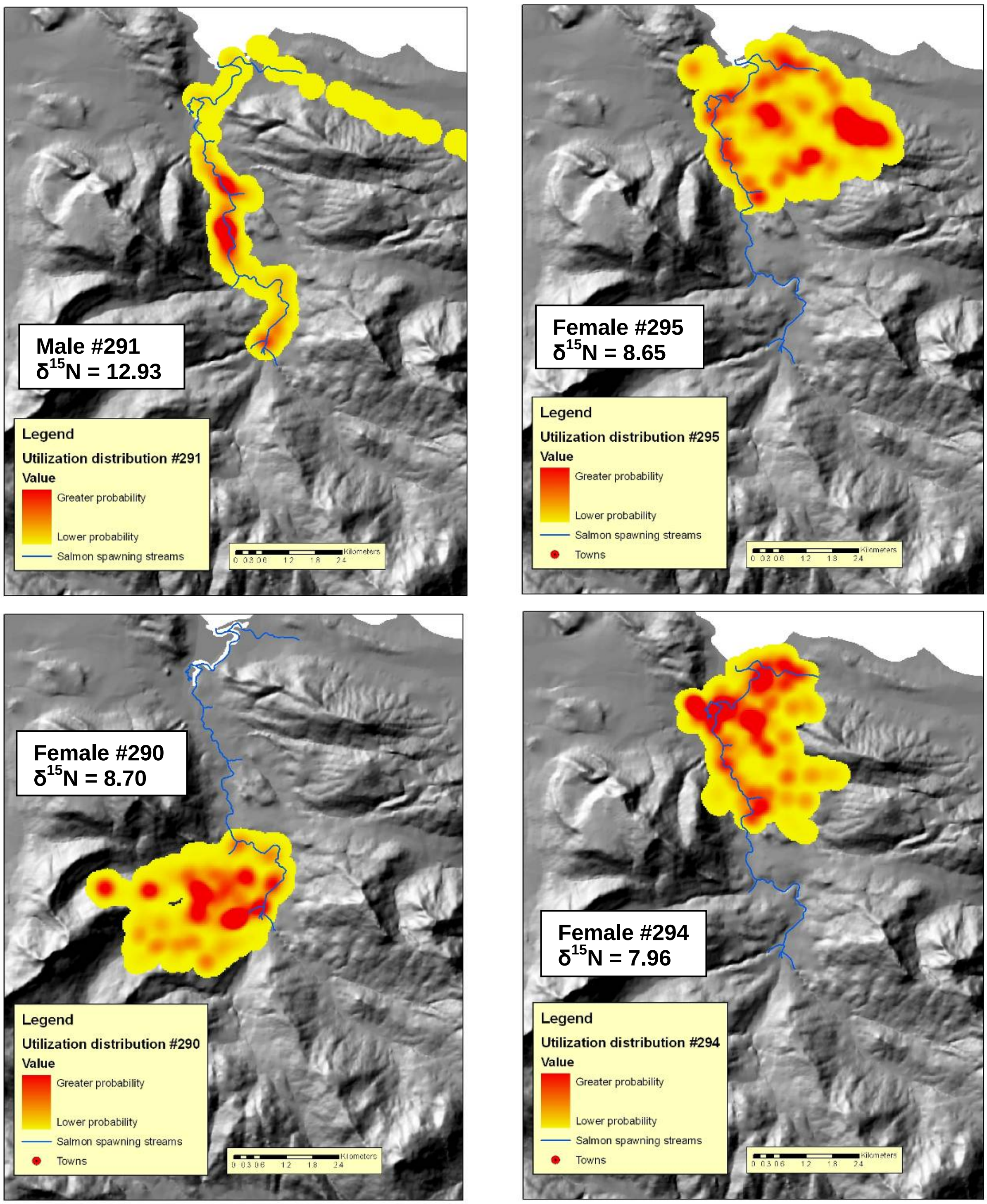

Figure 4. Utilization distributions of selected brown bears on Spasski Creek with differing amounts of salmon in their diets based on stable isotope analysis of hair samples. A larger value for $\delta^{15}N$ indicates more salmon in the diet. Although all bears showed overlap of their use distributions with a salmon stream, the amount of salmon in the diet varied substantially among animals.

Table 1. Stable isotope values ($\delta^{15}N$ and $\delta^{13}C$) for brown bear hair samples collected along 2 streams on northeast Chichagof Island during late summer and early fall 2003. Spasski Creek watershed had been highly altered by clearcut logging and Freshwater Creek was relatively unaltered. Mean values ($\delta^{15}N$ and $\delta^{13}C$) for males were significantly greater than values for females.

Stable isotopes	Spasski Creek			Freshwater Creek			*P* value
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	
Males							
$\delta^{15}N$	4	10.84	0.99	2	12.30	0.22	0.38
$\delta^{13}C$	4	-19.56	0.72	2	-18.11	0.04	0.24
Females							
$\delta^{15}N$	18	7.77	0.47	22	9.72	0.57	0.02
$\delta^{13}C$	18	-21.58	0.27	22	-20.19	0.36	0.01

Chapter 4

EVALUATING A BEAR-USE PROTOCOL ON NORTHEAST CHICHAGOF ISLAND, SOUTHEAST ALASKA

Stephen B. Lewis, Rodney W. Flynn, and LaVern R. Beier

INTRODUCTION

Long term conservation of brown bears (*Ursus arctos*) is of high public interest for a variety of reasons, including viewing, hunting, ecosystem values, and intrinsic human values. Coastal brown bears have been a significant wildlife species on the Tongass National Forest since the beginning of the Tongass Land Management Plan (TLMP) revision process (Sidle and Suring 1986). During this revision, bear experts expressed concern about the long-term population viability of brown bears unless adequate riparian vegetation was maintained, especially in areas with spawning salmon (*Oncorhynchus* spp.; USDA Forest Service 1997). These panelists strongly recommended that a minimum 150-m, no-harvest buffer be maintained along streams considered important for brown bear foraging (Swanston et al. 1996). However, during finalization of the revised TLMP, this recommendation was changed to protection specific locations on streams deemed “important brown bear foraging sites” (e.g., waterfalls used as fishing sites) and became a Wildlife Standards and Guidelines (S&G; USDA Forest Service 1997).

In the revised TLMP, a Bear Habitat Management S&G recommended establishing a 150 m (500 ft) forested buffer at sites where additional protective measures are needed to provide cover among brown bears while feeding, or between brown bears and humans (U.S. Forest Service 1997). This buffer is in addition to those provided by the Riparian and Beach & Estuary Fringe Forest-wide S&Gs and the Old-growth Habitat and other natural setting Land Use Designations (U.S. Forest Service 1997). However, it remained unclear how these areas would be delineated on the ground. In 1998, the Tongass Plan Implementation Team (TPIT), comprised of Forest Service and other Federal and State agency personnel, attempted to clarify this management direction. In a letter to the Tongass Leadership Team, TPIT developed a process for determining important brown bear foraging sites, as follows (7 Aug 1998 Letter to Tongass Leadership Team from the Tongass Plan Implementation Team, on file at ADF&G, Division of Wildlife Conservation, Douglas, AK):

1. Identify Class 1 streams supporting spawning salmon (salmon streams) within the analysis area;
2. Of these salmon streams, delineate those stream segments classified as the Moderate Gradient/Mixed Control and Flood Plain process group;
3. Apply the TLMP Riparian S&Gs to the salmon streams and identify segments that are protected by a 500-ft (150-m) wide or greater protective buffer on both sides of the salmon stream;

4. Along segments of salmon streams not protected in 3) above, visit the area looking for evidence of brown bear use. If time, funding or other factors limit the time in the field, focus work on the Moderate Gradient/Mixed Control and Flood Plain process group reaches of the stream;
    a. Fish and wildlife biologists with expertise in brown bear habitat should visit and walk salmon spawning habitats along streams after the peak of the salmon run.
    b. Examine the number of brown bear trails and resting sites along a given length of stream. Areas that are important for brown bears have extensive trail systems often connecting them to nearby hills and bluffs overlooking the lower elevation riparian zone. The understory vegetation in these areas will usually be trampled by extensive bear activity.
5. Document the field observations on aerial photos and maps. If ADF&G personnel did not take part in the field work, coordinate with the local Habitat and/or Wildlife Conservation biologist to see if they can provide any additional information. Consultation with ADF&G and others will be especially important for project areas on the mainland.

However, despite this effort, quantifiable field criteria were not established and judgment-laden words (e.g., extensive trail systems) were left up to the discretion of each biologist evaluating individual timber sales.

As part of a larger study of brown bear use of riparian and beach zones, we set out to clarify this management recommendation. Our goal was to develop a practical field protocol for evaluating bear use of riparian areas when laying out timber sales to identify areas of important foraging activity. Specifically, we wanted to design a practical protocol for evaluating brown bear use of streams by quantifying bear signs, evaluating protocols using data gathered on northeast Chichagof Island, and testing the feasibility of using the protocol to determine important foraging areas.

STUDY AREA AND METHODS

We studied brown bears on northeast Chichagof Island in Southeast Alaska (Fig. 1, Chapter 1 for details). We investigated important foraging areas on Spasski, Freshwater, Game, Kennel, and Head of Bay Creeks (Fig. 1). We selected streams based on forest cover and the level of management of the surrounding landscape for other objectives of our study. We sampled stream reaches that either had salmon spawning areas or were isolated from salmon spawning habitats by a blocking feature (e.g., falls). Each stream was characterized by alternating riffles and pools, periodic gravel bars, and significant amounts of large woody debris.

We reviewed previous work on ground-based sign surveys for brown bears in Southeast Alaska (e.g., Bloom 1998; Whitman, ADF&G, unpublished data) and discussed the issue with Forest Service, U.S. Fish and Wildlife, and ADF&G biologists familiar with brown bear biology. Several issues were considered, including: 1) timing of surveys; 2) standardization of sign to record; 3) transect layout; 4) amount of time spent on a survey; and 5) utility of the data to determining important bear foraging sites. Based on these discussions, we designed a protocol to sample streams and quantify use by brown bears based on observed sign.

We developed this protocol to test on streams located on northeast Chichagof Island. We selected 9 500-m stream sections (Fig. 2). These were broken into 100-m sub-sections. We ran transects of 150, 90, or 30 m perpendicular to the streams and parallel transects of 100 m connecting the ends of perpendicular transects (Fig. 2; Flynn et al. 2004). These distances corresponded to buffer distances from TLMP: 30-m (100-ft) Riparian S&G (buffer primarily given to salmon bearing streams); and 150-m (500-ft) Wildlife S&G (buffer for important brown bear foraging areas). At the start of each stream section, we randomly selected the distance of the first perpendicular transect, and then followed a predetermined progression (i.e., 30 m, then 90 m, then 150 m) to determine distances. We based the perpendicular bearing on the general azimuth of each stream section (i.e., if stream bearing was 180°, perpendicular bearing was 90° or 270°; Fig. 2).

We started each transect at the stream edge and measured the distance to the nearest meter with a hip-chain. We recorded the types of bear sign and distance from the stream while walking along each transect using a compass. We differentiated 2 categories of bear sign, based on their persistence time: 1) long-term types (i.e., that persist across years; e.g., perennial trails, beds, rub trees) and short-term types (i.e., that do not persist across years; e.g., ephemeral trails, salmon carcasses, and scats). We divided bear sign into categories: 1) perennial trails = long-term trails that persist across years; 2) ephemeral trails = trails or broken vegetation that will not persist through the winter; 3) fish remains; 4) scat; 5) beds; 6) rub trees; and 7) digging, grazing, or foraging (not fish) locations. We ran surveys after salmon spawning in the fall to capture sign types that would be lost over the winter. Field crews were trained to standardize the recording of bear sign. The intensity of bear sign (trails, scats, daybeds, etc.) was used as a measure of bear use.

The spatial distribution of bear-sign locations in relation to the stream zone was examined and displayed using GIS software (ArcView GIS 3.3, ESRI, Redlands, CA). We used extension Distance/Azimuth (D/A; website: http://www.jennessent.com/arcview/distance_azimuth.htm) to project each sign from the start point (determined by GPS). This was necessary because a perpendicular bearing in one sub-section of stream may not be perpendicular in the next section and thus the measured distance might not reflect each sign's true distance from the stream. Using the D/A extension, we projected signs and then determined the closest distance to the stream.

The intensity (i.e., density) of bear sign was used as a measure of bear use. We calculated the density of bear sign by tallying the number of each type of sign on each transect and dividing by the total distance traversed on that transect. We multiplied that number by 100 to generate the density value of sign/100 m. We compared these values between salmon reaches and non-salmon reaches using only transects perpendicular to the stream using a *t*-test.

We further examined density of sign by comparing densities of bear sign on Freshwater and Spasski Creeks. Based on the utilization distributions of GPS-collared brown bears (this report, Chapter 1, Fig. 3), we split transect groups into those in areas of high bear-use and those in areas of low bear-use. We compared these values using only transects perpendicular to the stream using a *t*-test.

RESULTS

We sampled 2 streams (32 transects) in October 2003 and 6 streams (79 transects) in October 2004 for evidence of bear use (Fig. 1, Table 1). We sampled streams in October because many bears had left the streams (S. Lewis, Alaska Department of Fish and Game, personal observation) but before most of the stream-side shrubs had lost their leaves and vegetation had died. Within those streams, 6 reaches were located along salmon spawning habitat and 3 were located above stream obstructions that blocked salmon (Fig. 1).

During the 2 years, we found 980 signs of bear-use, the most common of which was bear trails (71%; 525 perennial and 169 ephemeral; Table 2). Other indicators of bear use included signs of foraging (15%; 95% of which were diggings for skunk cabbage), beds (7%), scats (4%), salmon remains (3%), and rub-trees (trace; Table 2). Most bear sign we detected (89%) was found along stream reaches with spawning salmon (Table 2). Some sign (e.g., fish remains, rub trees) was only found where salmon spawned and some types of sign (e.g., scats, beds) were detected rarely away from salmon spawning reaches (Table 2).

We found different types of bear sign at variable distances from the stream edge (Table 2). Perennial trails were slightly farther from streams, on average, than ephemeral trails (Tables 2). Fish remains and scats were found closer to stream edges while rub trees were found well away from the stream edges (Table 2). We found little difference between reaches with salmon and without salmon in the distance to different types of sign (when we had an adequate sample on both types of reaches; Table 2). We detected all types of bear sign except rub trees more frequently close to stream edges (Table 3); rub trees were found equally at all distances from the stream edge (Table 3).

The density of each different type of bear sign differed between stream reaches with spawning salmon and those without (Table 4). Perennial trails were twice as dense along salmon reaches as non-salmon reaches and ephemeral trails were nearly 5 times as dense where salmon occurred (Table 4). Only rub tree density was not significantly different between stream types (Table 4).

We used density values from transects measured at 1 reach on Spasski Creek (11 transects), 1 on the West Fork of Freshwater Creek (10 transects) and 1 on the North Fork of Freshwater Creek (8 transects) for areas with high activity (Fig. 1). We used 1 reach from upper West Fork of Freshwater Creek (8 transects) as our low activity area (Fig. 1). Within streams with spawning salmon, we found few differences in density of bear sign between high and low use bear areas (Table 5). Only the density of fish carcasses was significantly different with approximately 5 times as many carcasses in the high use area compared with the low. The density of ephemeral trails was marginally significant between the two areas with approximately 3 times as many of these types of trail in the high use areas as the low use areas (Table 5).

DISCUSSION

We designed a protocol to measure brown bear sign along salmon-spawning streams on northeast Chichagof Island and evaluated it during 2003 and 2004. Our protocol involved hiking transects away from streams on transects to quantify different kinds of bear sign, both perennial and ephemeral. Using this protocol, we were able to meet our objective of documenting bear use of salmon streams by counting sign.

We documented different types of sign, their distance to the stream, and the density of the sign in the reaches we sampled. By hiking transects perpendicular to the stream course, digitizing these detections, and adjusting the distance to the stream, we were able to get an accurate sample of signs of bear use on these streams. Indeed, we were able to clearly differentiate reaches where spawning salmon occurred, and thus bears were fishing, from reaches where no spawning occurred. While these areas still had some bear sign, it was significantly less dense than where spawning salmon occurred.

While useful in determining gross differences in bear use (i.e., high use at salmon streams versus low use at non-salmon streams), our protocol failed to achieve our ultimate goal of differentiating important foraging areas based on bear sign. We did not detect a difference in density of various types of bear sign between areas of high bear use and low bear use, based on GPS collar data.

Our evaluation of this protocol identified concerns with this sign survey approach. These survey techniques require sending biologists to hike transects along salmon streams during spawning seasons when bear densities are high. Hiking transects that leave the stream and enter dense vegetation where bears may be bedded down or consuming salmon is especially dangerous. This activity will eventually lead to surprise encounters between bears and biologists that could result in bears being killed in defense of life and property, or worse.

Each survey should be conducted after the peak time on a stream when the fish are most abundant and the bears most actively fishing. This timing in turn depends on many uncontrollable variables such as the timing of the salmon run, weather during the run, and individual bear fishing behavior, and can differ across streams. If the survey is conducted too early, many ephemeral trails will not yet be created by bears, but surveying too late will result in lost fish carcasses and dead vegetation (and thus missed ephemeral trails).

Similarly, surveys should be conducted during the fall of the year, just after salmon spawning is complete. While some types of sign (e.g., perennial trails, beds) persist across years, much sign (e.g., ephemeral trails, fish remains, and trampled vegetation) is lost during the winter (S. Lewis, personal observation). Ephemeral trails are created by bears knocking down shrubs and grasses at or near the stream. Once these plants die for the winter these trails become difficult to identify and when plants re-grow in the spring, all sign of those trails are lost. Most salmon remains have a very short half-life on the forest floor (S. Lewis, personal observation). Jaws persist longer but are easily lost amidst forest litter on the forest floor.

Yearly salmon abundance is another important variable to consider. Within each stream, salmon abundance can vary annually (ADF&G unpublished data, Halupka et al. 2000), leading to variation in the amount of stream habitat utilized for spawning. This could result in an area that receives extensive fishing by bears in one year, but used very little during other years. In areas not used for spawning each year, long term sign of bear use (e.g., perennial trails, beds) would persist but extensive trampling of vegetation, carcass remains, and scats would not be found each year. Therefore, misleading results could be obtained from this sign survey if conducted on a portion of a stream that was not used by bears during the preceding spawning season.

Other attempts have been made to clarify this management recommendation. Bloom (1998) described an attempt to determine important bear foraging sites using transects to count bear sign, but concluded that more work was needed to determine the amount of bear sign needed to constitute important foraging areas. Their technique, which involved hiking transects along established bear trails and counting side trails and other sign types, did show some correlation between bear use and salmon abundance but failed to establish a quantifiable demarcation in amounts of bear use.

A different alternative to transect-based sign surveys to describe bear use has been used by Christensen (2002) and Christensen and Van Dyke (2004) in other areas. They used a sign-mapping technique that provides a density map of intensity of bear sign (e.g., trails). Their approach provides a more extensive look at the type and density of sign in specific areas. However, it requires much more time walking trails and documenting sign, with the associated risks described above. Additionally, it requires relatively sophisticated GIS analysis to produce these maps. The combined time (of data collection and analysis) this technique requires makes it unrealistic for district biologists to complete for each and every timber sale.

Determining a cost- and time-effective method to identify areas that are important for brown bear foraging has been a difficult task for researchers and managers in Southeast Alaska. Since the revision of the TLMP, there has been a desire for a protocol that Forest Service district biologists can use to identify those areas that deserve additional buffering based on their importance to foraging brown bears. This has been, and continues to be, an elusive goal.

MANAGEMENT IMPLICATIONS

We found the transect method for sampling spawning streams to determine the importance for foraging bears was not well suited to the problems associated with the S&G. A protocol involving line transects along salmon streams was able to identify foraging areas but could not differentiate between high- and low-use areas. While reasonably inexpensive and quick to complete, these transects can be dangerous because of proximity to bears and can be affected by variables that are hard to control. While sign surveys can document gross amounts of bear use along streams, evidenced by the differences in sign density between lengths along salmon streams versus those not on salmon streams, these types of surveys do not provide precise information about the numbers of bears using areas of stream (i.e., no differences between high and low use areas). Therefore, we do not recommend a sign survey approach for determining which areas should have additional buffers associated with important foraging areas. We recommend following and extending the letter of clarification on the Brown Bear Habitat S&G. Specifically, we recommend removing all sections covered in beach buffers, then applying a 150-m (500-ft) no-cut buffer to any remaining sections of stream that support spawning salmon.

FIGURES

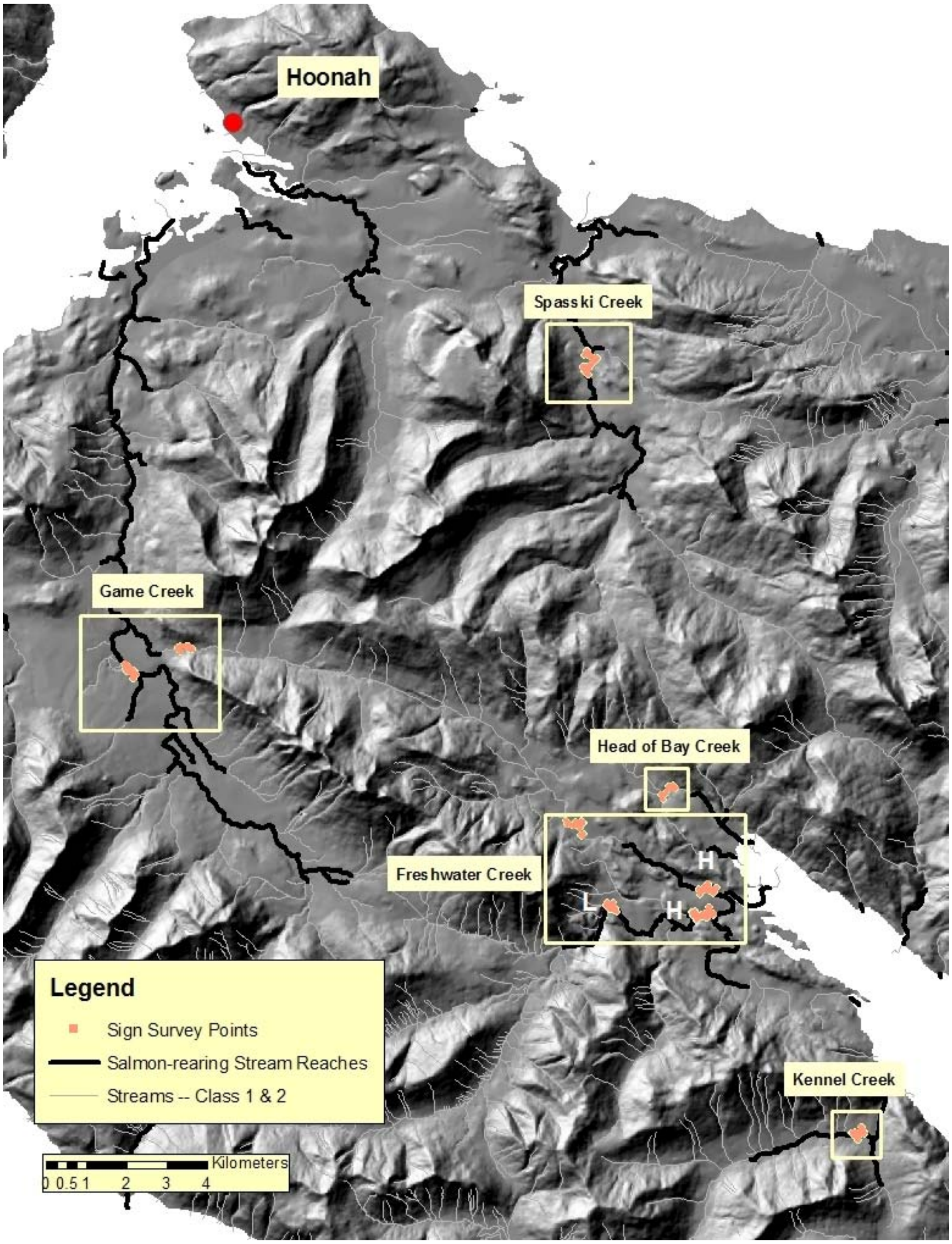

Figure 1. Brown bear sign survey locations on class 1 and 2 streams and reaches with salmon rearing habitat, northeast Chichagof Island, 2001 – 2003. Groups of points signify location of survey. H indicates transects with high bear use on Freshwater Creek; L indicates reach with low bear use.

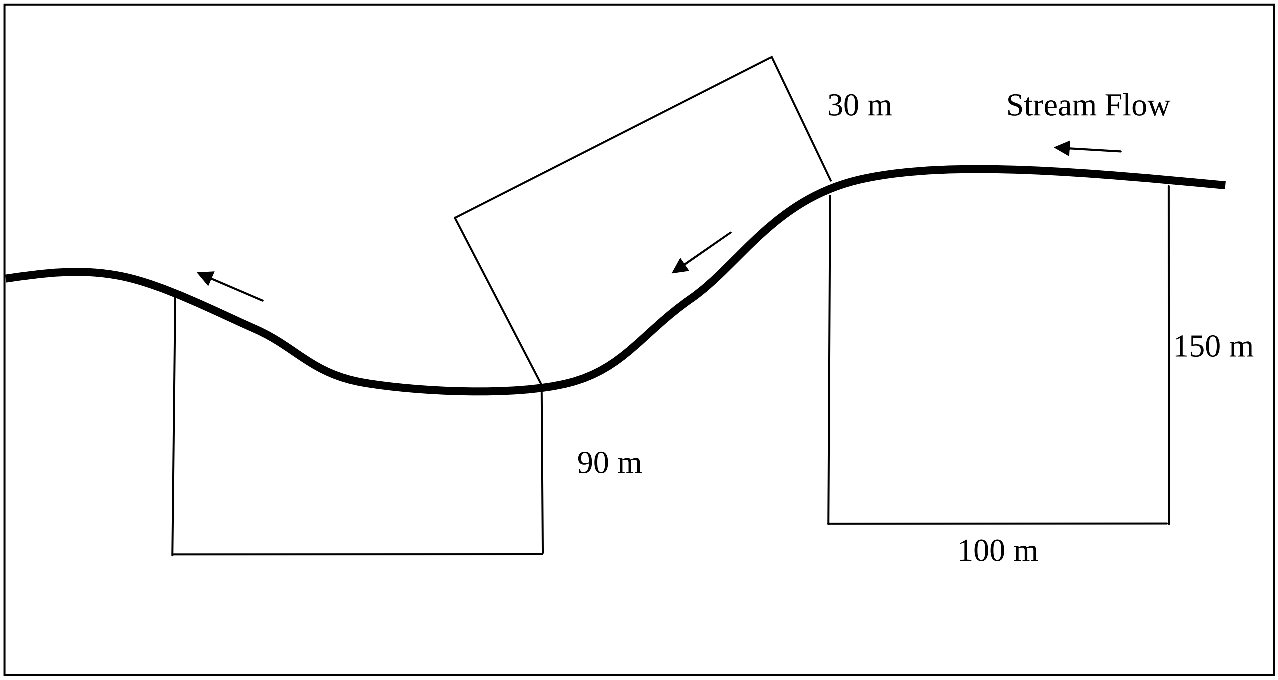

Figure 2. Sampling scheme for brown bear sign surveys conducted on northeast Chichagof, 2002 and 2003. Each survey consisted of 500 m of linear stream distance, broken down in to 5 – 6 3-transect subsections. The first transect of each subsection was perpendicular to the direction of stream flow and a predetermined distance (i.e., 30 m, 90 m, or 150 m). The middle transect was 100 m. The returning transect (i.e., back to the stream) was measured as it was conducted.

TABLES

Table 1. Stream reaches surveyed for brown bear sign on northeast Chichagof Island, 2003 and 2004.

Stream	Reaches surveyed	No. transects[a]	Distance surveyed (m)
Game Creek	2	19	1678
Head of Bay Creek	1	13	949
Kennel Creek	1	11	1095
N. F. Freshwater Creek	2	24	2329
Spasski Creek	1	17	1648
W. F. Freshwater Creek	2	27	2602
Total	9	111	10301

[a] Includes transects perpendicular and parallel to the stream course.

Table 2. Types of brown bear sign detected and distance to streams of that sign on surveys conducted on streams on northeast Chichagof Island, 2003 and 2004.

	Salmon reaches			Non-salmon reaches			Overall		
Sign Type	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Trail – perennial	437	40.8	38.3	88	38.8	39.5	525	40.4	38.5
Trail – ephemeral	155	31.0	32.5	14	39.6	52.9	169	31.8	34.5
Fish Remains	30	20.3	22.0	0	~	~	30	20.3	22.0
Scat	36	27.2	26.1	1	51.2	~	37	27.8	26.1
Bed	65	30.7	25.1	2	16.3	6.7	67	30.3	24.8
Rub Tree	4	96.9	71.9	0	~	~	4	96.9	71.9
Foraging	140	44.0	42.4	8	30.9	55.5	148	43.3	43.1
Total	867	~	~	113	~	~	980	~	~

Table 3. Types of brown bear sign detected and distance to streams of that sign on surveys conducted on transects perpendicular to streams on northeast Chichagof Island, 2003 and 2004.

	Salmon reaches			Non-salmon reaches			Overall		
Sign Type	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Trail – perennial	313	24.8	19.6	64	30.6	34.8	377	25.7	22.9
Trail – ephemeral	117	19.6	16.9	11	34.3	46.3	128	20.9	21.2
Fish Remains	26	14.3	9.4	0	~	~	26	14.3	9.4
Scat	34	23.4	17.1	1	51.2	~	34	23.4	17.1
Bed	42	22.8	18.1	2	16.3	6.7	44	22.5	17.8
Rub Tree	2	37.3	26.5	0	~	~	2	37.3	26.5
Foraging	98	21.6	15.1	4	50.3	78.6	102	22.7	20.8
Total	632	~	~	81	~	~	713	~	~

Table 4. Density (no. of occurrences/100-m transect) of brown bear sign on perpendicular transects on streams on northeast Chichagof Island, 2003 and 2004.

	Salmon reaches[a]			Non-salmon reaches[b]					
Sign Type	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	*t*	df	*P*
Trail – perennial	6.6	4.0	0.0-17.4	3.9	2.5	0.0-10.0	3.5	59	0.001
Trail – ephemeral	2.7	2.7	0.0-10.0	0.6	1.1	0.0-3.3	4.7	71	<0.000
Trail – combined	9.4	4.0	3.3-21.7	4.6	2.5	0.0-10.0	6.1	60	<0.000
Fish Remains	0.7	2.0	0.0-13.0	0.0	0.0	0.0-0.0	2.6	51	0.012
Scat	1.1	2.4	0.0-14.3	0.0	0.0	0.0-0.0	3.2	51	0.003
Bed	0.7	1.0	0.0-4.4	0.2	0.7	0.0-3.3	2.6	49	0.014
Rub Tree	0.0	0.1	0.0-1.0	0.0	0.0	0.0-0.0	1.2	51	0.201
Foraging	1.8	2.8	0.0-13.3	0.2	0.5	0.0-2.0	4.1	59	<0.000

[a] *n* = 52 transects in 6 areas.
[b] *n* = 21 transects in 3 area.

Table 5. Density (no. of occurrences/100-m transect) of brown bear sign on perpendicular transects on between high and low areas of bear activity, based on radiocollared brown bears, on northeast Chichagof Island, 2003 and 2004.

	High use[a]			Low use[b]					
Sign Type	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	*t*	df	*P*
Trail – perennial	6.6	4.2	0.0-14.3	7.2	2.8	4.0-10.0	-0.4	35	0.717
Trail – ephemeral	3.3	3.1	0.0-10.0	1.3	1.6	0.0-4.5	1.9	35	0.060
Trail – combined	10.0	4.0	4.4-21.4	8.4	2.1	5.3-10.0	1.1	35	0.283
Fish Remains	0.4	0.7	0.0-2.5	0.1	0.2	0.0-0.7	2.2	31	0.033
Scat	1.1	2.9	0.0-14.3	1.3	2.2	0.0-6.7	-1.2	35	0.902
Bed	0.7	0.8	0.0-2.7	1.1	1.3	0.0-3.3	-1.2	35	0.228
Rub Tree	0.1	0.2	0.0-1.0	0.0	0.0	0.0-0.0	0.7	35	0.503
Foraging	2.6	3.4	0.0-13.3	0.6	0.7	0.0-2.0	2.9	34	0.006

[a] *n* = 29 transects in 3 areas.
[b] *n* = 8 transects in 1 area.

Table 6. Average percent of each type of brown bear sign within distance bins on sign surveys conducted on transects on streams on northeast Chichagof Island, 2003 and 2004.

	Salmon reaches[a]				Non-salmon reaches				Overall			
Sign Type	<30	30-90	90-150	>150	<30	30-90	90-150	>150	<30	30-90	90-150	>150
Trail – perennial	56	31	11	3	53	34	12	0	55	32	11	2
Trail – ephemeral	67	24	9	1	52	26	0	22	62	24	6	8
Fish Remains	88	8	4	0	0	0	0	0	58	5	3	0
Scat	65	34	1	0	0	33	0	0	43	34	1	0
Bed	62	35	3	0	67	0	0	0	63	23	2	0
Rub Tree	8	8	8	8	0	0	0	0	6	6	6	06
Foraging	56	28	4	12	83	0	0	17	65	18	3	14

[a] Distances in meters.

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APPENDIX A. BROWN BEAR HABITAT ANALYSIS

14 June 2006

Habitat Map

GIS Files:

National Wetlands Inventory (clipped to NEC and Edited) - Nec_nwi.shp

1. Extended to low-tide shore line in USFS Veg_Mod coverage and modified per Orthophotos;
2. Inland boundaries edited to match actual high-tide shoreline in Orthophotos (1997);
3. Spasski and Freshwater edited to better match E2EM type using Orthophotos.

Variable = SYS_CLASS

USFS Managed Stands (clipped to NEC and Edited) - Ci_mgd_std.shp

Variable used = YEAR_ORIGI (year of harvest).

1. New cuts in Spasski added and boundaries adjusted using new low-elevation photos;
2. Boundaries in other areas with bear points adjusted to match Orthophotos;

USFS Veg_Mod coverage (clipped to NEC and Edited) - ci_veg_mod_edited.shp

VEGECODE; NFCON, SLOPE_CLAS

1. Boundaries adjusted to match nec_nwi.shp and changes in ci_mgd_std.shp;

Habitat Categories

1. Other nonhabitat (Drop from analysis)
   [VEGCODE = 'NF' and NFCON = 'U'];
   [VEGCODE = 'NF' and NFCON = 'R' and ELEVFT ≤ 1,000];
   [VEGCODE = 'NF' and NFCON = 'P';
   [VEGCODE = 'NF' and NFCON = 'W' and ELEVFT ≤ 1,000].

2. Nonvegetated estuary
   [SYS_CLAS (Estuary)= 'E2AB' or 'E2RB' or 'E2RS' or 'E2US'];
   [VEGECODE] = 'W' and [NFCOND] = 'X' and [ELEVFT] >100.
   3. Vegetated estuary
   [SYS_CLAS = 'E2EM'];

4. Alpine
   [VEGECODE = 'NF' and NFCON = 'H'] and [ELEVFT > 1,800].
   [VEGECODE = 'NF' and NFCON = 'R'] and [ELEVFT > 1,000].
   [ELEVFT > 1,800].

5. Other herbaceous
   [VEGECODE = 'NF' and NFCON = 'G'].

6. Avalanche slope
   [VEGECODE = ‘NF’ and NFCON = ‘S’ and ELEVFT ≤ 1,800];
   [VEGECODE = ‘NF’ and NFCON = ‘A’ and SLOPECLAS ≥ 2 and ELEVFT ≤ 1,800];
   [VEGECODE = ‘NF’ and NFCON = ‘H’ and ELEVFT ≤ 1,800];
   [VEGECODE = ‘NF’ and NFCON = ‘L’ and ELEVFT ≤ 1,800];
   [VEGECODE = ‘UF’ and SLOPECLAS = 4 and ELEVFT ≤ 1,800];

7. Other shrub
   [VEGECODE = ‘NF’ and NFCON = ‘A’ and SLOPECLAS = 1 and ELEVFT ≤ 1,800];
   [VEGECODE = ‘NM’ and NFCON = ‘M’ and ELEVFT ≤ 1,800];
   [VEGECODE = ‘NF’ and NFCON = ‘I’ and ELEVFT ≤ 1,800]

8. Scrub forest
   [VEGECODE = ‘FM’]
   [VEGECODE = ‘UF’ and SLOPECLAS < 4 AND ELEVFT ≤ 1,800];
   9. Open forest
   [VEGECODE = ‘V4HY’ or ‘V4-S’ or ‘V4-N’ or ‘V5HY’];

10. Closed forest
   [VEGECODE = ‘V5-S’ or ‘V5-N’or ‘V67’ or ‘V67F’];
   [VEGECODE = ‘XX’];

11. Recent clearcuts
   [YEAR > 1996 and YEAR <2003];

12. Older clearcuts
   [YEAR > 1970 and YEAR <1996];

13. 2nd growth
   [YEAR ≤ 1970];

14. Natural 2nd Growth
   [VEGECODE = ‘SC3’];

15. Freshwater (Drop)
   [VEGECODE] = ‘W’ and [NFCOND] = ‘C’
   [VEGECODE] = ‘W’ and [NFCOND] = ‘N’

16. Mass wasting (Drop)
   [VEGECODE] = ‘NF’ and [NFCOND] = ‘W’ and [ELEVFT] > 300

99. Salt water (Drop)
   [VEGECODE] = ‘W’ and [NFCOND] = ‘X’ and [ELEVFT] <100

Habitat Maps Combined

The 3 habitat maps combined using Union Tool;
Like Polygons combined using Dissolve Tool;
New “Habitat” variable created based on previous habitat definitions.
File = NEC_Brbear_habitat06.mdb

Combined Habitat Categories

2. Estuary (2, 3, & 5);
4. Alpine;
6. Avalanche slope;
7. Other shrub;
8. Scrub forest;
9. Open forest;
10. Closed forest;
11. Recent clearcuts;
12. Older clearcuts;
13. Second growth (13 & 14);

Additional GRID coverages:

1. dist2salmon.shp Distance to salmon spawning stream in feet.
   File created from creating a distance grid around necsalmon.shp
   Variable = Dist2salmon.

2. nec_dist2b Distance to shoreline in clipped NEC file in feet.
   File created from creating a distance grid around shoreline).
   Variable = Dist2beach

3. ripar_index Riparian index from Dave Albert based on a function of slope and distance from stream
   Variable = ripar_i.

4. nec_dem_strm DEM based on STRM clipped to NEC in feet
   Variable = Elevft.

5. nec_slope_strm Grid of slope based on STRM clipped to NEC in degrees
   Variable = Slope.

6. nec_aspect_strm Grid of aspect based on STRM clipped to NEC
   Variable = Aspect.

Brown bear locations

All brown bear GPS locations

Geodatabase = BrbearGPS_CI-S-ALLbears.mdb

Brbearall = All successful GPS locations for all Chichagof Island bears 2001-2004

GRIDS Sampled

Each of the 6 GRIDs sampled at each bear point location.

Variables = Dist2salmon, Dist2beach, ripar_i, Elevft, Slope, Aspect.

Locations Buffered

Each location point buffered by a radius of 25 m to create polygon file.

File = BrbearHab_Buffer

Habitat Maps Sampled

The Union (NEC_Brbear_habitat06.mdb) of the 3 landcover vector landcover maps (Nec_nwi.shp; Ci_mgd_std.shp; and ci_veg_mod_edited.shp) sampled by the location polygons using the ArcMap Intersect Tool to extract the habitat information.

Variables = SYS_CLASS, YEAR_ORIGI, VEGECODE, NFCON, SLOPE_CLAS.

Complete Habitat File

Variables retained
Each record represents a piece of the habitat polygon
Variables retained from the location file:
FIX_
Bearno
Sex
AST
Status_Text
Latitude
Long
Altitude_m
PDOP
HDOP
TDOP
Temp
Activity_Sensor

Variables added as points from GRIDS:
Record_numb
Dist2beach
Dist2salmon

Aspect
Slope
Elevft
HYDRICSMU
ripar_i

Variables added from habitat map
Habitat
SYS_CLASS
YEAR_ORIGI
VEGECODE
NFCON
SLOPE_CLAS
Shape_length
Shape_area

APPENDIX B. BROWN BEAR SIGN SURVEY PROTOCOL.

1.) Select Class 1 streams to be surveyed.

2.) Along each stream, delineate 500m stream reaches in:
    a. Lower/Middle – Spawning/ bear fishing portion of stream.
    b. Upper – Above salmon spawning areas and bear activity other than fishing.

3.) Survey stream after salmon spawning has concluded (late-September – October 2003).

4.) Locate starting points for 1st survey transect using GIS. Create map of each reach to facilitate location of starting point in field. Determine bearing that is perpendicular to the approximate fall line of stream along 1 km reach.

5.) Transects will alternate sides of the stream and vary in distance surveyed away from the stream from 30 m (~100 ft) to 90 m (~300 ft) to 150 m (~500 ft). Distance from stream for each transect will be determined using a random start and systematic progression thereafter.
    a. Locate starting points in field using photo/map prepared in GIS, GPS location and mark with flagging so they can be repeated in spring;
    b. Transects will be separated into 3 segments
        i. Segment A = perpendicular to the stream on bearing determined from map, distance determined prior to beginning.
        ii. Segment B = turn 90 degrees and walk 100 m parallel to the stream;
        iii. Segment C = turn 90 degrees and walk back to the stream, distance to stream is measured.
    c. Start next transect on opposite side of stream from where segment C of last transect ended.

6.) Each sign of bear use will be noted with distance from stream along transect along the 2 perpendicular and 1 parallel segments of each transect.
    a. Distances along transects will be measured with hip chain.
    b. Types of sign include: Perennial bear trails (trails used yearly that persist across years); Ephemeral bear trials (trails used this year that will not persist into next year [i.e., tracks, beaten vegetation]); fish remains (carcasses, bones, gill plates); bear scat (within 2 m of transect); bear beds (within 5 m of transect); rub trees (within 5 m of transect); bear digging/grazing (within 2 m of transect).
    c. Basic habitat types (plant association + muskeg and clearcut) will be assigned at the beginning of each segment, and at each point where it changes with distance noted.
    d. Slope will be measured with clinometer at start and end of each segment, then averaged over segment.

APPENDIX C. BROWN BEAR SIGN SURVEY DATASHEET KEY

Transect: 1 – 10;

Length = 30 m, 90 m, or 150 m away (perpendicular) from stream, 100 m parallel to stream, and measure back to stream (perpendicular);

- Randomly select distance of first transect, them follow progression (30, 90, 150); (i.e., if first transect is 90, next is 150, next is 30, next is 90, etc.)
- Bearing should be determined from topo of area as the perpendicular to fall line of stream over length of reach (1 km).

Segment: A = perpendicular transect heading away from stream; B = parallel transect heading up or down stream; C = perpendicular transect heading back to stream.

Bearing: Segment A – get initial bearing from map; Segment B – 90º from 1st bearing; Segment C – 180º from 1st bearing.

Distance: Segment A – randomly determined; Segment B – 100 m; Segment C – measure back to stream edge.

Channel = type: 1 = Fast Riffle; 2 = Slow Riffle; 3 = Glide; 4 = Pool;

Slope: measured with clinometer at beginning and end of transect.

Comments: Species of fish carcass, plant being dug or grazed, etc.

Transect/Segment: transect number / segment letter

Sign #: tally of all types of sign along transect; start with 1 at beginning of <u>segment</u>, end at end of <u>segment</u>.

Sign Type:

1 = Perennial bear trail: long term trail that persists across years
2 = Ephemeral trail: tracks or broken vegetation that is a trail just this year
3 = Fish Remains
4 = Bear Scat
5 = Bear Bed (w/in 5 m of transect)
6 = Rub Tree (w/in 5 m of transect)
7 = Digging
8 = Grazing/foraging

Distance (m): Distance from start of segment measured on hip chain (in meters).

Habitat Type: number of habitat type from Plant Association Guide; Muskeg = 111; gravel bar = 888; clearcut = 999;

APPENDIX D. BROWN BEAR SIGN SURVEY DATASHEET

Date: ________________   Personnel: _________________________________   Page 1 of ___
Stream: ____   Reach: _________________________

Transect	Segment	Bearing	Distance	Channel	Slope	Comments
1	A					
	B			—		
	C					
2	A					
	B			—		
	C					
3	A					
	B			—		
	C					
4	A					
	B			—		
	C					
5	A					
	B			—		
	C					
6	A					
	B			—		
	C					

Comments:

Date: ____________________Personnel: ____________________________Page ___ of ____

Stream: ____ Reach: _______________________

Transect / Segment	Sign #	Sign Type	Distance (m)	Habitat Type	Comments

Transect / Segment	Sign #	Sign Type	Distance (m)	Habitat Type	Comments